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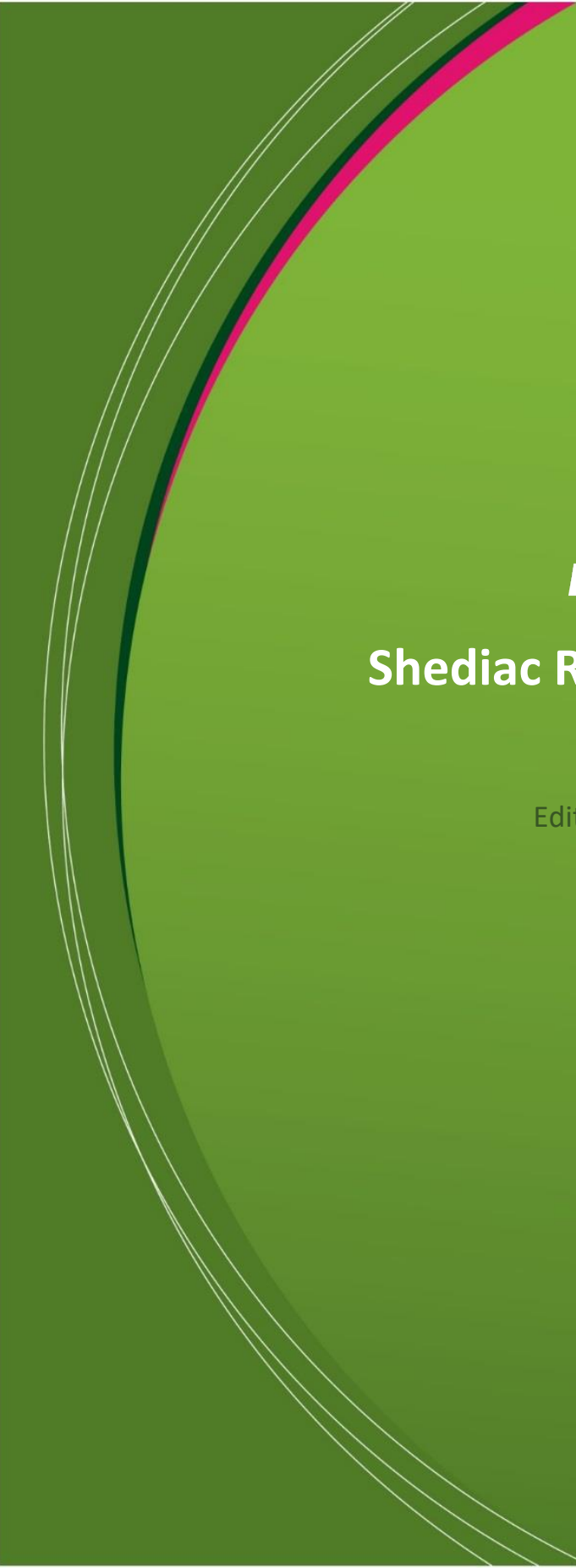
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Shediac Residential Energy Study: The Complete Reports

Edited by Ajit Pardasani and Jennifer A. Veitch



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Table of Contents

Foreword	iii
Preface and Acknowledgements	v
Chapter 1: Research Plan and Methods	1
Chapter 2: Modelling Household Electricity Use Data to Facilitate Data Exchange	156
Chapter 3: Modelling Smart Energy Technology Data to Facilitate Data Exchange	163
Chapter 4: Energy Use Characterization of Dwellings	169
Chapter 5: Performance and Perception Evaluations of Solar Photovoltaics and Battery Energy Storage Systems	189
Chapter 6: Effect of Time-of-Day Electricity Rates	249
Chapter 7: Technical and User Evaluation of Cold-Climate Mini-split Heat Pumps	311
Chapter 8: Understanding Smart Thermostat Use	341
Chapter 9: Understanding Energy Behaviours, Attitudes, and Perceptions	380
Chapter 10: A Summary of Results and Implications	405

Foreword

Brent Staeben, NB Power

Welcome to a collection of research that reflects the energy, innovation, and collaboration behind one of New Brunswick's most ambitious community projects—the Shediac Smart Energy Community Project. These papers chapters in this manuscript showcase the scientific work carried out by Canada's National Research Council (NRC) during a multi-year initiative led by NB Power, Siemens, and the Town of Shediac. Together, we set out to explore what a smarter, cleaner, and more connected energy future could look like—not in theory, but in practice.

NB Power launched this project with a clear goal: to understand how smart energy technologies could be integrated into everyday life in a real community. We wanted to learn how homes, businesses, and public infrastructure could work together to reduce energy use, lower emissions, and improve grid reliability. Shediac, with its engaged residents and forward-thinking leadership, was the perfect place to bring this vision to life.

From the beginning, we knew this project would be complex. It involved dozens of technologies, hundreds of participants, a very diverse housing mix and a wide range of research topics—from building energy performance and consumer behavior to distributed energy resources and advanced grid controls. We also knew we needed a research partner with deep expertise, national reach, and a collaborative spirit. That's why we chose the NRC. Their scientists and engineers brought rigor, creativity, open minds and open hearts, and a shared commitment to solving real-world problems.

The Shediac Smart Energy Community Project wasn't just about testing gadgets—it was about understanding systems. We looked at how solar panels, smart thermostats, and battery storage could interact with the grid. We studied how people responded to new tools and incentives. We measured energy savings, carbon reductions, and improvements in comfort and reliability. And we did it all while navigating the unprecedented challenges of the COVID-19 pandemic.

The pandemic tested our resilience. Supply chains slowed, fieldwork was delayed, and in-person engagement became nearly impossible. But thanks to the dedication of our partners and the flexibility of our approach, we adapted. We shifted timelines, reimagined outreach, and kept the research moving forward. In many ways, the pandemic made our work even more relevant—highlighting the importance of local energy resilience and digital solutions.

The results speak for themselves. The project achieved measurable reductions in peak electricity demand and greenhouse gas emissions. It demonstrated how smart technologies can empower consumers and support utilities. It provided valuable insights into building retrofits, energy literacy, and the role of data in decision-making. And it laid the groundwork for future smart energy communities across Canada.

This was a true team effort. NB Power is deeply grateful to Siemens for their technical leadership, to the Town of Shediac for their vision and support, and to the NRC for their outstanding research. We also want to thank the residents of Shediac, who opened their homes and shared their experiences to help us learn and grow.

What we accomplished in Shediac is more than a pilot—it's a blueprint. It shows how utilities, governments, researchers, and communities can work together to build a better energy future. It's

relevant not just for New Brunswick, but for every province looking to make energy smarter, greener, and more people-centered.

We hope these papers inspire new ideas, spark collaboration, and help others take the next step toward a sustainable energy future. Thank you for being part of the journey.

Brent Staeben, MA, MSc

Director of Strategic Funding Opportunities,
NB Power

Preface and Acknowledgements

Ajit Pardasani and Jennifer A. Veitch

The Shediac Smart Energy Community Project and its component the Shediac Residential Energy Study were conceived by our friends at New Brunswick Power (NB Power) with inspiration from the Town of Shediac and in response to the needs of the time. The National Research Council of Canada (NRC)— and our research team including we two researchers in particular — were privileged to have been chosen to serve as the Research Partner to help make it happen together with NB Power and Siemens.

This book is a compilation of the ten research reports that emerged from the Shediac Residential Energy Study at its conclusion in the spring of 2025. It is a complete summary of what was done and what was learned from the primary analyses of the data from all sources. Chapters 1-3 provide the research design details. Chapters 4-9 provide detailed results for each component of the study. Chapter 10 summarizes the whole and highlights implications.

This was always an ambitious project, with a long path from concept to completion. The original schedule demanded a rapid recruitment of participants and a short lead-in to the deployment of technologies. Just as we were poised to complete home assessments leading to research group assignment, the COVID-19 pandemic added unforeseen complications. All contact with research participants stopped for some months; in-person contact was delayed farther and new safety protocols made contact more complicated when home visits were allowed. At first, this stoppage was disorienting and frustrating (as life was at that time), but out of that dark cloud came a silver lining. Team members from all the partners came together in frequent online meetings to develop a revised research design, data-sharing mechanisms, and participant communications. Staff from NB Power, Siemens, and the NRC became One Team dedicated to the success of the Shediac Residential Energy Study. Although the path to completion became longer as a result of the pandemic, the final result was better.

Although the authorship of each chapter shows only NRC names, none of this work would have been possible without the tremendous efforts of all involved. Listing their names in the Acknowledgements section below is an inadequate recognition of the dedicated teamwork, sustained over years, that went into this project.

This has been the fifth project that either or both of us have conducted for and with NB Power since 2014, and was by far the most complex and challenging. Apart from their scientific and applied outcomes, and the professional challenges and lessons learned, each project has built deeper relationships with our friends in New Brunswick. We feel fortunate to have had these opportunities.

Acknowledgements

The Shediac Residential Energy Study was one element of the Shediac Smart Energy Community Project, which was part of the Smart Grid Atlantic initiative. Innovation, Science, and Economic Development Canada, Natural Resources Canada, New Brunswick Power, and the National Research Council of Canada funded the work. Siemens Canada and the Town of Shediac were partners.

We thank Brent Staeben (NBP) for his inspiration, wisdom, and unfailing support.

We thank Trevor Nightingale (NRC) for his sponsorship and support.

We thank the Town of Shediac and its residents, for inspiring and then welcoming this research project.

We especially thank our wonderful participants for their willingness to welcome strangers into their homes for home assessments, for sharing their energy use data, for trying new technologies (or not, depending on their research group assignments), for answering many, many survey questions, and for staying with us for what was, in the end, over four years of data collection.

From the NRC we thank Gordon Duval (Chair, NRC Research Ethics Board), Daniel Lowcay, Guy Newsham, Elias Purunenn, Edward Vuong, and Henry Xue.

From NB Power we are grateful to Blair Allen, Vibor Batra, Mathieu Blanchard, Janine Brown, Edgar Gallibois, Scott Garinther, Brenda Gillis, Clifton Hargrove, James Hartley, Patricia Hennigar, Sonya Hull, Michael Kervin, Kirk Lewis, Marie Lyons, Norma McCarthy, Cindy Morris, Sara Mudge, Deborah Nobes, Barbara Porter, George Porter, Melanie Ryan, and Saranya Sundararaj – and many more who played supporting roles.

From Siemens Canada we acknowledge Karen Cormier and Giles Counsell.

Technical contributions were provided by consultants and contractors to NBP at the firms HomeSol, GreenFoot, J+D Electric, Mpower, Util-Assist, UtiliSmart, and Vertex Solar.

Chapter 1: Research Plan and Methods

Jennifer A. Veitch, Ajit Pardasani, Natalia Cooper, Anca D. Galasiu, Sandra Mancini, Yitian (Vera) Hu, and Hadia Awad

Executive Summary

Electric utilities face unprecedented challenges and exciting opportunities as they strive to reduce fossil fuel use, increase grid capacity, and maintain grid stability. Two of these challenges could be addressed with renewable energy generation, such as hydro, wind, and solar power. However, battery energy storage and smart, internet-enabled tools are also needed for demand management to ensure the reliable integration of renewable sources into the grid. Reducing or shifting peak demand to times of day when cost-effective renewable sources are available has the potential to reduce carbon emissions. Demand management can be automated using utility control over smart devices, or can be achieved with behavioural strategies, including price signals to motivate changes as to when electricity is used. Successful integration of these tools requires testing of both the technology and customer acceptance.

This report summarizes the research methods and objectives of the Shediac Residential Energy Study, a five-year project undertaken in a small town in New Brunswick, addressing both the technical and customer aspects of smart energy technologies. The project was initiated by New Brunswick Power as a means to gain the experience and knowledge needed to modernize its electrical grid to meet its customers' increasing energy needs, and the pace of decarbonization. Together with other components, reported elsewhere, this project was part of the Smart Grid Atlantic initiative funded by Natural Resources Canada and Innovation Science and Economic Development.

The Shediac Residential Energy Study was a quasi-experiment in a field setting, involving at its peak over 529 households and with 333 remaining in the project at its conclusion. Participants' homes were evaluated twice between 2020 and 2022 to determine their suitability for the installation of energy technologies to be evaluated. Three hundred and forty (340) homes with compatible heating systems received smart thermostats during this period. Following the baseline phase, in spring 2022 75 homes received a 5 kW rooftop solar photovoltaic panel array + 13.5 kWh battery energy storage unit, and 23 homes received high-efficiency cold-climate mini-split heat pumps. The remaining 337 homes participated as part of the no-technology baseline group. Half of all the homes (N=211) were enrolled in a trial of time-of-day electricity rates. These interventions were in place from May 2022 through March 2024. In addition, the project included trials of utility interventions on distributed energy resources. This involved 316 dispatchable water heater control devices in homes that had NB Power rental hot water tanks and that accepted to receive the devices, and the 75 battery energy storage units. The dependent variables included household time-series electricity data, smart thermostat settings, water heater operation data, solar inverter and battery energy storage performance data, and participant attitudes, perceptions, comfort, and behaviours collected through repeated online surveys.

The National Research Council of Canada research team was responsible for data analysis and interpretation of the technical data and the survey data. This general report sets the stage for the series of specific reports about the performance and customer experience and acceptance for each technology.

1 Introduction

1.1 Background

As part of responding to national challenges to reduce greenhouse gas emissions, electric utilities face new challenges to reduce the use of fossil-fuel based electricity generation and to integrate renewable energy sources into their grids while managing loads to maintain grid stability. Smart, internet-enabled technologies are available that with customer permission may be used to manage electrical loads; these tools are known as distributed energy resources (DERs). Less directly, price signals to customers can motivate changes in the time of day when they use electrical energy, with higher prices being charged for usage during peak demand periods in order to promote usage in lower-demand times. Successful integration of these technologies will depend on utility experience with the technologies on a small scale to address technical issues and on a deep understanding of customer attitudes towards the technologies in order to smooth acceptance for large-scale deployments. This project addressed both the technical and the human aspects of these challenges.

Responding to a decision by The Town of Shediac made a commitment to become “Atlantic Canada’s first Smart Energy Community”, New Brunswick Power (NBP) developed this research project in 2018 as a means to gain the experience and knowledge needed to modernize its electrical grid to meet its customers’ increasing energy needs and the pace of decarbonization (New Brunswick Power, 2023a). Although at present, 80% of its electricity generation is carbon-free (from hydroelectricity and nuclear generation), the NBP 2023 Integrated Resource Plan (IRP; New Brunswick Power, 2023b) sets the goal of a net-zero, carbon-free electricity generation system by 2035. The IRP outlines various pathways toward a net-zero electricity system, including the expansion of new wind and solar generation and new battery energy storage systems. Electricity generation from wind and solar is variable and weather-dependent. As the installed capacity for wind and solar generation increases, the ability to dispatch these resources with high predictability becomes increasingly important to maintaining reliability. Additionally, the growing frequency and intensity of extreme weather events raise concerns about grid reliability and stability.

NBP participated in the Smart Grid Atlantic (SGA) initiative funded by Natural Resources Canada (NRCan) and Innovation Science and Economic Development (ISED). The aim of the SGA initiative was to conduct demonstration projects to explore the potential of tariffs, controls, and DERs to support smart grid development, and to inform building codes. Other SGA projects involved other partners; the work reported here took place with the National Research Council of Canada (NRC) as lead research partner and Siemens Canada as lead industry partner. A large fraction of NBP’s part in the SGA initiative took place in the Town of Shediac with three activities launched in 2018:

- Testing several technology and behavioural interventions in Shediac homes under the banner the “Shediac Residential Energy Study” to explore the influence of behavioural and technology interventions on peak demand, daily energy use, and customer acceptance.
- Converting two commercial buildings in Shediac (the Multipurpose Centre (MPC) and the Government of Canada Pension Centre (PC)) to net-zero-carbon emission buildings.
- Installing and commissioning one grid-connected 1.63 megawatt (MW) solar farm, designed to provide clean electricity to the MPC and the PC. The NRC was not involved in the solar farm activity, which had no research component.

The NRC led the design of the study, co-developed all participant communications, managed research ethics, developed and administered participant surveys, and analyzed data from all sources (smart meters, smart thermostats, water heater control devices, solar and battery energy storage management

systems, bill settlement data, and surveys). This report describes the research plan; other documents address the results from the study. NRC also supported the transition of two commercial buildings towards net zero operational carbon, and that work is also reported separately.

Parts of the research plan were changed during the study for various reasons: Because of the COVID-19 pandemic, because the pause during the early stage of the pandemic offered the opportunity to refine the plan, or because one of the original technology choices (a novel internet-connected thermal storage heat pump) was determined to be not ready for this application. This report describes the project as it was finally conducted.

1.2 Research design and objectives

The Shediac Residential Energy Study was a quasi-experiment in a field setting, and designed as best as possible following the guidance of Cook and Campbell (1979). The independent variables were (1) complex home energy technologies: 5 kW rooftop solar photovoltaic panel array + 13.5 kWh battery energy storage (SOL), and high-efficiency cold-climate mini-split heat pumps (CC-MSHP), each compared to a no-technology baseline group (no-TECH) and (2) time-of-day (TOD) electricity rates. In addition, the project included trials of utility interventions on dispatchable DERs, which were water heater control devices and the battery energy storage units. The dependent variables included household time-series electricity data, smart thermostat settings, water heater operation data, solar inverter and battery energy storage performance data, and participant attitudes, perceptions, comfort, and behaviours collected through repeated online surveys.

The combined research team from NBP, Siemens, and the NRC established research objectives for the project and reviewed them midway through the project. Table 1 provides a concise description of the independent variables and their effects on the dependent variables, categorised by the objective, along with the data sources used for assessment.

Table 1. Research framework of independent variables and the dependent variables that were examined in relation to each, grouped by category and showing the data sources for each dependent variable.

Category	Independent variables	Dependent variables	Data sources
Time-of-day (TOD) electricity rates	TOD/no-TOD [without solar]	peak demand total household energy thermostat setpoints shadow report credits perceptions/satisfaction self-reported habits	Smart meter Smart meter Smart thermostat Bill data Surveys Surveys
Smart grid equipment	Rooftop solar PV + battery energy storage vs no technology (SOL)	peak demand total household energy thermostat setpoints thermal comfort environmental attitudes tech satisfaction, desires energy habits	Smart meter Smart meter Smart thermostat Surveys Surveys Surveys Surveys
Solar energy program	SOL	energy export to grid electricity bills, solar energy credits resilience (battery performance if there is an outage) shadow report satisfaction & comprehension program satisfaction satisfaction with resilience	Smart meter & battery data Bill data Battery data Surveys Surveys Surveys
Efficiency	High-efficiency cold-climate mini-split heat pumps (CC-MSHP)	total household energy peak demand thermostat setpoints thermal comfort tech satisfaction, desires	Smart meter Smart meter Smart thermostat Surveys Surveys
DERs interventions	Water heater devices (WHD)	awareness of interventions comfort during interventions acceptability of interventions A/B comparisons of energy performance during interventions Magnitude of peak reduction from WHD	Surveys Surveys Surveys WHD data WHD data

2 Method

2.1 Procedure

The work was always planned to occur in phases, but the schedule was changed considerably by the COVID-19 pandemic.

Phase 1 was designed to take in a pool of participants and to identify those who might be eligible for receiving complex technology. This consisted of the initial recruitment of participants, a home assessment and an online survey to collect demographic and other baseline information. This began in January 2020. The home assessments were completed just as the pandemic began around mid-March 2020, at which time all participant contact stopped for several months. Phase 1 continued until June 30, 2022.

Recognizing the need to extend the project duration to accommodate pandemic delays, the design of the study was modified and Phase 1a began in June 2020 with a planned duration until June 30, 2023. All participants possessing a compatible heating system as indicated in the results from home assessment (HA1, Appendix A.1) were offered a free installation of up to 5 smart thermostats for their home; as a result, 340 homes received a total of 828 smart thermostats. Those with NBP rental electric water heaters were also offered a dispatchable water heater control device to enable the DERs interventions; 316 were installed. The installation of the smart thermostats and dispatchable water heater control devices was interrupted several times by changes in the COVID-19 related public health status, with the last being installed in the autumn of 2021. Phase 1a also included a second home assessment (HA2, Appendix A.2) of those homes for which HA1 had suggested compatibility with the complex technologies intended for test.

Smart electricity meters were installed in all participating homes in November 2019 through January 2020, and upgraded to new bi-directional meters in late autumn 2020. In May 2021, all participants received access to an online portal (“Participant Energy Portal”) through which they could view their electricity usage at an hourly level in close to real time. The online portal was also used for the TOD trial (described below), which launched in May 2022.

Phase 2 began in May 2022 with offers of rooftop solar photovoltaic panel array + battery energy storage systems (SOL) to 75 participants and offers of thermal storage heat pumps (TSHP) to 24 participants. Installations of the SOL systems began in June 2022 and continued through to December 2022; the SOL intervention included a solar energy credit (SEC) program through which participants were paid for electricity that was sent to the electrical grid. The TSHP installations began in the summer of 2022; technical problems with the specific technology resulted in the TSHP systems being removed and replaced with high-efficiency cold climate mini-split heat pumps (CC-MSHP) in October and November 2022. The original end date for Phase 2 was June 30, 2023. This was extended by nine months to March 31, 2024 to ensure a full year of data collection for all participants in the various technology groups.

Figure 1 shows the timeline and main events. Figure 2 shows the distribution of participants to research groups as the study unfolded.

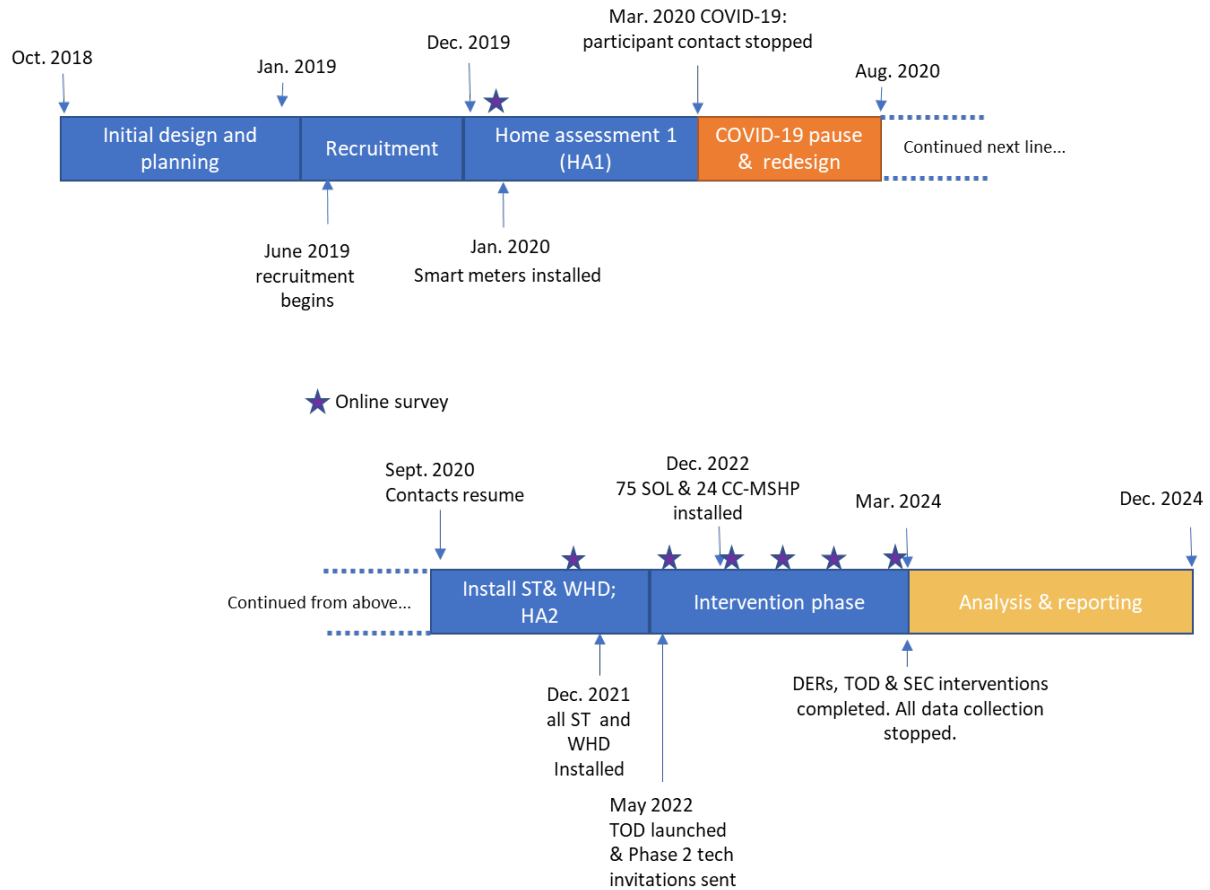


Figure 1. The timeline of major project events, not to scale.

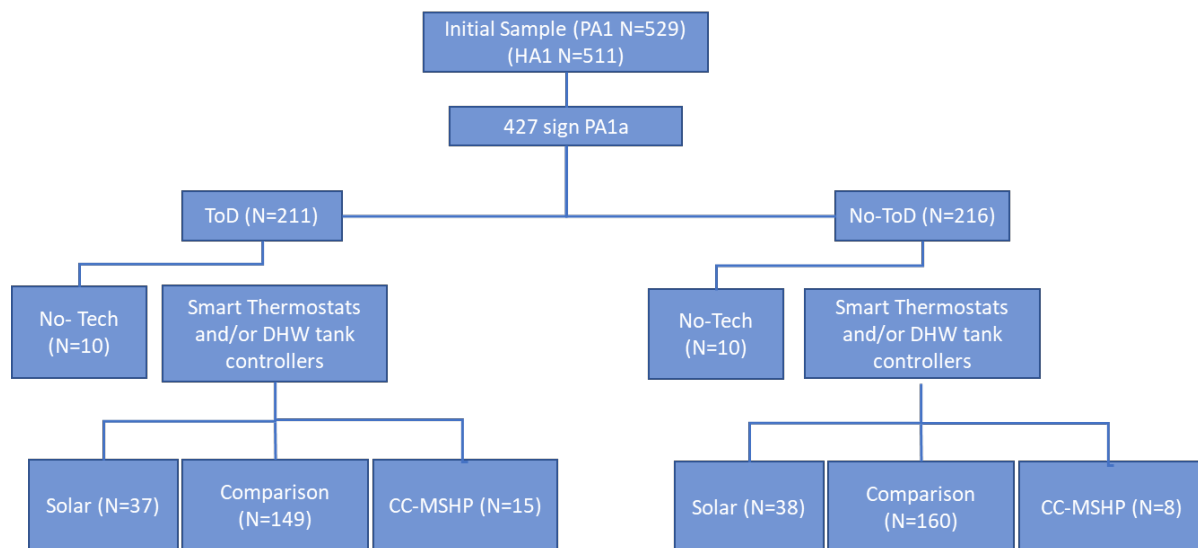


Figure 2. As the procedure unfolded, participants were distributed to research groups in the numbers reported here.

2.2 Participants

All parts of this project that engaged individual participants were reviewed and approved by the NRC Research Ethics Board under Protocol 2019-34.

The participants in this project were residents of Shediac, New Brunswick. The requirements for participation were:

- Home located in the Town of Shediac;
- Participant is the legal owner of the home;
- Participant lives in the home year-round;
- Home is single-detached, semi-detached, or a row housing unit, but not an apartment or part of a stacked condo unit;
- Participant had the ability to receive emails and respond to surveys electronically;
- Home had only one electricity meter;
- Participant's NBP account in good standing.

Initial recruitment took place in autumn 2019 following town hall presentations, local media announcements (newspapers, radio), and on the Town of Shediac and NBP Facebook pages.

Participants in this project signed Participation Agreements at several points. NBP hosted a website for the project under which each participant had a personal Participant Landing Page; this page served as an archive for all project information and Participation Agreements throughout the project. The agreements and the sample size at each step were:

Phase 1 (signed between Oct. 2019 and Jan. 2020): Agreement for surveys, energy monitoring, and home assessments through June 30, 2022:

N = 529

Phase 1a (signed between Oct. 2020 and Apr. 2021): Participation extended to June 30, 2023 and smart thermostats and water heater devices offered for all compatible homes:

N = 427.

N=17 declined (96 % acceptance). The remainder had dropped out because of home sales.

Phase 2, (signed between May and Sept. 2022): Complex technology agreement:

N=99

All other remaining participants (N=337) were included under Phase 1a agreements.

Phase 2 extension (signed between Mar. and May 2023): Participation extended to March 31, 2024:

N = 334.

N=55 of the Phase 1a group declined to extend (86% acceptance).

Most of the attrition during the project occurred because participants had sold their homes and moved elsewhere. They were not permitted to remain in the study even if they remained in the town because their energy data would not be comparable in a new building.

Participants were compensated for their contributions to the study as follows:

- For each completed application to the project and for each completed survey numbers 1-6, NBP donated \$10 to the Beausejour Family Resource Centre in Shediac; for each completed survey number 7, the donation was \$20. These donations totalled \$34,140 over the life of the project.

- Participants whose homes were compatible with smart thermostats received up to 5 smart thermostats for their heating systems as part of phase 1a, installed free of charge. Unless they requested removal, they kept the thermostats after the end of the project.
- Participants received credits on their NBP bills once per year, as follows:
 - \$150 to all participants in spring 2021
 - \$150 to participants without complex technologies in both spring 2022 and 2023 (not to those who received complex technologies)
 - \$150 to all participants in spring 2024.
- Participants in the TOD group received credits on their monthly electricity bills if their time of electricity use led to the bill calculated using the TOD rates led to lower charges compared to the regular flat-rate bill. However, they were not penalized if bill calculated using the TOD rates were higher than the regular bill. This is described further below.
- Participants who were assigned to the solar + battery energy storage research group received, free of charge, a 5 kW rooftop solar photovoltaic panel array and a battery energy storage unit (estimated value ~\$28,000). The equipment remained the property of NBP until the end of the project, at which time ownership was transferred to the participant. They also participated in a solar energy credit program, described below.
- Participants who were assigned to the heat pump group received, free of charge, a high-efficiency cold-climate mini-split heat pump (estimated value ~\$6500). The equipment remained the property of NBP until the end of the project, at which time ownership was transferred to the participant.

A sample of 529 participants signed the initial participation agreement and were invited to complete Survey 1. The characteristics of this sample are shown in Table 2, which combines information from Survey 1 (N=505 of 529 invited) and Home Assessment 1 (N=511)¹. Table 2 also shows, using the same data sources, the characteristics of the subset of the original sample that remained at the end of the project, with one exception in that the primary heating system shown for 2024 was updated to reflect the system in the home after the installation of project equipment in December 2022.

Comparing the samples at the start and end of the project reveals the following:

- The distribution of the sex of the person responding to the survey remained stable, although other data show that the same individual was not always the survey respondent.
- Participant ages increased, as would be expected over four years.
- There was little change in the number of occupants per house from the start to the end; a few homes with more than 4 occupants had fewer four years later.
- Household income was slightly higher at the end of the study. This is not the result of selective attrition; the survey 1 incomes of the subset of participants remaining at the end of the study has the same distribution as the full sample (data not shown).
- The percentage of homes in which someone is at home all day increased dramatically from the start to the end. This is likely to have been caused by the changes in work patterns following the pandemic and by the increase in the number of participants older than retirement age.

¹ Note that nearly every data source for this project has some missing data.

- The percentage of homes with mini-split heat pumps increased during the life of the project, and the percentage of homes with electric baseboard heating as their primary heat source decreased. A tabulation at the end of the project determined that by December 2022, only 21% of the sample of homes had no heat pump (either mini-split or central). Nine per cent had independently acquired a heat pump during the project (despite the project having asked participants to avoid any substantial home alteration), and 4.3% (23 homes) had been given a high-efficiency cold-climate mini-split heat pump as part of the project.

Overall, we conclude that attrition during the project was not a source of bias in these data. However, comparisons involving the primary heating system type are complicated by the changes in heating system introduced independently by some participants, because it is difficult to identify exactly when the changes took place.

Table 2 also shows the 2021 Census of Canada results for the Town of Shediac (Statistics Canada, 2023). The responding participants had a higher proportion of men than the census data for all of Shediac. The selection criteria for the study required that participants live in owner-occupants of dwellings that did not include apartments. This limited the sample to 63.4% of the population of Shediac. Differences between the sample and the Shediac population might be explained by in part by this selection. For example, the study sample has a lower percentage of people between ages 20 and 30 than the population, Home ownership is less likely for the younger age cohort. The sample also has both a lower proportion of low-income participants and a higher proportion of high-income participants than the population, which is likely to be partly related to the requirement for home ownership. Dwelling types are reported here as a percentage of the eligible dwellings (i.e., excluding any form of apartment). Even with this limitation, detached homes are a higher proportion of the sample than the population, perhaps because they are more likely to be owned than other dwelling types.

Table 2. Sample characteristics of participants and their homes (as reported at project start) for the full sample at the start and the subset who remained at the end of the project, and for the 2021 Census of Canada results for Shediac.

Variable	Category	December 2019		March 2024		2021 Census
		N	%	N	%	%
Survey respondent sex	Male	297	59.5	146	58.6	46.0 (in all dwelling types)
	Female	200	40.1	103	41.4	54.0 (in all dwelling types)
	Prefer not to answer	2	0.4			
Participant age (years)	21-30	23	5.1	5	2.0	9.6 (in all dwelling types)
	31-40	84	18.6	26	10.5	11.8 (in all dwelling types)
	41-50	108	23.9	55	22.3	14.9 (in all dwelling types)
	51-60	100	22.2	51	20.6	17.1 (in all dwelling types)
	61-70	83	18.4	64	25.9	23.0 (in all dwelling types)
	71-80	43	9.5	37	15.0	18.6 (in all dwelling types)
	81+	6	1.3	8	3.2	4.9 (in all dwelling types)
	Prefer not to say	4	0.8	1	0.4	
Household income ² (\$)	<20K	4	0.8			17.2 (in all dwelling types)
	20K to 40K	38	7.6			33.1 (in all dwelling types)
	40 K to 60K	69	13.8	6	10.2	21.6 (in all dwelling types)
	60 K to 80K	68	13.6	5	8.5	11.9 (in all dwelling types)
	80 K to 100K	68	13.6	7	11.9	6.0 (in all dwelling types)
	100K to 150K	138	27.5	16	27.1	8.6 (in all dwelling types)
	>150K	86	17.2	21	35.6	1.6 (in all dwelling types)
	Don't know	30	6.0	4	6.8	
Number of household occupants	1	40	8.0	23	9.2	34.0 (in all dwelling types)
	2	211	42.1	120	48.2	42.2 (in all dwelling types)
	3	115	23	50	20.1	11.7 (in all dwelling types)
	4	105	21	48	19.3	8.3 (in all dwelling types)
	5 or more	30	6.0	8	3.2	3.7 (in all dwelling types)
Daily occupancy pattern	Home all day	195	38.8	167	67.1	
	Home some of the day	144	28.7	50	20.1	
	Away all day	163	32.5	32	12.9	
Home size (square feet)	<1000	36	6.8	20	5.7	
	1000 - 2000	360	67.9	234	66.3	
	2000 - 3000	93	17.5	67	19.0	
	3000 - 4000	15	2.8	10	2.8	
	4000 - 5000	6	1.1	3	0.8	
	> 5000	1	0.2	0	0.0	
	Unknown	19	3.6	19	5.4	
Dwelling type	detached	471	93.1	308	93.1	83.4 (of eligible types)
	semidetached	20	4.0	12	3.6	7.3 (of eligible types)
	townhouse	8	1.6	7	2.1	3.6 (of eligible types)
	mobile	7	1.4	4	1.2	5.7 (of eligible types)
Primary heating system	mini-split	256	50.4	218	65.7	
	baseboards	114	22.4	31	9.3	
	central heat pump	89	17.5	62	18.7	
	central furnace	30	5.9	14	4.2	
	radiant floor	8	1.6	5	1.5	
	fireplace	11	2.2	2	0.6	
Construction Year	Before 1961	69	14.1	43	13.4	
	1961-1974	57	11.6	34	10.6	
	1975-1984	60	12.2	41	12.7	
	1985-1994	38	7.8	25	7.8	
	1995-2004	99	20.2	64	19.9	
	2005-2009	80	16.3	57	17.7	
	After 2010	82	16.7	57	17.7	
	Unknown	5	1.0	1	0.3	

2.3 Interventions

2.3.1 TOD electricity rates intervention

2.3.1.1 Electricity rate structure

TOD rates are a behavioural intervention. By charging a different price for electricity used at different times of day, utilities aim to shift electricity consumption from times of day when demand (and often production cost) is high to times of generally lower demand. In New Brunswick, the period of peak demand generally occurs on cold winter weekday mornings between 7:00 and 9:00. This was the period targeted with this intervention.

The TOD rates tested in this project are shown in Table 3. The mid-peak rate was the flat rate charged to all New Brunswickers. The rate structure with the peak rate $\sim 2.25\times$ the mid-peak rate was chosen following extensive evaluation of various rate structure options by both NBP and NRC (Newsham, 2019) with the goal of achieving revenue neutrality for the utility under expected performance scenarios. The scenarios were modelled from data collected in an earlier project (Pardasani et al., 2018) and from smart meter data collected in the present study. The rates increased in the second year of the trial together with the general increase in the approved flat rate for electricity on April 1, 2023. The TOD rate structure did not change as a result of this increase.

Table 3. The TOD electricity rates tested in this trial.

	Weekdays		Weekends and holidays	
	May 2022 – Mar. 2023	Apr. 2023 – Mar. 2024	May 2022 – Mar. 2023	Apr. 2023 – Mar. 2024
On-peak 7:00 – 9:00	\$ 0.2564	\$ 0.2752	\$ 0.1138	\$ 0.1215
Mid-peak 9:00 – 22:00	\$ 0.1138	\$ 0.1215		
Off-peak 22:00 – 7:00	\$ 0.0738	\$ 0.0784		

2.3.1.2 Assignment to research groups

Assignment to the research groups for TOD (who received the intervention, described below) and no-TOD (who received no intervention) was a structured random assignment. In December 2021, the NRC used data from HA1, survey 1, and household energy monitoring to balance assignments in an automated tool in order to achieve equality in the two groups on the following attributes:

1. 2020 electricity load profile based on the smart meter data
2. Shift in peak demand in 2021 from 2020, based on the smart meter data, due to the impact of COVID-19 on the energy use profile.
3. Daily occupancy schedule of participants as reported in survey 1
4. Primary heating system type (from HA1)
5. Dwelling type (e.g., detached, semi-detached, from HA1)
6. Floor area (from HA1)
7. Household income as reported in survey 1

² Household income was last measured in survey 6 in November 2023.

The assignment procedure also took into account the expected technology group assignments, so that the homes that would be offered either heat pumps or solar + battery energy storage systems included half TOD and half no-TOD participants.

Of the 427 active participants in spring 2022 who had signed the Phase 1A agreement (and therefore would remain in the project until June 30, 2023), half were assigned to the TOD group (N=211) and half to the no-TOD (N=212) group. Four participants for whom there was no data on any or all of these attributes did not receive any TOD intervention materials and their energy use, billing, and survey data were excluded from further TOD analyses.

Analyses of the TOD data were conducted separately for the participants who were in the SOL group (37 TOD / 38 no-TOD) and all others (174 TOD / 174 no-TOD). As described below, the presence of the battery energy storage unit and its different modes of operation dramatically affected the pattern of household electricity use and masked the effects of behavioural changes. The CC-MSHP group was comparable to any other participant with respect to the possibility of behavioural changes in the timing of electricity use and so their data were included with the no technology baseline group for TOD analyses.

2.3.1.3 TOD information to participants

The TOD intervention began in the beginning of May 2022. Participants in the TOD group received paper brochures in the mail announcing and explaining the program. Owing to a printing error, the original brochure showed the weekend rate as being the same as the off-peak rate, so a replacement brochure was mailed later in the month. Behavioural tips on how to shift usage were also posted on the individual's Participant Landing Page accessible on the NBP web site.

Each month, TOD participants received shadow reports corresponding to their billing periods. These reports were delivered through the Participant Energy Portal, where all participants could view their electricity usage. The reports illustrated what their current bill would be under the TOD rate structure and reported any TOD bill credits that would appear on their monthly bill. The report was designed to help participants understand the consequences of their actions on their electricity usage and the potential bill savings of shifting their usage to different times of day at which they used electricity. Participants received an e-mail notification each month about the posting of that month's shadow report by e-mail, serving as regular reminders of the program. Additionally, TOD participants saw a line on their regular electricity bill stating "Shediac Residential Energy Study Time-of-Day Credit – See your Shadow Report for Details". Participants were billed for their electricity use at the regular flat rate approved by the New Brunswick Energy & Utilities Board, but if their shadow report indicated that a lower amount would have been charged based on the time-of-day usage, they received a corresponding credit on their monthly bill. If the shadow report indicated that TOD rates would have resulted in a higher charge, this was reported to them but there was no penalty applied to the bill: the TOD credit was \$0.

For winter 2022, TOD participants were provided with specific instructions about how to take advantage of TOD rates using their heating system, tailored to the heating system (of the six types) that had been identified in HA1. These instructions were made available through the Participant Landing Page for download on demand, and were announced to the participants via e-mail reminders. For homes with electric baseboard heating, the instructions included instructions for adjusting thermostat setpoints for a morning preheat before the peak period and a setback during the peak period. This approach had previously been demonstrated to effectively reduce peak loads through automated thermostat setpoint adjustments by the utility company (Pardasani et al., 2018).

In spring 2023 the team reviewed the outcomes of the TOD program over the preceding winter. This is detailed in the separate report on the TOD intervention. It became clear that homes that had used a night-time setback experienced a higher morning peak; the preheat instruction had not helped. Unlike the previous demonstration, where the utility company automatically adjusted thermostat setpoints to reduce peak demand, this study required manual adjustments, which likely contributed to the ineffectiveness. For winter 2023, the instruction changed. All participants were instructed to choose a single thermostat setpoint for the winter, set their heating system, and then not change it: “set it and forget it”, with no night-time setback and no preheat. This instruction was delivered with in-person workshops between October – December 2023, with a posted instruction on the Participant Landing Page, and reminders to view the information sent by e-mail and telephone messages.

2.3.2 CC-MSHP intervention

2.3.2.1 System description

After encountering technical issues with the initial installation of thermal storage heat pump technology, homes in this research group received a high-efficiency cold-climate mini split heat pump installed in one of the principal rooms of the home. It had a capacity of 9,640 BTUh and a coefficient of performance (CoP) of 2.13 at -25°C. Five models from different manufacturers were evaluated, and the specific model was chosen because of its greater efficiency at very cold temperatures. Each home also received a smart thermostat suitable to the CC-MSHP. There was no utility control over the thermostats and no data were received from them. The homes in this research group already had electric baseboard heating, which became the backup heat source to support the CC-MSHP.

2.3.2.2 Assignment to the CC-MSHP research group

Home assessment 1 (HA1) provided information about the homes that identified those who might be suitable for the complex technology installations, subject to a more detailed home assessment (HA2). The HA1 screening criteria were:

- The home is heated with electric baseboard heating.
- There is no heat pump in the home.
- The home has WiFi.

Homes that met these criteria and that were still in the project in Phase 1a received a second home assessment to provide the additional information required for a thermal storage HP (TSHP) group assignment. This home assessment verified that in the intervening time no heat pump had been installed, and that there was an unobstructed wall area in a regularly inhabited room that was at least 2.14 m (7 ft) wide by 1.22 m (4 ft) high. This space requirement was to ensure that the originally planned thermal storage heat pump unit would fit in the room.

It had been intended to install up to 50 TSHP, but following HA2 there were only 33 homes that were compatible with the technology. All of these were offered TSHP (the originally selected technology). Of these, ten either declined the technology, never responded to the invitation, or had left the study. Thus, there were 23 participants in this research group.

The consent procedure for accepting a technology offer was comprehensive:

- An informational e-mail;
- A home visit by an NBP employee and a representative of the installer, to discuss details of the possible installation;

- A written consent form signed by all registered owners of the home, after a minimum 7-day review period.

Midway through the installations of the TSHP in these homes, it became apparent that there was a technical problem with the units that risked causing damage to participants' homes, and that could not be easily solved.³ The decision was made to change this intervention to avoid unintended harms. Because of the short timelines, the decision was made to change the intervention to a high-efficiency cold-climate mini-split heat pump (CC-MSHP), and not to attempt DERs interventions with it because there was insufficient time to make the necessary technical arrangements. The installation review visit was repeated for the new technology to confirm the acceptability of the arrangements.

The original group of 33 participants offered the technology included 19 in the TOD group and 14 in the no-TOD group. Of the final set of 23 participants with CC-MSHP, 15 were in the TOD group and 8 were in the no-TOD group.

2.3.3 SOL intervention

2.3.3.1 System description and programming

This intervention involved the installation of a 5 kW rooftop solar photovoltaic panel array and a solar inverter with 13.5 kWh battery energy storage (maximum 5 kW charge or discharge rate) in the homes of compatible, and willing, participants. The systems were programmed differently for the TOD and no-TOD groups.

For the TOD group, the programming used a time-based control algorithm. Overnight during the off-peak rate period, the battery recharged from the grid at the off-peak rate if it was not already fully charged. Between 7:00 and 9:00, the household electricity demand was met first from the battery (with any extra needs met from the grid). During the day when mid-peak rates were in effect, household needs were provided first by solar generation, and then from the battery if needed. Excess solar-generated energy over and above household demand was used first to charge the battery. If the battery was fully charged, the excess was sent to the electrical grid and the participant received a Solar Energy Credit of \$0.0487 per kWh on their NBP bill. The battery was never permitted to drop below a 20% reserve. The effects of this programming on their TOD bill credits (together with the effects of any behavioural changes in the time of their electricity use) were reported to participants in this group on the shadow reports available monthly on the Participant Energy Portal.

For the no-TOD group, the battery energy storage was programmed as a resilient energy solution to provide power during any grid outage. During the day, household needs were provided first by solar generation and then by the electrical grid. Excess energy, if any was generated, was sent to the grid and the participant received a Solar Energy Credit of \$0.0487 per kWh on their NBP bill. The battery was kept charged at 100% as a backup reserve in case of an outage which proved to be useful during the widespread outage when Hurricane Fiona hit New Brunswick on September 24, 2022 (Cooper et al., 2025). All grid draws (for household needs and for battery charging) took place at the standard flat rate regardless of the time of day.

Participants in the SOL group received monthly Solar Energy Credit reports delivered through the Participant Energy Portal. The report detailed the amount of energy exported to the electrical grid and calculated the credit to be paid on their NBP monthly bill. The posting of each month's Solar Energy

³ Homes that had already experienced damage to finishes were repaired at NB Power's expense.

Credit report was announced to the participants by e-mail. Their NBP bills also carried a line labelled Shediak Project Solar Energy Credit – See your Solar Energy Credit Report.

2.3.3.2 Assignment to the SOL research group

Compatibility for the SOL system was determined following HA2, and required:

- 200 Amp electrical service with a breaker panel for which circuit breakers could be purchased to complete the SOL install;
- A minimum wall space of 2.74 m x 1.83 m (9 ft x 6 ft) in an uninhabited area either inside the home (i.e., a mechanical room or unfinished basement area) or in an attached heated garage, to house the battery and electrical equipment;
- WiFi;
- Sufficient roof area in the desired orientation for solar energy production;
- Roof in a good state of repair;
- For batteries to be installed in a basement, stairs strong enough and wide enough to allow two people to safely carry a 100 kg (220 lb) battery;
- For batteries to be installed in a basement, no history of basement flooding;
- For batteries to be installed in a garage, an available space such that one would neither drive into or back into the battery, and far enough away from a parked car that one would not hit the battery with an open car door;
- No whole-home generator already installed; partial home generators were acceptable provided there was no transfer switch in the existing configuration.

HA2 revealed that there were 94 homes that met these compatibility criteria. The NRC chose 75 of these homes to receive initial offers, while attempting to match the no-TECH group on seven parameters listed below:

- 2020 load profile (based on the smart meter data)
- Income as reported in survey 1
- Shift in peak energy usage in 2021 from 2020 (based on the smart meter data)
- Schedule of participants as reported in survey 1
- Primary heating system type (from HA1)
- Dwelling type (e.g., detached, semi-detached, row house, from HA1)
- Floor area (from HA1)

The balancing of participant income and floor area attributes posed a challenge as only larger homes tended to be compatible and these tended to be owned by higher-income people. Of the initial offers, 69 participants accepted. The NRC selected an additional six participants in the second round, who accepted the offer. Of these, 73 remained to the end of the project. Homes that were compatible but who did not receive technology offers remained in the no-TECH baseline group, although one participant left the project as a result of not receiving an offer.

The consent procedure for the SOL group was more complex than for other groups:

- An informational e-mail;
- A home visit by an NBP employee and a representative of the installer, to discuss details of the possible installation;
- Receipt by the homeowner of a detailed proposal from the installer;
- A written consent form signed after a minimum 7-day cooling-off period.

2.3.4 Utility dispatch of DERs: Water heater devices

Part of this project included the development by Siemens Canada of a system for electricity load control. One of the target devices to be controlled was electric water heaters. As part of Phase 1a, homes with rental NBP electric water heaters were invited to allow the installation of a dispatchable water heater device with a cellular modem connection, and to permit these devices to be used to send signals to control the operation of the water heater up to 20% of the weekdays during the study period. The effects of the signals were not expected to be noticeable to participants, but if a participant felt they had been inconvenienced by the signals they could contact NBP to report it.

NRC developed a group assignment to split the sample of 316 homes with WHD into balanced groups (A and B) to permit comparisons between the energy consumption between those receiving signals and those who did not for any given intervention.

Siemens Canada is responsible for the analysis of the data concerning DERs interventions. These are reported separately.

2.3.5 Utility dispatch of DERs: Battery energy storage

Homes in the SQL research group were dispatched through DERs interventions by Siemens Canada to evaluate their contribution to manage the load on the electrical grid. Participants were not alerted to these interventions, but had been assured that the battery would never drop below 20% charge and would always be in a state of readiness in the event of severe weather days or outages. Dispatch signals began on Dec 1, 2022 and ended on Jan 31, 2023 and targeted both TOD and no-TOD groups. The timing of signals was determined by NBP to minimize the costs of generation and procurement of electricity. Though most dispatch signals were scheduled to curtail grid demand during peak hours in the morning (7 a.m. to 9 a.m.) and the evening (6 p.m. to 9 p.m.), many were also scheduled at other times of the day to reduce utility costs, always on weekdays. The initial goal was to perform two dispatches per week and three during extreme cold weeks, but actual numbers varied.

Siemens Canada is responsible for the analysis of the data concerning DERs interventions. These are reported separately.

2.4 Data sources

2.4.1 Device telemetry data and NRC SQL data warehouse

This category of data includes all automated data transfers from devices installed by NBP or its contractors for this project.

- Smart meters reporting electricity draw (averaged over every 15 min);
- Smart thermostats (various brands and numbers per home depending on heating system type) reporting air temperature and temperature setpoint every 5 min;
- Dispatchable WHD reporting the device state (on/off) every 5 min;
- Solar photovoltaic panel array and battery energy management system 15 min interval data for grid draw, solar power generation, grid export, battery charge/discharge, and state of charge.

The automated data were shared by NBP through their secure file transfer protocol (sftp) server with NRC. A data completeness checker was implemented by NRC to check for the missing data and prepare missing data reports which were then shared with NBP for troubleshooting. The data was simultaneously shared by NBP with NRC and Siemens' Energy System Platform through CSV files. Figure 3 shows the data flow from various devices to the SQL data warehouse at the NRC; Chapters 2 and 3 provide more detail.

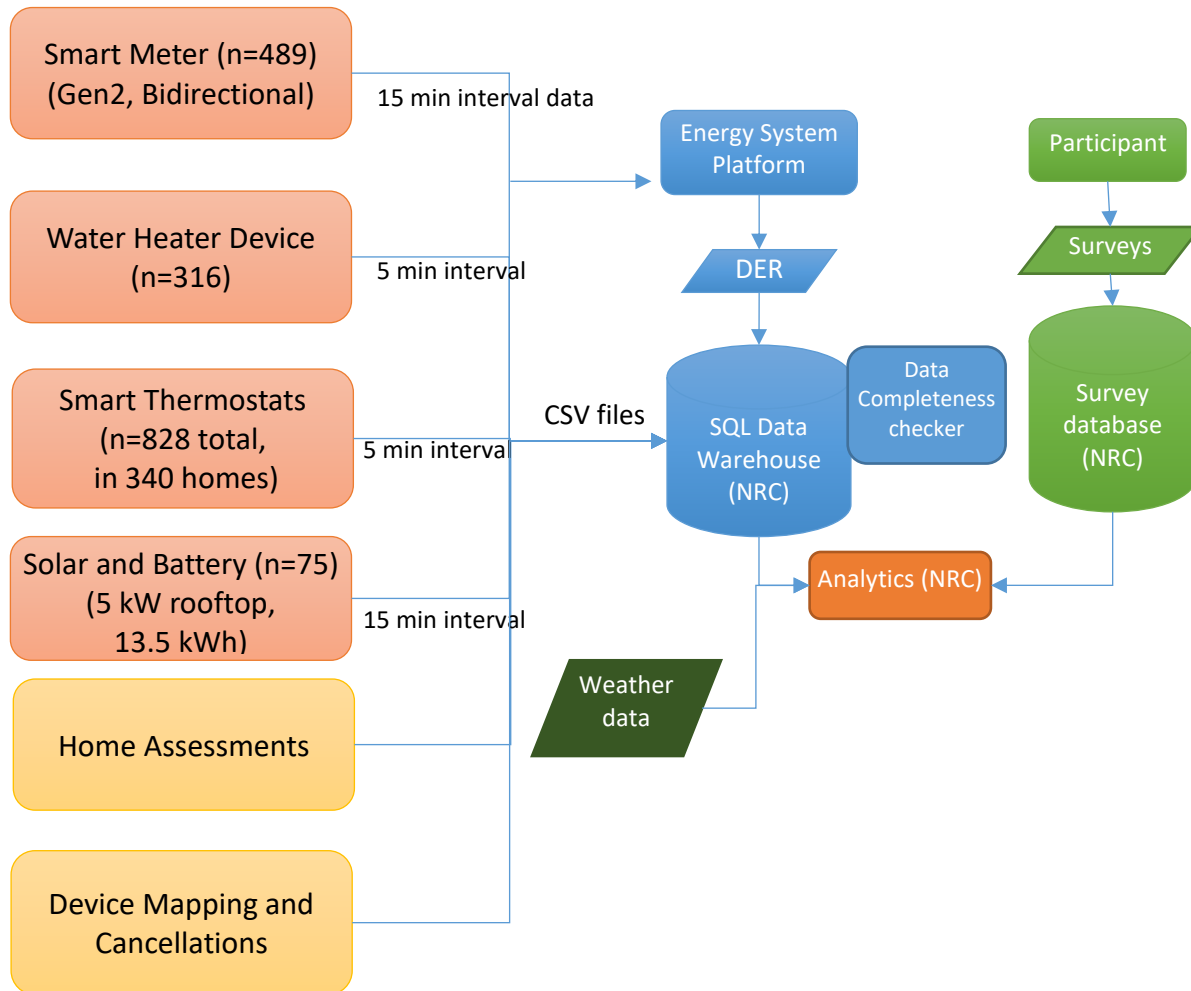


Figure 3. This figure shows the data sources and their integration into the NRC SQL data warehouse and separate survey database.

Hourly weather data was downloaded from the Environment Canada weather station #6918 (Bouctouche weather station, 35 km from Shediac on the coast) up to October 3, 2021 and then station #50309 (Greater Moncton Int'l, 22 km inland from Shediac) from October 4, 2021 to March 31, 2024. The Bouctouche weather station stopped reporting data on Oct. 3, 2021.

Home assessment data, metadata on device locations in homes, and mapping of device identifiers to web IDs was recorded in CSV files and integrated into the NRC data warehouse. Cancellations were processed manually as they occurred and reported to the NRC.

Survey data handling is described below.

2.4.2 Home assessments

NBP conducted assessments of all homes using local contractors hired for this project in November 2019 through January 2020 (HA1) to collect data on the type of building (i.e., detached, semi-detached, row house), vintage, primary energy source for heating (e.g., electricity, propane, wood, etc.), type of heating system (e.g., electric baseboard, mini-split heat pump, wood stove, etc.), floor area, water heater type and size, the electrical capacity of the panel, and orientation, etc. See Appendix A.1 for the

full contents of HA1. Each home assessment, including the pictures from the home, was evaluated by NBP to determine which of the energy technologies might be compatible with the home.

A second assessment of homes (HA2) that might be compatible with either the solar + storage (SOL) or thermal storage (TS) technologies was conducted to provide more specific information to verify compatibility with these technologies (e.g., structural stability of the roof; space to accommodate the battery energy storage unit, etc.). See Appendix A.2.1 for the HA2 questions for SOL and Appendix A.2.2 for the HA2 questions for TS.

Data from both HA1 and HA2 were used for TOD and technology group assignments. They also contribute together with the telemetry and survey data as required during the analyses.

2.4.3 Electricity bill settlement and project-related credits

During the TOD trial, NBP provided to the NRC monthly downloads of participant's regular billing data and the bill settlement data corresponding to the shadow reports. The project was required to maintain the usual billing process for its customers, which requires a manual reading of the electricity meter for each household. As a result, electricity bills are generated on different days for each customer.

The data reported for the monthly electricity bills were: meter reading date; number of days since last reading; monthly usage (kWh); dollar amount billed. The data reported for the bill settlement file were: meter reading date; number of days since last reading; monthly usage (kWh); dollar amount billed; on-peak usage (kWh); mid-peak usage (kWh); off-peak usage (kWh); on-peak cost (\$), mid-peak cost (\$); off-peak cost (\$); solar energy export (kWh); solar energy credit (\$); TOD credit (\$).

For the behavioural analyses, the settlement and credit data were averaged over seasons. The project followed the convention of meteorological seasons, in which spring begins on March 1, summer on June 1, autumn on September 1, and winter on December 1.

2.4.4 Participant surveys

Participants completed seven surveys during the project. All surveys were conducted by the NRC online using a secure server located in Ottawa, Canada. Participants were invited by e-mail to participate, and provided with a 3-week period in which to complete the survey. Reminders were sent weekly to those who had not participated yet. Each participant had a unique access code that was used to match the data across surveys and with the other data sources.

Appendices B.1 through B.7 show the contents of each survey. Table 4 shows the main themes covered by each survey, the dates on which the survey was launched, and the sample size (invited and participated).

Survey questions came from several sources. Basic demographics and dwelling characteristics followed the Statistics Canada Households and the Environment survey (Statistics Canada, 2008), and had been used previously by Pardasani et al. (2018). Thermal comfort was assessed using the ASHRAE thermal sensation scale (ASHRAE, 2023) and the McIntyre thermal preference scale (McIntyre, 1980). Questions about device usability were adapted from Dugar, Donn, & Osterhaus (2013), and had been previously applied to smart thermostats (Pardasani et al. 2018). Some questions about project and utility satisfaction were borrowed from NBP customer surveys and were used in the same format to permit comparisons.

NRC included questions about individual values, normative expectations, and energy-related intentions in order to test the value-beliefs-norms model of environmentally responsible behaviours (Stern, 2000). Values were assessed and classified using the tool developed by Steg et al. (2014). Survey #7 included questions about norms and intentions that were adapted from Dello Russo et al. (2023).

Other questions were developed by the combined NRC-NBP team to ensure that all concepts relevant to the project objectives had been included (e.g., about the importance of having backup electricity in case of an outage). These questions were structured to match other question types and response formats in the surveys.

Table 4. Summary of the seven surveys.

Survey #	Date launched	Date closed	# Invited	# Participated	Participation rate	Principal concepts
1	2019-12-05	2020-03-11	529	505	95.5%	Household composition Thermal comfort & habits Appliances Habits Values (Steg et al. 2014)
2	2021-11-22	2021-12-15	444	340	76.6%	Habits Thermal comfort & habits Thermostat understanding ST ratings TOD perceptions
3	2022-06-27	2022-07-19	436	333	76.4%	update demographics etc., changes to home since Nov 2021 update Values (repeat to update) summer thermal comfort
4	2022-12-08	2023-01-27	404	313	77.5%	Project satisfaction (technology specific) SOL, CC-MSHP satisfaction TOD: understanding shadow report TOD perceptions (repeat survey #2) SOL only: emergency resilience experience (Hurricane Fiona)
5	2023-06-21	2023-07-17	389	297	76.3%	Project feedback Open-ended questions about energy use
6	2023-12-14	2024-01-12	333	258	77.5%	SOL – SEC understanding, satisfaction thermostat usability, setpoints, thermal comfort water heater satisfaction
7	2024-03-11	2024-04-12	331	249	75.2%	primary & secondary heating systems primary cooling system attitudes - energy attitudes - solar TOD (repeat surveys #2 and #4) Feedback on the project

3 Data analysis plans

Data from all sources have been used to produce integrated reports that combine device data with survey data from participants on targeted topics. Table 5 shows a list of all planned reports stemming from this project.

Table 5. The set of reports planned to emerge from the Shediac Residential Energy Study.

Category	Topic area	Data sources	Reference
Research design	Research plan & methods	Project records	This chapter
Background	Review of residential time-varying rate pilot projects and programs: Effects in winter	Literature review	Newsham (2019)
Method	Relational data model for exchange of smart meter data	Smart meter data and SQL database	Pardasani (2025a)
Method	Relational data model for exchange of all other data	WHD, smart thermostats, solar & battery	Pardasani (2025b)
Results	Household energy use characterisation for participating homes WHD results	Smart meter data, monthly bills, Home Assessment Data, NBP Energy Planning Survey, WHD (not DERs days)	Pardasani, Veitch, Hu, Awad, & Cooper (2025b)
Results	Impact of solar and battery technology on the peak reduction and bill savings for TOD and no-TOD groups Solar perceptions & satisfaction including resilience	Solar and battery telemetry, mapping file, surveys Focus limited to homes in the SOL group.	Cooper, Awad, Veitch, Mancini, Galasiu, & Pardasani (2025)
Results	Impact of TOD on no-TECH household energy usage based on difference in differences analysis, TOD attitudes & perceptions including 2023 workshops	Smart meter data, surveys Focus limited to participants without SOL.	Pardasani, Veitch, Hu, Awad, & Cooper (2025c)
Results	Thermostat programming habits for participants in TOD and no-TOD groups and correlation to energy usage & heating system type Thermostat questions from surveys (e.g., usability)	Thermostat telemetry data, smart meter data, surveys All participants included	Pardasani, Veitch, Hu, Cooper, & Szajbely (2025d)
Results	Peak reduction and energy savings from MSHP Survey data from people with other MSHP and the project ones	Smart meter data, mapping files, weather data, surveys Limited to people with MSHP (project or not)	Hu, Pardasani, Veitch, Cooper, & Awad (2025)
Results	Mental models, values, and energy use behaviours, perceptions, attitudes, etc.	Surveys, open-ended data (all participants)	Veitch, Cooper, Pardasani, & Hu (2025)
Results	Project summary	Integrates reports into a summary on the whole project	Pardasani, Veitch, Cooper, & Awad (2025a)

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Appendix A - Home assessments

A.1 Home assessment 1 (HA1)

Home assessors used an Excel spreadsheet with drop-down menus (shown below).


National Research Council Canada
Conseil national de recherches Canada


Energie NB Power

Shediac Smart Energy Community Project - Residential Energy Study

Home Assessment Data Collection Form

This document is to be completed by the site assessor

Customer Name:

Email Address:

Street Address:

Unique ID:

Telephone:

General Dwelling Characteristics

Type of dwelling:

Year of Construction:

Above Grade Storeys:

Have any Energy Efficiency Upgrades been completed on the home?

If yes, check all that apply:

☐ Windows
☐ basement insulation
☐ heating system upgrade

☐ siding
☐ attic insulation
☐ water heater upgrade

☐ air sealing
☐ wall insulation

Were any renovations completed in the past 2 years?

Dimensions

Select closest house shape

☒ Square
☐ Rectangle
☐ L shaped
☐ square/rectangle with jut out
☐ Other

Length

Width

L1

L2

W1

W2

Perimeter

Length

Width

L1

L2

W1

W2

Perimeter

Is there an attached garage?

Is it heated electrically?

Basement:

Type:

Heated electrically?

(Don't forget photos of front and right side of house!)

House Orientation and Roof Characteristics

Roof type: Condition:

orientation of largest roof area: Orientation of largest glazed surface area:

Are there any visible signs of shading? Source:

(please take a photo showing largest roof area if not visible in above photos)

Heating Systems

Primary Heating System Fuel: System Type:

Secondary Heating System: System Type:

When is the secondary heating system used?

If central heating, type of thermostat:

Humidifier: Type: Setpoint:

IF ELECTRIC BASEBOARD ONLY, COMPLETE THE FOLLOWING SECTION:

Room Type	Baseboard length	Type
Master Bedroom	5 ft	non-programmable
Bedroom 2	4 ft	non-programmable
Bedroom 3	4 ft	non-programmable
Bedroom 4	4 ft	non-programmable
Master Bathroom	3 ft	non-programmable
Bathroom 1	2 ft	non-programmable
Bathroom 2	2 ft	non-programmable
Bathroom 3	2 ft	non-programmable
Basement	10 ft	non-programmable
Electrical Room	2 ft	un baseboard
Laundry Room	2 ft	non-programmable
Kitchen	5 ft	non-programmable
Dining Room	4 ft	non-programmable
Dan/office	3 ft	non-programmable
Living Room	6 ft	programmable
Pentry	2 ft	non-programmable
Loft/Attic	3 ft	non-programmable

(Please take photos of heating system(s). If electric baseboard, one will suffice!)

Water Heater

Fuel: Type:

If electric:

NBP rental unit: Age: Gallons:

Cellular Strength near water heater:

(Please take photo of water heater and name plate if accessible)

Electrical Entrance

Location of electrical panel: Panel Type:

Size: amp Make: Model:

2-pole breaker space availability: spot(s) Are there any plugs near the panel?

(Please take photos showing panel, name plates/rating and available spots)

Panel Accessibility - please describe how hard or easy it was to get to the breaker panel

Ex: narrow, winding stair case. Ladder to cellar. Wide, open staircase with few turns.

behind wood pile in garage. Hiding behind newly installed heat pump. Easily accessible in mechanical room/open basement area.

Please provide measurements for each of the following:

Width of staircase: ft Width of doorway to mechanical room/closet: ft

Is there any empty wall space near or around the panel? ft Length: ft Width: ft (please capture in photo)

Internet

Router Location: Ports available:

Service Provider: Type:

Photos

Please confirm you have taken photos of each of the following:

☐ Front of House
☐ Primary Heating
☐ Electrical Panel

☐ Right side
☐ Secondary Heating
☐ Panel name plate

☐ Roof (from ground)
☐ Water Heater
☐ Room where panel is installed

☐ Stairway/access to panel

Comments

Was there something you weren't able to access or document? Please explain why and provide photo evidence

A.g. woodpile blocking access/visibility to water heater, shelf or boxes in the way of electrical panel, dog wouldn't let you into the bedroom to measure baseboards, etc.

Site Assessor Declaration

I visited this site and recorded the information based on my own observations.

Site Assessor Signature: _____ Date: _____

Column1				N		Electric baseboards			electricity
Detached				NE		Central Furnace or Boiler			oil
Duplex or semidetached		Y		E		Central heat pump - air source			natural gas
Townhouse or row house		N		SE		Central heat pump - geo			propane
Mini-home		?		SE		Mini-split			wood/pellet
Other, please specify:				SW		stove(s) /fireplace(s)			
		m		W		Electric radiant heating (floor or ceiling)			
		ft		NW					
Before 1961									
1961-1974									
1975-1984		full height (6-8 ft)			nearby trees				basic, non-programmable
1985-1994		Partial (4-5 ft)			adjacent buildings or structures				programmable
1995-2004		Crawlspace (< 4 ft)							smart thermostat - manufacturer
2005-2009					never				multiple/zoned
After 2010		asphalt shingle			always				
Do not know		wood shingle			only when home				
		rubber shingle			evenings only				central
		metal			mornings only				stand alone
		tile			Weekends				
					holidays			<20%	
					coldest nights of the year			20-30%	
		poor (holes, visible rot or shingles missing)			only if power failure			30-40%	
		okay (possible signs of wear but overall looks okay)						40%+	
		great (no visible issues)							
		snow covered							
Entry		non-programmable			storage tank				
Family Room		programmable			instantaneous		Bell		
Living Room		smart			boiler - indirect or combi		Rogers		
Dining Room		on baseboard					Eastlink		
Kitchen							Primus		
Den/office	< 5	20			2+ bars		Xplornet		
Laundry Room	5-10	40			no/poor signal				
Master Bedroom	10-15	50							
Bedroom 2	15+	60							
Bedroom 3		80				60		DSL/High Speed	
Bedroom 4						100		Cable	
Loft/Attic						200		FibreOp	
Basement						300		Satellite	
Electrical Room	Basement				breaker	400			
Main Bathroom	Mechanical Room				fuse ?				
Bathroom 1	Main floor closet								
Bathroom 2	Garage								
Bathroom 3	Other								
Other					Siemens	0-1			
	Main Floor Living Room				Schneider Electric		2		
	Basement/Family Room				Square D	2+			
	Mechanical Room				Eaton				
	Other				Homeline				
					Leviton				
					Other				
					unknown				

WebID	Primary Fuel	Picture of Front of House
Dwelling Type	Primary Heating System	Picture Of Right House
Construction Year	Secondary Fuel	Picture Of Roof
Total Above Grade Stories	Secondary Heating System	Picture Of Primary Heating
Upgrades Made To House	When is Secondary System Used	Picture Of Secondary Heating
Upgrades To Windows	High Performance Heat Pump Exists	Picture Of Water Heater
Upgrades To Basement	Central Heating Thermostat Type	Picture Of Electrical Panel
Upgrades To Heating System	Humidifier Exists	Picture Of Panel Name Plate
Upgrades To Siding	Humidifier Type	Picture Of Panel Room
Upgrades To Attic	Humidifier Setpoint	Picture Of Entrance To Panel
Upgrades To Water Heater	Water Heater Fuel Type	Comments
Upgrades To Air Sealing	Water Heater Type	
Upgrades To Wall Insulation	Water Heater Is NBP Rental	
Renovations In Last Two Years	Water Heater Age	
House Area	Water Heater Volume	

House Perimeter	Cell Strength near Heater	
House Foot print	Panel Location	
House Area	Panel Type	
Attached Garage Exists	Electrical Panel Amperage	
Attached Garage Electrically Heated	Panel Make	
Basement Exists	Electrical Panel Model	
Basement Type	Electrical Panel Two Pole Breaker Space Available	
Basement Electrically Heated	Electrical Panel Plugs Near Panel	
Roof Type	Electrical Panel Accessibility Comments	
Roof Condition	Electrical Panel Width of Staircase	
Largest Roof Area Orientation	Electrical Panel Width of Doorway	
Largest Glazed Roof Area Orientation	Electrical Panel Empty Nearby Space Length	
Roof Shaded	Electrical Panel Empty Near by Space Width	
Roof Source of Shade	Internet Router Location	
	Internet Router Ports Available	
	Internet Router ISP	
	Internet Router Internet Type	

A.2 Home assessment 2 (HA2)

A.2.1 SOL assessment 2

Commercial references have been removed from this form.

SOL group SITE INSPECTION CHECKLIST - NB POWER	
CUSTOMER NUMBER:	
Yes / No / NA	PHYSICAL & MECHANICAL
	Suitable non-living area for Battery in home maintained between 0-30 Celsius
	Walls and ceiling of proposed Battery location in home are finished (i.e.: not bare studs)
	Suitable non-living area for Battery in heated garage maintained between 0-30 Celsius
	Description of heating system in garage:
	Walls and ceiling of proposed Battery location in garage are finished (i.e.: not bare studs)
	Description of insulation or estimate of insulation value:
	Battery can be installed out driving path and above vehicle bumper height in garage
	Proposed Battery Installation locations are 3 metres from path of egress or entrance/exit doors
	Smoke/fire alarm is installed in proposed Battery installation locations
	Proposed Battery Installation locations unlikely to experience flooding
	Suitable anchors for mounting Battery have been identified
	All equipment can be safely transported from driveway to the installation area(s)
	Doorways, hallways, stairwells, turns, ceiling heights have adequate clearances for equipment
	Description of any deficiencies: NONE
	Stairs and floors along access route are structurally sound to accommodate the weight of all equipment
	Description of any deficiencies: NONE
	Requirements for door frame, floor and wall protection have been identified
	Adequate wall space for Gateway, solar inverter and other supporting hardware near main electrical panel
	Cable/conduit entry and exit points have been determined for each piece of equipment
	Adequate space available to work around equipment in the installation area(s)
	Adequate space beside the utility meter for Battery and solar disconnects has been identified
	Safe access route onto roof has been identified
	Adequate south/east/west facing roof area free from shade and obstructions is available for solar
	Roof pitch is acceptable
	Roof decking, trusses and rafters are in good condition
	Description of any deficiencies: POOR SHINGLES
	Roof measurements have been recorded and set-backs have been accounted for
	Appropriate anchor points for mounting system have been identified and measured
	Additional material and labour requirements have been identified and accounted for
Yes / No / NA	ELECTRICAL & COMMUNICATIONS
	Strong Wi-Fi signal at proposed Gateway location
	Strong cellular signal at proposed Gateway location
	Primary internet modem can be hardwired to the Gateway
	Adequate space for CT's in the main panel/backup panel/generator transfer switch
	Length of cable runs between equipment will fall within maximum allowable range
	Generator transfer switch on site
	Additional material and labour requirements have been identified and accounted for
Yes / No / NA	SUPPORTING DOCUMENTATION
	Picture(s) of all relevant electrical service panels on the property with doors open and breaker sizes in focus
	Picture(s) of proposed installation area for Battery in home
	Picture(s) of proposed installation area for Battery in garage/outbuilding
	Picture(s) of proposed installation area for Gateway, solar inverter and supporting hardware
	Picture(s) of proposed installation area for solar panels
	Battery SLD Template complete
	Solar layout/design complete

A.2.2 Thermal storage assessment 2

TS Home Assessment (2021)  The survey will take approximately 7 minutes to complete. * Required 1. WebID: * 2. Were there heat pumps installed since initial assessment? * ☐ Yes ☐ No 3. Type of Heat Pump * ☐ Ducted (Central) ☐ Ductless (Single head) ☐ Ductless (Multihead) 4. What is the capacity of the heat pump(s) in BTU? * 5. Electrical Service - Panel Type * ☐ Fuse Box ☐ Breaker Panel 6. Is there space for a double pole breaker? * ☐ Yes ☐ No	7. Electrical Service - Rating (in Amps): * ☐ 60A ☐ 100A ☐ 125A ☐ 200A ☐ Other 8. What is the wifi signal strength (in dB)? * 9. What is the name of the most appropriate room for a heat pump installation? * 10. How is this area currently heated? * ☐ Electrical baseboard heating ☐ Central air ☐ Biomass ☐ Other 11. How is the current heating system controlled? * 12. Describe the selected area: shape; windows; doors, openings, etc.? * 13. What is the approximate zone length (m)? *

14. What is the approximate zone width (m)? *

15. Describe the selected installation wall? *

☐ Interior

☐ Exterior

16. Does the installation require a condensate pump? *

☐ Yes

☐ No

17. Results of assessment *

☐ Compatible

☐ Compatible WITH Conditions

☐ Not Compatible

18. Summary of Assessment

19. Installation Notes *

Appendix B - Surveys

All surveys were presented in the participant's preferred language (English or French). Only the English versions are shown here. The French translations are available on request.

Some questions were presented in a reverse-coded direction. The presentation here shows the coding as it was used for analysis. Questions for which coding was presented in the reverse direction are marked.

The scale definitions for values and clothing insulation (CLO) are included here. Scales developed as part of the project are defined in Veitch et al. (2025).

B.1 Survey #1 – December 2019

Question	Scale
Access Code	
How long have you lived in this dwelling?	Years
How long have you lived in this dwelling?	Months
Who lives in this dwelling? Please select the sex of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=Male 2=Female 3=Prefer not to say
Who lives in this dwelling? Please select the age of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=0-10 2=11-20 3=21-30 4=31-40 5=41-50 6=51-60 7=61-70 8=71-80 9=81+ 10=Prefer not to say
Have there been any changes to the occupancy of the house during the past two years?	0=No 1=Yes, please tell us what changed
Have there been any changes to the occupancy of the house during the past two years? Yes, please tell us what changed:	open-ended
On a regular workday, when are people in the dwelling?	1=Someone is home all the time 2=Someone is home for part of the workday 3=Everyone leaves after breakfast and returns after the workday
What is your best estimate of the total household income received by all household members from all sources, before taxes and deductions, during the last 12 months?	1=Less than \$20,000 (includes income loss) 2=\$20,000 to less than \$40,000 3=\$40,000 to less than \$60,000 4=\$60,000 to less than \$80,000 5=\$80,000 to less than \$100,000 6=\$100,000 to less than \$150,000 7=\$150,000 and over 8=Don't know
Please rate your typical thermal sensation in the winter at home:	-3=Cold -2=Cool -1=Slightly cool 0=Neutral 1=Slightly warm 2=Warm 3=Hot

Question	Scale
In general, in the winter at home I would like to feel...	-1=Cooler 0=No change 1=Warmer
How often do you take the following actions to improve your thermal comfort at home during the winter? <i>Have a hot or cold drink</i> <i>Use a portable heater</i> <i>Use a portable fan</i> <i>Change the thermostat</i> <i>Add or remove a layer of clothing</i> <i>Open or close the window</i>	1=Never 2=Once per month 3=2-4 times per month 4=Once per week 5=2-4 times per week 6=At least once per day 7=Several times per day 8=Not an option for me
Please give us details about other actions you may take to improve your thermal comfort:	open-ended
Please select the clothes usually worn by you and members of your family at home in the winter:	0=no 1=yes
 ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐	CLO=SUM ((Pyjama*.57), (House Coat*.69), (Long Sleeve Underwear Top*.20), (Long Underwear Bottom*.15), (Briefs*.035), (Camisole*.06), (T-shirt*.08), (Short Sleeve Shirt*.19), (Long Sleeve Shirt*.25), (Sweater*.36), (Jacket*.36), (Coat*.44), (Pants*.195), (Shorts*.155), (Socks*.02), (Slippers*.03), (Sandals*.02), (Sneakers*.025), (Boots*.10)). Could you please rate how important each value is for you AS A GUIDING PRINCIPLE IN YOUR LIFE? EQUALITY: equal opportunity for all RESPECTING THE EARTH: harmony with other species SOCIAL POWER: control over others, dominance PLEASURE: joy, gratification of desires UNITY WITH NATURE: fitting into nature A WORLD AT PEACE: free of war and conflict WEALTH: material possessions, money
	-1=Opposed to my values 0=Not important 1=Important (1) 2=Important (2) 3=Important (3) 4=Important (4) 5=Important (5) 6=Very important 7=Of supreme Importance

Question	Scale
AUTHORITY: the right to lead or command SOCIAL JUSTICE: correcting injustice, care for the weak ENJOYING LIFE: enjoying food, sex, leisure, etc. PROTECTING THE ENVIRONMENT: preserving nature INFLUENTIAL: having an impact on people and events HELPFUL: working for the welfare of others PREVENTING POLLUTION: protecting natural resources SELF-INDULGENT: doing pleasant things AMBITIOUS: hard working, aspiring	HEDONIC=MEAN (Pleasure, LifeJoy, Indulge). EGOISTIC=MEAN (SoPower, Wealth, Authority, Influence, Ambition). ALTRUISTIC=MEAN (Equality, Peace, SoJust, Helpful). BIOSPHERIC=MEAN (Nature, Respect, ProEnvir, PrevPoll).
How do you control your current thermostat?	1=I program my thermostat with different set points and schedules 2=I manually change the settings throughout the season depending on my schedule and the weather 3=I use a single set point throughout the season
Thermostat set point during winter: At home and awake Thermostat set point during summer for air conditioning: At home and awake Thermostat set point during winter: Away from home Thermostat set point during summer for air conditioning: Away from home Thermostat set point during winter: While sleeping Thermostat set point during summer for air conditioning: While sleeping	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 22=Other
How do you decide what temperature to set your thermostat to?	1=Based on comfort 2=Based on utility bill
Please indicate how old your major appliances are: Primary refrigerator Electric range Dishwasher Separate freezer Clothes washer Clothes dryer Secondary refrigerator	1=0-5 years 2=6-10 years 3=10+ years 4=Don't have 5=Don't know
Please indicate if your major appliances are ENERGY STAR certified: Primary refrigerator Electric range Dishwasher Separate freezer Clothes washer Clothes dryer Secondary refrigerator	1=Yes 2=No 3=Don't know 4=Not applicable

Question	Scale
Please indicate how many times per week you do the following in your home: Laundry loads	open-ended
Laundry loads: Usual wash water temperature	1=Hot 2=Warm 3=Cold
Please indicate how many times per week you do the following in your home: Dryer loads	open-ended
Dryer loads: Usual air temperature	1=Hot 2=Medium 3=Low heat 4=No heat
Please indicate if you own, and how many times per week you use, the following in your home: Electric fire place Electric fire place: Times per week Hot tub Hot tub: Times per week Automobile block heater Automobile block heater: Times per week Portable electric heater Portable electric heater: Times per week	1=yes 0=no Times per week: open-ended

B.2 Survey #2 – November 2021

Question	Scale
Access Code	
Have there been any changes to the number of people living in this home since January 2020?	0=No 1=Yes, please specify:
Have there been any changes to the number of people living in this home since January 2020? Yes, please specify	open-ended
On a regular workday, when are people in the dwelling?	1=Someone is home all the time 2=Someone is home for part of the workday 3=Everyone leaves after breakfast and returns after the workday
Has the daily pattern of people being at home changed during the pandemic?	1=More people are at home due to pandemic (work or school) 2=Only minor changes (working part time, or temporary changes but now back to normal) 3=No change in occupancy due to pandemic 4=Other, please specify:
Has the daily pattern of people being at home changed during the pandemic? Other, please specify	open-ended
If you have school-age children, do they attend in-person school, or virtual school?	0=I do not have school-age children 1=Full time in-person school 2=Half time at home, half time in school 3=Full time at-home virtual schooling
What is your best estimate of the total household income received by all household members from all sources, before taxes and deductions, during the last 12 months?	1=Less than \$20,000 (includes income loss) 2=\$20,000 to less than \$40,000 3=\$40,000 to less than \$60,000 4=\$60,000 to less than \$80,000 5=\$80,000 to less than \$100,000 6=\$100,000 to less than \$150,000 7=\$150,000 and over 8=Don't know

Question	Scale
Who in your household completed a survey for this investigation previously?	1=I personally completed the first survey 2=Someone else completed the first survey 3=No one in our house completed the first survey
What is your sex?	0=Male 1=Female 2=Prefer not to answer
In what age group are you?	1=18 to 30 2=31 to 40 3=41 to 50 4=51 to 60 5=Older than 60
Please rate your typical thermal sensation at home, in general, during the past month:	-3=Cold -2=Cool -1=Slightly Cool 0=Neutral 1=Slightly Warm 2=Warm 3=Hot
In general, during the past month at home I have wanted to feel...	-1=Cooler 0=No Change 1=Warmer
Have there been any changes in the ways you use energy at home because of the pandemic?	0=No 1=Yes 2=Not sure
What has changed? Check all that apply. <i>Increased use of heating /air-conditioning</i> <i>Increase in light use</i> <i>Increase in laundry-dryer loads</i> <i>Only minimal changes (cooking times, TV times, etc.)</i> <i>Other, please specify</i>	1=selected 0=not selected
What has changed? Check all that apply. Specify	open-ended
Did you purchase any new appliances or technologies for your home or garden in the last year? (Not including any technologies installed for the Shediak Residential Energy Study)	1=Yes 0=No
Which appliances/technologies did you purchase and when did you start using this new appliance or technology? <i>Electric vehicle</i> <i>Fireplace</i> <i>Hot tub</i> <i>Swimming pool</i> <i>Fridge</i> <i>Separate freezer</i> <i>Minibar</i> <i>Heat pump</i> <i>Air purifier</i> <i>Air conditioning</i> <i>Television</i> <i>Other</i>	0=Did not purchase 1=Not in use yet 2=In last 2 weeks 3=Last month 4=Last 6 months 5=A year ago
Which appliances/technologies did you purchase and when did you start using this new appliance or technology? Specify	open-ended
Avoiding the need for new electrical generating stations is important to me.	0=Strongly disagree 1=Disagree
It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is reliable for everyone.	2=Neither agree nor disagree 3=Agree
Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	4=Strongly agree

Question	Scale
How satisfied are you with the contact you had with NB Power at the time you signed up for the research project?	
How satisfied are you with the site assessor who visited your house to qualify your home to participate in this research project?	
Have you felt that you had to change your household routine in any way in order to participate in the research project?	1=Yes 0=No
Overall, how do you feel about your participation in this research project?	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Strongly satisfied
Please describe how your household heating system works. Explain how your heating system keeps your home comfortable and how the thermostat affects the temperature in your home.	open-ended
What type of thermostat do you currently have in your home?	0=I don't have a thermostat 1=I have a manual thermostat 2=I have a programmable thermostat 3=I have an internet-connected smart thermostat 4=I am expecting to receive an internet-connected smart thermostat from NB Power in this project, but it is not yet installed 5=I don't know
Please select the most important objective in your use of a thermostat:	1=I care about how energy use affects the environment 2=I want to feel comfortable 3=I want to save money on my energy bills 4=Not sure
When I feel too cold, I turn up the thermostat and the heat comes on until it reaches the new temperature; then it turns off.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
When I set a new temperature, the higher I set it, the faster the house heats up.	
I turn down the thermostat before I have a big crowd over to visit, so it doesn't get too hot when they are here.	
When I set a lower temperature on the thermostat, the heat doesn't come on until the temperature drops to the new setting.	
I keep my thermostats at the same setting always because it uses more energy to reheat the house than it would to keep it at one temperature.	
We'd like to know about your familiarity with features of your current thermostats. Please select the circle (radio button) that best describes your opinion of the thermostats.	0=I do not know how to change setting options manually on my thermostats. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I can easily change setting options manually on my thermostats.

Question	Scale
	0=I cannot/don't know how to program my thermostats directly on the thermostat (e.g., rather than using the web interface). 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I can easily program my thermostats directly on the thermostat (e.g., without using a computer for the web interface).
	0=I don't use my thermostat's user guide. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I use my thermostat's user guide.
	0=I am the only one who adjusts thermostat settings. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=All the people in the household adjust thermostat settings.
	0=I switch off my thermostat on a daily or weekly basis (turning off heating or cooling system). 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I almost never switch off my thermostat (turning off heating or cooling system).

Question	Scale
We'd like to know about your familiarity with features of your current thermostats. Please select the circle (radio button) that best describes your opinion of the thermostats.	0=I can easily program my smart thermostats using a web interface. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I cannot/don't know how to program my smart thermostats using a web interface.
	0=I fully understand the meaning of the icons, symbols and abbreviations shown on the thermostat displays and the web interface. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I don't know/don't understand the meaning of the icons, symbols and abbreviations shown on the thermostat displays and the web interface.
How satisfied are you with the electrician who installed the equipment for this research project?	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Strongly satisfied
Would you recommend these thermostats to other people?	1=Yes 0=No
We'd like to know about your satisfaction with the smart thermostats that were installed for this project. Please select the circle (radio button) that best describes your opinion of the thermostats.	0= Does not look like a temperature control 1= 2= 3= 4= 5= 6= 7= 8= 9= 10= Looks like a temperature control ► Reverse coded

Question	Scale
	0= Does not look attractive 1= 2= 3= 4= 5= 6= 7= 8= 9= 10= Looks attractive ► Reverse coded
	0=Difficult to use 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Easy to use
	0=Very inaccurate 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Very accurate
	0=Very slow to react 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Very quick to react
	0=Very difficult to learn 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Very easy to learn

Question	Scale
Our house has felt comfortable since the smart thermostats were installed.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
In your opinion, what do you think your biggest energy consumption devices are in your home? Please select the top three: <i>Refrigerator</i> <i>Electric range</i> <i>Dishwasher</i> <i>Separate freezer</i> <i>Clothes washer</i> <i>Clothes dryer</i> <i>Fireplace</i> <i>Hot tub</i> <i>Swimming pool</i> <i>Electric vehicle</i> <i>Minibar</i> <i>Heat pump</i> <i>Air purifier</i> <i>Air conditioning</i> <i>TV</i> <i>Personal electronics</i> <i>Lighting</i> <i>Electric baseboard heaters</i> <i>Central electric furnace</i> <i>Other, please specify</i>	1=selected 0=not selected
In your opinion, what do you think your biggest energy consumption devices are in your home? Please select the top three: Specify	open-ended
What is your approximate monthly electricity consumption (kWh) in the winter?	1=Below 1,000 kWh 2=1,000-3,000 kWh 3=3,001-5,000 kWh 4=Over 5,000 kWh 5=Don't know
What is your approximate monthly electricity consumption (kWh) in the summer?	1=Below 200 kWh 2=200-600 kWh 3=601-1,000 kWh 4=Over 1,000 kWh 5=Don't know
How much attention do you usually pay to your electricity bill?	1=I have a full understanding of my electricity bill 2=I can find what I am looking for 3=I don't know what some numbers mean 4= I don't know where or how to review my electricity bills 5=I don't pay any attention to my electricity bill
Please indicate when are you most likely to do: Laundry loads	1=Morning (5am-9am)
Please indicate when are you most likely to do: Dryer loads	2=During the day (10am-3pm) 3=Evening (4pm-8pm) 4=Night time (9pm-11pm) 5=Not sure 6=Other

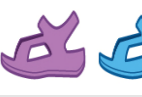
Question	Scale
Please indicate how many times per week do you usually use: <i>Electric fireplace</i> <i>Hot tub</i> <i>Automotive block heater</i> <i>Portable electric heater</i> <i>Swimming pool</i> <i>Electric vehicle</i> <i>Air purifier</i>	1=Every day 2=2-4 times a week 3=Once a week 4=2-4 times a month 5=Once a month 6=Not sure 7=Never
When do you think your peak usage happens during the day?	1=Morning (6am–9am) 2=Midday (9am–2pm) 3=Afternoon (2pm–5pm) 4=Evening (5pm–10pm) 5=Night time (10pm–6am) 6=Other, please specify
When do you think your peak usage happens during the day?	open-ended
What is your current knowledge of time-of-day pricing?	4=I believe that I am extremely knowledgeable about time-of-day pricing 3=I believe that I am moderately knowledgeable about time-of-day pricing 2=I believe that I am somewhat knowledgeable about time-of-day pricing 1=I believe that I am slightly knowledgeable about time-of-day pricing 0=I believe that I am not at all knowledgeable about time-of-day pricing
What do you think the main benefits of time-of-day rates might be? Please select the top two: <i>Lower electricity bill for some consumers</i> <i>Reduced energy consumption</i> <i>Environmental benefits</i> <i>More revenue for the utility</i> <i>Other, please specify:</i>	1=selected 0=not selected
What do you think the main benefits of time-of-day rates might be? Please select the top two: Specify	open-ended
If time-of-day rates applied to you, do you think you would take advantage of them?	0=No 1=Yes 2=Not sure
How much do you think you could save on energy consumption if you were being charged time-of-day rates for the electricity you use?	0=No saving at all 1=1-4% saving 2=5-7% saving 3=8-10% saving 4=More than 10% saving 5=Not sure 6=Other
Which action do you think you can do to move your energy consumption from peak time to off-peak time? Please select the top three that would apply to you: <i>Do laundry in the evening/night</i> <i>Run the dishwasher in the evenings</i> <i>Turn off lights</i> <i>Turn off appliances when not in use</i> <i>Set thermostat to lower temperatures overnight</i> <i>Pre-heat the house early in the morning before peak time</i> <i>Other, please specify:</i>	1=selected 0=not selected
Which action do you think you can do to move your energy consumption from peak time to off-peak time? Please select the top three that would apply to you: Specify	open-ended

Question	Scale
How often do you think you will be able to adopt energy efficient behaviours/actions to get full advantage of time-of-day rates?	1=Every day 2=2-4 times a week 3=Once a week 4=2-4 times a month 5=Once a month 6=Not sure 7=I don't think I will be able to change my energy behaviours

B.3 Survey #3 – June 2022

Question	Scale
Access Code	
How long have you lived in this dwelling?	Years
How long have you lived in this dwelling?	Months
Who lives in this dwelling? Please select the sex of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=Male 2=Female 3=Prefer not to say
Who lives in this dwelling? Please select the age of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=0-10 2=11-20 3=21-30 4=31-40 5=41-50 6=51-60 7=61-70 8=71-80 9=81+ 10=Prefer not to say
What is your best estimate of the total household income received by all household members from all sources, before taxes and deductions, during the last 12 months?	1=Less than \$20,000 (includes income loss) 2=\$20,000 to less than \$40,000 3=\$40,000 to less than \$60,000 4=\$60,000 to less than \$80,000 5=\$80,000 to less than \$100,000 6=\$100,000 to less than \$150,000 7=\$150,000 and over 8=Don't know
Who in your household completed a survey for this investigation previously?	1=I personally completed the previous surveys 2=Someone else completed the other surveys 3=No one in our house completed the other surveys 4=Different people completed the different surveys
Have there been any changes to the number of people living in this home since November 2021?	0=No 1=Yes, please specify
Have there been any changes to the occupancy of the house since November 2021? Yes, please tell us what changed:	open-ended
On a regular workday, when are people in the dwelling?	1=Someone is home all the time 2=Someone is home for part of the workday 3=Everyone leaves after breakfast and returns after the workday

Question	Scale
Has the daily pattern of people being at home changed since November 2021?	1=More people are at home due to pandemic (work or school) 2=Only minor changes (working part time, or few weeks/months and then back to normal) 3=No change in occupancy due to pandemic 4=Other, please specify:
Has the daily pattern of people being at home changed since November 2021? Other, please specify	open-ended
If you have school-age children, do they attend in-person school, or virtual school?	0=I do not have school-age children 1=Full time in-person school 2=Half time at home, half time in school 3=Full time at-home virtual schooling 4=Full time home schooling
Have there been any changes in the ways you use energy at home since November 2021?	0=No 1=Yes 2=Not sure
What has changed? Check all that apply. <i>Increased use of heating /air-conditioning</i> <i>Increase in light use</i> <i>Increase in laundry-dryer loads</i> <i>Only minimal changes (cooking times, TV times, etc.)</i> <i>Other, please specify</i>	1=selected 0=not selected
What has changed? Check all that apply. Specify	open-ended
Did you purchase any new appliances or technologies for your home or garden since November 2021? (Not including any technologies installed for the Shediak Residential Energy Study)	1=Yes 0=No
Which appliances/technologies did you purchase and when did you start using this new appliance or technology? <i>Electric vehicle</i> <i>Fireplace</i> <i>Hot tub</i> <i>Swimming pool</i> <i>Fridge</i> <i>Separate freezer</i> <i>Minibar</i> <i>Heat pump</i> <i>Air purifier</i> <i>Air conditioning</i> <i>Television</i> <i>Other</i>	0=Did not purchase 1=Not in use yet 2=In last 2 weeks 3=Last month 4=Last 6 months 5=A year ago
Which appliances/technologies did you purchase and when did you start using this new appliance or technology? Specify	open-ended
Please rate your typical thermal sensation in the summer at home:	-3=Cold -2=Cool -1=Slightly cool 0=Neutral 1=Slightly warm 2=Warm 3=Hot
In general, in the summer at home I would like to feel...	-1=Cooler 0=No change 1=Warmer

Question	Scale
How often do you take the following actions to improve your thermal comfort at home during the summer? <i>Have a hot or cold drink</i> <i>Use a portable heater</i> <i>Use a portable fan</i> <i>Change the thermostat</i> <i>Add or remove a layer of clothing</i> <i>Open or close the window</i> <i>Adjust a window blind or curtain</i>	1=Never 2=Once per month 3=2-4 times per month 4=Once per week 5=2-4 times per week 6=At least once per day 7=Several times per day 8=Not an option for me
Please give us details about other actions you may take to improve your thermal comfort:	open-box
Please select the clothes usually worn by you and members of your family at home in the summer:	0=no 1=yes
 ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐	
CLO =SUM ((Pyjama*.57), (House Coat*.69), (Long Sleeved Underwear Top*.20), (Long Underwear Bottom*.15), (Briefs*.035), (Camisole*.06), (T-shirt*.08), (Short Sleeved Shirt*.19), (Long Sleeved Shirt*.25), (Sweater*.36), (Jacket*.36), (Coat*.44), (Pants*.195), (Shorts*.155), (Socks*.02), (Slippers*.03), (Sandals*.02), (Sneakers*.025), (Boots*.10)).	
Could you please rate how important each value is for you AS A GUIDING PRINCIPLE IN YOUR LIFE? <i>EQUALITY: equal opportunity for all</i> <i>RESPECTING THE EARTH: harmony with other species</i> <i>SOCIAL POWER: control over others, dominance</i> <i>PLEASURE: joy, gratification of desires</i> <i>UNITY WITH NATURE: fitting into nature</i> <i>A WORLD AT PEACE: free of war and conflict</i> <i>WEALTH: material possessions, money</i>	-1=Opposed to my values 0=Not important 1=Important (1) 2=Important (2) 3=Important (3) 4=Important (4) 5=Important (5) 6=Very important 7=Of supreme Importance

Question	Scale
AUTHORITY: the right to lead or command SOCIAL JUSTICE: correcting injustice, care for the weak ENJOYING LIFE: enjoying food, sex, leisure, etc. PROTECTING THE ENVIRONMENT: preserving nature INFLUENTIAL: having an impact on people and events HELPFUL: working for the welfare of others PREVENTING POLLUTION: protecting natural resources SELF-INDULGENT: doing pleasant things AMBITIOUS: hard working, aspiring	HEDONIC=MEAN (Pleasure, LifeJoy, Indulge). EGOISTIC=MEAN (SoPower, Wealth, Authority, Influen, Ambition). ALTRUISTIC=MEAN (Equality, Peace, SoJust, Helpful). BIOSPHERIC=MEAN (Nature, Respect, ProEnvir, PrevPoll).
How do you control your current thermostat?	1=I program my thermostat with different set points and schedules 2=I manually change the settings throughout the season depending on my schedule and the weather 3=I use a single set point throughout the season
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during winter:	1=10 °C
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during summer for air conditioning (if any):	2=11 °C
Please tell us the setpoints for your thermostat when you are: Away from home: Set point during winter:	3=12 °C
Please tell us the setpoints for your thermostat when you are: Away from home: Set point during summer for air conditioning (if any):	4=13 °C
Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during winter:	5=14 °C
Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during summer for air conditioning (if any):	6=15 °C
	7=16 °C
	8=17 °C
	9=18 °C
	10=19 °C
	11=20 °C
	12=21 °C
	13=22 °C
	14=23 °C
	15=24 °C
	16=25 °C
	17=26 °C
	18=27 °C
	19=28 °C
	20=29 °C
	21=30 °C
	22=Other
How do you decide what temperature to set your thermostat to?	1=Based on comfort 2=Based on utility bill

B.4 Survey #4 – December 2022

This survey had six variations. All participants received the core questions. Additional questions were directed at participants based on their research group assignments (SOL, CC-MSHP, and TOD), and for SOL participants, whether or not their system had been commissioned before Hurricane Fiona in September 2022.

B.4.1 Survey #4a: Core + TOD + CC-MSHP and SOL + SOL commissioned before Sept 26 [Hurricane Fiona]

Question	Scale
Access Code	
How long have you lived in this dwelling?	Years
How long have you lived in this dwelling?	Months

Question	Scale
Who lives in this dwelling? Please select the sex of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=Male 2=Female 3=Prefer not to say
Who lives in this dwelling? Please select the age of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=0-10 2=11-20 3=21-30 4=31-40 5=41-50 6=51-60 7=61-70 8=71-80 9=81+ 10=Prefer not to say
What is your best estimate of the total household income received by all household members from all sources, before taxes and deductions, during the last 12 months?	1=Less than \$20,000 (includes income loss) 2=\$20,000 to less than \$40,000 3=\$40,000 to less than \$60,000 4=\$60,000 to less than \$80,000 5=\$80,000 to less than \$100,000 6=\$100,000 to less than \$150,000 7=\$150,000 and over 8=Don't know
Who in your household completed a survey for this investigation previously?	1=I personally completed the previous surveys 2=Someone else completed the other surveys 3=No one in our house completed the other surveys 4=Different people completed the different surveys
Have there been any changes to the number of people living in this home since June 2022?	0=No 1=Yes, please specify
Have there been any changes to the occupancy of the house since June 2022? Yes, please specify:	open-ended
On a regular workday, when are people in the dwelling?	1=Someone is home all the time 2=Someone is home for part of the workday 3=Everyone leaves after breakfast and returns after the workday
If you have school-age children, do they attend in-person school, or virtual school?	0=I do not have school-age children 1=Full time in-person school 2=Half time at home, half time in school 3=Full time at-home virtual schooling 4=Full time home schooling
Have there been any changes in the ways you use energy at home compared to last year at this time?	0=No 1=Yes 2=Not sure
What has changed? Check all that apply. <i>Increased use of heating /air-conditioning.</i> <i>Increase in light use.</i> <i>Increase in laundry-dryer loads.</i> <i>Only minimal changes (cooking times, TV times, etc.).</i> <i>Lower heating setpoint (lower use of heating).</i> <i>Programmed temperature changes.</i> <i>Fewer laundry dryer loads.</i> <i>Using energy at different times of day than before.</i> <i>Other</i>	1=selected 0=not selected
What has changed? Check all that apply. Other, Specify	open-ended

Question	Scale
Which appliances/technologies did you purchase and when did you start using this new appliance or technology? <i>Electric vehicle</i> <i>Fireplace</i> <i>Hot tub</i> <i>Swimming pool</i> <i>2nd Fridge</i> <i>Separate freezer</i> <i>Minibar</i> <i>Heat pump</i> <i>Air purifier</i> <i>Air conditioning</i> <i>Television</i> <i>Water softener</i> <i>Back up generator</i> <i>Solar PV + battery</i> <i>Automobile block heater</i> <i>Portable electric heater</i> <i>Other</i>	0=Do not own 1=Not in use yet 2=Last month 3=Last 6 months 4=Between Jan 2020 and June 2022 5=Before Jan 2020
Which appliances/technologies did you purchase and when did you start using this new appliance or technology? Other, Specify	open-ended
How satisfied are you with the communications with the project team about the project?	0=Very dissatisfied 1=Dissatisfied
Overall, your participation in the Shediac Residential Energy Study?	2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
Have you felt that you had to change your household routine in any way in order to participate in the research project?	1=Yes 0=No
What type of thermostat do you currently have in your home?	0=I don't have a thermostat 1=I have a manual thermostat 2=I have a programmable thermostat 3=I have one (or more) internet-connected smart thermostat(s) 4=I don't know
How do you control your current thermostat?	1=I program my thermostat with different set points and schedules 2=I manually change the settings throughout the season depending on my schedule and the weather 3=I use a single set point throughout the season
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during winter:	1=10 °C 2=11 °C
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during summer for air conditioning (if any):	3=12 °C 4=13 °C 5=14 °C
Please tell us the setpoints for your thermostat when you are: Away from home: Set point during winter:	6=15 °C 7=16 °C
Please tell us the setpoints for your thermostat when you are: Away from home: Set point during summer for air conditioning (if any):	8=17 °C 9=18 °C 10=19 °C
Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during winter:	11=20 °C 12=21 °C

Question	Scale
Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during summer for air conditioning (if any):	13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 22=Other
How do you decide what temperature to set your thermostat to?	1=Based on comfort 2=Based on utility bill
Please select the most important objective in your use of a thermostat:	1=I care about how energy use affects the environment 2=I want to feel comfortable 3=I want to save money on my energy bills 4=Not sure
Avoiding the need for new electrical generating stations is important to me.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is reliable for everyone.	
Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	
It is acceptable for utilities to adjust individual customer electrical demand to deliver the least costly electricity supply for everyone.	
Please indicate your agreement or disagreement with the statements below. When I feel too cold, I turn up the thermostat and the heat comes on until it reaches the new temperature; then it turns off.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree 5=Not applicable
Please indicate your agreement or disagreement with the statements below. When I set a new temperature, the higher I set it, the faster the house heats up.	
Please indicate your agreement or disagreement with the statements below. I turn down the thermostat before I have a big crowd over to visit, so it doesn't get too hot when they are here.	
Please indicate your agreement or disagreement with the statements below. When I set a lower temperature on the thermostat, the heat doesn't come on until the temperature drops to the new setting.	
Please indicate your agreement or disagreement with the statements below. I keep my thermostats at the same setting always because it uses more energy to reheat the house than it would to keep it at one temperature.	

Question	Scale
We'd like to know about your familiarity with features of your current thermostats. Please select the circle (radio button) that best describes your opinion of the thermostats.	0=I do not know how to change setting options manually on my thermostats. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I can easily change setting options manually on my thermostats.
	0=I don't use my thermostat's user guide. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I use my thermostat's user guide.
	0=I am the only one who adjusts thermostat settings. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=All the people in the household adjust thermostat settings.
	0=I switch off my thermostat on a daily or weekly basis (turning off heating or cooling system). 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I almost never switch off my thermostat (turning off heating or cooling system).

Question	Scale
	0=I have smart thermostats, but I cannot/don't know how to program my thermostats directly on the thermostat (e.g., rather than using the web interface). 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I have smart thermostats, and I can easily program my thermostats directly on the thermostat (e.g., without using a computer for the web interface). 0=I fully understand the meaning of the icons, symbols and abbreviations shown on the thermostat displays and the web interface. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I don't know/don't understand the meaning of the icons, symbols and abbreviations shown on the thermostat displays and the web interface. 0=I can easily program my smart thermostats using a web interface. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I cannot/don't know how to program my smart thermostats using a web interface.
In your own words, what do you think is the most efficient way to operate your heating system?	open-ended
What is your priority for using your heating system?	0=Being comfortable is my top priority 1=Saving energy is my top priority 2=Keeping my NB Power bills low is my top priority 3=I try to balance efficiency and comfort 4=I don't know

Question	Scale
In your opinion, what do you think your biggest energy consumption devices are in your home? Please rank the top three, with #1 consuming the most energy:	1=Air conditioning 2=Air purifier 3=Automobile block heater 4=Clothes dryer 5=Clothes washer 6=Dishwasher 7=Heating system 8=Electric range 9=Electric vehicle 10=Fireplace 11=Hot tub 12=Lighting 13=Minibar 14=Personal electronics 15=Refrigerator 16=Separate freezer or second fridge 17=Swimming pool 18=TV 19=Other 20=Water heater
Please specify which 'Other' device you ranked among the top three energy consumption devices in your home:	open-ended
What is your approximate monthly electricity consumption (kWh) in the winter?	1=Below 1,000 kWh 2=1,000-3,000 kWh 3=3,001-5,000 kWh 4=Over 5,000 kWh 5=Don't know
What is your approximate monthly electricity consumption (kWh) in the summer?	1=Below 200 kWh 2=200-600 kWh 3=601-1,000 kWh 4=Over 1,000 kWh 5=Don't know
How much attention do you usually pay to your electricity bill?	1=I have a full understanding of my electricity bill 2=I can find what I am looking for 3=I don't know what some numbers mean 4= I don't know where or how to review my electricity bills 5=I don't pay any attention to my electricity bill
Please indicate when are you most likely to do: Laundry loads	1=Morning (5am-9am) 2=During the day (10am-3pm)
Please indicate when are you most likely to do: Dryer loads	3=Evening (4pm-8pm) 4=Night time (9pm-11pm) 5=Not sure 6=Other
Please indicate how many times per week do you usually use: <i>Electric fireplace</i> <i>Hot tub</i> <i>Automotive block heater</i> <i>Portable electric heater</i> <i>Swimming pool</i> <i>Electric vehicle</i> <i>Air purifier</i>	1=Every day 2=2-4 times a week 3=Once a week 4=2-4 times a month 5=Once a month 6=Not sure 7=Never

Question	Scale
When do you think your peak usage happens during the day?	1=Morning (6am–9am) 2=Midday (9am–2pm) 3=Afternoon (2pm–5pm) 4=Evening (5pm–10pm) 5=Night time (10pm–6am) 6=Other, please specify
When do you think your peak usage happens during the day?	open-ended
What is your current knowledge of time-of-day pricing?	4=I believe that I am extremely knowledgeable about time-of-day pricing 3=I believe that I am moderately knowledgeable about time-of-day pricing 2=I believe that I am somewhat knowledgeable about time-of-day pricing 1=I believe that I am slightly knowledgeable about time-of-day pricing 0=I believe that I am not at all knowledgeable about time-of-day pricing
What do you think the main benefits of time-of-day rates might be? Please select the top two: Lower electricity bill for some consumers	1=selected 0=not selected
What do you think the main benefits of time-of-day rates might be? Please select the top two: Reduced energy consumption	
What do you think the main benefits of time-of-day rates might be? Please select the top two: Environmental benefits	
What do you think the main benefits of time-of-day rates might be? Please select the top two: More revenue for the utility	
What do you think the main benefits of time-of-day rates might be? Please select the top two: Other, please specify:	
What do you think the main benefits of time-of-day rates might be? Please select the top two: Specify	open-ended
Do you visit your Shediac Project Energy Portal to view your electricity consumption?	0=No 1=Yes 2=I don't know what that is
You are in the Time-of-Day Rates group in this project. Do you try to take advantage of them?	0=No 1=Yes 2=Not sure
How much do you believe you save on your energy bill because of the time-of-day credit on your NB Power bill?	0=No saving at all 1=1-4% saving 2=5-7% saving 3=8-10% saving 4=More than 10% saving 5=Not sure 6=Other
Which actions do you try to use to move your energy consumption from peak time to off-peak time? Please select the top three that would apply to you: <i>Do laundry in the evening/night</i> <i>Run the dishwasher in the evenings</i> <i>Turn off lights</i> <i>Turn off appliances when not in use</i> <i>Set thermostat to lower temperatures overnight</i> <i>Hang your clothes to dry instead of using a clothes dryer</i> <i>Pre-heat the house early in the morning before peak time</i> <i>Other, please specify:</i>	1=selected 0=not selected

Question	Scale
Which actions do you try to use to move your energy consumption from peak time to off-peak time? Please select the top three that would apply to you: Specify	open-ended
How often do you think you will be able to adopt energy efficient behaviours/actions to get full advantage of time-of-day rates?	1=Every day 2=2-4 times a week 3=Once a week 4=2-4 times a month 5=Once a month 6=Not sure 7=I don't think I will be able to change my energy behaviours
Have you viewed or downloaded your Shadow Report from the Shediak Energy Portal to see your Time-of-Day energy use each month?	0=No 1=Yes 2=I don't know what that is
How satisfied are you with...The Time-of-Day Rates brochure you received in the mail in spring 2022.	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
How satisfied are you with...Information about how to change your daily pattern of energy use, downloadable from your Participant Landing Page.	
How satisfied are you with...The information about your Time of Day credit on your Shadow Report.	
How satisfied are you with...The information you received about the technology offer when it was first presented to you?	
How satisfied are you with...The installer who came to your house to install technology for this project?	
How satisfied are you with...The performance of the technology that has been installed?	
How satisfied are you with...The information provided to you about your technology when it was installed?	
How satisfied are you with...Communications with the Shediak Project Team about any issues with your technology?	
Would you recommend this technology to others?	0=No 1=Yes
Please tell us what you like or don't like about the technology you received in this project:	open-ended
During Tropical Storm Fiona, did you experience a power outage?	0=No 1=Yes
During Tropical Storm Fiona, did you notice that the energy storage battery provided power in your home?	0=No 1=Yes
Before and during Tropical Storm Fiona, were you reassured because you had the energy storage battery to provide backup power?	0=I was not reassured at all by having the energy storage battery. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I was very reassured by having the energy storage battery.

Question	Scale
What is your opinion of the availability of back-up power from the energy storage battery?	0=I don't care about it 1=It's nice to have it, but I already had a generator 2=It is a helpful addition but doesn't provide enough power to meet my needs 3=I'm completely happy with the available back-up power in the event of an outage

B.4.2 Survey #4b: Core + No-TOD + CC-MSHP and SOL+ SOL commissioned before Sept 26 [Hurricane Fiona]

Question	Scale
Access code	
How long have you lived in this dwelling?	Years
How long have you lived in this dwelling?	Months
Who lives in this dwelling? Please select the sex of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=Male 2=Female 3=Prefer not to say
Who lives in this dwelling? Please select the age of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=0-10 2=11-20 3=21-30 4=31-40 5=41-50 6=51-60 7=61-70 8=71-80 9=81+ 10=Prefer not to say
What is your best estimate of the total household income received by all household members from all sources, before taxes and deductions, during the last 12 months?	1=Less than \$20,000 (includes income loss) 2=\$20,000 to less than \$40,000 3=\$40,000 to less than \$60,000 4=\$60,000 to less than \$80,000 5=\$80,000 to less than \$100,000 6=\$100,000 to less than \$150,000 7=\$150,000 and over 8=Don't know
Who in your household completed a survey for this investigation previously?	1=I personally completed the previous surveys 2=Someone else completed the other surveys 3=No one in our house completed the other surveys 4=Different people completed the different surveys
Have there been any changes to the number of people living in this home since June 2022?	0=No 1=Yes, please specify
Have there been any changes to the occupancy of the house since June 2022? Yes, please specify:	open-ended
On a regular workday, when are people in the dwelling?	1=Someone is home all the time 2=Someone is home for part of the workday 3=Everyone leaves after breakfast and returns after the workday
If you have school-age children, do they attend in-person school, or virtual school?	0=I do not have school-age children 1=Full time in-person school 2=Half time at home, half time in school 3=Full time at-home virtual schooling 4=Full time home schooling

Have there been any changes in the ways you use energy at home compared to last year at this time?	0=No 1=Yes 2=Not sure
What has changed? Check all that apply. <i>Increased use of heating /air-conditioning.</i> <i>Increase in light use.</i> <i>Increase in laundry-dryer loads.</i> <i>Only minimal changes (cooking times, TV times, etc.).</i> <i>Lower heating setpoint (lower use of heating).</i> <i>Programmed temperature changes.</i> <i>Fewer laundry dryer loads.</i> <i>Using energy at different times of day than before.</i> <i>Other, please specify:</i>	1=selected 0=not selected
What has changed? Check all that apply. Specify	open-ended
Which appliances/technologies did you purchase and when did you start using this new appliance or technology? <i>Electric vehicle</i> <i>Fireplace</i> <i>Hot tub</i> <i>Swimming pool</i> <i>2nd Fridge</i> <i>Separate freezer</i> <i>Minibar</i> <i>Heat pump</i> <i>Air purifier</i> <i>Air conditioning</i> <i>Television</i> <i>Water softener</i> <i>Back up generator</i> <i>Solar PV + battery</i> <i>Automobile block heater</i> <i>Portable electric heater</i> <i>Other</i>	0=Do not own 1=Not in use yet 2=Last month 3=Last 6 months 4=Between Jan 2020 and June 2022 5=Before Jan 2020
Which appliances/technologies did you purchase and when did you start using this new appliance or technology? Other, Specify	open-ended
How satisfied are you with the communications with the project team about the project?	0=Very dissatisfied 1=Dissatisfied
Overall, your participation in the Shediak Residential Energy Study?	2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
Have you felt that you had to change your household routine in any way in order to participate in the research project?	1=Yes 0=No
What type of thermostat do you currently have in your home?	0=I don't have a thermostat 1=I have a manual thermostat 2=I have a programmable thermostat 3=I have one (or more) internet-connected smart thermostat(s) 4=I don't know
How do you control your current thermostat?	1=I program my thermostat with different set points and schedules 2=I manually change the settings throughout the season depending on my schedule and the weather 3=I use a single set point throughout the season
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during winter:	
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during summer for air conditioning (if any):	

Please tell us the setpoints for your thermostat when you are: Away from home: Set point during winter:	1=10 °C 2=11 °C
Please tell us the setpoints for your thermostat when you are: Away from home: Set point during summer for air conditioning (if any):	3=12 °C 4=13 °C
Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during winter:	5=14 °C 6=15 °C
Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during summer for air conditioning (if any):	7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 22=Other
How do you decide what temperature to set your thermostat to?	1=Based on comfort 2=Based on utility bill
Please select the most important objective in your use of a thermostat:	1=I care about how energy use affects the environment 2=I want to feel comfortable 3=I want to save money on my energy bills 4=Not sure
Avoiding the need for new electrical generating stations is important to me.	0=Strongly disagree 1=Disagree
It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is reliable for everyone.	2=Neither agree nor disagree 3=Agree
Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	4=Strongly agree
It is acceptable for utilities to adjust individual customer electrical demand to deliver the least costly electricity supply for everyone.	
Please indicate your agreement or disagreement with the statements below. When I feel too cold, I turn up the thermostat and the heat comes on until it reaches the new temperature; then it turns off.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree
Please indicate your agreement or disagreement with the statements below. When I set a new temperature, the higher I set it, the faster the house heats up.	3=Agree 4=Strongly agree 5=Not applicable
Please indicate your agreement or disagreement with the statements below. I turn down the thermostat before I have a big crowd over to visit, so it doesn't get too hot when they are here.	
Please indicate your agreement or disagreement with the statements below. When I set a lower temperature on the thermostat, the heat doesn't come on until the temperature drops to the new setting.	
Please indicate your agreement or disagreement with the statements below. I keep my thermostats at the same setting always because it uses more energy to reheat the house than it would to keep it at one temperature.	

We'd like to know about your familiarity with features of your current thermostats. Please select the circle (radio button) that best describes your opinion of the thermostats.	0=I do not know how to change setting options manually on my thermostats. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I can easily change setting options manually on my thermostats.
	0=I don't use my thermostat's user guide. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I use my thermostat's user guide.
	0=I am the only one who adjusts thermostat settings. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=All the people in the household adjust thermostat settings.
	0=I switch off my thermostat on a daily or weekly basis (turning off heating or cooling system). 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I almost never switch off my thermostat (turning off heating or cooling system).

	0=I have smart thermostats, but I cannot/don't know how to program my thermostats directly on the thermostat (e.g., rather than using the web interface). 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I have smart thermostats, and I can easily program my thermostats directly on the thermostat (e.g., without using a computer for the web interface).
	0=I fully understand the meaning of the icons, symbols and abbreviations shown on the thermostat displays and the web interface. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I don't know/don't understand the meaning of the icons, symbols and abbreviations shown on the thermostat displays and the web interface.
	0=I can easily program my smart thermostats using a web interface. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I cannot/don't know how to program my smart thermostats using a web interface.
In your own words, what do you think is the most efficient way to operate your heating system?	open-ended
What is your priority for using your heating system?	0=Being comfortable is my top priority 1=Saving energy is my top priority 2=Keeping my NB Power bills low is my top priority 3=I try to balance efficiency and comfort 4=I don't know

In your opinion, what do you think your biggest energy consumption devices are in your home? Please rank the top three, with #1 consuming the most energy:	1=Air conditioning 2=Air purifier 3=Automobile block heater 4=Clothes dryer 5=Clothes washer 6=Dishwasher 7=Heating system 8=Electric range 9=Electric vehicle 10=Fireplace 11=Hot tub 12=Lighting 13=Minibar 14=Personal electronics 15=Refrigerator 16=Separate freezer or second fridge 17=Swimming pool 18=TV 19=Other 20=Water heater
Please specify which 'Other' device you ranked among the top three energy consumption devices in your home:	open-ended
What is your approximate monthly electricity consumption (kWh) in the winter?	1=Below 1,000 kWh 2=1,000-3,000 kWh 3=3,001-5,000 kWh 4=Over 5,000 kWh 5=Don't know
What is your approximate monthly electricity consumption (kWh) in the summer?	1=Below 200 kWh 2=200-600 kWh 3=601-1,000 kWh 4=Over 1,000 kWh 5=Don't know
How much attention do you usually pay to your electricity bill?	1=I have a full understanding of my electricity bill 2=I can find what I am looking for 3=I don't know what some numbers mean 4= I don't know where or how to review my electricity bills 5=I don't pay any attention to my electricity bill
Please indicate when are you most likely to do: Laundry loads Please indicate when are you most likely to do: Dryer loads	1=Morning (5am-9am) 2=During the day (10am-3pm) 3=Evening (4pm-8pm) 4=Night time (9pm-11pm) 5=Not sure 6=Other
Please indicate how many times per week do you usually use: Electric fireplace	1=Every day 2=2-4 times a week 3=Once a week 4=2-4 times a month 5=Once a month 6=Not sure 7=Never
Please indicate how many times per week do you usually use: Hot tub	
Please indicate how many times per week do you usually use: Automotive block heater	
Please indicate how many times per week do you usually use: Portable electric heater	
Please indicate how many times per week do you usually use: Swimming pool	
Please indicate how many times per week do you usually use: Electric vehicle	
Please indicate how many times per week do you usually use: Air purifier	

When do you think your peak usage happens during the day?	1=Morning (6am–9am) 2=Midday (9am–2pm) 3=Afternoon (2pm–5pm) 4=Evening (5pm–10pm) 5=Night time (10pm–6am) 6=Other, please specify
When do you think your peak usage happens during the day?	open-ended
What is your current knowledge of time-of-day pricing?	4=I believe that I am extremely knowledgeable about time-of-day pricing 3=I believe that I am moderately knowledgeable about time-of-day pricing 2=I believe that I am somewhat knowledgeable about time-of-day pricing 1=I believe that I am slightly knowledgeable about time-of-day pricing 0=I believe that I am not at all knowledgeable about time-of-day pricing
What do you think the main benefits of time-of-day rates might be? Please select the top two: <i>Lower electricity bill for some consumers</i> <i>Reduced energy consumption</i> <i>Environmental benefits</i> <i>More revenue for the utility</i> <i>Other, please specify:</i>	1=selected 0=not selected
What do you think the main benefits of time-of-day rates might be? Please select the top two: Specify	open-ended
Do you visit your Shediak Project Energy Portal to view your electricity consumption?	0=No 1=Yes 2=I don't know what that is
How satisfied are you with...The information you received about the technology offer when it was first presented to you?	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
How satisfied are you with...The installer who came to your house to install technology for this project?	
How satisfied are you with...The performance of the technology that has been installed?	
How satisfied are you with...The information provided to you about your technology when it was installed?	
How satisfied are you with...Communications with the Shediak Project Team about any issues with your technology?	
Would you recommend this technology to others?	0=No 1=Yes
Please tell us what you like or don't like about the technology you received in this project:	open-ended
If time-of-day electricity rates applied to you, do you think you would take advantage of them?	0=No 1=Yes 2=Not sure
How much do you think you could save on energy consumption if you were being charged time-of-day rates for the electricity you use?	0=No saving at all 1=1-4% saving 2=5-7% saving 3=8-10% saving 4=More than 10% saving 5=Not sure 6=Other

Which actions do you think you can do to move your energy consumption from peak time to off-peak time? Please select the top three that would apply to you: Do laundry in the evening/night Run the dishwasher in the evenings Turn off lights Turn off appliances when not in use Set thermostat to lower temperatures overnight Hang your clothes to dry instead of using a clothes dryer Pre-heat the house early in the morning before peak time Other, please specify:	1=selected 0=not selected
Which actions do you think you can do to move your energy consumption from peak time to off-peak time? Please select the top three that would apply to you: Specify	open-ended
How often do you think you will be able to adopt energy efficient behaviours/actions to get full advantage of time-of-day rates?	1=Every day 2=2-4 times a week 3=Once a week 4=2-4 times a month 5=Once a month 6=Not sure 7=I don't think I will be able to change my energy behaviours
During Tropical Storm Fiona, did you experience a power outage?	0=No 1=Yes
During Tropical Storm Fiona, did you notice that the energy storage battery provided power in your home?	0=No 1=Yes
Before and during Tropical Storm Fiona, were you reassured because you had the energy storage battery to provide backup power?	0=I was not reassured at all by having the energy storage battery. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I was very reassured by having the energy storage battery.
What is your opinion of the availability of back-up power from the energy storage battery?	0=I don't care about it 1=It's nice to have it, but I already had a generator 2=It is a helpful addition but doesn't provide enough power to meet my needs 3=I'm completely happy with the available back-up power in the event of an outage

B.4.3 Survey #4c: Core + TOD + CC-MSHP and SOL [not commissioned before Hurricane Fiona, no added questions]

Question	Scale
Access code	
How long have you lived in this dwelling?	Years
How long have you lived in this dwelling?	Months

Who lives in this dwelling? Please select the sex of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=Male 2=Female 3=Prefer not to say
Who lives in this dwelling? Please select the age of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=0-10 2=11-20 3=21-30 4=31-40 5=41-50 6=51-60 7=61-70 8=71-80 9=81+ 10=Prefer not to say
What is your best estimate of the total household income received by all household members from all sources, before taxes and deductions, during the last 12 months?	1=Less than \$20,000 (includes income loss) 2=\$20,000 to less than \$40,000 3=\$40,000 to less than \$60,000 4=\$60,000 to less than \$80,000 5=\$80,000 to less than \$100,000 6=\$100,000 to less than \$150,000 7=\$150,000 and over 8=Don't know
Who in your household completed a survey for this investigation previously?	1=I personally completed the previous surveys 2=Someone else completed the other surveys 3=No one in our house completed the other surveys 4=Different people completed the different surveys
Have there been any changes to the number of people living in this home since June 2022?	0=No 1=Yes, please specify
Have there been any changes to the occupancy of the house since June 2022? Yes, please specify:	open-ended
On a regular workday, when are people in the dwelling?	1=Someone is home all the time 2=Someone is home for part of the workday 3=Everyone leaves after breakfast and returns after the workday
If you have school-age children, do they attend in-person school, or virtual school?	0=I do not have school-age children 1=Full time in-person school 2=Half time at home, half time in school 3=Full time at-home virtual schooling 4=Full time home schooling
Have there been any changes in the ways you use energy at home compared to last year at this time?	0=No 1=Yes 2=Not sure
What has changed? Check all that apply. <i>Increased use of heating /air-conditioning.</i> <i>Increase in light use.</i> <i>Increase in laundry-dryer loads.</i> <i>Only minimal changes (cooking times, TV times, etc.).</i> <i>Lower heating setpoint (lower use of heating).</i> <i>Programmed temperature changes.</i> <i>Fewer laundry dryer loads.</i> <i>Using energy at different times of day than before.</i> <i>Other, please specify:</i>	1=selected 0=not selected
What has changed? Check all that apply. Specify	open-ended

Which appliances/technologies did you purchase and when did you start using this new appliance or technology? <i>Electric vehicle</i> <i>Fireplace</i> <i>Hot tub</i> <i>Swimming pool</i> <i>2nd Fridge</i> <i>Separate freezer</i> <i>Minibar</i> <i>Heat pump</i> <i>Air purifier</i> <i>Air conditioning</i> <i>Television</i> <i>Water softener</i> <i>Back up generator</i> <i>Solar PV + battery</i> <i>Automobile block heater</i> <i>Portable electric heater</i> <i>Other</i>	0=Do not own 1=Not in use yet 2=Last month 3=Last 6 months 4=Between Jan 2020 and June 2022 5=Before Jan 2020
Which appliances/technologies did you purchase and when did you start using this new appliance or technology? Other, Specify	open-ended
How satisfied are you with the communications with the project team about the project?	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very Satisfied
Overall, your participation in the Shediac Residential Energy Study?	
Have you felt that you had to change your household routine in any way in order to participate in the research project?	1=Yes 0=No
What type of thermostat do you currently have in your home?	0=I don't have a thermostat 1=I have a manual thermostat 2=I have a programmable thermostat 3=I have one (or more) internet-connected smart thermostat(s) 4=I don't know
How do you control your current thermostat?	1=I program my thermostat with different set points and schedules 2=I manually change the settings throughout the season depending on my schedule and the weather 3=I use a single set point throughout the season
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during winter:	
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during summer for air conditioning (if any):	
Please tell us the setpoints for your thermostat when you are: Away from home: Set point during winter:	
Please tell us the setpoints for your thermostat when you are: Away from home: Set point during summer for air conditioning (if any):	
Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during winter:	

Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during summer for air conditioning (if any):	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 22=Other
How do you decide what temperature to set your thermostat to?	1=Based on comfort 2=Based on utility bill
Please select the most important objective in your use of a thermostat:	1=I care about how energy use affects the environment 2=I want to feel comfortable 3=I want to save money on my energy bills 4=Not sure
Avoiding the need for new electrical generating stations is important to me.	0=Strongly disagree 1=Disagree
It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is reliable for everyone.	2=Neither agree nor disagree 3=Agree
Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	4=Strongly agree
It is acceptable for utilities to adjust individual customer electrical demand to deliver the least costly electricity supply for everyone.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
Please indicate your agreement or disagreement with the statements below. When I feel too cold, I turn up the thermostat and the heat comes on until it reaches the new temperature; then it turns off.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree
Please indicate your agreement or disagreement with the statements below. When I set a new temperature, the higher I set it, the faster the house heats up.	3=Agree 4=Strongly agree 5=Not applicable
Please indicate your agreement or disagreement with the statements below. I turn down the thermostat before I have a big crowd over to visit, so it doesn't get too hot when they are here.	
Please indicate your agreement or disagreement with the statements below. When I set a lower temperature on the thermostat, the heat doesn't come on until the temperature drops to the new setting.	
Please indicate your agreement or disagreement with the statements below. I keep my thermostats at the same setting always because it uses more energy to reheat the house than it would to keep it at one temperature.	

We'd like to know about your familiarity with features of your current thermostats. Please select the circle (radio button) that best describes your opinion of the thermostats	0=I do not know how to change setting options manually on my thermostats. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I can easily change setting options manually on my thermostats.
	0=I don't use my thermostat's user guide. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I use my thermostat's user guide.
	0=I am the only one who adjusts thermostat settings. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=All the people in the household adjust thermostat settings.
	0=I switch off my thermostat on a daily or weekly basis (turning off heating or cooling system). 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I almost never switch off my thermostat (turning off heating or cooling system).

	0=I have smart thermostats, but I cannot/don't know how to program my thermostats directly on the thermostat (e.g., rather than using the web interface). 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I have smart thermostats, and I can easily program my thermostats directly on the thermostat (e.g., without using a computer for the web interface).
	0=I fully understand the meaning of the icons, symbols and abbreviations shown on the thermostat displays and the web interface. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I don't know/don't understand the meaning of the icons, symbols and abbreviations shown on the thermostat displays and the web interface.
	0=I can easily program my smart thermostats using a web interface. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I cannot/don't know how to program my smart thermostats using a web interface.
In your own words, what do you think is the most efficient way to operate your heating system?	open-ended
What is your priority for using your heating system?	0=Being comfortable is my top priority 1=Saving energy is my top priority 2=Keeping my NB Power bills low is my top priority 3=I try to balance efficiency and comfort 4=I don't know
In your opinion, what do you think your biggest energy consumption devices are in your home? Please rank the top three, with #1 consuming the most energy:	

	1=Air conditioning 2=Air purifier 3=Automobile block heater 4=Clothes dryer 5=Clothes washer 6=Dishwasher 7=Heating system 8=Electric range 9=Electric vehicle 10=Fireplace 11=Hot tub 12=Lighting 13=Minibar 14=Personal electronics 15=Refrigerator 16=Separate freezer or second fridge 17=Swimming pool 18=TV 19=Other 20=Water heater
Please specify which 'Other' device you ranked among the top three energy consumption devices in your home:	open-ended
What is your approximate monthly electricity consumption (kWh) in the winter?	1=Below 1,000 kWh 2=1,000-3,000 kWh 3=3,001-5,000 kWh 4=Over 5,000 kWh 5=Don't know
What is your approximate monthly electricity consumption (kWh) in the summer?	1=Below 200 kWh 2=200-600 kWh 3=601-1,000 kWh 4=Over 1,000 kWh 5=Don't know
How much attention do you usually pay to your electricity bill?	1=I have a full understanding of my electricity bill 2=I can find what I am looking for 3=I don't know what some numbers mean 4= I don't know where or how to review my electricity bills 5=I don't pay any attention to my electricity bill
Please indicate when are you most likely to do: Laundry loads	1=Morning (5am-9am) 2=During the day (10am-3pm) 3=Evening (4pm-8pm) 4=Night time (9pm-11pm) 5=Not sure 6=Other
Please indicate when are you most likely to do: Dryer loads	
Please indicate how many times per week do you usually use: Electric fireplace	1=Every day 2=2-4 times a week 3=Once a week 4=2-4 times a month 5=Once a month 6=Not sure 7=Never
Please indicate how many times per week do you usually use: Hot tub	
Please indicate how many times per week do you usually use: Automotive block heater	
Please indicate how many times per week do you usually use: Portable electric heater	
Please indicate how many times per week do you usually use: Swimming pool	
Please indicate how many times per week do you usually use: Electric vehicle	
Please indicate how many times per week do you usually use: Air purifier	

When do you think your peak usage happens during the day?	1=Morning (6am–9am) 2=Midday (9am–2pm) 3=Afternoon (2pm–5pm) 4=Evening (5pm–10pm) 5=Night time (10pm–6am) 6=Other, please specify
When do you think your peak usage happens during the day?	open-ended
What is your current knowledge of time-of-day pricing?	4=I believe that I am extremely knowledgeable about time-of-day pricing 3=I believe that I am moderately knowledgeable about time-of-day pricing 2=I believe that I am somewhat knowledgeable about time-of-day pricing 1=I believe that I am slightly knowledgeable about time-of-day pricing 0=I believe that I am not at all knowledgeable about time-of-day pricing
What do you think the main benefits of time-of-day rates might be? Please select the top two: Lower electricity bill for some consumers	1=selected 0=not selected
What do you think the main benefits of time-of-day rates might be? Please select the top two: Reduced energy consumption	
What do you think the main benefits of time-of-day rates might be? Please select the top two: Environmental benefits	
What do you think the main benefits of time-of-day rates might be? Please select the top two: More revenue for the utility	
What do you think the main benefits of time-of-day rates might be? Please select the top two: Other, please specify:	
What do you think the main benefits of time-of-day rates might be? Please select the top two: Specify	open-ended
Do you visit your Shediac Project Energy Portal to view your electricity consumption?	0=No 1=Yes 2=I don't know what that is
You are in the Time-of-Day Rates group in this project. Do you try to take advantage of them?	0=No 1=Yes 2=Not sure
How much do you believe you save on your energy bill because of the time-of-day credit on your NB Power bill?	0=No saving at all 1=1-4% saving 2=5-7% saving 3=8-10% saving 4=More than 10% saving 5=Not sure 6=Other
Which actions do you try to use to move your energy consumption from peak time to off-peak time? Please select the top three that would apply to you: <i>Do laundry in the evening/night</i> <i>Run the dishwasher in the evenings</i> <i>Turn off lights</i> <i>Turn off appliances when not in use</i> <i>Set thermostat to lower temperatures overnight</i> <i>Hang your clothes to dry instead of using a clothes dryer</i> <i>Pre-heat the house early in the morning before peak time</i> <i>Other, please specify:</i>	1=selected 0=not selected
Which actions do you try to use to move your energy consumption from peak time to off-peak time? Please select the top three that would apply to you: Specify	open-ended

How often do you think you will be able to adopt energy efficient behaviours/actions to get full advantage of time-of-day rates?	1=Every day 2=2-4 times a week 3=Once a week 4=2-4 times a month 5=Once a month 6=Not sure 7=I don't think I will be able to change my energy behaviours
Have you viewed or downloaded your Shadow Report from the Shediak Energy Portal to see your Time-of-Day energy use each month?	0=No 1=Yes 2=I don't know what that is
How satisfied are you with...The Time-of-Day Rates brochure you received in the mail in spring 2022.	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
How satisfied are you with...Information about how to change your daily pattern of energy use, downloadable from your Participant Landing Page.	
How satisfied are you with...The information about your Time of Day credit on your Shadow Report.	
How satisfied are you with...The information you received about the technology offer when it was first presented to you?	
How satisfied are you with...The installer who came to your house to install technology for this project?	
How satisfied are you with...The performance of the technology that has been installed?	
How satisfied are you with...The information provided to you about your technology when it was installed?	
How satisfied are you with...Communications with the Shediak Project Team about any issues with your technology?	
Would you recommend this technology to others?	0=No 1=Yes
Please tell us what you like or don't like about the technology you received in this project:	open-ended

B.4.4 Survey #4d: Core + No-TOD + CC-MSHP and SOL [not commissioned before Hurricane Fiona, no added questions]

Question	Scale
Access code	
How long have you lived in this dwelling?	Years
How long have you lived in this dwelling?	Months
Who lives in this dwelling? Please select the sex of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=Male 2=Female 3=Prefer not to say
Who lives in this dwelling? Please select the age of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=0-10 2=11-20 3=21-30 4=31-40 5=41-50 6=51-60 7=61-70 8=71-80 9=81+ 10=Prefer not to say

What is your best estimate of the total household income received by all household members from all sources, before taxes and deductions, during the last 12 months?	1=Less than \$20,000 (includes income loss) 2=\$20,000 to less than \$40,000 3=\$40,000 to less than \$60,000 4=\$60,000 to less than \$80,000 5=\$80,000 to less than \$100,000 6=\$100,000 to less than \$150,000 7=\$150,000 and over 8=Don't know
Who in your household completed a survey for this investigation previously?	1=I personally completed the previous surveys 2=Someone else completed the other surveys 3=No one in our house completed the other surveys 4=Different people completed the different surveys
Have there been any changes to the number of people living in this home since June 2022?	0=No 1=Yes, please specify
Have there been any changes to the occupancy of the house since June 2022? Yes, please specify:	open-ended
On a regular workday, when are people in the dwelling?	1=Someone is home all the time 2=Someone is home for part of the workday 3=Everyone leaves after breakfast and returns after the workday
If you have school-age children, do they attend in-person school, or virtual school?	0=I do not have school-age children 1=Full time in-person school 2=Half time at home, half time in school 3=Full time at-home virtual schooling 4=Full time home schooling
Have there been any changes in the ways you use energy at home compared to last year at this time?	0=No 1=Yes 2=Not sure
What has changed? Check all that apply. Increased use of heating /air-conditioning.	1=selected 0=not selected
What has changed? Check all that apply. Increase in light use.	
What has changed? Check all that apply. Increase in laundry-dryer loads.	
What has changed? Check all that apply. Only minimal changes (cooking times, TV times, etc.).	
What has changed? Check all that apply. Lower heating setpoint (lower use of heating).	
What has changed? Check all that apply. Programmed temperature changes.	
What has changed? Check all that apply. Fewer laundry dryer loads.	
What has changed? Check all that apply. Using energy at different times of day than before.	
What has changed? Check all that apply. Other, please specify:	
What has changed? Check all that apply. Specify	open-ended

Which appliances/technologies did you purchase and when did you start using this new appliance or technology? <i>Electric vehicle</i> <i>Fireplace</i> <i>Hot tub</i> <i>Swimming pool</i> <i>2nd Fridge</i> <i>Separate freezer</i> <i>Minibar</i> <i>Heat pump</i> <i>Air purifier</i> <i>Air conditioning</i> <i>Television</i> <i>Water softener</i> <i>Back up generator</i> <i>Solar PV + battery</i> <i>Automobile block heater</i> <i>Portable electric heater</i> <i>Other</i>	0=Do not own 1=Not in use yet 2=Last month 3=Last 6 months 4=Between Jan 2020 and June 2022 5=Before Jan 2020
Which appliances/technologies did you purchase and when did you start using this new appliance or technology? Other, Specify	open-ended
How satisfied are you with the communications with the project team about the project?	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
Overall, your participation in the Shediac Residential Energy Study?	
Have you felt that you had to change your household routine in any way in order to participate in the research project?	1=Yes 0=No
What type of thermostat do you currently have in your home?	0=I don't have a thermostat 1=I have a manual thermostat 2=I have a programmable thermostat 3=I have one (or more) internet-connected smart thermostat(s) 4=I don't know
How do you control your current thermostat?	1=I program my thermostat with different set points and schedules 2=I manually change the settings throughout the season depending on my schedule and the weather 3=I use a single set point throughout the season
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during winter:	
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during summer for air conditioning (if any):	
Please tell us the setpoints for your thermostat when you are: Away from home: Set point during winter:	
Please tell us the setpoints for your thermostat when you are: Away from home: Set point during summer for air conditioning (if any):	
Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during winter:	

Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during summer for air conditioning (if any):	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 22=Other
How do you decide what temperature to set your thermostat to?	1=Based on comfort 2=Based on utility bill
Please select the most important objective in your use of a thermostat:	1=I care about how energy use affects the environment 2=I want to feel comfortable 3=I want to save money on my energy bills 4=Not sure
Avoiding the need for new electrical generating stations is important to me.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is reliable for everyone.	
Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	
It is acceptable for utilities to adjust individual customer electrical demand to deliver the least costly electricity supply for everyone.	
Please indicate your agreement or disagreement with the statements below. When I feel too cold, I turn up the thermostat and the heat comes on until it reaches the new temperature; then it turns off.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree 5=Not applicable
Please indicate your agreement or disagreement with the statements below. When I set a new temperature, the higher I set it, the faster the house heats up.	
Please indicate your agreement or disagreement with the statements below. I turn down the thermostat before I have a big crowd over to visit, so it doesn't get too hot when they are here.	
Please indicate your agreement or disagreement with the statements below. When I set a lower temperature on the thermostat, the heat doesn't come on until the temperature drops to the new setting.	
Please indicate your agreement or disagreement with the statements below. I keep my thermostats at the same setting always because it uses more energy to reheat the house than it would to keep it at one temperature.	

We'd like to know about your familiarity with features of your current thermostats. Please select the circle (radio button) that best describes your opinion of the thermostats.	0=I do not know how to change setting options manually on my thermostats. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I can easily change setting options manually on my thermostats.
	0=I don't use my thermostat's user guide. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I use my thermostat's user guide.
	0=I am the only one who adjusts thermostat settings. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=All the people in the household adjust thermostat settings.
	0=I switch off my thermostat on a daily or weekly basis (turning off heating or cooling system). 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I almost never switch off my thermostat (turning off heating or cooling system).

	0=I have smart thermostats, but I cannot/don't know how to program my thermostats directly on the thermostat (e.g., rather than using the web interface). 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I have smart thermostats, and I can easily program my thermostats directly on the thermostat (e.g., without using a computer for the web interface).
	0=I fully understand the meaning of the icons, symbols and abbreviations shown on the thermostat displays and the web interface. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I don't know/don't understand the meaning of the icons, symbols and abbreviations shown on the thermostat displays and the web interface.
	0=I can easily program my smart thermostats using a web interface. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I cannot/don't know how to program my smart thermostats using a web interface.
In your own words, what do you think is the most efficient way to operate your heating system?	open-ended
What is your priority for using your heating system?	0=Being comfortable is my top priority 1=Saving energy is my top priority 2=Keeping my NB Power bills low is my top priority 3=I try to balance efficiency and comfort 4=I don't know
In your opinion, what do you think your biggest energy consumption devices are in your home? Please rank the top three, with #1 consuming the most energy:	

	1=Air conditioning 2=Air purifier 3=Automobile block heater 4=Clothes dryer 5=Clothes washer 6=Dishwasher 7=Heating system 8=Electric range 9=Electric vehicle 10=Fireplace 11=Hot tub 12=Lighting 13=Minibar 14=Personal electronics 15=Refrigerator 16=Separate freezer or second fridge 17=Swimming pool 18=TV 19=Other 20=Water heater
Please specify which 'Other' device you ranked among the top three energy consumption devices in your home:	open-ended
What is your approximate monthly electricity consumption (kWh) in the winter?	1=Below 1,000 kWh 2=1,000-3,000 kWh 3=3,001-5,000 kWh 4=Over 5,000 kWh 5=Don't know
What is your approximate monthly electricity consumption (kWh) in the summer?	1=Below 200 kWh 2=200-600 kWh 3=601-1,000 kWh 4=Over 1,000 kWh 5=Don't know
How much attention do you usually pay to your electricity bill?	1=I have a full understanding of my electricity bill 2=I can find what I am looking for 3=I don't know what some numbers mean 4= I don't know where or how to review my electricity bills 5=I don't pay any attention to my electricity bill
Please indicate when are you most likely to do: Laundry loads	1=Morning (5am-9am) 2=During the day (10am-3pm) 3=Evening (4pm-8pm) 4=Night time (9pm-11pm) 5=Not sure 6=Other
Please indicate when are you most likely to do: Dryer loads	
Please indicate how many times per week do you usually use: <i>Electric fireplace</i> <i>Hot tub</i> <i>Automotive block heater</i> <i>Portable electric heater</i> <i>Swimming pool</i> <i>Electric vehicle</i> <i>Air purifier</i>	1=Every day 2=2-4 times a week 3=Once a week 4=2-4 times a month 5=Once a month 6=Not sure 7=Never

When do you think your peak usage happens during the day?	1=Morning (6am–9am) 2=Midday (9am–2pm) 3=Afternoon (2pm–5pm) 4=Evening (5pm–10pm) 5=Night time (10pm–6am) 6=Other, please specify
When do you think your peak usage happens during the day?	open-ended
What is your current knowledge of time-of-day pricing?	4=I believe that I am extremely knowledgeable about time-of-day pricing 3=I believe that I am moderately knowledgeable about time-of-day pricing 2=I believe that I am somewhat knowledgeable about time-of-day pricing 1=I believe that I am slightly knowledgeable about time-of-day pricing 0=I believe that I am not at all knowledgeable about time-of-day pricing
What do you think the main benefits of time-of-day rates might be? Please select the top two: Lower electricity bill for some consumers Reduced energy consumption Environmental benefits More revenue for the utility Other, please specify:	1=selected 0=not selected
What do you think the main benefits of time-of-day rates might be? Please select the top two: Specify	open-ended
Do you visit your Shediak Project Energy Portal to view your electricity consumption?	0=No 1=Yes 2=I don't know what that is
How satisfied are you with...The information you received about the technology offer when it was first presented to you?	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
How satisfied are you with...The installer who came to your house to install technology for this project?	
How satisfied are you with...The performance of the technology that has been installed?	
How satisfied are you with...The information provided to you about your technology when it was installed?	
How satisfied are you with...Communications with the Shediak Project Team about any issues with your technology?	
Would you recommend this technology to others?	0=No 1=Yes
Please tell us what you like or don't like about the technology you received in this project:	open-ended
If time-of-day electricity rates applied to you, do you think you would take advantage of them?	0=No 1=Yes 2=Not sure
How much do you think you could save on energy consumption if you were being charged time-of-day rates for the electricity you use?	0=No saving at all 1=1-4% saving 2=5-7% saving 3=8-10% saving 4=More than 10% saving 5=Not sure 6=Other

Which actions do you think you can do to move your energy consumption from peak time to off-peak time? Please select the top three that would apply to you: Do laundry in the evening/night Run the dishwasher in the evenings Turn off lights Turn off appliances when not in use Set thermostat to lower temperatures overnight Hang your clothes to dry instead of using a clothes dryer Pre-heat the house early in the morning before peak time Other, please specify:	1=selected 0=not selected
Which actions do you think you can do to move your energy consumption from peak time to off-peak time? Please select the top three that would apply to you: Specify	open-ended
How often do you think you will be able to adopt energy efficient behaviours/actions to get full advantage of time-of-day rates?	1=Every day 2=2-4 times a week 3=Once a week 4=2-4 times a month 5=Once a month 6=Not sure 7=I don't think I will be able to change my energy behaviours

B.4.5 Survey #4e: Core + TOD [no-Tech]

Question	Scale
Access code	
How long have you lived in this dwelling?	Years
How long have you lived in this dwelling?	Months
Who lives in this dwelling? Please select the sex of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=Male 2=Female 3=Prefer not to say
Who lives in this dwelling? Please select the age of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=0-10 2=11-20 3=21-30 4=31-40 5=41-50 6=51-60 7=61-70 8=71-80 9=81+ 10=Prefer not to say
What is your best estimate of the total household income received by all household members from all sources, before taxes and deductions, during the last 12 months?	1=Less than \$20,000 (includes income loss) 2=\$20,000 to less than \$40,000 3=\$40,000 to less than \$60,000 4=\$60,000 to less than \$80,000 5=\$80,000 to less than \$100,000 6=\$100,000 to less than \$150,000 7=\$150,000 and over 8=Don't know
Who in your household completed a survey for this investigation previously?	1=I personally completed the previous surveys 2=Someone else completed the other surveys 3=No one in our house completed the other surveys 4=Different people completed the different surveys

Have there been any changes to the number of people living in this home since June 2022?	0=No 1=Yes, please specify
Have there been any changes to the occupancy of the house since June 2022? Yes, please specify:	open-ended
On a regular workday, when are people in the dwelling?	1=Someone is home all the time 2=Someone is home for part of the workday 3=Everyone leaves after breakfast and returns after the workday
If you have school-age children, do they attend in-person school, or virtual school?	0=I do not have school-age children 1=Full time in-person school 2=Half time at home, half time in school 3=Full time at-home virtual schooling 4=Full time home schooling
Have there been any changes in the ways you use energy at home compared to last year at this time?	0=No 1=Yes 2=Not sure
What has changed? Check all that apply. Increased use of heating /air-conditioning. Increase in light use. Increase in laundry-dryer loads. Only minimal changes (cooking times, TV times, etc.). Lower heating setpoint (lower use of heating). Programmed temperature changes. Fewer laundry dryer loads. Using energy at different times of day than before. Other, please specify:	1=selected 0=not selected
What has changed? Check all that apply. Specify	open-ended
Which appliances/technologies did you purchase and when did you start using this new appliance or technology? Electric vehicle Fireplace Hot tub Swimming pool 2nd Fridge Separate freezer Minibar Heat pump Air purifier Air conditioning Television Water softener Back up generator Solar PV + battery Automobile block heater Portable electric heater Other	0=Do not own 1=Not in use yet 2=Last month 3=Last 6 months 4=Between Jan 2020 and June 2022 5=Before Jan 2020
Which appliances/technologies did you purchase and when did you start using this new appliance or technology? Other, Specify	open-ended
How satisfied are you with the communications with the project team about the project?	0=Very dissatisfied 1=Dissatisfied
Overall, your participation in the Shediak Residential Energy Study?	2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
Have you felt that you had to change your household routine in any way in order to participate in the research project?	1=Yes 0=No

What type of thermostat do you currently have in your home?	0=I don't have a thermostat 1=I have a manual thermostat 2=I have a programmable thermostat 3=I have one (or more) internet-connected smart thermostat(s) 4=I don't know
How do you control your current thermostat?	1=I program my thermostat with different set points and schedules 2=I manually change the settings throughout the season depending on my schedule and the weather 3=I use a single set point throughout the season
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during winter:	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 22=Other
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during summer for air conditioning (if any):	
Please tell us the setpoints for your thermostat when you are: Away from home: Set point during winter:	
Please tell us the setpoints for your thermostat when you are: Away from home: Set point during summer for air conditioning (if any):	
Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during winter:	
Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during summer for air conditioning (if any):	
How do you decide what temperature to set your thermostat to?	1=Based on comfort 2=Based on utility bill
Please select the most important objective in your use of a thermostat:	1=I care about how energy use affects the environment 2=I want to feel comfortable 3=I want to save money on my energy bills 4=Not sure
Avoiding the need for new electrical generating stations is important to me.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is reliable for everyone.	
Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	
It is acceptable for utilities to adjust individual customer electrical demand to deliver the least costly electricity supply for everyone.	
Please indicate your agreement or disagreement with the statements below. When I feel too cold, I turn up the thermostat and the heat comes on until it reaches the new temperature; then it turns off.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree 5=Not applicable
Please indicate your agreement or disagreement with the statements below. When I set a new temperature, the higher I set it, the faster the house heats up.	
Please indicate your agreement or disagreement with the statements below. I turn down the thermostat before I have a big crowd over to visit, so it doesn't get too hot when they are here.	

Please indicate your agreement or disagreement with the statements below. When I set a lower temperature on the thermostat, the heat doesn't come on until the temperature drops to the new setting.	
Please indicate your agreement or disagreement with the statements below. I keep my thermostats at the same setting always because it uses more energy to reheat the house than it would to keep it at one temperature.	
We'd like to know about your familiarity with features of your current thermostats. Please select the circle (radio button) that best describes your opinion of the thermostats.	0=I do not know how to change setting options manually on my thermostats. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I can easily change setting options manually on my thermostats.
	0=I don't use my thermostat's user guide. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I use my thermostat's user guide.
	0=I am the only one who adjusts thermostat settings. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=All the people in the household adjust thermostat settings.
	0=I switch off my thermostat on a daily or weekly basis (turning off heating or cooling system). 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I almost never switch off my thermostat (turning off heating or cooling system).

	0=I have smart thermostats, but I cannot/don't know how to program my thermostats directly on the thermostat (e.g., rather than using the web interface). 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I have smart thermostats, and I can easily program my thermostats directly on the thermostat (e.g., without using a computer for the web interface).
	0=I fully understand the meaning of the icons, symbols and abbreviations shown on the thermostat displays and the web interface. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I don't know/don't understand the meaning of the icons, symbols and abbreviations shown on the thermostat displays and the web interface.
	0=I can easily program my smart thermostats using a web interface. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I cannot/don't know how to program my smart thermostats using a web interface.
In your own words, what do you think is the most efficient way to operate your heating system?	open-ended
What is your priority for using your heating system?	0=Being comfortable is my top priority 1=Saving energy is my top priority 2=Keeping my NB Power bills low is my top priority 3=I try to balance efficiency and comfort 4=I don't know
In your opinion, what do you think your biggest energy consumption devices are in your home? Please rank the top three, with #1 consuming the most energy:	

	1=Air conditioning 2=Air purifier 3=Automobile block heater 4=Clothes dryer 5=Clothes washer 6=Dishwasher 7=Heating system 8=Electric range 9=Electric vehicle 10=Fireplace 11=Hot tub 12=Lighting 13=Minibar 14=Personal electronics 15=Refrigerator 16=Separate freezer or second fridge 17=Swimming pool 18=TV 19=Other 20=Water heater
Please specify which 'Other' device you ranked among the top three energy consumption devices in your home:	open-ended
What is your approximate monthly electricity consumption (kWh) in the winter?	1=Below 1,000 kWh 2=1,000-3,000 kWh 3=3,001-5,000 kWh 4=Over 5,000 kWh 5=Don't know
What is your approximate monthly electricity consumption (kWh) in the summer?	1=Below 200 kWh 2=200-600 kWh 3=601-1,000 kWh 4=Over 1,000 kWh 5=Don't know
How much attention do you usually pay to your electricity bill?	1=I have a full understanding of my electricity bill 2=I can find what I am looking for 3=I don't know what some numbers mean 4= I don't know where or how to review my electricity bills 5=I don't pay any attention to my electricity bill
Please indicate when are you most likely to do: Laundry loads	1=Morning (5am-9am) 2=During the day (10am-3pm) 3=Evening (4pm-8pm) 4=Night time (9pm-11pm) 5=Not sure 6=Other
Please indicate when are you most likely to do: Dryer loads	
Please indicate how many times per week do you usually use: Electric fireplace Hot tub Automotive block heater Portable electric heater Swimming pool Electric vehicle Air purifier	1=Every day 2=2-4 times a week 3=Once a week 4=2-4 times a month 5=Once a month 6=Not sure 7=Never

When do you think your peak usage happens during the day?	1=Morning (6am–9am) 2=Midday (9am–2pm) 3=Afternoon (2pm–5pm) 4=Evening (5pm–10pm) 5=Night time (10pm–6am) 6=Other, please specify
When do you think your peak usage happens during the day?	open-ended
What is your current knowledge of time-of-day pricing?	4=I believe that I am extremely knowledgeable about time-of-day pricing 3=I believe that I am moderately knowledgeable about time-of-day pricing 2=I believe that I am somewhat knowledgeable about time-of-day pricing 1=I believe that I am slightly knowledgeable about time-of-day pricing 0=I believe that I am not at all knowledgeable about time-of-day pricing
What do you think the main benefits of time-of-day rates might be? Please select the top two: Lower electricity bill for some consumers Reduced energy consumption Environmental benefits More revenue for the utility Other, please specify:	1=selected 0=not selected
What do you think the main benefits of time-of-day rates might be? Please select the top two: Specify	open-ended
Do you visit your Shediak Project Energy Portal to view your electricity consumption?	0=No 1=Yes 2=I don't know what that is
You are in the Time-of-Day Rates group in this project. Do you try to take advantage of them?	0=No 1=Yes 2=Not sure
How much do you believe you save on your energy bill because of the time-of-day credit on your NB Power bill?	0=No saving at all 1=1-4% saving 2=5-7% saving 3=8-10% saving 4=More than 10% saving 5=Not sure 6=Other
Which actions do you try to use to move your energy consumption from peak time to off-peak time? Please select the top three that would apply to you: <i>Do laundry in the evening/night</i> <i>Run the dishwasher in the evenings</i> <i>Turn off lights</i> <i>Turn off appliances when not in use</i> <i>Set thermostat to lower temperatures overnight</i> <i>Hang your clothes to dry instead of using a clothes dryer</i> <i>Pre-heat the house early in the morning before peak time</i> <i>Other, please specify:</i>	1=selected 0=not selected
Which actions do you try to use to move your energy consumption from peak time to off-peak time? Please select the top three that would apply to you: Specify	open-ended

How often do you think you will be able to adopt energy efficient behaviours/actions to get full advantage of time-of-day rates?	1=Every day 2=2-4 times a week 3=Once a week 4=2-4 times a month 5=Once a month 6=Not sure 7=I don't think I will be able to change my energy behaviours
Have you viewed or downloaded your Shadow Report from the Shediac Energy Portal to see your Time-of-Day energy use each month?	0=No 1=Yes 2=I don't know what that is
How satisfied are you with...The Time-of-Day Rates brochure you received in the mail in spring 2022.	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
How satisfied are you with...Information about how to change your daily pattern of energy use, downloadable from your Participant Landing Page.	
How satisfied are you with...The information about your Time of Day credit on your Shadow Report.	

B.4.6 Survey #4f: Core + No-TOD [no-Tech]

Question	Scale
Access code	
How long have you lived in this dwelling?	Years
How long have you lived in this dwelling?	Months
Who lives in this dwelling? Please select the sex of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=Male 2=Female 3=Prefer not to say
Who lives in this dwelling? Please select the age of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=0-10 2=11-20 3=21-30 4=31-40 5=41-50 6=51-60 7=61-70 8=71-80 9=81+ 10=Prefer not to say
What is your best estimate of the total household income received by all household members from all sources, before taxes and deductions, during the last 12 months?	1=Less than \$20,000 (includes income loss) 2=\$20,000 to less than \$40,000 3=\$40,000 to less than \$60,000 4=\$60,000 to less than \$80,000 5=\$80,000 to less than \$100,000 6=\$100,000 to less than \$150,000 7=\$150,000 and over 8=Don't know
Who in your household completed a survey for this investigation previously?	1=I personally completed the previous surveys 2=Someone else completed the other surveys 3=No one in our house completed the other surveys 4=Different people completed the different surveys
Have there been any changes to the number of people living in this home since June 2022?	0=No 1=Yes, please specify

Have there been any changes to the occupancy of the house since June 2022? Yes, please specify:	open-ended
On a regular workday, when are people in the dwelling?	1=Someone is home all the time 2=Someone is home for part of the workday 3=Everyone leaves after breakfast and returns after the workday
If you have school-age children, do they attend in-person school, or virtual school?	0=I do not have school-age children 1=Full time in-person school 2=Half time at home, half time in school 3=Full time at-home virtual schooling 4=Full time home schooling
Have there been any changes in the ways you use energy at home compared to last year at this time?	0=No 1=Yes 2=Not sure
What has changed? Check all that apply. <i>Increased use of heating /air-conditioning.</i> <i>Increase in light use.</i> <i>Increase in laundry-dryer loads.</i> <i>Only minimal changes (cooking times, TV times, etc.).</i> <i>Lower heating setpoint (lower use of heating).</i> <i>Programmed temperature changes.</i> <i>Fewer laundry dryer loads.</i> <i>Using energy at different times of day than before.</i> <i>Other</i>	1=selected 0=not selected
What has changed? Check all that apply. Specify	open-ended
Which appliances/technologies did you purchase and when did you start using this new appliance or technology? <i>Electric vehicle</i> <i>Fireplace</i> <i>Hot tub</i> <i>Swimming pool</i> <i>2nd Fridge</i> <i>Separate freezer</i> <i>Minibar</i> <i>Heat pump</i> <i>Air purifier</i> <i>Air conditioning</i> <i>Television</i> <i>Water softener</i> <i>Back up generator</i> <i>Solar PV + battery</i> <i>Automobile block heater</i> <i>Portable electric heater</i> <i>Other</i>	0=Do not own 1=Not in use yet 2=Last month 3=Last 6 months 4=Between Jan 2020 and June 2022 5=Before Jan 2020
Which appliances/technologies did you purchase and when did you start using this new appliance or technology? Other, Specify	open-ended
How satisfied are you with the communications with the project team about the project?	0=Very dissatisfied 1=Dissatisfied
Overall, your participation in the Shediak Residential Energy Study?	2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
Have you felt that you had to change your household routine in any way in order to participate in the research project?	1=Yes 0=No

What type of thermostat do you currently have in your home?	0=I don't have a thermostat 1=I have a manual thermostat 2=I have a programmable thermostat 3=I have one (or more) internet-connected smart thermostat(s) 4=I don't know
How do you control your current thermostat?	1=I program my thermostat with different set points and schedules 2=I manually change the settings throughout the season depending on my schedule and the weather 3=I use a single set point throughout the season
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during winter:	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 22=Other
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during summer for air conditioning (if any):	
Please tell us the setpoints for your thermostat when you are: Away from home: Set point during winter:	
Please tell us the setpoints for your thermostat when you are: Away from home: Set point during summer for air conditioning (if any):	
Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during winter:	
Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during summer for air conditioning (if any):	
How do you decide what temperature to set your thermostat to?	1=Based on comfort 2=Based on utility bill
Please select the most important objective in your use of a thermostat:	1=I care about how energy use affects the environment 2=I want to feel comfortable 3=I want to save money on my energy bills 4=Not sure
Avoiding the need for new electrical generating stations is important to me.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is reliable for everyone.	
Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	
It is acceptable for utilities to adjust individual customer electrical demand to deliver the least costly electricity supply for everyone.	
Please indicate your agreement or disagreement with the statements below. When I feel too cold, I turn up the thermostat and the heat comes on until it reaches the new temperature; then it turns off.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree 5=Not applicable
Please indicate your agreement or disagreement with the statements below. When I set a new temperature, the higher I set it, the faster the house heats up.	
Please indicate your agreement or disagreement with the statements below. I turn down the thermostat before I have a big crowd over to visit, so it doesn't get too hot when they are here.	

Please indicate your agreement or disagreement with the statements below. When I set a lower temperature on the thermostat, the heat doesn't come on until the temperature drops to the new setting.	
Please indicate your agreement or disagreement with the statements below. I keep my thermostats at the same setting always because it uses more energy to reheat the house than it would to keep it at one temperature.	
We'd like to know about your familiarity with features of your current thermostats. Please select the circle (radio button) that best describes your opinion of the thermostats.	0=I do not know how to change setting options manually on my thermostats. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I can easily change setting options manually on my thermostats.
	0=I don't use my thermostat's user guide. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I use my thermostat's user guide.
	0=I am the only one who adjusts thermostat settings. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=All the people in the household adjust thermostat settings.
	0=I switch off my thermostat on a daily or weekly basis (turning off heating or cooling system). 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I almost never switch off my thermostat (turning off heating or cooling system).

	0=I have smart thermostats, but I cannot/don't know how to program my thermostats directly on the thermostat (e.g., rather than using the web interface). 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I have smart thermostats, and I can easily program my thermostats directly on the thermostat (e.g., without using a computer for the web interface).
	0=I fully understand the meaning of the icons, symbols and abbreviations shown on the thermostat displays and the web interface. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I don't know/don't understand the meaning of the icons, symbols and abbreviations shown on the thermostat displays and the web interface.
	0=I can easily program my smart thermostats using a web interface. 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=I cannot/don't know how to program my smart thermostats using a web interface.
In your own words, what do you think is the most efficient way to operate your heating system?	open-ended
What is your priority for using your heating system?	0=Being comfortable is my top priority 1=Saving energy is my top priority 2=Keeping my NB Power bills low is my top priority 3=I try to balance efficiency and comfort 4=I don't know

In your opinion, what do you think your biggest energy consumption devices are in your home? Please rank the top three, with #1 consuming the most energy:	1=Air conditioning 2=Air purifier 3=Automobile block heater 4=Clothes dryer 5=Clothes washer 6=Dishwasher 7=Heating system 8=Electric range 9=Electric vehicle 10=Fireplace 11=Hot tub 12=Lighting 13=Minibar 14=Personal electronics 15=Refrigerator 16=Separate freezer or second fridge 17=Swimming pool 18=TV 19=Other 20=Water heater
Please specify which 'Other' device you ranked among the top three energy consumption devices in your home:	open-ended
What is your approximate monthly electricity consumption (kWh) in the winter?	1=Below 1,000 kWh 2=1,000-3,000 kWh 3=3,001-5,000 kWh 4=Over 5,000 kWh 5=Don't know
What is your approximate monthly electricity consumption (kWh) in the summer?	1=Below 200 kWh 2=200-600 kWh 3=601-1,000 kWh 4=Over 1,000 kWh 5=Don't know
How much attention do you usually pay to your electricity bill?	1=I have a full understanding of my electricity bill 2=I can find what I am looking for 3=I don't know what some numbers mean 4= I don't know where or how to review my electricity bills 5=I don't pay any attention to my electricity bill
Please indicate when are you most likely to do: Laundry loads Please indicate when are you most likely to do: Dryer loads	1=Morning (5am-9am) 2=During the day (10am-3pm) 3=Evening (4pm-8pm) 4=Night time (9pm-11pm) 5=Not sure 6=Other
Please indicate how many times per week do you usually use: Electric fireplace	1=Every day 2=2-4 times a week 3=Once a week 4=2-4 times a month 5=Once a month 6=Not sure 7=Never
Please indicate how many times per week do you usually use: Hot tub	
Please indicate how many times per week do you usually use: Automotive block heater	
Please indicate how many times per week do you usually use: Portable electric heater	
Please indicate how many times per week do you usually use: Swimming pool	
Please indicate how many times per week do you usually use: Electric vehicle	
Please indicate how many times per week do you usually use: Air purifier	

When do you think your peak usage happens during the day?	1=Morning (6am–9am) 2=Midday (9am–2pm) 3=Afternoon (2pm–5pm) 4=Evening (5pm–10pm) 5=Night time (10pm–6am) 6=Other, please specify
When do you think your peak usage happens during the day?	open-ended
What is your current knowledge of time-of-day pricing?	4=I believe that I am extremely knowledgeable about time-of-day pricing 3=I believe that I am moderately knowledgeable about time-of-day pricing 2=I believe that I am somewhat knowledgeable about time-of-day pricing 1=I believe that I am slightly knowledgeable about time-of-day pricing 0=I believe that I am not at all knowledgeable about time-of-day pricing
What do you think the main benefits of time-of-day rates might be? Please select the top two: <i>Lower electricity bill for some consumers</i> <i>Reduced energy consumption</i> <i>Environmental benefits</i> <i>More revenue for the utility</i> <i>Other, please specify:</i>	1=selected 0=not selected
What do you think the main benefits of time-of-day rates might be? Please select the top two: Specify	open-ended
Do you visit your Shediak Project Energy Portal to view your electricity consumption?	0=No 1=Yes 2=I don't know what that is
If time-of-day electricity rates applied to you, do you think you would take advantage of them?	0=No 1=Yes 2=Not sure
How much do you think you could save on energy consumption if you were being charged time-of-day rates for the electricity you use?	0=No saving at all 1=1-4% saving 2=5-7% saving 3=8-10% saving 4=More than 10% saving 5=Not sure 6=Other
Which actions do you think you can do to move your energy consumption from peak time to off-peak time? Please select the top three that would apply to you: <i>Do laundry in the evening/night</i> <i>Run the dishwasher in the evenings</i> <i>Turn off lights</i> <i>Turn off appliances when not in use</i> <i>Set thermostat to lower temperatures overnight</i> <i>Hang your clothes to dry instead of using a clothes dryer</i> <i>Pre-heat the house early in the morning before peak time</i> <i>Other, please specify:</i>	1=selected 0=not selected
Which actions do you think you can do to move your energy consumption from peak time to off-peak time? Please select the top three that would apply to you: Specify	open-ended

How often do you think you will be able to adopt energy efficient behaviours/actions to get full advantage of time-of-day rates?	1=Every day 2=2-4 times a week 3=Once a week 4=2-4 times a month 5=Once a month 6=Not sure 7=I don't think I will be able to change my energy behaviours

B.5 Survey #5 – June 2023

Question	Scale
Access code	
Who in your household completed a survey for this investigation previously?	1=I personally completed the previous surveys 2=Someone else completed the other surveys 3=No one in our house completed the other surveys 4=Different people completed the different surveys
Have there been any changes to the number of people living in this home since June 2022?	0=No 1=Yes, please specify
Have there been any changes to the occupancy of the house since June 2022? Yes, please specify:	open-ended
On a regular workday, when are people in the dwelling?	1=Someone is home all the time 2=Someone is home for part of the workday 3=Everyone leaves after breakfast and returns after the workday
I feel a moral obligation to engage in energy behaviours that are beneficial for the environment.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
Most Canadians engage in energy behaviours that are beneficial for the environment.	
Most Canadians believe it is morally right to engage in energy behaviours that are beneficial for the environment.	
Most of my neighbors engage in energy behaviours that are beneficial for the environment.	
Most of my neighbors believe it is morally right to engage in energy behaviours that are beneficial for the environment.	
Avoiding the need to build new fossil-fuel-burning electrical generating stations is important to me.	
Increasing the use of renewable energy sources to generate electricity is important to me.	
Decreasing the use of nuclear generating stations is important to me.	
How we generate electricity is less important to me than making sure it's there when we need it.	
Keeping customer electricity bills as low as possible, no matter how it's generated, is important to me.	
Giving the utility the ability to adjust individual customer electrical demand is acceptable if it keeps costs low for everyone.	
It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is stable for everyone.	
Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	
In your opinion, what do you think your biggest energy consumption devices are in your home? Please rank the top three, with #1 consuming the most energy: 1	

In your opinion, what do you think your biggest energy consumption devices are in your home? Please rank the top three, with #1 consuming the most energy: 2	1=Air conditioning 2=Air purifier 3=Automobile block heater 4=Clothes dryer 5=Clothes washer 6=Dishwasher 7=Electric baseboard heaters/Central electric furnace 8=Electric range 9=Electric vehicle 10=Fireplace 11=Heat pump 12=Hot tub 13=Minibar 14=Personal electronics 15=Portable electric heater 16=Refrigerator 17=Separate freezer or second fridge 18=Swimming pool 19=TV 20=Water heater 21=Other 22=Lighting
In your opinion, what do you think your biggest energy consumption devices are in your home? Please rank the top three, with #1 consuming the most energy: 3	
Please specify which 'Other' device you ranked among the top three energy consumption devices in your home:	open-ended
Replace my light bulbs with energy efficient light bulbs.	0=Very unwilling 1=Somewhat unwilling 2=Neither willing nor unwilling 3=Somewhat willing 4=Very willing 5=I have already done this
Replace my appliances with more energy efficient appliances (e.g., a refrigerator with an Energy Star certification).	
Install solar panels on my home.	
Participate in a time-of-day electricity rate program.	
Install a mini-split heat pump.	
Upgrade the insulation or windows.	
Reduce my hot water consumption.	
Wash and rinse my clothes with hot water.	
Leave lights on when I am not using them.	
Lower my thermostat setting in winter to save energy.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
If I reduce my at-home energy consumption, I will personally receive financial benefits.	
If I do not reduce my at-home energy consumption, I will incur financial costs.	
If I invest in renewable energy sources (e.g., by installing solar panels), I will personally receive financial benefits.	
If I do not invest in renewable energy sources (e.g., by installing solar panels), I will personally incur financial costs.	
If I reduce my at-home energy consumption, I will have to give up some comfort and convenience. ► Reverse coded	
If I personally invest in renewable energy sources, it will cost me money.	
One down side to installing renewable energy sources like solar panels is that they can make the home look unattractive. ► Reverse coded	
Having a source of backup power to keep important electrical devices running during a power outage is important to me.	
If incentives were available, I would be willing to invest in energy storage that would provide back up power for my home if there was a grid outage.	
Having renewable energy sources like solar panels would make me more likely to invest in battery energy storage.	

If you personally had to pay, and there were no incentive programs available, how much money would you be willing to invest to provide your home with backup power in case of a power outage?	dollars (\$)
If you already have a backup power system, please tell us about the benefits it provides to you, and any challenges that you had in acquiring it. If you don't have a backup power system, how easy or difficult do you think it would be to get one?	open-ended
If you personally had to pay, and there were no incentive programs available, how much money would you be willing to invest in installing a 5,000-Watt solar panel system on your home or property, similar to the ones installed as part of this project?	dollars (\$)
If you personally had to pay, and there were no incentive programs available, how much money would you be willing to invest in installing a 5kW/2hr battery storage system in your home or property, similar to the ones installed as part of this project?	dollars (\$)
How much money per month would you expect to receive from a utility company in order for you to participate in a utility intervention program? The program would, for instance, allow the utility to adjust your water heater or other smart devices a few times each month in order to manage the electrical grid.	0= I would not need to be paid 1=\$5-\$10 2=\$11-\$20 3=\$21-\$30 4=\$31-\$40 5=\$41-\$50 6=I would never give control to the utility
Have you ever participated in an energy efficiency program outside of this project? Please use the text box to tell us which program, and what efficiency changes you made.	open-ended
How much did you invest in your home upgrades in this utility program?	dollars (\$)
How satisfied are you with...The communications with the project team about the project?	0=Very dissatisfied 1=Dissatisfied
How satisfied are you with...Your participation in the Shediak Residential Energy Study overall?	2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
Have you felt that you had to change your household routine in any way in order to participate in the research project?	0=No 1=Yes
What kinds of conversations about energy habits are happening in your household since the project began?	open-ended
Was the technology received during the study easy to use?	open-ended
What changes have you noticed in how you use energy at home since joining this project?	open-ended
What is the most important thing you have learned about smart energy technology at home?	open-ended
Looking to the future, how might you change your energy habits even more as a result of this project?	open-ended
Is there anything else you would like to tell us about your experiences in this project?	open-ended
When the project ends, we would like to be able to tell New Brunswickers about what it was like for our participants to be in this project. Would you be willing to allow us to anonymously quote your text answers to the six questions about your project experience that you just answered? The quotations could be used in newspaper or web articles or on posters or presentations about the project, either in the original language or translated. Your name will never be identified.	0=No 1=Yes

In general, how satisfied are you with NB Power?	0=Not at all satisfied 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Most satisfied
What is the reason for the rating you gave for your satisfaction with NB Power?	open-ended

B.6 Survey #6 – December 2023

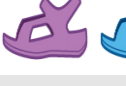
Participants who received smart thermostats from the project received a slightly different survey from the rest, to target opinions about that technology. This was done with a branching question within the survey. There was a different version for SOL participants, with questions about that technology.

B.6.1 Survey #6a: Core + smart thermostats - no-SOL

Question	Scale
Access code	
How long have you lived in this dwelling?	Years
How long have you lived in this dwelling?	Months
Who lives in this dwelling? Please select the sex of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=Male 2=Female 3=Prefer not to say
Who lives in this dwelling? Please select the age of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=0-10 2=11-20 3=21-30 4=31-40 5=41-50 6=51-60 7=61-70 8=71-80 9=81+ 10=Prefer not to say
What is your best estimate of the total household income received by all household members from all sources, before taxes and deductions, during the last 12 months?	1=Less than \$20,000 (includes income loss) 2=\$20,000 to less than \$40,000 3=\$40,000 to less than \$60,000 4=\$60,000 to less than \$80,000 5=\$80,000 to less than \$100,000 6=\$100,000 to less than \$150,000 7=\$150,000 and over 8=Don't know
Who in your household completed a survey for this investigation previously?	1=I personally completed the previous surveys 2=Someone else completed the other surveys 3=No one in our house completed the other surveys 4=Different people completed the different surveys
Have there been any changes to the number of people living in this home since June 2023?	0=No 1=Yes, please specify

Have there been any changes to the occupancy of the house since June 2023? Yes, please specify:	open-ended
On a regular workday, when are people in the dwelling?	1=Someone is home all the time 2=Someone is home for part of the workday 3=Everyone leaves after breakfast and returns after the workday
Have there been any changes in the ways you use energy at home compared to last year at this time?	0=No 1=Yes 2=Not sure
What has changed? Check all that apply. <i>Increased use of heating /air-conditioning.</i> <i>Increase in light use.</i> <i>Increase in laundry-dryer loads.</i> <i>Only minimal changes (cooking times, TV times, etc.).</i> <i>Lower heating setpoint (lower use of heating).</i> <i>Programmed temperature changes.</i> <i>Fewer laundry dryer loads.</i> <i>Using energy at different times of day than before.</i> <i>Other, please specify:</i>	1=selected 0=not selected
What has changed? Check all that apply. Specify	open-ended
Which appliances/technologies did you purchase and when did you start using this new appliance or technology? <i>Electric vehicle</i> <i>Fireplace</i> <i>Hot tub</i> <i>Swimming pool</i> <i>2nd Fridge</i> <i>Separate freezer</i> <i>Minibar</i> <i>Heat pump</i> <i>Air purifier</i> <i>Air conditioning</i> <i>Television</i> <i>Water softener</i> <i>Back up generator</i> <i>Solar PV + battery</i> <i>Automobile block heater</i> <i>Portable electric heater</i> <i>Other</i>	0=Do not own 1=Last month 2=Last 6 months 3=Between Nov 2022 and now 4=Between Nov 2019 and Nov 2022 5=Before Nov 2019 (Before the project started)
Which appliances/technologies did you purchase and when did you start using this new appliance or technology? Other, Specify	open-ended
Please indicate how often you usually use: Electric vehicle	1=Never 2=Once a month 3=A couple of times a month 4=Every week 5=A few times a week 6=Every day 7=Not sure
Please indicate how often you usually use: <i>Fireplace</i> <i>Hot tub</i> <i>Swimming pool</i> <i>Air purifier</i> <i>Automobile block heater</i> <i>Portable electric heater</i>	0=Never 1=Once a month 2=A couple of times a month 3=Every week 4=A few times a week 5=Every day 6=Not sure
Please indicate when are you most likely to do: Laundry loads	

Please indicate when are you most likely to do: Dryer loads	1=Morning (7am-9am) 2=During the day (9am-5pm) 3=Evening (5pm-10pm) 4=Overnight (10pm-7am) 5=Not sure 6=Other
Please indicate how many times per week you do: Laundry loads	number
Please indicate how many times per week you do: Dryer loads	number
What is the usual temperature of your laundry loads?	0=cold 1=warm 2=hot
What is the usual temperature of your dryer loads?	0=no heat 1=low 2=medium 3=hot
Hot water is always available when I need it.	0=Strongly disagree
The hot water setting on my tank is just right.	1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
I have experienced issues with my water heater while I have been in the project.	1=No 2=Yes, please specify
I have experienced issues with my water heater while I have been in the project. Yes, please specify:	open-ended
Do you visit your Shediac Project Energy Portal to view your electricity consumption?	0=No 1=Yes 2=I don't know what that is
Please rate your typical thermal sensation in the winter at home:	-3=Cold -2=Cool -1=Slightly cool 0=Neutral 1=Slightly warm 2=Warm 3=Hot
In general, in the winter at home I would like to feel...	-1=Cooler 0=No change 1=Warmer
How often do you take the following actions to improve your thermal comfort at home during the winter? Have a hot or cold drink Use a portable heater Use a portable fan Change the thermostat Add or remove a layer of clothing Open or close the window Adjust a window blind or curtain	1=Never 2=Once per month 3=2-4 times per month 4=Once per week 5=2-4 times per week 6=At least once per day 7=Several times per day 8=Not an option for me
Please give us details about other actions you may take to improve your thermal comfort:	open-ended
Please select the clothes usually worn by you and members of your family at home in the winter:	1=selected 0=not selected

 ☐  ☐  ☐  ☐  ☐	 ☐  ☐  ☐  ☐  ☐  ☐  ☐	 ☐  ☐  ☐  ☐  ☐  ☐  ☐	
CLO=SUM ((Pyjama*.57), (House Coat*.69), (Long Sleeved Underwear Top*.20), (Long Underwear Bottom*.15), (Briefs*.035), (Camisole*.06), (T-shirt*.08), (Short Sleeved Shirt*.19), (Long Sleeved Shirt*.25), (Sweater*.36), (Jacket*.36), (Coat*.44), (Pants*.195), (Shorts*.155), (Socks*.02), (Slippers*.03), (Sandals*.02), (Sneakers*.025), (Boots*.10)).			
What type of thermostat do you currently have in your home?		0=I don't have a thermostat 1=I have a manual thermostat 2=I have a programmable thermostat 3=I have one (or more) internet-connected smart thermostat(s) 4=I don't know	
How do you control your current thermostat?		1=I program my thermostat with different set points and schedules 2=I manually change the settings throughout the season depending on my schedule and the weather 3=I use a single set point throughout the season	
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during winter:			
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during summer for air conditioning (if any):			
Please tell us the setpoints for your thermostat when you are: Away from home: Set point during winter:			
Please tell us the setpoints for your thermostat when you are: Away from home: Set point during summer for air conditioning (if any):			
Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during winter:			

Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during summer for air conditioning (if any):	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 22=Other
How do you decide what temperature to set your thermostat to?	1=Based on comfort 2=Based on utility bill 3=Based on environmental considerations
Please select the most important objective in your use of a thermostat:	1=I care about how energy use affects the environment 2=I want to feel comfortable 3=I want to save money on my energy bills 4=Not sure
Please indicate your agreement or disagreement with the statements below. When I feel too cold, I turn up the thermostat and the heat comes on until it reaches the new temperature; then it turns off.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree 5=Not applicable
Please indicate your agreement or disagreement with the statements below. When I set a new temperature, the higher I set it, the faster the house heats up.	
Please indicate your agreement or disagreement with the statements below. I turn down the thermostat before I have a big crowd over to visit, so it doesn't get too hot when they are here.	
Please indicate your agreement or disagreement with the statements below. When I set a lower temperature on the thermostat, the heat doesn't come on until the temperature drops to the new setting.	
Please indicate your agreement or disagreement with the statements below. I keep my thermostats at the same setting always because it uses more energy to reheat the house than it would to keep it at one temperature.	
I have received smart, internet-connected thermostats from NB Power as part of the project.	0=No 1=Yes

We'd like to know about your satisfaction with the smart thermostats that were installed for this project. Please select the circle (radio button) that best describes your opinion of the thermostats.	0= Does not look like a temperature control 1= 2= 3= 4= 5= 6= 7= 8= 9= 10= Looks like a temperature control ► Reverse coded
	0= Does not look attractive 1= 2= 3= 4= 5= 6= 7= 8= 9= 10= Looks attractive ► Reverse coded
	0=Difficult to use 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Easy to use
	0=Very inaccurate 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Very accurate
	0=Very slow to react 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Very quick to react

	0=Very difficult to learn 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Very easy to learn
Our house has felt comfortable since the smart thermostats were installed.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
The information provided to you about your NB Power-provided smart thermostats?	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
The communications with the Shediac Project Team about any issues with your smart thermostats?	
Would you recommend these thermostats to other people?	0=No 1=Yes
Please tell us what you like or don't like about the smart thermostats:	open-ended

B.6.2 Survey #6b: Core + smart thermostats + SOL

Question	Scale
Access code	
How long have you lived in this dwelling?	Years
How long have you lived in this dwelling?	Months
Who lives in this dwelling? Please select the sex of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=Male 2=Female 3=Prefer not to say
Who lives in this dwelling? Please select the age of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=0-10 2=11-20 3=21-30 4=31-40 5=41-50 6=51-60 7=61-70 8=71-80 9=81+ 10=Prefer not to say
What is your best estimate of the total household income received by all household members from all sources, before taxes and deductions, during the last 12 months?	1=Less than \$20,000 (includes income loss) 2=\$20,000 to less than \$40,000 3=\$40,000 to less than \$60,000 4=\$60,000 to less than \$80,000 5=\$80,000 to less than \$100,000 6=\$100,000 to less than \$150,000 7=\$150,000 and over 8=Don't know

Question	Scale
Who in your household completed a survey for this investigation previously?	1=I personally completed the previous surveys 2=Someone else completed the other surveys 3=No one in our house completed the other surveys 4=Different people completed the different surveys
Have there been any changes to the number of people living in this home since June 2023?	0=No 1=Yes, please specify
Have there been any changes to the occupancy of the house since June 2023? Yes, please specify:	open-ended
On a regular workday, when are people in the dwelling?	1=Someone is home all the time 2=Someone is home for part of the workday 3=Everyone leaves after breakfast and returns after the workday
Have there been any changes in the ways you use energy at home compared to last year at this time?	0=No 1=Yes 2=Not sure
What has changed? Check all that apply. <i>Increased use of heating /air-conditioning.</i> <i>Increase in light use.</i> <i>Increase in laundry-dryer loads.</i> <i>Only minimal changes (cooking times, TV times, etc.).</i> <i>Lower heating setpoint (lower use of heating).</i> <i>Programmed temperature changes.</i> <i>Fewer laundry dryer loads.</i> <i>Using energy at different times of day than before.</i> <i>Other, please specify:</i>	1=selected 0=not selected
What has changed? Check all that apply. Specify	open-ended
Which appliances/technologies did you purchase and when did you start using this new appliance or technology? <i>Electric vehicle</i> <i>Fireplace</i> <i>Hot tub</i> <i>Swimming pool</i> <i>2nd Fridge</i> <i>Separate freezer</i> <i>Minibar</i> <i>Heat pump</i> <i>Air purifier</i> <i>Air conditioning</i> <i>Television</i> <i>Water softener</i> <i>Back up generator</i> <i>Solar PV + battery</i> <i>Automobile block heater</i> <i>Portable electric heater</i> <i>Other</i>	0=Do not own 1=Last month 2=Last 6 months 3=Between Nov 2022 and now 4=Between Nov 2019 and Nov 2022 5=Before Nov 2019 (Before the project started)
Which appliances/technologies did you purchase and when did you start using this new appliance or technology? Other, Specify	open-ended
Please indicate how often you usually use: Electric vehicle	1=Never 2=Once a month 3=A couple of times a month 4=Every week 5=A few times a week 6=Every day 7=Not sure

Question	Scale
Please indicate how often you usually use: <i>Fireplace</i> <i>Hot tub</i> <i>Swimming pool</i> <i>Air purifier</i> <i>Automobile block heater</i> <i>Portable electric heater</i>	0=Never 1=Once a month 2=A couple of times a month 3=Every week 4=A few times a week 5=Every day 6=Not sure
Please indicate when are you most likely to do: Laundry loads	1=Morning (7am-9am)
Please indicate when are you most likely to do: Dryer loads	2=During the day (9am-5pm) 3=Evening (5pm-10pm) 4=Overnight (10pm-7am) 5=Not sure 6=Other
Please indicate how many times per week you do: Laundry loads	number
Please indicate how many times per week you do: Dryer loads	number
What is the usual temperature of your laundry loads?	0=cold 1=warm 2=hot
What is the usual temperature of your dryer loads?	0=no heat 1=low 2=medium 3=hot
Hot water is always available when I need it.	0=Strongly disagree
The hot water setting on my tank is just right.	1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
I have experienced issues with my water heater while I have been in the project.	1=No 2=Yes, please specify
I have experienced issues with my water heater while I have been in the project. Yes, please specify:	open-ended
Do you visit your Shediak Project Energy Portal to view your electricity consumption?	0=No 1=Yes 2=I don't know what that is
Please rate your typical thermal sensation in the winter at home:	-3=Cold -2=Cool -1=Slightly cool 0=Neutral 1=Slightly warm 2=Warm 3=Hot
In general, in the winter at home I would like to feel...	-1=Cooler 0=No change 1=Warmer
How often do you take the following actions to improve your thermal comfort at home during the winter? <i>Have a hot or cold drink</i> <i>Use a portable heater</i> <i>Use a portable fan</i> <i>Change the thermostat</i> <i>Add or remove a layer of clothing</i> <i>Open or close the window</i> <i>Adjust a window blind or curtain</i>	1=Never 2=Once per month 3=2-4 times per month 4=Once per week 5=2-4 times per week 6=At least once per day 7=Several times per day 8=Not an option for me
Please give us details about other actions you may take to improve your thermal comfort:	open-ended
Please select the clothes usually worn by you and members of your family at home in the winter:	1=selected 0=not selected

Question		Scale
 ☐  ☐  ☐  ☐  ☐	 ☐  ☐  ☐  ☐  ☐  ☐  ☐	 ☐  ☐  ☐  ☐  ☐  ☐  ☐
CLO=SUM ((Pyjama*.57), (House Coat*.69), (Long Sleeved Underwear Top*.20), (Long Underwear Bottom*.15), (Briefs*.035), (Camisole*.06), (T-shirt*.08), (Short Sleeved Shirt*.19), (Long Sleeved Shirt*.25), (Sweater*.36), (Jacket*.36), (Coat*.44), (Pants*.195), (Shorts*.155), (Socks*.02), (Slippers*.03), (Sandals*.02), (Sneakers*.025), (Boots*.10)).		
What type of thermostat do you currently have in your home?		0=I don't have a thermostat 1=I have a manual thermostat 2=I have a programmable thermostat 3=I have one (or more) internet-connected smart thermostat(s) 4=I don't know
How do you control your current thermostat?		1=I program my thermostat with different set points and schedules 2=I manually change the settings throughout the season depending on my schedule and the weather 3=I use a single set point throughout the season
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during winter:		
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during summer for air conditioning (if any):		
Please tell us the setpoints for your thermostat when you are: Away from home: Set point during winter:		
Please tell us the setpoints for your thermostat when you are: Away from home: Set point during summer for air conditioning (if any):		
Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during winter:		

Question	Scale
Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during summer for air conditioning (if any):	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 22=Other
How do you decide what temperature to set your thermostat to?	1=Based on comfort 2=Based on utility bill 3=Based on environmental considerations
Please select the most important objective in your use of a thermostat:	1=I care about how energy use affects the environment 2=I want to feel comfortable 3=I want to save money on my energy bills 4=Not sure
Please indicate your agreement or disagreement with the statements below. When I feel too cold, I turn up the thermostat and the heat comes on until it reaches the new temperature; then it turns off.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree 5=Not applicable
Please indicate your agreement or disagreement with the statements below. When I set a new temperature, the higher I set it, the faster the house heats up.	
Please indicate your agreement or disagreement with the statements below. I turn down the thermostat before I have a big crowd over to visit, so it doesn't get too hot when they are here.	
Please indicate your agreement or disagreement with the statements below. When I set a lower temperature on the thermostat, the heat doesn't come on until the temperature drops to the new setting.	
Please indicate your agreement or disagreement with the statements below. I keep my thermostats at the same setting always because it uses more energy to reheat the house than it would to keep it at one temperature.	
I have received smart, internet-connected thermostats from NB Power as part of the project.	0=No 1=Yes

Question	Scale
We'd like to know about your satisfaction with the smart thermostats that were installed for this project. Please select the circle (radio button) that best describes your opinion of the thermostats.	0= Does not look like a temperature control 1= 2= 3= 4= 5= 6= 7= 8= 9= 10= Looks like a temperature control ► Reverse coded
	0= Does not look attractive 1= 2= 3= 4= 5= 6= 7= 8= 9= 10= Looks attractive ► Reverse coded
	0=Difficult to use 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Easy to use
	0=Very inaccurate 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Very accurate
	0=Very slow to react 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Very quick to react

Question	Scale
	0=Very difficult to learn 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Very easy to learn
Our house has felt comfortable since the smart thermostats were installed.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
The information provided to you about your NB Power-provided smart thermostats?	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
The communications with the Shediac Project Team about any issues with your smart thermostats?	
Would you recommend these thermostats to other people?	0=No 1=Yes
Please tell us what you like or don't like about the smart thermostats:	open-ended
The solar panel and battery energy storage system has increased the overall value of my home.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree 5=Not applicable
I believe the solar panels increased my overall energy consumption. ► Reverse coded	
I find it reassuring to know that the battery can take over if there is a power outage.	
The solar panels on the roof make my home look less attractive. ► Reverse coded	
Having rooftop solar panels reduces my energy consumption.	
There is an environmental benefit to solar energy.	
It is acceptable for the utility to adjust the battery operation to maintain a stable electrical system for New Brunswick.	
I have experienced challenges or issues with my solar panels.	
Yes, please tell us how they were resolved:	0=No 1=Yes, please tell us how they were resolved: open-ended
I am thinking of returning the solar panels and battery energy storage after the project is finished.	0=No 1=Yes
Have you viewed or downloaded your Solar Energy Credit Report from the Shediac Energy Portal to see your Solar Energy Credit details each month?	0=No 1=Yes 3=I don't know what that is
The report information about the solar energy credit is clear and understandable.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree

B.7 Survey #7 – March 2024

B.7.1 Survey #7a: Core + TOD + No-SOL

Question	Scale
Access code	
Who in your household completed a survey for this investigation previously?	1=I personally completed the previous surveys 2=Someone else completed the other surveys 3=No one in our house completed the prior surveys 4=Different people completed the different surveys
Who lives in this dwelling? Please select the sex of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=Male 2=Female 3=Prefer not to say
Who lives in this dwelling? Please select the age of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=0-10 2=11-20 3=21-30 4=31-40 5=41-50 6=51-60 7=61-70 8=71-80 9=81+ 10=Prefer not to say
Have there been any changes to the number of people living in this home since December 2023?	0=No 1=Yes, please specify
	open-ended
On a regular workday, when are people in the dwelling?	1=Someone is home all the time 2=Someone is home for part of the workday 3=Everyone leaves after breakfast and returns after the workday
What activities take place in your home between...? <i>Cooking 7:00 a.m. and 9:00 a.m</i> <i>Cooking 5:00 p.m. and 7:00 p.m</i> <i>Showering or bathing 7:00 a.m. and 9:00 a.m</i> <i>Showering or bathing 5:00 p.m. and 7:00 p.m</i> <i>Laundry 7:00 a.m. and 9:00 a.m</i> <i>Laundry 5:00 p.m. and 7:00 p.m</i> <i>Getting ready for the work/school day 7:00 a.m. and 9:00 a.m</i> <i>Getting ready for the work/school day 5:00 p.m. and 7:00 p.m</i> <i>Increase the temperature in my home 7:00 a.m. and 9:00 a.m</i> <i>Increase the temperature in my home 5:00 p.m. and 7:00 p.m</i> <i>Dishwashing 7:00 a.m. and 9:00 a.m</i> <i>Dishwashing 5:00 p.m. and 7:00 p.m</i> <i>Charge an electric vehicle 7:00 a.m. and 9:00 a.m</i> <i>Charge an electric vehicle 5:00 p.m. and 7:00 p.m</i> <i>Use a gaming system 7:00 a.m. and 9:00 a.m</i> <i>Use a gaming system 5:00 p.m. and 7:00 p.m</i> <i>Turn on the TV 7:00 a.m. and 9:00 a.m</i> <i>Turn on the TV 5:00 p.m. and 7:00 p.m</i> <i>Use home office equipment for work or schoolwork (computers, printers, monitors, etc.) 7:00 a.m. and 9:00 a.m</i> <i>Use home office equipment for work or schoolwork (computers, printers, monitors, etc.) 5:00 p.m. and 7:00 p.m</i> <i>Other 7:00 a.m. and 9:00 a.m</i> <i>Other 5:00 p.m. and 7:00 p.m</i>	1=selected 0=not selected

What other activities take place in your home between 7:00 a.m and 9:00 a.m.?	Open-ended
What other activities take place in your home between 5:00 p.m. and 7:00 p.m.?	
What happens in your home during the day on most workdays? <i>House work Mornings</i> <i>House work Afternoons</i> <i>House work Evenings</i> <i>Office work Mornings</i> <i>Office work Afternoons</i> <i>Office work Evenings</i> <i>Home-schooling Mornings</i> <i>Home-schooling Afternoons</i> <i>Home-schooling Evenings</i> <i>Hobbies Mornings</i> <i>Hobbies Afternoons</i> <i>Hobbies Evenings</i> <i>Computer gaming Mornings</i> <i>Computer gaming Afternoons</i> <i>Computer gaming Evenings</i> <i>Socializing Mornings</i> <i>Socializing Afternoons</i> <i>Socializing Evenings</i>	1=selected 0=not selected
On how many workdays per week does working from home happen in your dwelling?	0=None 1=One day per week 2=Two days per week 3=Three days per week 4=Four days per week 5=Five days per week
What is your primary heating system?	0=I/We don't have one 1=Forced air furnace (e.g., gas or electric) 2=Electric baseboard heaters 3=Heating stove (e.g., wood or propane) 4=Boiler with hot water or steam radiators 5=Radiant heating (e.g., in floor or wall panel) 6=Central heat pump 7=Ductless heat pump/mini-split heat pump/In-room heat pump 8=Don't know 9=Other, specify
What is your primary heating system? Other	open-ended
What is your secondary heating system?	0=I/We don't have one 1=Forced air furnace (e.g., gas or electric) 2=Electric baseboard heaters 3=Heating stove (e.g., wood or propane) 4=Boiler with hot water or steam radiators 5=Radiant heating (e.g., in floor or wall panel) 6=Central heat pump 7=Ductless heat pump/mini-split heat pump/In-room heat pump 8=Don't know 9=Other, specify
What is your secondary heating system? Other	open-ended

What is your primary cooling system?	0=I/We don't have one 1=Central air conditioning 2=Window air conditioning 3=Central heat pump 4=Ductless heat pump/mini-split heat pump/In-room heat pump 5=Don't know 6=Other, specify
What is your primary cooling system? Other	open-ended
How satisfied are you with the performance of your heat pump(s)?	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
What are the benefits of having a heat pump that you have noticed?	open-ended
What are the disadvantages of heat pumps you would like to tell us about?	open-ended
Would you recommend these heat pumps to other people?	1=No 2=Yes
Please rate your typical thermal sensation in the winter at home:	-3=Cold -2=Cool -1=Slightly cool 0=Neutral 1=Slightly warm 2=Warm 3=Hot
In general, in the winter at home I would like to feel...	-1=Cooler 0=No change 1=Warmer
How often do you take the following actions to improve your thermal comfort at home during the winter? <i>Have a hot or cold drink</i> <i>Use a portable heater</i> <i>Use a portable fan</i> <i>Change the thermostat</i> <i>Add or remove a layer of clothing</i> <i>Open or close the window</i> <i>Adjust a window blind or curtain</i>	1=Never 2=Once per month 3=2-4 times per month 4=Once per week 5=2-4 times per week 6=At least once per day 7=Several times per day 8=Not an option for me
Please give us details about other actions you may take to improve your thermal comfort:	open-ended
How do you control your current thermostat? If your home has multiple thermostats, please answer the following questions for the principal room that is occupied when people are at home.	1=I program my thermostat with different set points and schedules 2=I manually change the settings throughout the season depending on my schedule and the weather 3=I use a single set point throughout the season 4=I don't have a thermostat
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during winter:	
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during summer for air conditioning (if any):	

Please tell us the setpoints for your thermostat when you are: Away from home: Set point during winter:	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 23=OFF 24=Other
Please tell us the setpoints for your thermostat when you are: Away from home: Set point during summer for air conditioning (if any):	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 22=Other 23=OFF

Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during winter:	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 23=OFF 24=Other
Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during summer for air conditioning (if any):	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 22=Other 23=OFF
How do you decide what temperature to set your thermostat to?	1=Based on comfort 2=Based on utility bill 3=Based on environmental considerations
How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to? Maximizing comfort:	
How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to? Minimizing utility bill:	
How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to? Minimizing environmental impact:	

How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to? Thermostat default settings:	0=Not at all important 1= 2= 3= 4= 5= 6= 7= 8= 9=Very important
How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to? Social norms	
When I feel too cold, I turn up the thermostat and the heat comes on until it reaches the new temperature; then it turns off.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree 5=Not applicable
When I set a new temperature, the higher I set it, the faster the house heats up.	
I turn down the thermostat before I have a big crowd over to visit, so it doesn't get too hot when they are here.	
When I set a lower temperature on the thermostat, the heat doesn't come on until the temperature drops to the new setting.	
I keep my thermostats at the same setting always because it uses more energy to reheat the house than it would to keep it at one temperature.	
I have received smart, internet-connected thermostats from NB Power as part of the project.	1=No 2=Yes
We'd like to know about your satisfaction with the smart thermostats that were installed for this project. Please select the circle (radio button) that best describes your opinion of the thermostats.	0= Does not look like a temperature control 1= 2= 3= 4= 5= 6= 7= 8= 9= 10= Looks like a temperature control ► Reverse coded
	0= Does not look attractive 1= 2= 3= 4= 5= 6= 7= 8= 9= 10= Looks attractive ► Reverse coded
	0=Difficult to use 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Easy to use

	0=Very inaccurate 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Very accurate
	0=Very slow to react 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Very quick to react
	0=Very difficult to learn 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Very easy to learn
Our house has felt comfortable since the smart thermostats were installed.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
How satisfied are you with the performance of the smart thermostats you received from the project?	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
Would you recommend these thermostats to other people?	0=No 1=Yes
Hot water is always available when I need it.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
The hot water setting on my tank is just right.	
I have experienced issues with my water heater while I have been in the project.	0=No 1=Yes
I have experienced issues with my water heater while I have been in the project. Specify.	open-ended
If NB Power were to offer you a program in which they could send signals to your water heater, would you sign up for it?	0=No 1=Yes
Why not? Are there conditions under which you might decide to sign up?	open-ended

I feel a moral obligation to engage in energy behaviours that are beneficial for the environment.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
Most Canadians engage in energy behaviours that are beneficial for the environment.	
Most Canadians believe it is morally right to engage in energy behaviours that are beneficial for the environment.	
Most of my neighbours engage in energy behaviours that are beneficial for the environment.	
Most of my neighbours believe it is morally right to engage in energy behaviours that are beneficial for the environment.	
Avoiding the need to build new fossil-fuel-burning electrical generating stations is important to me.	
Increasing the use of renewable energy sources to generate electricity is important to me.	
Decreasing the use of nuclear generating stations is important to me.	
How we generate electricity is less important to me than making sure it's there when we need it.	
Increasing the amount of non-emitting electricity generation is important to me.	
Keeping customer electricity bills as low as possible, no matter how it's generated, is important to me.	
Giving the utility the ability to adjust individual customer electrical demand is acceptable if it keeps costs low for everyone.	
It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is stable for everyone.	
Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	
Avoiding the need for new electrical generating stations is important to me.	
It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is reliable for everyone.	
Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	
It is acceptable for utilities to adjust individual customer electrical demand to deliver the least costly electricity supply for everyone.	
Have you felt that you had to change your household routine in any way in order to participate in the research project?	0=No 1=Yes
What kinds of conversations about energy habits are happening in your household since the project began?	open-ended
What changes have you noticed in how you use energy at home since joining this project?	open-ended
What is the most important thing you have learned about smart energy technology at home?	open-ended
Looking to the future, how might you change your energy habits even more as a result of this project?	open-ended
What might be the benefits to you as an NB Power customer of utility programs that are enabled by smart grid technologies?	open-ended
What might be disadvantages to you as an NB Power customer of utility programs to promote smart grid technologies?	open-ended
Replace my light bulbs with energy efficient light bulbs.	0=Very unwilling 1=Somewhat unwilling 2=Neither willing nor unwilling 3=Somewhat willing 4=Very willing 5=I have already done this
Replace my appliances with more energy efficient appliances (e.g., a refrigerator with an Energy Star certification).	
Install solar panels on my home (or increase the number of panels, if you have them already).	
Participate in a time-of-day electricity rate program.	
Install a mini-split heat pump.	
Schedule appliances to operate at off-peak times.	

Upgrade the insulation or windows.	
Reduce my hot water consumption.	
Wash and rinse my clothes with hot water.	
Leave lights on when I am not using them.	
Lower my thermostat setting in winter to save energy.	
If I reduce my at-home energy consumption, I will personally receive financial benefits.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
If I do not reduce my at-home energy consumption, I will incur financial costs.	
If I invest in renewable energy sources (e.g., by installing solar panels), I will personally receive financial benefits.	
If I do not invest in renewable energy sources (e.g., by installing solar panels), I will personally incur financial costs.	
If I reduce my at-home energy consumption, I will have to give up some comfort and convenience. ► Reverse coded	
If I personally invest in renewable energy sources, it will cost me money.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
One down side to installing renewable energy sources like solar panels is that they can make the home look unattractive.	
Having a source of backup power to keep important electrical devices running during a power outage is important to me.	
If incentives were available, I would be willing to invest in energy storage that would provide back up power for my home if there was a grid outage.	
How important is it to you to have backup power in case of an electricity outage?	0=Not at all important 1= 2= 3= 4= 5= 6= 7= 8= 9=Very important
How much money per month would you expect to receive from a utility company in order for you to participate in a utility intervention program?	0=I would not need to be paid 1=\$5-\$10 2=\$11-\$20 3=\$21-\$30 4=\$31-\$40 5=\$41-\$50 6=I would never give control to the utility
What is your approximate monthly electricity consumption (kWh) in the winter?	1=Below 1,000 kWh 2=1,000-3,000 kWh 3=3,001-5,000 kWh 4=Over 5,000 kWh 5=Don't know
What is your approximate monthly electricity consumption (kWh) in the summer?	1=Below 200 kWh 2=200-600 kWh 3=601-1,000 kWh 4=Over 1,000 kWh 5=Don't know
How much attention do you usually pay to your electricity bill?	1=I have a full understanding of my electricity bill 2=I can find what I am looking for 3=I don't know what some numbers mean 4=I don't know where or how to review my electricity bills 5=I don't pay any attention to my electricity bill

When do you think your peak usage happens during the day?	1=Morning (6am–9am) 2=Midday (9am–2pm) 3=Afternoon (2pm–5pm) 4=Evening (5pm–10pm) 5=Night time (10pm–6am) 6=Other, specify
When do you think your peak usage happens during the day? Specify	open-ended
What is your current knowledge of time-of-day pricing?	4=I believe that I am extremely knowledgeable about time-of-day pricing 3=I believe that I am moderately knowledgeable about time-of-day pricing 2=I believe that I am somewhat knowledgeable about time-of-day pricing 1=I believe that I am slightly knowledgeable about time-of-day pricing 0=I believe that I am not at all knowledgeable about time-of-day pricing
What do you think the main benefits of time-of-day rates might be? Please select the top two: <i>Lower electricity bill for some consumers</i> <i>Reduced energy consumption</i> <i>Environmental benefits</i> <i>More revenue for the utility</i> <i>Lower peak demand for electricity</i> <i>Other, please specify:</i>	1=selected 0=not selected
What do you think the main benefits of time-of-day rates might be? Specify	open-ended
How interested would you be to learn about choices for how you could be billed for the electricity you use?	0=Not at all interested 1= 2= 3= 4= 5= 6= 7= 8= 9=Very interested
How likely is it that you would choose to be billed using a new billing option if it would allow you to lower your bill, even if it took some effort on your part?	0=Not at all likely 1= 2=
How likely is it that you would choose to be billed using a new billing option if it would allow you to lower your bill with some effort on your part, and the new system was more complicated for you to understand?	3= 4= 5= 6= 7= 8= 9=Very likely
If NB Power offered a Time-of-Day rate program in the future, would you sign up for it?	0=No 1=Yes
Why not? Please check any reasons that apply to you. Too much effort	1=selected
Why not? Please check any reasons that apply to you. My daily schedule is complicated enough without changing it	0=not selected
Why not? Please check any reasons that apply to you. Too inconvenient	
Why not? Please check any reasons that apply to you. Too little reward	
Why not? Please check any reasons that apply to you. I think it would only benefit the utility	
Why not? Please check any reasons that apply to you. I don't understand how it would work	

Why not? Please check any reasons that apply to you. Other, please specify:	
Why not? Please check any reasons that apply to you. Specify	open-ended
What would be needed to make it worthwhile for you to take advantage of time-of-day rates?	open-ended
You are in the Time-of-Day Rates group in this project. Did you try to take advantage of them during this project?	0=No 1=Yes
Why not? Please check any reasons that apply to you. <i>Too much effort</i> <i>My daily schedule is complicated enough without changing it</i> <i>Too inconvenient</i> <i>Too little reward</i> <i>I think it would only benefit the utility</i> <i>I didn't understand how it worked</i> <i>Other, please specify:</i>	1=selected 0=not selected
Why not? Please check any reasons that apply to you. Specify:	open-ended
What would have been needed to make it worthwhile for you to take advantage of time-of-day rates?	open-ended
How much do you believe you saved on your energy bill because of the time-of-day credit on your NB Power bill?	0=No saving at all 1=1-4% saving 2=5-7% saving 3=8-10% saving 4=More than 10% saving 9=Not sure
Which actions have you used to move your energy consumption from peak time to off-peak time? Please select the top three: <i>Do laundry in the evening/night</i> <i>Run the dishwasher in the evenings or overnight</i> <i>Turn off lights</i> <i>Schedule my appliances to run in the evening or overnight</i> <i>Turn off appliances when not in use</i> <i>Set thermostat to lower temperatures overnight</i> <i>Hang your clothes to dry instead of using a clothes dryer</i> <i>Pre-heat the house early in the morning before peak time</i> <i>Set it and forget it for my thermostat</i> <i>Other, please specify:</i>	1=selected 0=not selected
Which actions have you used to move your energy consumption from peak time to off-peak time? Specify	open-ended
How often do you think you have been able to adopt energy efficient behaviours/actions to get full advantage of time-of-day rates?	1=Every day 2=2-4 times a week 3=Once a week 4=2-4 times a month 5=Once a month 6=Not sure 7=I don't think I have been able to change my energy behaviours
How easy or difficult was it for you to change the timing of your electricity use to take advantage of time-of-day rates?	0=Very easy 1= 2= 3= 4= 5= 6= 7= 8= 9=Very difficult

Thinking of the bill credits you received during the time-of-day trial, were the benefits worth the effort of changing the timing of your electricity use?	0=The benefits were not at all worth the effort 1= 2= 3= 4= 5= 6= 7= 8= 9=The benefits were definitely worth the effort
How satisfied are you with the Time of Day program in this study?	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
Please tell us about your experiences in the time-of-day trial. What worked? What didn't work?	open-ended
Having renewable energy sources like solar panels would make me more likely to invest in battery energy storage.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
If there were incentives for battery energy storage, I would be more likely to purchase a renewable energy system.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
If you already have a backup power system, please tell us about the benefits it provides to you, and any challenges that you had in acquiring it. If you don't have a backup power system, how easy or difficult do you think it would be to get one?	open-ended
Imagine you were thinking of purchasing a 5,000-Watt solar panel system on your home or property, similar to the ones installed as part of this project. Generating electricity on your home would reduce your electricity bill. If there were no incentives to reduce the cost, how fast would you expect to break even on the investment?	1=1 year 2=5 years 3=10 years 4=20 years 5=I would never break even
If incentives were offered to encourage you to purchase a solar panel system for your home, what level of incentive would enable you to purchase and install a system?	1=0% 2=10% 3=20% 4=30% 5=40% 6=50% 7=60% 8=70% 9=80% 10=90% 11=100%
Imagine you were thinking of purchasing a 5kW/2hr battery energy storage system on your home or property, similar to the ones installed as part of this project. At the present time, it would have little effect on your electricity bill, but it would provide clean back-up power in the event of a power outage. If there were no incentives to reduce the cost, how much would you be willing to pay?	1=\$1,000 2=\$5,000 3=\$10,000 4=\$20,000 5=Price doesn't matter, I want to be sure to have power if there is an outage

If incentives were offered to encourage you to purchase a battery energy storage system for your home, what level of incentive would enable you to purchase and install a system?	1=0% 2=10% 3=20% 4=30% 5=40% 6=50% 7=60% 8=70% 9=80% 10=90% 11=100%
A solar panel and battery energy storage system would increase the overall value of my home.	0=Strongly disagree 1=Disagree
I believe that solar panels would increase my overall energy consumption. ► Reverse coded	2=Neither agree nor disagree 3=Agree
I would find it reassuring to know that the battery can power some of my home if there is a power outage.	4=Strongly agree
Having solar panels on the roof would make my home look less attractive. ► Reverse coded	
Having rooftop solar panels would reduce my energy consumption.	0=Strongly disagree 1=Disagree
There is an environmental benefit to solar energy.	2=Neither agree nor disagree 3=Agree
If I had a battery, it would be acceptable for the utility to adjust the battery operation to maintain a stable electrical system for New Brunswick.	4=Strongly agree
Having a solar panel system (with or without battery energy storage) would reduce my electricity bills.	
How satisfied are you with...The communications with the project team about the project?	0=Very dissatisfied 1=Dissatisfied
How satisfied are you with...Overall, your participation in the Shediak Residential Energy Study?	2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
In general, how satisfied are you with NB Power?	0=Not at all satisfied 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Most satisfied
What is the reason for the rating you gave for your satisfaction with NB Power?	open-ended
Are you willing to be contacted to participate in focus group sessions about smart energy technologies run by the Université de Moncton and/or NB Power after the project is finished?	0=No 1=Yes
When the project ends, we would like to be able to tell New Brunswickers about what it was like for our participants to be in this project. Would you be willing to allow us to anonymously quote your text answers to questions in this survey? The quotations could be used in newspaper or web articles or on posters or presentations about the project, either in the original language or translated. Your name will never be identified.	0=No 1=Yes
This is the last survey in the project. Is there anything else you would like to tell us about your experiences with the Shediak Residential Energy Study?	open-ended

B.7.2 Survey #7b: Core + TOD + SOL

Question	Scale
Access code	
Who in your household completed a survey for this investigation previously?	1=I personally completed the previous surveys 2=Someone else completed the other surveys 3=No one in our house completed the prior surveys 4=Different people completed the different surveys
Who lives in this dwelling? Please select the sex of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=Male 2=Female 3=Prefer not to say
Who lives in this dwelling? Please select the age of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=0-10 2=11-20 3=21-30 4=31-40 5=41-50 6=51-60 7=61-70 8=71-80 9=81+ 10=Prefer not to say
Have there been any changes to the number of people living in this home since December 2023?	0=No 1=Yes, please specify
	open-ended
On a regular workday, when are people in the dwelling?	1=Someone is home all the time 2=Someone is home for part of the workday 3=Everyone leaves after breakfast and returns after the workday
What activities take place in your home between...? <i>Cooking 7:00 a.m. and 9:00 a.m</i> <i>Cooking 5:00 p.m. and 7:00 p.m</i> <i>Showering or bathing 7:00 a.m. and 9:00 a.m</i> <i>Showering or bathing 5:00 p.m. and 7:00 p.m</i> <i>Laundry 7:00 a.m. and 9:00 a.m</i> <i>Laundry 5:00 p.m. and 7:00 p.m</i> <i>Getting ready for the work/school day 7:00 a.m. and 9:00 a.m</i> <i>Getting ready for the work/school day 5:00 p.m. and 7:00 p.m</i> <i>Increase the temperature in my home 7:00 a.m. and 9:00 a.m</i> <i>Increase the temperature in my home 5:00 p.m. and 7:00 p.m</i> <i>Dishwashing 7:00 a.m. and 9:00 a.m</i> <i>Dishwashing 5:00 p.m. and 7:00 p.m</i> <i>Charge an electric vehicle 7:00 a.m. and 9:00 a.m</i> <i>Charge an electric vehicle 5:00 p.m. and 7:00 p.m</i> <i>Use a gaming system 7:00 a.m. and 9:00 a.m</i> <i>Use a gaming system 5:00 p.m. and 7:00 p.m</i> <i>Turn on the TV 7:00 a.m. and 9:00 a.m</i> <i>Turn on the TV 5:00 p.m. and 7:00 p.m</i> <i>Use home office equipment for work or schoolwork (computers, printers, monitors, etc.) 7:00 a.m. and 9:00 a.m</i> <i>Use home office equipment for work or schoolwork (computers, printers, monitors, etc.) 5:00 p.m. and 7:00 p.m</i> <i>Other 7:00 a.m. and 9:00 a.m</i> <i>Other 5:00 p.m. and 7:00 p.m</i>	1=selected 0=not selected
What other activities take place in your home between 7:00 a.m and 9:00 a.m.?	Open-ended

What other activities take place in your home between 5:00 p.m. and 7:00 p.m.?	
What happens in your home during the day on most workdays? <i>House work Mornings</i> <i>House work Afternoons</i> <i>House work Evenings</i> <i>Office work Mornings</i> <i>Office work Afternoons</i> <i>Office work Evenings</i> <i>Home-schooling Mornings</i> <i>Home-schooling Afternoons</i> <i>Home-schooling Evenings</i> <i>Hobbies Mornings</i> <i>Hobbies Afternoons</i> <i>Hobbies Evenings</i> <i>Computer gaming Mornings</i> <i>Computer gaming Afternoons</i> <i>Computer gaming Evenings</i> <i>Socializing Mornings</i> <i>Socializing Afternoons</i> <i>Socializing Evenings</i>	1=selected 0=not selected
On how many workdays per week does working from home happen in your dwelling?	0=None 1=One day per week 2=Two days per week 3=Three days per week 4=Four days per week 5=Five days per week
What is your primary heating system?	0=I/We don't have one 1=Forced air furnace (e.g., gas or electric) 2=Electric baseboard heaters 3=Heating stove (e.g., wood or propane) 4=Boiler with hot water or steam radiators 5=Radiant heating (e.g., in floor or wall panel) 6=Central heat pump 7=Ductless heat pump/mini-split heat pump/In-room heat pump 8=Don't know 9=Other, specify
What is your primary heating system? Other	open-ended
What is your secondary heating system?	0=I/We don't have one 1=Forced air furnace (e.g., gas or electric) 2=Electric baseboard heaters 3=Heating stove (e.g., wood or propane) 4=Boiler with hot water or steam radiators 5=Radiant heating (e.g., in floor or wall panel) 6=Central heat pump 7=Ductless heat pump/mini-split heat pump/In-room heat pump 8=Don't know 9=Other, specify
What is your secondary heating system? Other	open-ended

What is your primary cooling system?	0=I/We don't have one 1=Central air conditioning 2=Window air conditioning 3=Central heat pump 4=Ductless heat pump/mini-split heat pump/In-room heat pump 5=Don't know 6=Other, specify
What is your primary cooling system? Other	open-ended
How satisfied are you with the performance of your heat pump(s)?	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
What are the benefits of having a heat pump that you have noticed?	open-ended
What are the disadvantages of heat pumps you would like to tell us about?	open-ended
Would you recommend these heat pumps to other people?	1=No 2=Yes
Please rate your typical thermal sensation in the winter at home:	-3=Cold -2=Cool -1=Slightly cool 0=Neutral 1=Slightly warm 2=Warm 3=Hot
In general, in the winter at home I would like to feel...	-1=Cooler 0=No change 1=Warmer
How often do you take the following actions to improve your thermal comfort at home during the winter? <i>Have a hot or cold drink</i> <i>Use a portable heater</i> <i>Use a portable fan</i> <i>Change the thermostat</i> <i>Add or remove a layer of clothing</i> <i>Open or close the window</i> <i>Adjust a window blind or curtain</i>	1=Never 2=Once per month 3=2-4 times per month 4=Once per week 5=2-4 times per week 6=At least once per day 7=Several times per day 8=Not an option for me
Please give us details about other actions you may take to improve your thermal comfort:	open-ended
How do you control your current thermostat? If your home has multiple thermostats, please answer the following questions for the principal room that is occupied when people are at home.	1=I program my thermostat with different set points and schedules 2=I manually change the settings throughout the season depending on my schedule and the weather 3=I use a single set point throughout the season 4=I don't have a thermostat
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during winter:	
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during summer for air conditioning (if any):	

Please tell us the setpoints for your thermostat when you are: Away from home: Set point during winter:	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 23=OFF 24=Other
Please tell us the setpoints for your thermostat when you are: Away from home: Set point during summer for air conditioning (if any):	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 22=Other 23=OFF

Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during winter:	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 23=OFF 24=Other
Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during summer for air conditioning (if any):	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 22=Other 23=OFF
How do you decide what temperature to set your thermostat to?	1=Based on comfort 2=Based on utility bill 3=Based on environmental considerations
How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to? Maximizing comfort:	
How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to? Minimizing utility bill:	
How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to? Minimizing environmental impact:	

How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to? Thermostat default settings:	0=Not at all important 1= 2= 3= 4= 5= 6= 7= 8= 9=Very important
How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to? Social norms	
When I feel too cold, I turn up the thermostat and the heat comes on until it reaches the new temperature; then it turns off.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree 5=Not applicable
When I set a new temperature, the higher I set it, the faster the house heats up.	
I turn down the thermostat before I have a big crowd over to visit, so it doesn't get too hot when they are here.	
When I set a lower temperature on the thermostat, the heat doesn't come on until the temperature drops to the new setting.	
I keep my thermostats at the same setting always because it uses more energy to reheat the house than it would to keep it at one temperature.	
I have received smart, internet-connected thermostats from NB Power as part of the project.	1=No 2=Yes
We'd like to know about your satisfaction with the smart thermostats that were installed for this project. Please select the circle (radio button) that best describes your opinion of the thermostats.	0= Does not look like a temperature control 1= 2= 3= 4= 5= 6= 7= 8= 9= 10= Looks like a temperature control ► Reverse coded
	0= Does not look attractive 1= 2= 3= 4= 5= 6= 7= 8= 9= 10= Looks attractive ► Reverse coded
	0=Difficult to use 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Easy to use

	0=Very inaccurate 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Very accurate
	0=Very slow to react 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Very quick to react
	0=Very difficult to learn 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Very easy to learn
Our house has felt comfortable since the smart thermostats were installed.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
How satisfied are you with the performance of the smart thermostats you received from the project?	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
Would you recommend these thermostats to other people?	0=No 1=Yes
Hot water is always available when I need it.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
The hot water setting on my tank is just right.	
I have experienced issues with my water heater while I have been in the project.	0=No 1=Yes
I have experienced issues with my water heater while I have been in the project. Specify.	open-ended
If NB Power were to offer you a program in which they could send signals to your water heater, would you sign up for it?	0=No 1=Yes
Why not? Are there conditions under which you might decide to sign up?	open-ended

I feel a moral obligation to engage in energy behaviours that are beneficial for the environment.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
Most Canadians engage in energy behaviours that are beneficial for the environment.	
Most Canadians believe it is morally right to engage in energy behaviours that are beneficial for the environment.	
Most of my neighbours engage in energy behaviours that are beneficial for the environment.	
Most of my neighbours believe it is morally right to engage in energy behaviours that are beneficial for the environment.	
Avoiding the need to build new fossil-fuel-burning electrical generating stations is important to me.	
Increasing the use of renewable energy sources to generate electricity is important to me.	
Decreasing the use of nuclear generating stations is important to me.	
How we generate electricity is less important to me than making sure it's there when we need it.	
Increasing the amount of non-emitting electricity generation is important to me.	
Keeping customer electricity bills as low as possible, no matter how it's generated, is important to me.	
Giving the utility the ability to adjust individual customer electrical demand is acceptable if it keeps costs low for everyone.	
It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is stable for everyone.	
Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	
Avoiding the need for new electrical generating stations is important to me.	
It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is reliable for everyone.	
Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	
It is acceptable for utilities to adjust individual customer electrical demand to deliver the least costly electricity supply for everyone.	
Have you felt that you had to change your household routine in any way in order to participate in the research project?	0=No 1=Yes
What kinds of conversations about energy habits are happening in your household since the project began?	open-ended
What changes have you noticed in how you use energy at home since joining this project?	open-ended
What is the most important thing you have learned about smart energy technology at home?	open-ended
Looking to the future, how might you change your energy habits even more as a result of this project?	open-ended
What might be the benefits to you as an NB Power customer of utility programs that are enabled by smart grid technologies?	open-ended
What might be disadvantages to you as an NB Power customer of utility programs to promote smart grid technologies?	open-ended
Replace my light bulbs with energy efficient light bulbs.	0=Very unwilling 1=Somewhat unwilling 2=Neither willing nor unwilling 3=Somewhat willing 4=Very willing 5=I have already done this
Replace my appliances with more energy efficient appliances (e.g., a refrigerator with an Energy Star certification).	
Install solar panels on my home (or increase the number of panels, if you have them already).	
Participate in a time-of-day electricity rate program.	
Install a mini-split heat pump.	
Schedule appliances to operate at off-peak times.	

Upgrade the insulation or windows.	
Reduce my hot water consumption.	
Wash and rinse my clothes with hot water.	
Leave lights on when I am not using them.	
Lower my thermostat setting in winter to save energy.	
If I reduce my at-home energy consumption, I will personally receive financial benefits.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
If I do not reduce my at-home energy consumption, I will incur financial costs.	
If I invest in renewable energy sources (e.g., by installing solar panels), I will personally receive financial benefits.	
If I do not invest in renewable energy sources (e.g., by installing solar panels), I will personally incur financial costs.	
If I reduce my at-home energy consumption, I will have to give up some comfort and convenience. ► Reverse coded	
If I personally invest in renewable energy sources, it will cost me money.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
One down side to installing renewable energy sources like solar panels is that they can make the home look unattractive.	
Having a source of backup power to keep important electrical devices running during a power outage is important to me.	
If incentives were available, I would be willing to invest in energy storage that would provide back up power for my home if there was a grid outage.	
How important is it to you to have backup power in case of an electricity outage?	
How much money per month would you expect to receive from a utility company in order for you to participate in a utility intervention program?	0=Not at all important 1= 2= 3= 4= 5= 6= 7= 8= 9=Very important
What is your approximate monthly electricity consumption (kWh) in the winter?	0=I would not need to be paid 1=\$5-\$10 2=\$11-\$20 3=\$21-\$30 4=\$31-\$40 5=\$41-\$50 6=I would never give control to the utility
What is your approximate monthly electricity consumption (kWh) in the summer?	1=Below 1,000 kWh 2=1,000-3,000 kWh 3=3,001-5,000 kWh 4=Over 5,000 kWh 5=Don't know
How much attention do you usually pay to your electricity bill?	1=Below 200 kWh 2=200-600 kWh 3=601-1,000 kWh 4=Over 1,000 kWh 5=Don't know
	1=I have a full understanding of my electricity bill 2=I can find what I am looking for 3=I don't know what some numbers mean 4=I don't know where or how to review my electricity bills 5=I don't pay any attention to my electricity bill

When do you think your peak usage happens during the day?	1=Morning (6am–9am) 2=Midday (9am–2pm) 3=Afternoon (2pm–5pm) 4=Evening (5pm–10pm) 5=Night time (10pm–6am) 6=Other, specify
When do you think your peak usage happens during the day? Specify	open-ended
What is your current knowledge of time-of-day pricing?	4=I believe that I am extremely knowledgeable about time-of-day pricing 3=I believe that I am moderately knowledgeable about time-of-day pricing 2=I believe that I am somewhat knowledgeable about time-of-day pricing 1=I believe that I am slightly knowledgeable about time-of-day pricing 0=I believe that I am not at all knowledgeable about time-of-day pricing
What do you think the main benefits of time-of-day rates might be? Please select the top two: <i>Lower electricity bill for some consumers</i> <i>Reduced energy consumption</i> <i>Environmental benefits</i> <i>More revenue for the utility</i> <i>Lower peak demand for electricity</i> <i>Other, please specify:</i>	1=selected 0=not selected
What do you think the main benefits of time-of-day rates might be? Specify	open-ended
How interested would you be to learn about choices for how you could be billed for the electricity you use?	0=Not at all interested 1= 2= 3= 4= 5= 6= 7= 8= 9=Very interested
How likely is it that you would choose to be billed using a new billing option if it would allow you to lower your bill, even if it took some effort on your part?	0=Not at all likely 1= 2= 3= 4= 5= 6= 7= 8= 9=Very likely
How likely is it that you would choose to be billed using a new billing option if it would allow you to lower your bill with some effort on your part, and the new system was more complicated for you to understand?	
If NB Power offered a Time-of-Day rate program in the future, would you sign up for it?	0=No 1=Yes
Why not? Please check any reasons that apply to you. <i>Too much effort</i> <i>My daily schedule is complicated enough without changing it</i> <i>Too inconvenient</i> <i>Too little reward</i> <i>I think it would only benefit the utility</i> <i>I didn't understand how it worked</i> <i>Other, please specify:</i>	1=selected 0=not selected
Why not? Please check any reasons that apply to you. Specify	open-ended

What would be needed to make it worthwhile for you to take advantage of time-of-day rates?	open-ended
You are in the Time-of-Day Rates group in this project. Did you try to take advantage of them during this project?	0=No 1=Yes
Why not? Please check any reasons that apply to you. <i>Too much effort</i> <i>My daily schedule is complicated enough without changing it</i> <i>Too inconvenient</i> <i>Too little reward</i> <i>I think it would only benefit the utility</i> <i>I didn't understand how it worked</i> <i>Other, please specify:</i>	1=selected 0=not selected
Why not? Please check any reasons that apply to you. Specify:	open-ended
What would have been needed to make it worthwhile for you to take advantage of time-of-day rates?	open-ended
How much do you believe you saved on your energy bill because of the time-of-day credit on your NB Power bill?	0=No saving at all 1=1-4% saving 2=5-7% saving 3=8-10% saving 4=More than 10% saving 9=Not sure
Which actions have you used to move your energy consumption from peak time to off-peak time? Please select the top three: <i>Do laundry in the evening/night</i> <i>Run the dishwasher in the evenings or overnight</i> <i>Turn off lights</i> <i>Schedule my appliances to run in the evening or overnight</i> <i>Turn off appliances when not in use</i> <i>Set thermostat to lower temperatures overnight</i> <i>Hang your clothes to dry instead of using a clothes dryer</i> <i>Pre-heat the house early in the morning before peak time</i> <i>Set it and forget it for my thermostat</i> <i>Other, please specify:</i>	1=selected 0=not selected
Which actions have you used to move your energy consumption from peak time to off-peak time? Specify	open-ended
How often do you think you have been able to adopt energy efficient behaviours/actions to get full advantage of time-of-day rates?	1=Every day 2=2-4 times a week 3=Once a week 4=2-4 times a month 5=Once a month 6=Not sure 7=I don't think I have been able to change my energy behaviours
How easy or difficult was it for you to change the timing of your electricity use to take advantage of time-of-day rates?	0=Very easy 1= 2= 3= 4= 5= 6= 7= 8= 9=Very difficult

Thinking of the bill credits you received during the time-of-day trial, were the benefits worth the effort of changing the timing of your electricity use?	0=The benefits were not at all worth the effort 1= 2= 3= 4= 5= 6= 7= 8= 9=The benefits were definitely worth the effort
How satisfied are you with the Time of Day program in this study?	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
Please tell us about your experiences in the time-of-day trial. What worked? What didn't work?	open-ended
The solar panel and battery energy storage system has increased the overall value of my home.	0=Strongly disagree 1=Disagree
I believe the solar panels and battery energy storage increased my overall energy consumption. ► Reverse coded	2=Neither agree nor disagree 3=Agree
I find it reassuring to know that the battery can power some of my home if there is a power outage.	4=Strongly agree
The solar panels on the roof make my home look less attractive. ► Reverse coded	
Having rooftop solar panels reduces my energy consumption.	0=Strongly disagree 1=Disagree
There is an environmental benefit to solar energy.	2=Neither agree nor disagree 3=Agree
It is acceptable for the utility to adjust the battery operation to maintain a stable electrical system for New Brunswick.	4=Strongly agree
Having a solar panel system with battery energy storage reduced my electricity bills.	
How satisfied are you with the performance of your solar + battery energy storage system?	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
Would you recommend this system to other people?	0=No 1=Yes
I have experienced challenges or issues with my solar panels and/or battery.	0=No 1=Yes
I have experienced challenges or issues with my solar panels and/or battery. Please tell us about the situation and how it was resolved:	open-ended
During the project, adjustments were made to your battery operation to test whether this could be a means to manage the electricity grid. Do you think you noticed these adjustments?	0=No 1=Yes
During the project, adjustments were made to your battery operation to test whether this could be a means to manage the electricity grid. Do you think you noticed these adjustments? Please tell us what you noticed:	open-ended
If NB Power were to offer a program that gave you an incentive to allow it to adjust your battery on occasion, do you think you would join it?	0=No 1=Yes
What do you think would be fair terms for such a program?	open-ended
I am thinking of returning the solar panels and battery energy storage after the project is finished.	0=No 1=Yes
I am thinking of returning the solar panels and battery energy storage after the project is finished. Please give us your reasons why:	open-ended
How satisfied are you with...The communications with the project team about the project?	

How satisfied are you with...Overall, your participation in the Shediac Residential Energy Study?	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
In general, how satisfied are you with NB Power?	0=Not at all satisfied 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Most satisfied
What is the reason for the rating you gave for your satisfaction with NB Power?	open-ended
Are you willing to be contacted to participate in focus group sessions about smart energy technologies run by the Université de Moncton and/or NB Power after the project is finished?	0=No 1=Yes
When the project ends, we would like to be able to tell New Brunswickers about what it was like for our participants to be in this project. Would you be willing to allow us to anonymously quote your text answers to questions in this survey? The quotations could be used in newspaper or web articles or on posters or presentations about the project, either in the original language or translated. Your name will never be identified.	0=No 1=Yes
This is the last survey in the project. Is there anything else you would like to tell us about your experiences with the Shediac Residential Energy Study?	open-ended

B.7.3 Survey #7c: Core + No-TOD + No-SOL

Question	Scale
Access code	
Who in your household completed a survey for this investigation previously?	1=I personally completed the previous surveys 2=Someone else completed the other surveys 3=No one in our house completed the prior surveys 4=Different people completed the different surveys
Who lives in this dwelling? Please select the sex of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=Male 2=Female 3=Prefer not to say
Who lives in this dwelling? Please select the age of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=0-10 2=11-20 3=21-30 4=31-40 5=41-50 6=51-60 7=61-70 8=71-80 9=81+ 10=Prefer not to say

Have there been any changes to the number of people living in this home since December 2023?	0=No 1=Yes, please specify
	open-ended
On a regular workday, when are people in the dwelling?	1=Someone is home all the time 2=Someone is home for part of the workday 3=Everyone leaves after breakfast and returns after the workday
What activities take place in your home between...? <i>Cooking 7:00 a.m. and 9:00 a.m</i> <i>Cooking 5:00 p.m. and 7:00 p.m</i> <i>Showering or bathing 7:00 a.m. and 9:00 a.m</i> <i>Showering or bathing 5:00 p.m. and 7:00 p.m</i> <i>Laundry 7:00 a.m. and 9:00 a.m</i> <i>Laundry 5:00 p.m. and 7:00 p.m</i> <i>Getting ready for the work/school day 7:00 a.m. and 9:00 a.m</i> <i>Getting ready for the work/school day 5:00 p.m. and 7:00 p.m</i> <i>Increase the temperature in my home 7:00 a.m. and 9:00 a.m</i> <i>Increase the temperature in my home 5:00 p.m. and 7:00 p.m</i> <i>Dishwashing 7:00 a.m. and 9:00 a.m</i> <i>Dishwashing 5:00 p.m. and 7:00 p.m</i> <i>Charge an electric vehicle 7:00 a.m. and 9:00 a.m</i> <i>Charge an electric vehicle 5:00 p.m. and 7:00 p.m</i> <i>Use a gaming system 7:00 a.m. and 9:00 a.m</i> <i>Use a gaming system 5:00 p.m. and 7:00 p.m</i> <i>Turn on the TV 7:00 a.m. and 9:00 a.m</i> <i>Turn on the TV 5:00 p.m. and 7:00 p.m</i> <i>Use home office equipment for work or schoolwork (computers, printers, monitors, etc.) 7:00 a.m. and 9:00 a.m</i> <i>Use home office equipment for work or schoolwork (computers, printers, monitors, etc.) 5:00 p.m. and 7:00 p.m</i> <i>Other 7:00 a.m. and 9:00 a.m</i> <i>Other 5:00 p.m. and 7:00 p.m</i>	1=selected 0=not selected
What other activities take place in your home between 7:00 a.m and 9:00 a.m.?	open-ended
What other activities take place in your home between 5:00 p.m. and 7:00 p.m.?	open-ended
What happens in your home during the day on most workdays? <i>House work Mornings</i> <i>House work Afternoons</i> <i>House work Evenings</i> <i>Office work Mornings</i> <i>Office work Afternoons</i> <i>Office work Evenings</i> <i>Home-schooling Mornings</i> <i>Home-schooling Afternoons</i> <i>Home-schooling Evenings</i> <i>Hobbies Mornings</i> <i>Hobbies Afternoons</i> <i>Hobbies Evenings</i> <i>Computer gaming Mornings</i> <i>Computer gaming Afternoons</i> <i>Computer gaming Evenings</i> <i>Socializing Mornings</i> <i>Socializing Afternoons</i> <i>Socializing Evenings</i>	1=selected 0=not selected

On how many workdays per week does working from home happen in your dwelling?	0=None 1=One day per week 2=Two days per week 3=Three days per week 4=Four days per week 5=Five days per week
What is your primary heating system?	0=I/We don't have one 1=Forced air furnace (e.g., gas or electric) 2=Electric baseboard heaters 3=Heating stove (e.g., wood or propane) 4=Boiler with hot water or steam radiators 5=Radiant heating (e.g., in floor or wall panel) 6=Central heat pump 7=Ductless heat pump/mini-split heat pump/In-room heat pump 8=Don't know 9=Other, specify
What is your primary heating system? Other	open-ended
What is your secondary heating system?	0=I/We don't have one 1=Forced air furnace (e.g., gas or electric) 2=Electric baseboard heaters 3=Heating stove (e.g., wood or propane) 4=Boiler with hot water or steam radiators 5=Radiant heating (e.g., in floor or wall panel) 6=Central heat pump 7=Ductless heat pump/mini-split heat pump/In-room heat pump 8=Don't know 9=Other, specify
What is your secondary heating system? Other	open-ended
What is your primary cooling system?	0=I/We don't have one 1=Central air conditioning 2=Window air conditioning 3=Central heat pump 4=Ductless heat pump/mini-split heat pump/In-room heat pump 5=Don't know 6=Other, specify
What is your primary cooling system? Other	open-ended
How satisfied are you with the performance of your heat pump(s)?	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
What are the benefits of having a heat pump that you have noticed?	open-ended
What are the disadvantages of heat pumps you would like to tell us about?	open-ended
Would you recommend these heat pumps to other people?	1=No 2=Yes
Please rate your typical thermal sensation in the winter at home:	-3=Cold -2=Cool -1=Slightly cool 0=Neutral 1=Slightly warm 2=Warm 3=Hot

In general, in the winter at home I would like to feel...	-1=Cooler 0=No change 1=Warmer
How often do you take the following actions to improve your thermal comfort at home during the winter? <i>Have a hot or cold drink</i> <i>Use a portable heater</i> <i>Use a portable fan</i> <i>Change the thermostat</i> <i>Add or remove a layer of clothing</i> <i>Open or close the window</i> <i>Adjust a window blind or curtain</i>	1=Never 2=Once per month 3=2-4 times per month 4=Once per week 5=2-4 times per week 6=At least once per day 7=Several times per day 8=Not an option for me
Please give us details about other actions you may take to improve your thermal comfort:	open-ended
How do you control your current thermostat? If your home has multiple thermostats, please answer the following questions for the principal room that is occupied when people are at home.	1=I program my thermostat with different set points and schedules 2=I manually change the settings throughout the season depending on my schedule and the weather 3=I use a single set point throughout the season 4=I don't have a thermostat
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during winter:	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 23=OFF 24=Other
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during summer for air conditioning (if any):	
Please tell us the setpoints for your thermostat when you are: Away from home: Set point during winter:	

Please tell us the setpoints for your thermostat when you are: Away from home: Set point during summer for air conditioning (if any):	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 22=Other 23=OFF
Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during winter:	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 23=OFF 24=Other

Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during summer for air conditioning (if any):	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 22=Other 23=OFF
How do you decide what temperature to set your thermostat to?	1=Based on comfort 2=Based on utility bill 3=Based on environmental considerations
How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to? Maximizing comfort:	0=Not at all important 1= 2= 3= 4= 5= 6= 7= 8= 9=Very important
How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to? Minimizing utility bill:	
How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to? Minimizing environmental impact:	
How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to? Thermostat default settings:	
How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to? Social norms	
When I feel too cold, I turn up the thermostat and the heat comes on until it reaches the new temperature; then it turns off.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree 5=Not applicable
When I set a new temperature, the higher I set it, the faster the house heats up.	
I turn down the thermostat before I have a big crowd over to visit, so it doesn't get too hot when they are here.	
When I set a lower temperature on the thermostat, the heat doesn't come on until the temperature drops to the new setting.	
I keep my thermostats at the same setting always because it uses more energy to reheat the house than it would to keep it at one temperature.	
I have received smart, internet-connected thermostats from NB Power as part of the project.	1=No 2=Yes

We'd like to know about your satisfaction with the smart thermostats that were installed for this project. Please select the circle (radio button) that best describes your opinion of the thermostats.	0= Does not look like a temperature control 1= 2= 3= 4= 5= 6= 7= 8= 9= 10= Looks like a temperature control ► Reverse coded
	0= Does not look attractive 1= 2= 3= 4= 5= 6= 7= 8= 9= 10= Looks attractive ► Reverse coded
	0=Difficult to use 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Easy to use
	0=Very inaccurate 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Very accurate
	0=Very slow to react 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Very quick to react

	0=Very difficult to learn 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Very easy to learn
Our house has felt comfortable since the smart thermostats were installed.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
How satisfied are you with the performance of the smart thermostats you received from the project?	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
Would you recommend these thermostats to other people?	0=No 1=Yes
Hot water is always available when I need it.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
The hot water setting on my tank is just right.	
I have experienced issues with my water heater while I have been in the project.	0=No 1=Yes
I have experienced issues with my water heater while I have been in the project. Specify.	open-ended
If NB Power were to offer you a program in which they could send signals to your water heater, would you sign up for it?	0=No 1=Yes
Why not? Are there conditions under which you might decide to sign up?	open-ended
I feel a moral obligation to engage in energy behaviours that are beneficial for the environment.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
Most Canadians engage in energy behaviours that are beneficial for the environment.	
Most Canadians believe it is morally right to engage in energy behaviours that are beneficial for the environment.	
Most of my neighbours engage in energy behaviours that are beneficial for the environment.	
Most of my neighbours believe it is morally right to engage in energy behaviours that are beneficial for the environment.	
Avoiding the need to build new fossil-fuel-burning electrical generating stations is important to me.	
Increasing the use of renewable energy sources to generate electricity is important to me.	
Decreasing the use of nuclear generating stations is important to me.	
How we generate electricity is less important to me than making sure it's there when we need it.	
Increasing the amount of non-emitting electricity generation is important to me.	
Keeping customer electricity bills as low as possible, no matter how it's generated, is important to me.	

Giving the utility the ability to adjust individual customer electrical demand is acceptable if it keeps costs low for everyone.	
It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is stable for everyone.	
Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	
Avoiding the need for new electrical generating stations is important to me.	
It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is reliable for everyone.	
Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	
It is acceptable for utilities to adjust individual customer electrical demand to deliver the least costly electricity supply for everyone.	
Have you felt that you had to change your household routine in any way in order to participate in the research project?	0=No 1=Yes
What kinds of conversations about energy habits are happening in your household since the project began?	open-ended
What changes have you noticed in how you use energy at home since joining this project?	open-ended
What is the most important thing you have learned about smart energy technology at home?	open-ended
Looking to the future, how might you change your energy habits even more as a result of this project?	open-ended
What might be the benefits to you as an NB Power customer of utility programs that are enabled by smart grid technologies?	open-ended
What might be disadvantages to you as an NB Power customer of utility programs to promote smart grid technologies?	open-ended
Replace my light bulbs with energy efficient light bulbs.	0=Very unwilling 1=Somewhat unwilling 2=Neither willing nor unwilling 3=Somewhat willing 4=Very willing 5=I have already done this
Replace my appliances with more energy efficient appliances (e.g., a refrigerator with an Energy Star certification).	
Install solar panels on my home (or increase the number of panels, if you have them already).	
Participate in a time-of-day electricity rate program.	
Install a mini-split heat pump.	
Schedule appliances to operate at off-peak times.	
Upgrade the insulation or windows.	
Reduce my hot water consumption.	
Wash and rinse my clothes with hot water.	
Leave lights on when I am not using them.	
Lower my thermostat setting in winter to save energy.	
If I reduce my at-home energy consumption, I will personally receive financial benefits.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
If I do not reduce my at-home energy consumption, I will incur financial costs.	
If I invest in renewable energy sources (e.g., by installing solar panels), I will personally receive financial benefits.	
If I do not invest in renewable energy sources (e.g., by installing solar panels), I will personally incur financial costs.	
If I reduce my at-home energy consumption, I will have to give up some comfort and convenience. ► Reverse coded	
If I personally invest in renewable energy sources, it will cost me money.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
One down side to installing renewable energy sources like solar panels is that they can make the home look unattractive.	
Having a source of backup power to keep important electrical devices running during a power outage is important to me.	

If incentives were available, I would be willing to invest in energy storage that would provide back up power for my home if there was a grid outage.	
How important is it to you to have backup power in case of an electricity outage?	0=Not at all important 1= 2= 3= 4= 5= 6= 7= 8= 9=Very important
How much money per month would you expect to receive from a utility company in order for you to participate in a utility intervention program?	0=I would not need to be paid 1=\$5-\$10 2=\$11-\$20 3=\$21-\$30 4=\$31-\$40 5=\$41-\$50 6=I would never give control to the utility
What is your approximate monthly electricity consumption (kWh) in the winter?	1=Below 1,000 kWh 2=1,000-3,000 kWh 3=3,001-5,000 kWh 4=Over 5,000 kWh 5=Don't know
What is your approximate monthly electricity consumption (kWh) in the summer?	1=Below 200 kWh 2=200-600 kWh 3=601-1,000 kWh 4=Over 1,000 kWh 5=Don't know
How much attention do you usually pay to your electricity bill?	1=I have a full understanding of my electricity bill 2=I can find what I am looking for 3=I don't know what some numbers mean 4=I don't know where or how to review my electricity bills 5=I don't pay any attention to my electricity bill
When do you think your peak usage happens during the day?	1=Morning (6am–9am) 2=Midday (9am–2pm) 3=Afternoon (2pm–5pm) 4=Evening (5pm–10pm) 5=Night time (10pm–6am) 6=Other, specify
When do you think your peak usage happens during the day? Specify	open-ended
What is your current knowledge of time-of-day pricing?	4=I believe that I am extremely knowledgeable about time-of-day pricing 3=I believe that I am moderately knowledgeable about time-of-day pricing 2=I believe that I am somewhat knowledgeable about time-of-day pricing 1=I believe that I am slightly knowledgeable about time-of-day pricing 0=I believe that I am not at all knowledgeable about time-of-day pricing

What do you think the main benefits of time-of-day rates might be? Please select the top two: <i>Lower electricity bill for some consumers</i> <i>Reduced energy consumption</i> <i>Environmental benefits</i> <i>More revenue for the utility</i> <i>Lower peak demand for electricity</i> <i>Other, please specify:</i>	1=selected 0=not selected
What do you think the main benefits of time-of-day rates might be? Specify	open-ended
How interested would you be to learn about choices for how you could be billed for the electricity you use?	0=Not at all interested 1= 2= 3= 4= 5= 6= 7= 8= 9=Very interested
How likely is it that you would choose to be billed using a new billing option if it would allow you to lower your bill, even if it took some effort on your part?	0=Not at all likely 1= 2= 3= 4= 5= 6= 7= 8= 9=Very likely
How likely is it that you would choose to be billed using a new billing option if it would allow you to lower your bill with some effort on your part, and the new system was more complicated for you to understand?	
If NB Power offered a Time-of-Day rate program in the future, would you sign up for it?	0=No 1=Yes
Why not? Please check any reasons that apply to you. <i>Too much effort</i> <i>My daily schedule is complicated enough without changing it</i> <i>Too inconvenient</i> <i>Too little reward</i> <i>I think it would only benefit the utility</i> <i>I didn't understand how it worked</i> <i>Other, please specify:</i>	1=selected 0=not selected
Why not? Please check any reasons that apply to you. Specify	open-ended
What would be needed to make it worthwhile for you to take advantage of time-of-day rates?	open-ended
How much do you think you could save on energy consumption if you were being charged time-of-day rates for the electricity you use?	0=No saving at all 1=1-4% saving 2=5-7% saving 3=8-10% saving 4=More than 10% saving 9=Not sure

Which actions do you think you can do to move your energy consumption from peak time to off-peak time? Please select the top three: <i>Do laundry in the evening/night</i> <i>Run the dishwasher in the evenings or overnight</i> <i>Turn off lights</i> <i>Schedule my appliances to run in the evening or overnight</i> <i>Turn off appliances when not in use</i> <i>Set thermostat to lower temperatures overnight</i> <i>Hang your clothes to dry instead of using a clothes dryer</i> <i>Pre-heat the house early in the morning before peak time</i> <i>Set it and forget it for my thermostat</i> <i>Other, please specify:</i>	1=selected 0=not selected
Which actions have you used to move your energy consumption from peak time to off-peak time? Specify	open-ended
How often do you think you would be able to adopt energy efficient behaviours/actions to get full advantage of time-of-day rates?	1=Every day 2=2-4 times a week 3=Once a week 4=2-4 times a month 5=Once a month 6=Not sure 7=I don't think I have been able to change my energy behaviours
How easy or difficult would it be for you to change the timing of your electricity use to take advantage of time-of-day rates?	0=Very easy 1= 2= 3= 4= 5= 6= 7= 8= 9=Very difficult
Having renewable energy sources like solar panels would make me more likely to invest in battery energy storage.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
If there were incentives for battery energy storage, I would be more likely to purchase a renewable energy system.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
If you already have a backup power system, please tell us about the benefits it provides to you, and any challenges that you had in acquiring it. If you don't have a backup power system, how easy or difficult do you think it would be to get one?	open-ended
Imagine you were thinking of purchasing a 5,000-Watt solar panel system on your home or property, similar to the ones installed as part of this project. Generating electricity on your home would reduce your electricity bill. If there were no incentives to reduce the cost, how fast would you expect to break even on the investment?	1=1 year 2=5 years 3=10 years 4=20 years 5=I would never break even

If incentives were offered to encourage you to purchase a solar panel system for your home, what level of incentive would enable you to purchase and install a system?	1=0% 2=10% 3=20% 4=30% 5=40% 6=50% 7=60% 8=70% 9=80% 10=90% 11=100%
Imagine you were thinking of purchasing a 5kW/2hr battery energy storage system on your home or property, similar to the ones installed as part of this project. At the present time, it would have little effect on your electricity bill, but it would provide clean back-up power in the event of a power outage. If there were no incentives to reduce the cost, how much would you be willing to pay?	1=\$1,000 2=\$5,000 3=\$10,000 4=\$20,000 5=Price doesn't matter, I want to be sure to have power if there is an outage
If incentives were offered to encourage you to purchase a battery energy storage system for your home, what level of incentive would enable you to purchase and install a system?	1=0% 2=10% 3=20% 4=30% 5=40% 6=50% 7=60% 8=70% 9=80% 10=90% 11=100%
A solar panel and battery energy storage system would increase the overall value of my home.	0=Strongly disagree 1=Disagree
I believe that solar panels would increase my overall energy consumption. ► Reverse coded	2=Neither agree nor disagree 3=Agree
I would find it reassuring to know that the battery can power some of my home if there is a power outage.	4=Strongly agree
Having solar panels on the roof would make my home look less attractive. ► Reverse coded	
Having rooftop solar panels would reduce my energy consumption.	0=Strongly disagree 1=Disagree
There is an environmental benefit to solar energy.	2=Neither agree nor disagree 3=Agree
If I had a battery, it would be acceptable for the utility to adjust the battery operation to maintain a stable electrical system for New Brunswick.	4=Strongly agree
Having a solar panel system (with or without battery energy storage) would reduce my electricity bills.	
How satisfied are you with...The communications with the project team about the project?	0=Very dissatisfied 1=Dissatisfied
How satisfied are you with...Overall, your participation in the Shediac Residential Energy Study?	2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied

In general, how satisfied are you with NB Power?	0=Not at all satisfied 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Most satisfied
What is the reason for the rating you gave for your satisfaction with NB Power?	open-ended
Are you willing to be contacted to participate in focus group sessions about smart energy technologies run by the Université de Moncton and/or NB Power after the project is finished?	0=No 1=Yes
When the project ends, we would like to be able to tell New Brunswickers about what it was like for our participants to be in this project. Would you be willing to allow us to anonymously quote your text answers to questions in this survey? The quotations could be used in newspaper or web articles or on posters or presentations about the project, either in the original language or translated. Your name will never be identified.	0=No 1=Yes
This is the last survey in the project. Is there anything else you would like to tell us about your experiences with the Shediac Residential Energy Study?	open-ended

B.7.4 Survey #7d: Core + No-TOD group + SOL

Question	Scale
Access code	
Who in your household completed a survey for this investigation previously?	1=I personally completed the previous surveys 2=Someone else completed the other surveys 3=No one in our house completed the prior surveys 4=Different people completed the different surveys
Who lives in this dwelling? Please select the sex of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=Male 2=Female 3=Prefer not to say
Who lives in this dwelling? Please select the age of all people who reside there: <i>Person 1 (You) through Person 10</i>	1=0-10 2=11-20 3=21-30 4=31-40 5=41-50 6=51-60 7=61-70 8=71-80 9=81+ 10=Prefer not to say
Have there been any changes to the number of people living in this home since December 2023?	0=No 1=Yes, please specify
	open-ended

On a regular workday, when are people in the dwelling?	1=Someone is home all the time 2=Someone is home for part of the workday 3=Everyone leaves after breakfast and returns after the workday
What activities take place in your home between...? <i>Cooking 7:00 a.m. and 9:00 a.m</i> <i>Cooking 5:00 p.m. and 7:00 p.m</i> <i>Showering or bathing 7:00 a.m. and 9:00 a.m</i> <i>Showering or bathing 5:00 p.m. and 7:00 p.m</i> <i>Laundry 7:00 a.m. and 9:00 a.m</i> <i>Laundry 5:00 p.m. and 7:00 p.m</i> <i>Getting ready for the work/school day 7:00 a.m. and 9:00 a.m</i> <i>Getting ready for the work/school day 5:00 p.m. and 7:00 p.m</i> <i>Increase the temperature in my home 7:00 a.m. and 9:00 a.m</i> <i>Increase the temperature in my home 5:00 p.m. and 7:00 p.m</i> <i>Dishwashing 7:00 a.m. and 9:00 a.m</i> <i>Dishwashing 5:00 p.m. and 7:00 p.m</i> <i>Charge an electric vehicle 7:00 a.m. and 9:00 a.m</i> <i>Charge an electric vehicle 5:00 p.m. and 7:00 p.m</i> <i>Use a gaming system 7:00 a.m. and 9:00 a.m</i> <i>Use a gaming system 5:00 p.m. and 7:00 p.m</i> <i>Turn on the TV 7:00 a.m. and 9:00 a.m</i> <i>Turn on the TV 5:00 p.m. and 7:00 p.m</i> <i>Use home office equipment for work or schoolwork (computers, printers, monitors, etc.) 7:00 a.m. and 9:00 a.m</i> <i>Use home office equipment for work or schoolwork (computers, printers, monitors, etc.) 5:00 p.m. and 7:00 p.m</i> <i>Other 7:00 a.m. and 9:00 a.m</i> <i>Other 5:00 p.m. and 7:00 p.m</i>	1=selected 0=not selected
What other activities take place in your home between 7:00 a.m and 9:00 a.m.?	open-ended
What other activities take place in your home between 5:00 p.m. and 7:00 p.m.?	open-ended
What happens in your home during the day on most workdays? <i>House work Mornings</i> <i>House work Afternoons</i> <i>House work Evenings</i> <i>Office work Mornings</i> <i>Office work Afternoons</i> <i>Office work Evenings</i> <i>Home-schooling Mornings</i> <i>Home-schooling Afternoons</i> <i>Home-schooling Evenings</i> <i>Hobbies Mornings</i> <i>Hobbies Afternoons</i> <i>Hobbies Evenings</i> <i>Computer gaming Mornings</i> <i>Computer gaming Afternoons</i> <i>Computer gaming Evenings</i> <i>Socializing Mornings</i> <i>Socializing Afternoons</i> <i>Socializing Evenings</i>	1=selected 0=not selected
On how many workdays per week does working from home happen in your dwelling?	0=None 1=One day per week 2=Two days per week 3=Three days per week 4=Four days per week 5=Five days per week

What is your primary heating system?	0=I/We don't have one 1=Forced air furnace (e.g., gas or electric) 2=Electric baseboard heaters 3=Heating stove (e.g., wood or propane) 4=Boiler with hot water or steam radiators 5=Radiant heating (e.g., in floor or wall panel) 6=Central heat pump 7=Ductless heat pump/mini-split heat pump/In-room heat pump 8=Don't know 9=Other, specify
What is your primary heating system? Other	open-ended
What is your secondary heating system?	0=I/We don't have one 1=Forced air furnace (e.g., gas or electric) 2=Electric baseboard heaters 3=Heating stove (e.g., wood or propane) 4=Boiler with hot water or steam radiators 5=Radiant heating (e.g., in floor or wall panel) 6=Central heat pump 7=Ductless heat pump/mini-split heat pump/In-room heat pump 8=Don't know 9=Other, specify
What is your secondary heating system? Other	open-ended
What is your primary cooling system?	0=I/We don't have one 1=Central air conditioning 2=Window air conditioning 3=Central heat pump 4=Ductless heat pump/mini-split heat pump/In-room heat pump 5=Don't know 6=Other, specify
What is your primary cooling system? Other	open-ended
How satisfied are you with the performance of your heat pump(s)?	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
What are the benefits of having a heat pump that you have noticed?	open-ended
What are the disadvantages of heat pumps you would like to tell us about?	open-ended
Would you recommend these heat pumps to other people?	1=No 2=Yes
Please rate your typical thermal sensation in the winter at home:	-3=Cold -2=Cool -1=Slightly cool 0=Neutral 1=Slightly warm 2=Warm 3=Hot
In general, in the winter at home I would like to feel...	-1=Cooler 0=No change 1=Warmer

How often do you take the following actions to improve your thermal comfort at home during the winter? <i>Have a hot or cold drink</i> <i>Use a portable heater</i> <i>Use a portable fan</i> <i>Change the thermostat</i> <i>Add or remove a layer of clothing</i> <i>Open or close the window</i> <i>Adjust a window blind or curtain</i>	1=Never 2=Once per month 3=2-4 times per month 4=Once per week 5=2-4 times per week 6=At least once per day 7=Several times per day 8=Not an option for me
Please give us details about other actions you may take to improve your thermal comfort:	open-ended
How do you control your current thermostat? If your home has multiple thermostats, please answer the following questions for the principal room that is occupied when people are at home.	1=I program my thermostat with different set points and schedules 2=I manually change the settings throughout the season depending on my schedule and the weather 3=I use a single set point throughout the season 4=I don't have a thermostat
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during winter:	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 23=OFF 24=Other
Please tell us the setpoints for your thermostat when you are: At home and awake: Set point during summer for air conditioning (if any):	
Please tell us the setpoints for your thermostat when you are: Away from home: Set point during winter:	

Please tell us the setpoints for your thermostat when you are: Away from home: Set point during summer for air conditioning (if any):	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 22=Other 23=OFF
Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during winter:	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 23=OFF 24=Other

Please tell us the setpoints for your thermostat when you are: While sleeping: Set point during summer for air conditioning (if any):	1=10 °C 2=11 °C 3=12 °C 4=13 °C 5=14 °C 6=15 °C 7=16 °C 8=17 °C 9=18 °C 10=19 °C 11=20 °C 12=21 °C 13=22 °C 14=23 °C 15=24 °C 16=25 °C 17=26 °C 18=27 °C 19=28 °C 20=29 °C 21=30 °C 22=Other 23=OFF
How do you decide what temperature to set your thermostat to?	1=Based on comfort 2=Based on utility bill 3=Based on environmental considerations
How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to? Maximizing comfort:	0=Not at all important 1= 2= 3= 4= 5= 6= 7= 8= 9=Very important
How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to? Minimizing utility bill:	
How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to? Minimizing environmental impact:	
How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to? Thermostat default settings:	
How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to? Social norms	
When I feel too cold, I turn up the thermostat and the heat comes on until it reaches the new temperature; then it turns off.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree 5=Not applicable
When I set a new temperature, the higher I set it, the faster the house heats up.	
I turn down the thermostat before I have a big crowd over to visit, so it doesn't get too hot when they are here.	
When I set a lower temperature on the thermostat, the heat doesn't come on until the temperature drops to the new setting.	
I keep my thermostats at the same setting always because it uses more energy to reheat the house than it would to keep it at one temperature.	
I have received smart, internet-connected thermostats from NB Power as part of the project.	1=No 2=Yes

We'd like to know about your satisfaction with the smart thermostats that were installed for this project. Please select the circle (radio button) that best describes your opinion of the thermostats.	0= Does not look like a temperature control 1= 2= 3= 4= 5= 6= 7= 8= 9= 10= Looks like a temperature control ► Reverse coded
	0= Does not look attractive 1= 2= 3= 4= 5= 6= 7= 8= 9= 10= Looks attractive ► Reverse coded
	0=Difficult to use 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Easy to use
	0=Very inaccurate 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Very accurate
	0=Very slow to react 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Very quick to react

	0=Very difficult to learn 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Very easy to learn
Our house has felt comfortable since the smart thermostats were installed.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
How satisfied are you with the performance of the smart thermostats you received from the project?	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
Would you recommend these thermostats to other people?	0=No 1=Yes
Hot water is always available when I need it.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
The hot water setting on my tank is just right.	
I have experienced issues with my water heater while I have been in the project.	0=No 1=Yes
I have experienced issues with my water heater while I have been in the project. Specify.	open-ended
If NB Power were to offer you a program in which they could send signals to your water heater, would you sign up for it?	0=No 1=Yes
Why not? Are there conditions under which you might decide to sign up?	open-ended
I feel a moral obligation to engage in energy behaviours that are beneficial for the environment.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
Most Canadians engage in energy behaviours that are beneficial for the environment.	
Most Canadians believe it is morally right to engage in energy behaviours that are beneficial for the environment.	
Most of my neighbours engage in energy behaviours that are beneficial for the environment.	
Most of my neighbours believe it is morally right to engage in energy behaviours that are beneficial for the environment.	
Avoiding the need to build new fossil-fuel-burning electrical generating stations is important to me.	
Increasing the use of renewable energy sources to generate electricity is important to me.	
Decreasing the use of nuclear generating stations is important to me.	
How we generate electricity is less important to me than making sure it's there when we need it.	
Increasing the amount of non-emitting electricity generation is important to me.	
Keeping customer electricity bills as low as possible, no matter how it's generated, is important to me.	

Giving the utility the ability to adjust individual customer electrical demand is acceptable if it keeps costs low for everyone.	
It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is stable for everyone.	
Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	
Avoiding the need for new electrical generating stations is important to me.	
It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is reliable for everyone.	
Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	
It is acceptable for utilities to adjust individual customer electrical demand to deliver the least costly electricity supply for everyone.	
Have you felt that you had to change your household routine in any way in order to participate in the research project?	0=No 1=Yes
What kinds of conversations about energy habits are happening in your household since the project began?	open-ended
What changes have you noticed in how you use energy at home since joining this project?	open-ended
What is the most important thing you have learned about smart energy technology at home?	open-ended
Looking to the future, how might you change your energy habits even more as a result of this project?	open-ended
What might be the benefits to you as an NB Power customer of utility programs that are enabled by smart grid technologies?	open-ended
What might be disadvantages to you as an NB Power customer of utility programs to promote smart grid technologies?	open-ended
Replace my light bulbs with energy efficient light bulbs.	0=Very unwilling 1=Somewhat unwilling 2=Neither willing nor unwilling 3=Somewhat willing 4=Very willing 5=I have already done this
Replace my appliances with more energy efficient appliances (e.g., a refrigerator with an Energy Star certification).	
Install solar panels on my home (or increase the number of panels, if you have them already).	
Participate in a time-of-day electricity rate program.	
Install a mini-split heat pump.	
Schedule appliances to operate at off-peak times.	
Upgrade the insulation or windows.	
Reduce my hot water consumption.	
Wash and rinse my clothes with hot water.	
Leave lights on when I am not using them.	
Lower my thermostat setting in winter to save energy.	
If I reduce my at-home energy consumption, I will personally receive financial benefits.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
If I do not reduce my at-home energy consumption, I will incur financial costs.	
If I invest in renewable energy sources (e.g., by installing solar panels), I will personally receive financial benefits.	
If I do not invest in renewable energy sources (e.g., by installing solar panels), I will personally incur financial costs.	
If I reduce my at-home energy consumption, I will have to give up some comfort and convenience. ► Reverse coded	
If I personally invest in renewable energy sources, it will cost me money.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
One down side to installing renewable energy sources like solar panels is that they can make the home look unattractive.	
Having a source of backup power to keep important electrical devices running during a power outage is important to me.	

If incentives were available, I would be willing to invest in energy storage that would provide back up power for my home if there was a grid outage.	
How important is it to you to have backup power in case of an electricity outage?	0=Not at all important 1= 2= 3= 4= 5= 6= 7= 8= 9=Very important
How much money per month would you expect to receive from a utility company in order for you to participate in a utility intervention program?	0=I would not need to be paid 1=\$5-\$10 2=\$11-\$20 3=\$21-\$30 4=\$31-\$40 5=\$41-\$50 6=I would never give control to the utility
What is your approximate monthly electricity consumption (kWh) in the winter?	1=Below 1,000 kWh 2=1,000-3,000 kWh 3=3,001-5,000 kWh 4=Over 5,000 kWh 5=Don't know
What is your approximate monthly electricity consumption (kWh) in the summer?	1=Below 200 kWh 2=200-600 kWh 3=601-1,000 kWh 4=Over 1,000 kWh 5=Don't know
How much attention do you usually pay to your electricity bill?	1=I have a full understanding of my electricity bill 2=I can find what I am looking for 3=I don't know what some numbers mean 4=I don't know where or how to review my electricity bills 5=I don't pay any attention to my electricity bill
When do you think your peak usage happens during the day?	1=Morning (6am–9am) 2=Midday (9am–2pm) 3=Afternoon (2pm–5pm) 4=Evening (5pm–10pm) 5=Night time (10pm–6am) 6=Other, specify
When do you think your peak usage happens during the day? Specify	open-ended
What is your current knowledge of time-of-day pricing?	4=I believe that I am extremely knowledgeable about time-of-day pricing 3=I believe that I am moderately knowledgeable about time-of-day pricing 2=I believe that I am somewhat knowledgeable about time-of-day pricing 1=I believe that I am slightly knowledgeable about time-of-day pricing 0=I believe that I am not at all knowledgeable about time-of-day pricing

What do you think the main benefits of time-of-day rates might be? Please select the top two: <i>Lower electricity bill for some consumers</i> <i>Reduced energy consumption</i> <i>Environmental benefits</i> <i>More revenue for the utility</i> <i>Other, please specify:</i>	1=selected 0=not selected
What do you think the main benefits of time-of-day rates might be? Specify	open-ended
How interested would you be to learn about choices for how you could be billed for the electricity you use?	0=Not at all interested 1= 2= 3= 4= 5= 6= 7= 8= 9=Very interested
How likely is it that you would choose to be billed using a new billing option if it would allow you to lower your bill, even if it took some effort on your part?	0=Not at all likely 1= 2=
How likely is it that you would choose to be billed using a new billing option if it would allow you to lower your bill with some effort on your part, and the new system was more complicated for you to understand?	3= 4= 5= 6= 7= 8= 9=Very likely
If NB Power offered a Time-of-Day rate program in the future, would you sign up for it?	0=No 1=Yes
Why not? Please check any reasons that apply to you. <i>Too much effort</i> <i>My daily schedule is complicated enough without changing it</i> <i>Too inconvenient</i> <i>Too little reward</i> <i>I think it would only benefit the utility</i> <i>I didn't understand how it worked</i> <i>Other, please specify:</i>	1=selected 0=not selected
Why not? Please check any reasons that apply to you. Specify	open-ended
What would be needed to make it worthwhile for you to take advantage of time-of-day rates?	open-ended
How much do you think you could save on energy consumption if you were being charged time-of-day rates for the electricity you use?	0=No saving at all 1=1-4% saving 2=5-7% saving 3=8-10% saving 4=More than 10% saving 9=Not sure

Which actions do you think you can do to move your energy consumption from peak time to off-peak time? Please select the top three: <i>Do laundry in the evening/night</i> <i>Run the dishwasher in the evenings</i> <i>Turn off lights</i> <i>Turn off appliances when not in use</i> <i>Set thermostat to lower temperatures overnight</i> <i>Hang your clothes to dry instead of using a clothes dryer</i> <i>Pre-heat the house early in the morning before peak time</i> <i>Other, please specify:</i>	1=selected 0=not selected
Which actions have you used to move your energy consumption from peak time to off-peak time? Specify	open-ended
How often do you think you would be able to adopt energy efficient behaviours/actions to get full advantage of time-of-day rates?	1=Every day 2=2-4 times a week 3=Once a week 4=2-4 times a month 5=Once a month 6=Not sure 7=I don't think I have been able to change my energy behaviours
How easy or difficult would it be for you to change the timing of your electricity use to take advantage of time-of-day rates?	0=Very easy 1= 2= 3= 4= 5= 6= 7= 8= 9=Very difficult
The solar panel and battery energy storage system has increased the overall value of my home.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
I believe the solar panels and battery energy storage increased my overall energy consumption. ► Reverse coded	
I find it reassuring to know that the battery can power some of my home if there is a power outage.	
The solar panels on the roof make my home look less attractive. ► Reverse coded	
Having rooftop solar panels reduces my energy consumption.	0=Strongly disagree 1=Disagree 2=Neither agree nor disagree 3=Agree 4=Strongly agree
There is an environmental benefit to solar energy.	
It is acceptable for the utility to adjust the battery operation to maintain a stable electrical system for New Brunswick.	
Having a solar panel system with battery energy storage reduced my electricity bills.	
How satisfied are you with the performance of your solar + battery energy storage system?	0=Very dissatisfied 1=Dissatisfied 2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
Would you recommend this system to other people?	0=No 1=Yes
I have experienced challenges or issues with my solar panels and/or battery.	0=No 1=Yes
I have experienced challenges or issues with my solar panels and/or battery. Please tell us about the situation and how it was resolved:	open-ended

During the project, adjustments were made to your battery operation to test whether this could be a means to manage the electricity grid. Do you think you noticed these adjustments?	0=No 1=Yes
During the project, adjustments were made to your battery operation to test whether this could be a means to manage the electricity grid. Do you think you noticed these adjustments? Please tell us what you noticed:	open-ended
If NB Power were to offer a program that gave you an incentive to allow it to adjust your battery on occasion, do you think you would join it?	0=No 1=Yes
What do you think would be fair terms for such a program?	open-ended
I am thinking of returning the solar panels and battery energy storage after the project is finished.	0=No 1=Yes
I am thinking of returning the solar panels and battery energy storage after the project is finished. Please give us your reasons why:	open-ended
How satisfied are you with...The communications with the project team about the project?	0=Very dissatisfied 1=Dissatisfied
How satisfied are you with...Overall, your participation in the Shediak Residential Energy Study?	2=Neither satisfied nor dissatisfied 3=Satisfied 4=Very satisfied
In general, how satisfied are you with NB Power?	0=Not at all satisfied 1= 2= 3= 4= 5= 6= 7= 8= 9= 10=Most satisfied
What is the reason for the rating you gave for your satisfaction with NB Power?	open-ended
Are you willing to be contacted to participate in focus group sessions about smart energy technologies run by the Université de Moncton and/or NB Power after the project is finished?	0=No 1=Yes
When the project ends, we would like to be able to tell New Brunswickers about what it was like for our participants to be in this project. Would you be willing to allow us to anonymously quote your text answers to questions in this survey? The quotations could be used in newspaper or web articles or on posters or presentations about the project, either in the original language or translated. Your name will never be identified.	0=No 1=Yes
This is the last survey in the project. Is there anything else you would like to tell us about your experiences with the Shediak Residential Energy Study?	open-ended

Chapter 2: Modelling Household Electricity Use Data to Facilitate Data Exchange

Ajit Pardasani

1 Introduction

This report provides an overview of the data model of smart meter and bill settlement data within the Shediac Residential Energy Study, a five-year -year project. This project is part of Smart Grid Atlantic (SGA), a four-year federally-funded program supporting energy technology projects in Nova Scotia and New Brunswick. Initiated by New Brunswick Power (NBP) in partnership with the Town of Shediac, Siemens Canada, and the National Research Council of Canada (NRC), the study was supported by \$35 million in grants from Natural Resources Canada and Industry Science and Economic Development Canada. The study aimed to gain the experience and knowledge necessary to modernize the electrical grid, while addressing increasing customer energy needs and the necessary pace of decarbonization. This was accomplished by piloting smart energy technologies in over 500 homes in Shediac to gather data and insights into how these technologies perform in everyday residential settings. An overview of the study is presented in a separate technical report (Pardasani et al., 2025).

This report details the data model for smart meter and monthly bill settlement data. Bidirectional smart meters were utilized to measure electricity flow from grid to participant households and exports from solar-equipped households back to NB Power. The document focuses on the data model for smart/interval meter data for both residential and two commercial buildings involved in the project. It does not cover the data models for smart thermostats, electric hot water heaters, solar, and battery storage systems, as these are addressed in another report (Pardasani, 2025).

The initial version of this document was developed at the project's onset in 2019, serving the dual purpose of establishing a common understanding among team members regarding the data model and laying the groundwork for file formats used by NB Power to share smart meter and bill settlement data with the NRC.

Unless otherwise specified in this document, the data was shared by NB Power with the NRC in Comma-Separated Values (CSV) files, using the Carriage Return Line Feed (CRLF) character to denote line breaks. The headers for the tables in the CSV files, as defined in this document, were not to be changed throughout the project. The data files were shared via NB Power's secure FTP server, to which the NRC was granted access through a password-protected account.

The time-series data ranged from midnight to midnight, with date and time values following the UTC time zone. Once placed in the designated folder on NB Power's SFTP server, the files were to remain accessible for the project's duration.

2 Mapping tables

Participant dwelling were identified through Premise Identifiers and mapping tables were required to initialize the NRC's energy use performance data warehouse by premise identifiers of the dwellings that received smart meters. Mapping tables also relate the premise ids to the feeders though feeder information was not used later in the analyses.

The installation of smart meters commenced in the Fall of 2019 and was spread over a period of few months. Therefore, the process of initializing and mapping the database with premise ids to feeders was kept flexible such that the mapping data could be imported in multiple files rather than one large file. NB Power created new mapping files with the new smart meter installations and shared these with the NRC to be loaded into NRC's energy use performance data warehouse. Scripts in the NRC's data warehouse created new mappings and updated previously existing mapping.

Schema to map Assets to Feeders

Table 1 shows the schema to map assets such as meters or premise ids to feeders.

Table 1. a general-purpose schema to map assets to feeders

Column Header	Data Type	Description
Meter_ID	Character	Meter ID at the dwelling
Asset Type	Character	Type of asset** (COM RES)
Location	Character	ID of feeder breaker

**Legend for asset type: COM – Commercial Building | RES – Residential Building

Premise IDs to Feeders Mapping

The schema shown in Table 1 is shown to map various assets to map to feeders as illustrated in Table 2. The location field provides the feeder information to which the building is connected. NRC's data warehouse is capable of importing multiple meter-feeder mapping files. NB Power was to retain the mapping of smart meter ids to their client addresses and not share this information with NRC through CSV files.

Table 2. An example of Premise_ids to feeder ids mapping file. The location field has feeder ids.

Premise_ID	Asset Type	Location
54634742	RES	6503B004
36377225	RES	6503B005
35363632	COM	6233R001
37374741	COM	6233R002
37375673	RES	6124B009

Premise_ID to WebID Mapping

Premise ID are the NB Power customer ids. Though there was no issue seen in sharing Premise IDs with the NRC, there was an additional layer of data privacy added to the data through WebIDs. These identifiers were used to exchange data with NB Power's contractors as such as thermostats and solar installers. A simple two-column mapping table shown in Table 3 was created by NB Power and shared once through a CSV file. Table 3 shows the concept using manufactured data.

Table 3. Mapping Premise IDs to WebIDs

WebID	Premise ID
0001	503003831
0002	503002266
0003	603002053
0004	603002212
0006	603002708

2.1 Time-series measurements

The tables in this section were designed to capture the time series data from the bidirectional smart meters at buildings. Data files contain values from midnight to midnight. The date and time values follow the UTC time zone unless otherwise stated.

Since the volume of data from NB Power to NRC's data warehouse was high, all telemetry data was sorted by NB Power by premise number at the time of export from their database to CSV files. In other words, the csv files had the data sorted by premise id to make data import into NRC's data warehouse more efficient.

2.1.1 Smart meter data

Residential and commercial buildings had smart meters installed to collect voltage and power data at 15-minute intervals. Table 4 defines the model for the smart meter data for active energy import and Table 5 defines the same for active energy export to the grid. Table 6 and Table 7 show examples of smart meter data for energy import and export respectively.

Table 4. Time series smart meter energy import data model

Column Header	Data Type	Description
Premise_ID	Character	Premise ID of the building
Time_Ending	Character	Time ending associated with the interval Format is dd-mm-yyyy hh:mm
Watt	numeric	Avg. power for energy imported by dwelling from the grid during the time interval.
Voltage_a	numeric	Avg. voltage during the time interval for phase 1
Voltage_b	numeric	Avg. voltage during the time interval for phase 2 Applicable to buildings that have smart meters with two three phase measurements Report Null if not applicable. Do not leave it blank
Voltage_c	numeric	Avg. voltage during the time interval for phase 3 Applicable to buildings that have smart meters with two three phase measurements Report Null if not applicable. Do not leave it blank
VA	numeric	Avg. VA for the time interval. Applicable to buildings that have smart meters with two three phase measurements Report Null if not applicable. Do not leave it blank
VEE Rule (Rule Number)	numeric	When VEE rule is not applicable, the flag will be 0. When VEE rule is applied to the data, the flag will be an integer value corresponding to the rule applied.

Table 5. Time series smart meter energy export data model. Only applicable to dwellings that have the solar and battery storage

Column Header	Data Type	Description
Premise_ID	Character	Premise ID of the building
Time_Ending	Character	Time ending associated with the interval Format is dd-mm-yyyy hh:mm
Watt_export	numeric	Avg. power for energy received from the customer by the grid during the time interval. For the time periods the electricity is not exported, the value of this field would be zero
VA	numeric	Avg. VA for the time interval. Applicable to buildings that have smart meters with two three phase measurements Report Null if not applicable. Do not leave it blank
VEE_Rule	numeric	When VEE rule is not applicable, the flag will be 0. When VEE rule is applied to the data, the flag will be an integer value corresponding to the rule applied.

Table 6. Time series smart meter energy import data table.

Premise_ID	Time_Ending	Watt	Voltage_a	Voltage_b	Voltage_c	VA	VEE Rule
40518345	18-12-2015 04:00	2572.5	123.1	Null	Null	Null	0
40540234	18-12-2015 04:00	5072.6	118.2	118.3	118.5	5200	1
40522134	18-12-2015 04:00	1972.7	117.3	117.1	117.5	5000	3
40518567	18-12-2015 04:15	2772.3	123.1	123.1	0	0	0

Table 7. Time series smart meter energy export data table. Only applicable to dwellings that have solar and battery storage

Premise_ID	Time_Ending	Watt_export	VA	VEE_Rule
40518345	18-07-2015 04:00	200.5	200.5	0
40540234	18-07-2015 04:00	100.6	100.6	0
40522134	18-07-2015 04:00	0	0	0
40518567	18-07-2015 04:15	40.5	40.5	0

2.1.2 Weather data

Hourly weather data was downloaded from the Environment Canada weather station #6918 (Boucoute weather station, 35 km from Shediac on the coast) up to October 3, 2021 and then station #50309 (Greater Moncton Int'l, 22 km inland from Shediac) from October 4, 2021 to March 31, 2024. The Boucoute weather station stopped reporting data on Oct. 3, 2021.

3 Monthly bill settlement data

This section defines the data requirements for monthly bills including the solar credits for participants that received the rooftop solar array. This billing data will be used as one of the inputs in analysis for understanding the impact of Time of Day (ToD) billing and demand control events on energy usage and bills.

Table 8 defines the requirements for the monthly bill settlements.

The monthly electricity billing data would be provided by NB Power by the billing period defined by the meter reading date and number of days or from the meter reading date to the bill end date. The reason is that not all bills may correspond to exactly one month, and start from 1st of the month, and end at the end of the month. See the proposed format below as an example:

Table 8. Data model for the monthly bill settlement files.

Column Header	Data Type	Description
Premise_ID	Character	Premise id of the participant dwelling. Numeric value always 9 digits long
Meter Reading Date	Character	Start date of the billing period. Format is dd-mm-yyyy
Number of Days	numeric	Number of days in the billing period.
Monthly Usage	numeric	Total Energy usage (kWh) for the billing period
Dollar Amount Billed	numeric	Dollar amount of Participant's Energy usage (only*) for the billing period before the solar credit *does not include any other fees such as: • service fee • hot water heater • Any other products or services
On-Peak	numeric	Energy used (kWh) during the peak hours for the billing period This value will be provided for <u>all</u> participants, not just participants in the TOD study.
Mid-Peak	numeric	Energy used (kWh) during the mid-peak hours for the billing period This value will be provided for <u>all</u> participants, not just participants in the TOD study.
Off-Peak	numeric	Energy used (kWh) during the off-peak hours for the billing period This value will be provided for <u>all</u> participants, not just participants in the TOD study.
On-Peak_\$\$	numeric	\$\$ of On Peak as calculated on the Shadow Report for the billing period For participants who are not in TOD this field will be NULL.
Mid-Peak_\$\$	numeric	\$\$ of Mid Peak as calculated on the Shadow Report for the billing period For participants who are not in TOD this field will be NULL
Off-Peak_\$\$	numeric	\$\$ of Off Peak as calculated on the Shadow Report for the billing period For participants who are not in TOD this field will be NULL
Solar Export	numeric	Solar energy received from customer (kWh) for the billing period For participants who are not in the Solar Energy Research Group this field will be NULL
Solar Energy Credit	Numeric	\$\$ Solar Energy Credit amount calculated for the Shadow Report for this billing period For participants who are not in the Solar Energy Research Group this field will be NULL
ToD Credit	numeric	This amount represents the difference between the program's Total TOD energy charge (On-Peak, Mid-Peak, and Off-peak) and the actual standard energy charge. The positive amount are payable to the participants.

4 File naming convention

This section specifies the file naming convention for exchanging time series data.

The initial part of the Shediak project overlapped with the NRC-NB Power partnership on the Conservation Voltage Reduction (CVR) project that also saw exchange of smart meter data from NB

Power to NRC. To avoid confusion and mix up of data files between the two projects, all telemetry data files in CVR project had the prefix of CVR for the CVR project and similarly the prefix of SGA for the telemetry data files for the Shediak project.

Smart meter data files for energy import (This is applicable to all participants dwellings):

When data multiple meters were in a single file the following data format was used:

SGA_sm_import_data_FeederIDPrefix_dd-mm-yyyy.csv

For example, SGA_sm_import_data_6529B001_01-09-2024.csv

The following file naming convention was used when data from one meter was reported in a file. This was applicable for the situations when smart meter data was reported late:

SGA_sm_data_FeederIDPrefix_smart_meter_id_dd-mm-yyyy.csv

Smart meter data files for energy export (only applicable to dwellings that have rooftop solar and battery storage):

For multiple meter data in a single file:

SGA_sm_export_data_FeederIDPrefix_dd-mm-yyyy.csv

For example, SGA_sm_import_data_6529B001_01-09-2024.csv

The following file naming convention was used when data from one meter is reported in a file. This case was applicable for the situations when smart meter data was reported late:

SGA_sm_data_export_FeederIDPrefix_smart_meter_id_dd-mm-yyyy.csv

Bill Settlement Files:

Since not all customers are billed on the same date, monthly billing files were shared by NB Power with NRC in batches. The file had monthly billing data for multiple premises. The following file naming convention was used by NB Power for reporting the monthly usage data:

SGA_Settlmentdata_mm-yyyy.CSV

5 Conclusions

The Shediak Residential Energy Study successfully demonstrated the feasibility and benefits of integrating smart energy technologies in residential settings. Over the duration of the project, nearly 500 participant homes were equipped with bidirectional smart meters, facilitating the regular sharing of 15-minute interval data with the NRC. This resulted in the seamless exchange of over 60 million records of smart meter data, distributed across 14,074 electricity import and 14,075 export files. The efficient data sharing and management underscore the robust design of the data models and processes employed.

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Appendix A - VEE Rules

VEE Flag	Name	Description	Threshold/Config	Notes
V0	VALID	No VEE operation performed on the interval	N/A	
V1	FAILED MAX DEMAND	Interval exceeded max demand threshold	10 kWh	NB Power to provide feedback on threshold value
V2	ESTIMATED	Interval value estimated using either Historic estimation or Class Load Profile estimation.	Historic Estimation (30 days)	- Historic estimation will be attempted first on interval and if unsuccessful <u>Class Load Profile</u> will be used for estimation - Historic estimate for each interval is based on the average of valid intervals from a set number of Like Days that are comparable to the day for which the estimation is required. - The Class Load Profile estimation routine will fill in missing intervals using intervals from a prototype class load profile.
V4	FAILED ESTIMATION	Historic and Class Load Profile estimation is unsuccessful for the interval	N/A	
V8	EDITED	Interval manually edited	N/A	- Where actual interval consumption data is not available and automated estimation processes have not been successful, UA may be required to manually inspect and approve interval consumption data or to edit the values. - Receiving meter read data with missing intervals would be extremely rare as UtilSmart will only send meter read data when data is available (no gaps).

Chapter 3: Modelling Smart Energy Technology Data to Facilitate Data Exchange

Ajit Pardasani

1 Introduction

This report provides an overview of the data model for time series data from smart energy technologies within the Shediac Residential Study, a five -year project. This project is part of Smart Grid Atlantic (SGA), a four-year federally-funded program supporting energy technology projects in Nova Scotia and New Brunswick. Initiated by New Brunswick Power (NBP) in partnership with the Town of Shediac, Siemens Canada, and the National Research Council of Canada (NRC), the study was supported by \$35 million in grants from Natural Resources Canada and Innovation, Science and Economic Development Canada. The study aimed to gain the experience and knowledge necessary to modernize the electrical grid, while addressing increasing customer energy needs and the necessary pace of decarbonization. This was accomplished by piloting smart energy technologies in over 500 homes in Shediac to gather data and insights into how these technologies perform in everyday residential settings. Research plan and methods are described in (Veitch, Pardasani, Cooper, Galasiu, Mancini, Hu, Awad, 2025) and an overview of the study is presented in a separate technical report (Pardasani, Veitch, Cooper, Awad, 2025).

This report details the data model for time series data from several smart energy technologies piloted at the Shediac study such as three different types of smart thermostats, Internet connected domestic hot water controller devices, and a 5 kW rooftop solar photovoltaic panel array + 13.5 kWh battery energy storage. Bidirectional smart meters were utilized to measure electricity flow from grid to participant households, and exports from solar-equipped households back to NB Power. The document focuses on the data from smart energy technologies and does not cover smart meters and bill settlement files, as these are addressed in another report (Pardasani, 2025).

The initial version of this document was developed at the project's onset in 2019, serving the dual purpose of establishing a common understanding among team members regarding the data model and laying the groundwork for file formats used by NB Power to share smart meter and bill settlement data with the NRC.

Unless otherwise specified in this document, the data was shared by NB Power with the NRC in Comma-Separated Values (CSV) files, using the Carriage Return Line Feed (CRLF) character to denote line breaks. The headers for the tables in the CSV files, as defined in this document, were not to be changed throughout the project. The data files were shared via NB Power's secure FTP server, to which the NRC was granted access through a password-protected account.

The time-series data ranged from midnight to midnight, with date and time values following the UTC time zone. Once placed in the designated folder on NB Power's SFTP server, the files were to remain accessible for the project's duration.

2 Smart thermostats

2.1 Thermostat telemetry

Three types of smart thermostat from different manufacturers were used, depending on the type of heating system. Table 1 shows the association of labels to the heating system types being controlled.

Table 1. Thermostat label and heating system it controlled

Label	Heating System
A	Central heat pump or furnace
B	MSHP
C	Resistive heating, including EB and radiant floor heating

If the home had more than one room heated with either MSHP or EB, up to five thermostats could be installed, in order to provide information on the majority of the heating load for the home. The combinations of MSHP as primary heating system with EB as backup, or in other rooms of the home, meant that there were five variations of device types installed: A only, A+B, B only, B+C, and C only.

Though all three types of thermostats have different data fields, NRC developed a universal data format for NB Power to share thermostat telemetry data with the NRC. NB Power mapped the individual fields of different thermostat types to this universal format shown in Table 2.

Table 2. Data fields for all thermostat types

Data Field	Data Type	Notes
ThermostatIdentifier:	Characters	Foreign key
Date	Date	
Time (UTC)	Time	
Heat Set Temp	Float	Setpoint temperature for heating
Cool Set Temp	Float	Setpoint temperature for cooling
Room Temp:	Float	Ambient temperature at thermostat location
Relative Humidity	Float	Relative humidity at thermostat location
System Setting Power	Char	On Off
System Mode	Char	Off Heat Cool
Heat Stage 1 (sec)	Integer	Only applicable to the central multi-stage systems
Aux Heat (sec)	Integer	How long the aux heat was on in the reported time interval
Cool Stage 1 (sec)	Integer	Only applicable to the central multi-stage systems
Fan (sec)	Integer	How long the fan was on in the reported time interval
Watt hours	Integer	Applicable to certain models of thermostats to control resistive heating
Temperature Tracking Sensor:	Char	Only applicable for the radiant floor heating systems.

Thermostat telemetry data was shared by NB Power through CSV files via their secure FTP server. The files were then ingested into the NRC's SQL data warehouse.

2.2 Thermostat mapping

Thermostat mapping files shown in Table 3 describe the data collected during the installation and commissioning of smart thermostats. They also link the thermostat ID to the WebID. There can be more than one thermostat associated with the WebID.

Table 3. Data model for the thermostat mapping file

Data Field	Data Type	Notes
WebID	Integer	A unique identifier for the dwelling.
Room	String	The location where the thermostat is installed (e.g., Basement, Dining, Kitchen).
Length of Baseboard	Float (in feet)	The length of the electric baseboard heater in the room, measured in feet (if applicable).
Thermostat Type	String	Indicates whether the thermostat is Smart, non-programmable, or Programmable.
Heating System	String	The type of heating system controlled by the thermostat (e.g., MSHP, Electric baseboards, Central Heat Pump).
Thermostat Device Type	String	The brand or model of the thermostat device such as Mysa, Intesis, and Ecobee, etc.
Thermostat Serial Number:	String	A unique identifier for the thermostat device
Date Installed	Date (YYYY-MM-DD format)	The date when the thermostat was installed.
Date Uninstalled	Date (YYYY-MM-DD format)	The date when the thermostat was uninstalled (if applicable).
Electric Resistance Heater Capacity (kW)	Float (in kilowatts)	The capacity of the electric resistance heater in kilowatts (if applicable for central systems).
Heat Pump Capacity (BTUs)	Integer (in BTUs)	The capacity of the heat pump in British Thermal Units (BTUs) (if applicable).
Zone Type	String	The type of zone control (e.g., Single, Multi-head).
Zone Control Points	Integer	The number of control points in the zone (if applicable).
Pre-Install Aux Controls Functioning	Boolean	Indicates if auxiliary controls were functioning before installation.
Pre-Install Compressor Minimum Outdoor Temperature Setting	Float (in degrees)	The minimum outdoor temperature setting for the compressor before installation.
Installed Aux Controls Functioning	Boolean	Indicates if auxiliary controls are functioning after installation.
Installed Compressor Minimum Outdoor Temperature Setting	Float (in degrees)	The minimum outdoor temperature setting for the compressor after installation.

3 Solar PV and battery energy storage

3.1 Telemetry data

This schema shown in Table 4 was designed to capture comprehensive solar inverter and battery energy management data, enabling analysis of battery performance, solar power generation, grid interaction, and site energy consumption over time.

The identifier for the solar PV and battery energy storage and date range were encoded in the telemetry data file name. There was one CSV file corresponding to each installation site. Following is an example of the file name.

STE20220628-00189-20240201-20240229.csv

Table 4. Data model for the solar PV and battery energy storage telemetry data

Data Field	Data Type	Notes (if applicable)
Timestamp (UTC)	DateTime	The timestamp of the recorded data in Coordinated Universal Time (UTC).
Battery Real Power (W)	Decimal	The real power output or consumption of the battery in watts.
Battery State of Energy (%)	Decimal	The state of charge of the battery as a percentage of maximum
Solar Real Power (W)	Decimal	The real power output from the solar PV inverter in watts.
Grid Real Power (W)	Decimal	The real power being drawn from or supplied to the grid in watts.
Site Real Power (W)	Decimal	The net real power consumption of the site in watts.

3.2 Mapping

This mapping schema shown in Table 5 ensures each device can be uniquely identified and tracked for its installation and uninstallation dates, along with its type and location. The same mapping file was used for the solar PV and battery energy storage, and thermal storage units that were later replaced with cold-climate mini-split heat pumps.

Table 5. Mapping schema for solar PV and battery storage energy systems

Data Field	Data Type	Notes (if applicable)
WebId	Integer	A unique identifier for each record.
TechType	String	Two possible values: SOL TS
Location	String	Location of the device within the property (e.g., Basement, Garage, Living Room). For Solar PV the location could be either garage or basement.
DeviceSerialNumber	String	The serial number of the device for identification. It is derived from the file name.
TechDateInstalled	Date	The date when the technology/device was installed
TechDateUninstalled	Date	The date when the technology/device was uninstalled, if applicable. This field is nullable because some devices might not have been uninstalled yet

4 Domestic hot water tank control device

Water heater control devices for demand response are Internet connected tools to reduce peak energy usage and reduce bills under time-of-day rate structures. These controllers allow utilities to remotely manage water heaters, shifting energy consumption to off-peak times, and enhancing grid efficiency. By integrating smart technology, they provide real-time monitoring and control, ensuring hot water supply while minimizing energy waste.

4.1 Telemetry data

Table 6 shows the schema to capture telemetry data from domestic hot water tank control devices.

Table 6. Telemetry data model for domestic hot water tank control devices

Data Field	Data Type	Notes (if applicable)
DeviceIdentifier	String	Foreign key
UTCDateTime	DateTime	Timestamp indicating the date and time the data was recorded, in Coordinated Universal Time (UTC). It follows the ISO 8601 format.
Energy (kWh)	Float	The energy consumption measured by the current transformer, recorded in kilowatt-hours (kWh). This field captures the energy usage of the device at each interval.
Relay	Integer (0 1)	Indicates the status of the relay. A value of '0' suggests that the relay is off, while '1' suggests that the relay is on, in response to a demand response signal

4.2 Mapping file

Table 7, below, is the mapping file for associating the WebID to the controller ID and date of installation.

Table 7. Data schema for mapping domestic hot water tank control devices meta data to device telemetry

Data Field	Data Type	Notes (if applicable)
WebID	Integer	A unique identifier for each dwelling.
WaterHeater_InstalledDeviceSerialNumber	String	A unique identifier for each domestic hot water tank controller device. This is likely a serial number or MAC address format.
WaterHeater_DateInstalled	Date	The date when the water heater device was installed.
WaterHeater_DateUninstalled	Date (nullable)	The date when the water heater device was uninstalled, if applicable.

5 Conclusions

The Shediac Residential Energy Study de-risked the decarbonization solutions by creating a unique and large dataset from smart thermostats, solar PV systems, battery energy storage, and domestic hot water tank control devices. Over the course of the study, 828 homes were equipped with smart thermostats, 75 homes received solar PV and battery systems, and 316 domestic hot water tank control devices were installed. The study collected a vast amount of data, including 199,494,105 smart thermostat records, 2,995,200 records from solar and battery systems, and 73,394,413 records from hot water tank devices. This extensive dataset has provided valuable insights into the performance of these technologies in real-world residential settings, highlighting the potential for smart energy solutions to contribute significantly to energy efficiency and grid modernization efforts.

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Chapter 4: Energy Use Characterization of Dwellings

Ajit Pardasani, Jennifer A. Veitch, Yitian (Vera) Hu, Hadia Awad, and Natalia Cooper

Executive Summary

This report is part of a series concerning the Shediac Residential Energy Study, a five-year project to evaluate smart energy technologies in homes in Shediac, New Brunswick. The study commenced in 2019 with the recruitment of participants, followed by installation of smart meters in early 2020 to collect time-series electricity use data. The baseline period for the study was from May 2021 to April 2022. After pandemic-related delays, the experimental phase of the study spanned from May 2022 to March 2024. The interventions included one behavioural intervention and two technology interventions in subsets of participant homes. The behavioural intervention involved time-of-day (TOD) electricity rates. The two technology interventions involved installation of cold-climate mini-split heat pumps (CC_MSHP) and (on different homes) installation of a 5 kW rooftop solar photovoltaic (PV) panel array, which included a solar inverter and a 13.5 kWh battery energy storage device with a maximum charge or discharge rate of 5 kW.

In this report we outline the general energy use characteristics of nearly 500 dwellings that participated in the Shediac study, utilising data collected from smart meters and smart energy devices installed by NB Power at participant homes. This pilot study offered a unique combination of data sets, including smart meter, smart thermostat, solar PV and battery energy storage, CC-MSHP, and occupancy, along with basic household characteristics and weather data. Various data analytic techniques were employed to derive insights into energy use patterns and peak demand, including how building and heating system characteristics influenced electricity usage. The characterization results were instrumental in assigning participants to research groups and ensuring balanced characteristics between control and experimental groups.

The analysis highlighted significant seasonal variations in electricity usage, with increased use and peak demand during colder months due to heating demands. Dwellings equipped with mini-split heat pumps exhibited the lowest energy use profiles and also recorded the lowest average daily morning peak during the winter.

Cluster analysis identified distinct household electricity usage patterns, enhancing the understanding of the impact of innovative energy technologies. These patterns can be utilized to pinpoint candidates for energy efficiency retrofits and demand response programs. The findings highlight the potential for smart technologies and energy-efficient systems to optimize residential energy use, thereby contributing to more sustainable energy practices in Shediac and elsewhere.

1 Introduction

This report is part of a series from the Shediac Residential Energy Study, a five-year field investigation examining the effects of innovative energy technologies on residential energy use, as well as participants' attitudes and satisfaction. The project tested time-of-day electricity rates, cold-climate mini-split heat pumps (CC-MSHP), and rooftop solar photovoltaic (PV) panels with battery energy storage. Many of the over 500 homes involved in the project received smart technologies and devices.

This report focuses on the baseline period from May 2021 to April 2022, integrating insights from dwelling characteristics, home assessments, smart meters, and device telemetry to offer a comprehensive understanding of energy usage patterns. The first report in the series (Veitch et al., 2025) provides an overview of the study's research framework, including outlines of the surveys, as well as building and telemetry data collected from households. Telemetry data were gathered from smart meters, smart thermostats, 5 kW solar PV and 13.5 kWh battery energy management system (SOL). The data fields associated with these devices are detailed by Pardasani (2025a, 2025b), and the summary of results is covered in Pardasani et al. (2025).

Space heating is the dominant energy use in New Brunswick where in 2021 nearly 60% of the total secondary energy in homes was used for space heating, and 18% for water heating. Nearly 45% of the secondary energy was provided by electricity (Natural Resources Canada [NRCan], 2023). The proportion of space heating loads in the peak of winter increases significantly depending on the outdoor temperature. A pilot study by NB Power on 50 occupied homes in Fredericton, which used electricity as the primary source of heating, estimated that the majority of homes had space heating loads ranging from 60-90% of total usage from January to March 2016 (Pardasani et al., 2018). Energy efficiency measures to reduce energy use associated with space heating clearly hold great potential to help utilities address the challenges of increased overall electricity demand and reduced carbon emissions.

In Canada, the National Building Code of Canada Part 9.36 (NBC) sets out energy efficiency requirements for the design and construction of new buildings (Canadian Commission on Building and Fire Codes, 2022). The NBC covers all aspects of building design, including building envelope, lighting, heating, ventilation, air conditioning systems, and service water heating. It provides a comprehensive framework for energy performance to reduce the energy consumption and greenhouse gas emissions. A similar framework or roadmap for energy retrofit of existing residential buildings stock for decarbonization does not exist. Heidari et al. (2022) highlighted the necessity of such a roadmap and proposed a comprehensive retrofit strategy to decarbonize and electrify existing single-family homes in Canada. The first step in developing a roadmap to tackle emissions from existing buildings involves understanding the current energy performance of these structures across regions and communities. This report takes a step in that direction by presenting the energy use characteristics of dwellings from the Shediac Residential Energy Study participants. The study analyzed a unique combination of data sets, including smart meters, smart thermostats, solar PV and battery energy storage, cold-climate mini-split heat pumps, and occupancy together with basic household information, to provide a holistic overview.

2 Household sample and descriptive data

Energy use in dwellings is influenced by several factors, including the occupants' schedules and behaviours, the physical characteristics of the dwellings, the efficiency and type of heating and cooling systems, and prevailing weather conditions. These data were collected during the first home assessment phase (HA1) in December 2019 (see Veitch et al. 2025). The histograms in Figure 1 show that most dwellings in the sample were built after 1995 and most houses had a floor area between 1001 to 2,000

sq. ft. Most participants in the sample lived in detached homes and used MSHP as their primary heating systems, as illustrated in Figure 2.

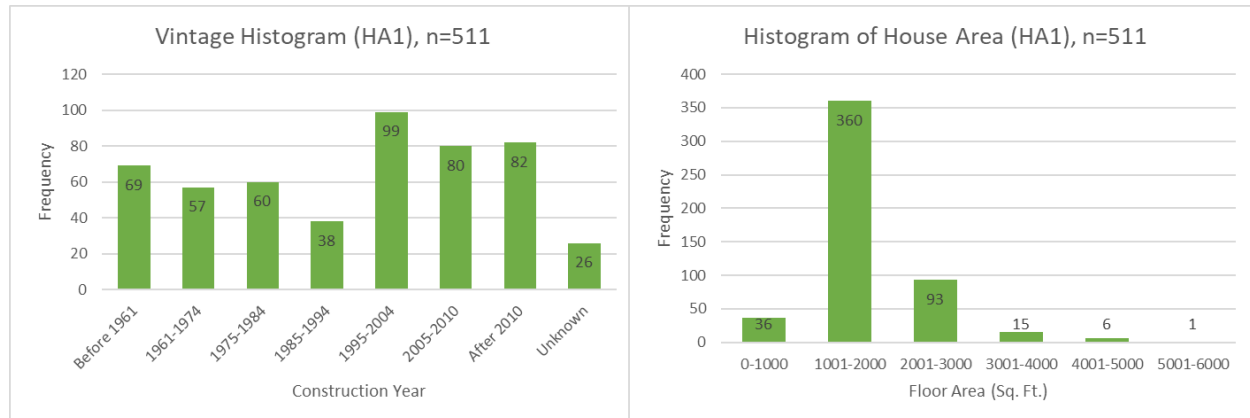


Figure 1. Distribution of vintages and house area from the first home assessment.

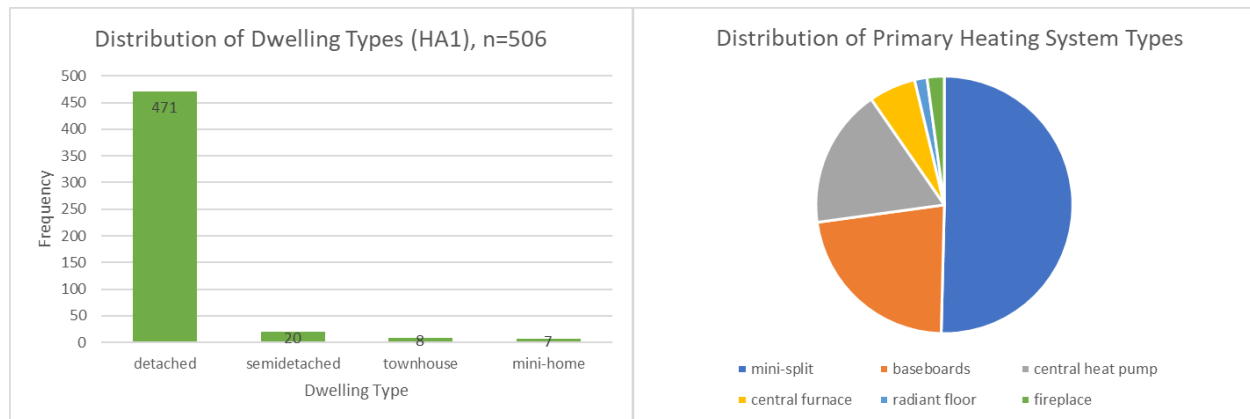


Figure 2. Distribution of house structures and types of primary heating systems.

A dwelling was designated as having a mini-split heat pump (MSHP) as the primary heating system if it featured either a multi-head MSHP unit or a single unit with a capacity exceeding 24,000 BTU. Conversely, if the MSHP was noted as a secondary heating system, the home typically had only one heat pump, contributing less than 50% of the heating load during winter. This guideline was established by NB Power to assist contractors in collecting data on home characteristics and heating, ventilation, and air conditioning (HVAC) systems. Because a home equipped with a mini-split heat pump (MSHP) could also have electric baseboards (EB), this rule helped establish which heating system should be deemed primary.

Table 1. Distribution of primary heating system at the beginning of the project and at the end of the project.

Primary Heating System	Dec-19		Mar-24	
	N	Percent%	N	Percent %
MSHP	256	50.4	218	65.7
Baseboards	114	22.4	31	9.3
Central Heat Pump	89	17.5	62	18.7
Central Furnace	30	5.9	14	4.2
Radiant Floor	8	1.6	5	1.5
Fireplace	11	2.2	2	0.6
Total	508		332	

Table 1 shows the distribution of primary heating systems at the beginning of the project and at the end of the project. The data on heating systems was collected at the time of recruitment in December 2019 through the initial home assessment (HA1) and was updated based on survey responses. The percentage of homes with MSHP increased during the course of the project, and the percentage of homes with EB heating as their primary heat source decreased. A tabulation at the end of the project determined that by December 2022, 84% of the homes had either MSHP or a central heat pump. Nine per cent had independently acquired a heat pump during the project, and 4.3% (23 homes) had been given a high-efficiency cold-climate mini-split heat pump as part of the project.

Table 2 shows how different primary heating systems are paired with secondary systems as per HA1, illustrating the variety and frequency of these combinations in the Shediac sample. Not all homes have a secondary heating system.

Table 2. Primary and secondary heating system configurations (Source: HA1).

Primary Heating System	Secondary Heating System
Mini-split heat pump (N=256)	Electric Baseboard (N=211)
	Wood Pellet Stoves/Fireplaces (N=17)
	Propane Stoves/Fireplaces (N=3)
	Central furnace or boiler (N=17)
	Electric radiant heating (N=4)
	Central heat pump – air (N=1)
Electric Baseboard (N=114)	Mini-split heat pump (N=48)
Wood/Pellet Stoves/Fireplaces (N=11)	Stoves/Fireplaces (N=25)
	Electric Baseboard (N=9)
Central furnace or boiler (N=30)	Central furnace or boiler (N=2)
	Electric Baseboard (N=9)
	Mini-split heat pump (N=4)
	Electric Fireplaces (N=1)
Central heat pump -air (N=83)	Wood/Pellet/Propane Stoves/Fireplaces (N=6)
	Electric Baseboard (N=33)
	Central Furnace or Boiler (N=20)
	Propane Stoves/Fireplaces (N=9)
	Wood/Pellet Stoves/Fireplaces (N=9)
	Electric radiant heating (N=1)
Central heat pump – geothermal (N=6)	Mini-split heat pump (N=6)
	Propane Stoves/Fireplaces (N=1)
	Wood/Pellet Stoves/Fireplaces (N=2)
	Central Furnace or Boiler (N=1)
	Electric radiant heating (N=1)
Electric radiant heating (floor or ceiling) (N=8)	Mini-split heat pump (N=1)
	Electric Baseboard (N=4)
	Mini-split heat pump (N=3)

The following pairings were observed to be most common:

1. MSHP as primary paired with EB as secondary: This combination is the most prevalent with 211 instances, (N=211).
2. MSHP as primary paired with central furnace or boiler, (N=17).
3. EB with MSHP, (N=48).
4. Central heat pump - air paired with EB, (N= 33).
5. EB with stoves and stoves/fireplaces: (N= 25)
6. Central heat pump -air and central furnace or boiler: (N= 20).
7. MSHP with stoves/fireplaces: (N= 17).

3 Data sources

Figure 3 illustrates the data sources and data flows used to support various analyses for this study; see Pardasani (2025a, 2025b) for details. The data falls into the following categories:

- **Device telemetry data** from bi-directional gen 2 smart meters, smart thermostats, dispatchable water heater controllers, and SOL. The number of devices and time interval are also shown.
- **Home assessments:** Two stages of home assessments were carried out. The first home assessment (HA1) collected data on the type of building structure, vintage, primary energy source for heating, type of heating system, and other attributes that affects the energy performance. The second assessment (HA2) of a subset of homes was conducted to verify each home's compatibility for installation of either of solar PV and battery energy storage or thermal storage technologies.

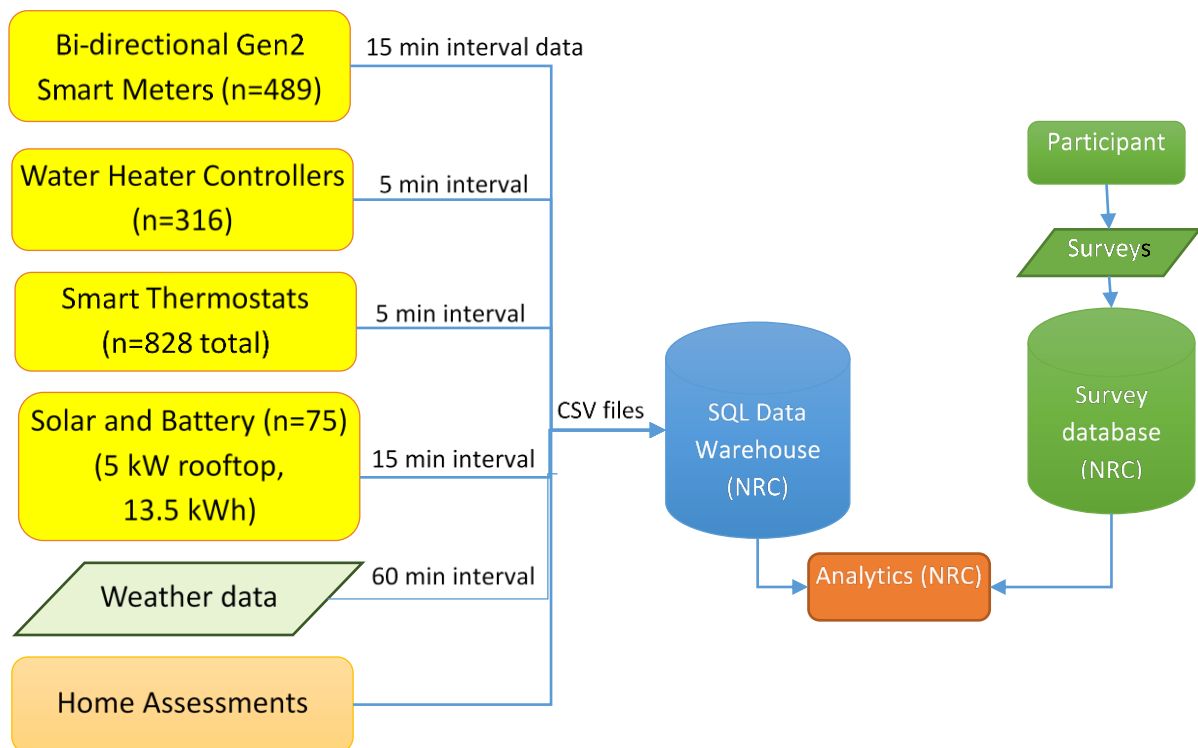


Figure 3. Data sources.

4 Profiling energy utilization of the Shediac sample

4.1 Monthly whole house electricity usage

Figure 4 illustrates the average whole house electricity usage in kWh per month for the baseline period of one full year from May 1, 2021 to April 30, 2022 for the participants' dwellings. The electricity usage varied significantly across the year. During the months characterized by moderate temperatures (May to September), the monthly usage was lower compared to the rest of the year, indicating less demand for heating in the shoulder seasons, and no heating demand in the summer season. For example, usage in May was about 1,415 kWh, and it decreased to its lowest at around 1,090 kWh in September before increasing to 1246 kWh in October.

However, during the colder months (November to March), the monthly usage increased because of increased heating demands, peaking in January at about 3,390 kWh. The heating load percentage during these months was also higher, indicating that a substantial portion of the total energy use was dedicated to heating.

Overall, the histogram in Figure 4 highlights a clear seasonal pattern in electricity usage, with lower energy use in the warmer months and higher energy use in the colder months.

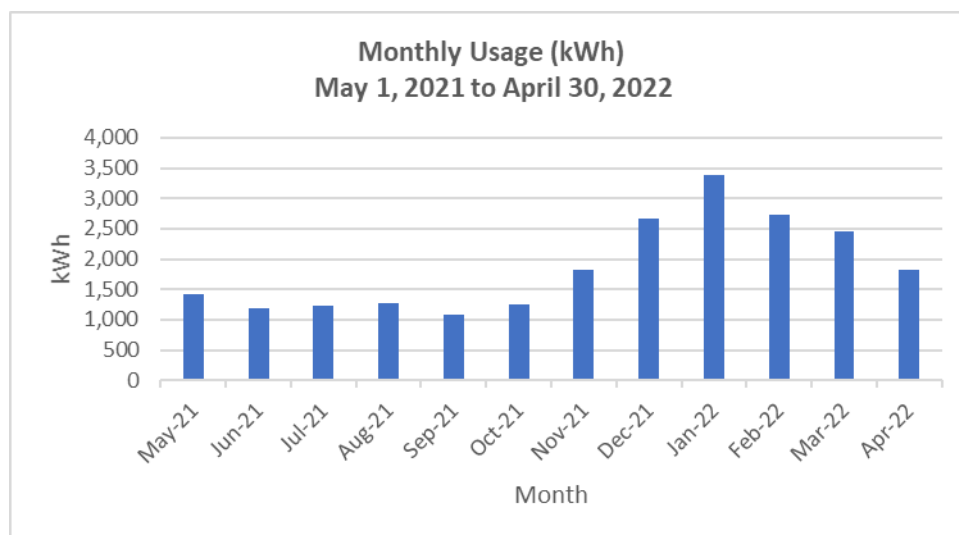


Figure 4. Monthly electricity usage in kWh for the baseline period.

Table 3 highlights the trend of colder temperatures leading to increased energy use for heating. The column "Heating Loads as % of Whole House Energy Usage" shows the percentage of total energy use that is attributed to space heating. The findings demonstrate that a larger proportion of energy was used for space heating as the outdoor temperature dropped. For instance, in January 2022, nearly 63% of the whole house's energy usage is estimated to have been used for space heating, with a corresponding monthly average outdoor temperature of -9.4°C.

Energy usage in heating months compared to the estimated use in non-heating months: This column in Table 3 compares the total energy usage during heating months to that in non-heating months. A higher value indicates substantially greater energy usage in heating months relative to non-heating months. For example, in January 2022, the energy usage was 271% of that in non-heating months, reflecting the high energy demand for heating during the coldest month of the year.

The column, 'B- Estimated household load without space heating (kWh)' is the average whole house energy use, prorated to the number of days in a month. It is derived by averaging energy use for the months from May 2021 to October 2021 when space heating loads are very low or absent. This includes water heating loads. Overall, the data highlights how colder temperatures lead to increased energy consumption for heating, with the highest heating loads and relative usage observed in the coldest months.

Table 3. Comparing total usage in heating months to non-heating months

Month	Outdoor Temp °C	A- Whole house monthly usage (kWh)	B- Estimated household load without space heating (kWh)	(A-B) Disaggregated heating load (kWh)	Heating load as % of whole house energy usage (A-B)/A	Energy usage in heating month compared to estimated use in non-heating months (A/B)
Nov-21	2.9	1,812	1,212	600	33%	150%
Dec-21	-3.1	2,676	1,252	1,424	53%	214%
Jan-22	-9.4	3,390	1,252	2,138	63%	271%
Feb-22	-5.2	2,729	1,131	1,598	59%	241%
Mar-22	-1.1	2,466	1,252	1,213	49%	197%
Apr-22	4.6	1,812	1,212	600	33%	149%

4.2 Domestic hot water (DHW) tank usage

A total of 316 water heater controller devices were installed on existing NB Power rental domestic hot water tanks of eligible participants by NB Power in 2021 to enable demand response. The devices monitor the electricity use and connect to the internet to upload data. The telemetry data from these devices inform the analysis of water in this section.

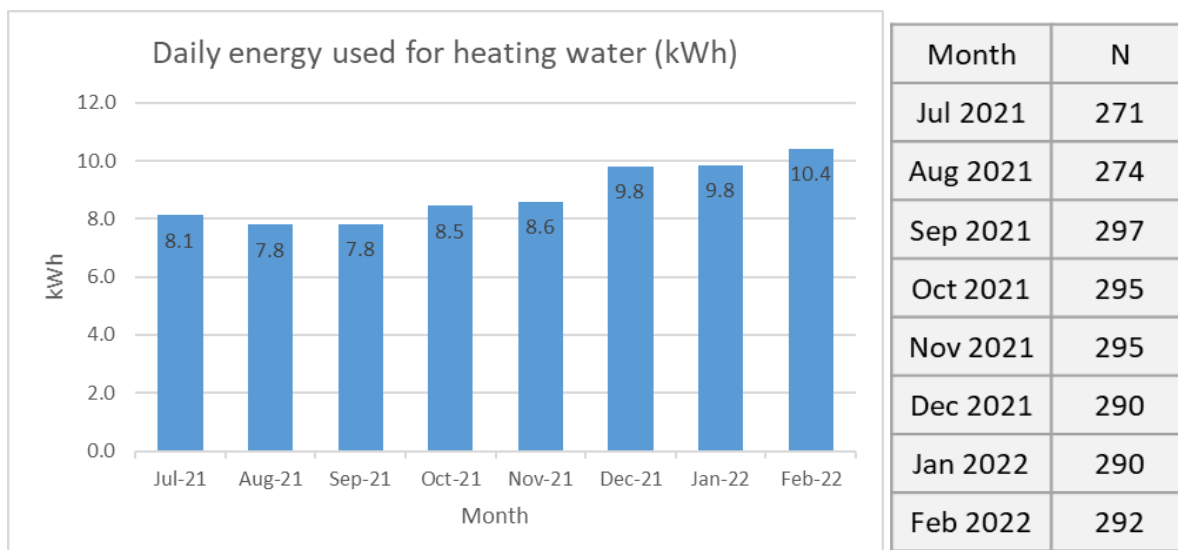


Figure 5. Left side bar chart shows the daily energy use for water heating from July 2021 to Feb 2022. The table on the right shows the number of installed devices for the corresponding months.

The histogram in Figure 5 shows that average daily electricity usage for hot water tanks increased from 8.1 kWh in July 2021 to 10.4 kWh in February 2022. This rise in energy consumption corresponds with the seasonal transition from summer to winter. A key factor contributing to this increase is the drop in

the inlet water temperature during the colder months, which necessitates more energy to heat the water to the desired temperature. The table on the right in Figure 5 shows the number of operational hot water tank controllers in months from July 2021 to February 2022.

Table 4. Cost to heat water using the prevailing NB Power rate of electricity @ 11.61¢ per kWh.

<i>Season</i>	<i>Energy usage per month (kWh)</i>	<i>Cost to heat water per month (\$)</i>
January 2022	303	\$35
July 2021	216	\$29

Table 4 shows the average cost of water heating per month for the sample with water heater devices. The cost increases slightly in the winter, corresponding to the increased energy use required to heat the inlet water. Table 5 shows the distribution of sizes for DHW tanks that received the controller devices.

Table 5. Distribution of DHW device installs by tank sizes.

<i>Size (gal)</i>	<i>Count</i>	<i>Percent</i>
40	112	36
50	106	35
60	74	24
80	12	4
Unknown	3	1
<i>Total</i>	<i>307</i>	

We analysed the dependency of DHW tank size on number of occupants and house area through correlation matrix shown in Table 6. The data on the number of occupants was obtained from the participant surveys and house area was estimated from the satellite imagery in December 2019 and then logged in HA1.

Table 6. Correlation matrix to analyse the relationship between the hot water tank volume, occupancy and house area.

	<i>Occupancy</i>	<i>House Area</i>	<i>HW Tank Vol.</i>
Occupancy	1.00		
House Area	0.12	1.00	
HW Tank Vol.	0.08	0.23	1.00

The correlation matrix indicates weak relationships between HW tank volume and the other variables. HW tank volume has nearly no correlation to occupancy ($r = 0.08$). HW tank volume shows a weak positive correlation of 0.23 with house area, indicating that larger house areas slightly tend to have larger hot water tank volumes, but the relationship is not strong. Overall, changes in HW tank volume are not strongly predicted by changes in occupancy or house area.

4.3 Average hourly monthly energy use

The distribution of whole house hourly electricity usage, derived from smart meter data, is presented in Figure 6, Figure 7, Figure 8. These charts illustrate the usage patterns for working and non-working days

during the baseline year (May 2021 to April 2022) which is further broken down by meteorological seasons i.e., Summer 2021, and Winter 2022, respectively.

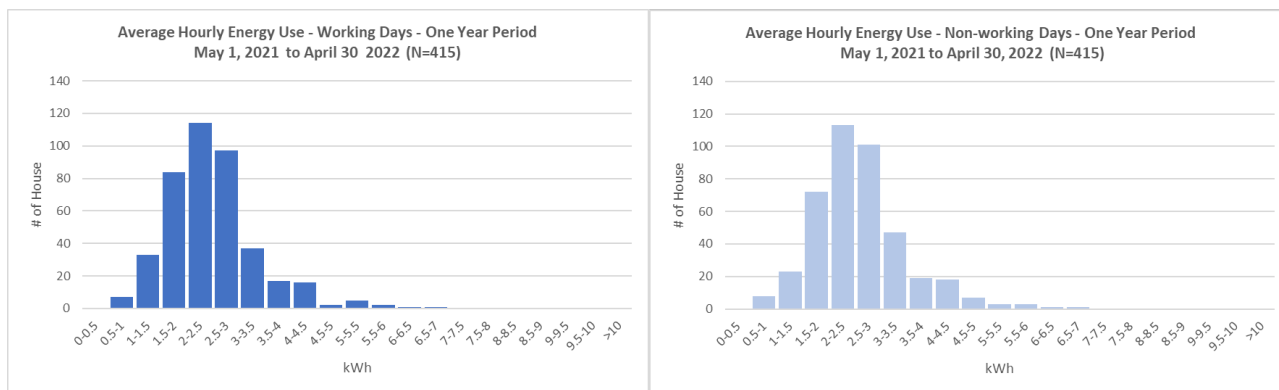


Figure 6. Average hourly whole house energy use for working and non-working days based on smart meter data for the one year baseline period (N=415).

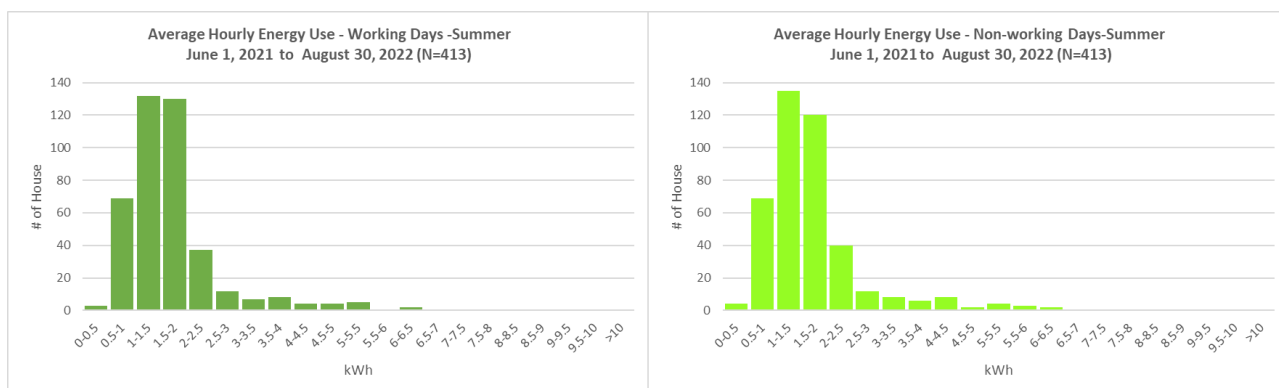


Figure 7. Average hourly whole house energy use for working (left) and non-working (right) days based on smart meter data for the summer 2021 (N=413).

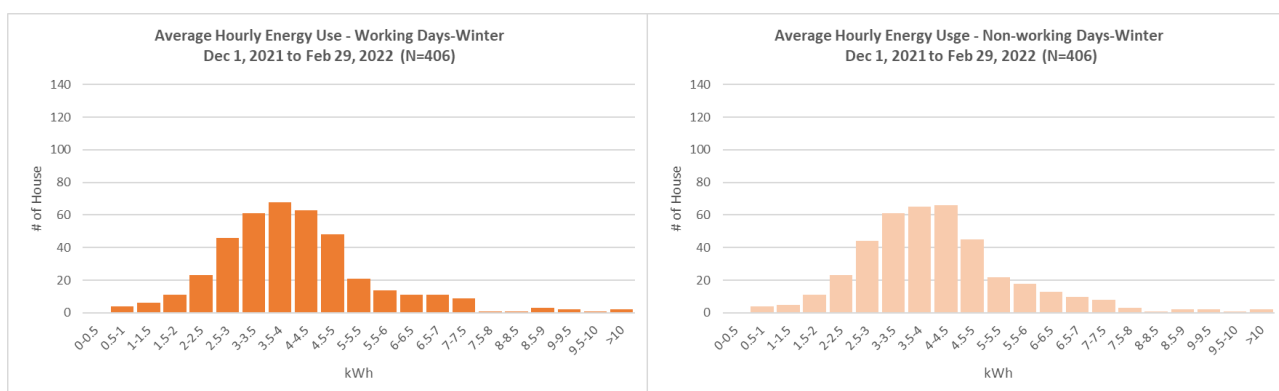


Figure 8. Average hourly whole house energy use for working and non-working days based on smart meter data for the Winter 2021 (N=406).

Figure 6 illustrates the distribution of average hourly electricity usage across 415 houses during working days over the one-year period from May 1, 2021, to April 30, 2022. The data reveals that the usage distributions are nearly similar for the work and non-work days with most common range for average hourly consumption is 2-2.5 kWh. This is followed by the 2.5-3 kWh and 1.5-2 kWh range. These findings

suggest that the majority of houses consume between 1.5 to 3 kWh of electricity per hour irrespective of days being working or non-working throughout the analyzed year.

The usage distribution for the summer in Figure 7 also demonstrates similarity for the work and non-work days with majority of homes with range for average hourly consumption in 1-2 kWh.

The distribution of average hourly electricity consumption across 406 houses during winter 2021 shown in Figure 8 reveals that the maximum number of houses for working days, 68, fall within the energy use range of 3.5-4 kWh per hour. Whereas, the maximum number of houses for non-working days, 66, fall within the higher range of 4-4.5 kWh per hour.

Number of Occupants

Table 7 shows the average hourly electricity usage by number of occupants for sample size of 316. The occupancy data was collected through surveys. The table also shows the number of homes for each occupancy category.

Table 7. Average hourly electricity usage by number of occupants in homes

<i>No. of Occupants in home</i>	1	2	3	4	5	6	7
Average Hourly Usage (kWh)	1.96	2.42	2.65	2.68	3.47	2.89	2.94
No. of Homes	26	136	73	63	13	2	3

Figure 9 illustrates the data in the table through a bar chart from one to five occupants. The data points for occupancy of six and seven excluded from the bar chart due to the very small sample size in those categories. The trendline shows increase in energy use as the number of occupants increase.

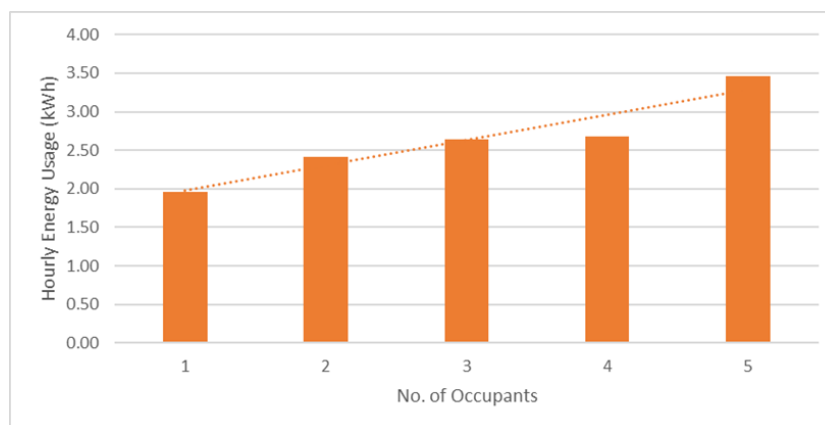


Figure 9. Hourly energy use by number of occupants for the period May 1, 2021 to April 30, 2022.

4.4 Energy use intensity

Energy use intensity (EUI) normalizes total energy use by the area of the dwelling (kWh/m²). For this sample, we calculated the EUI for various homes using their hourly energy use and house area of 416 dwellings for the baseline period. Figure 10 displays the rank-ordered data and highlights three tertiles: top, middle, and bottom. This tertile analysis can identify those with the most and least efficient energy use.

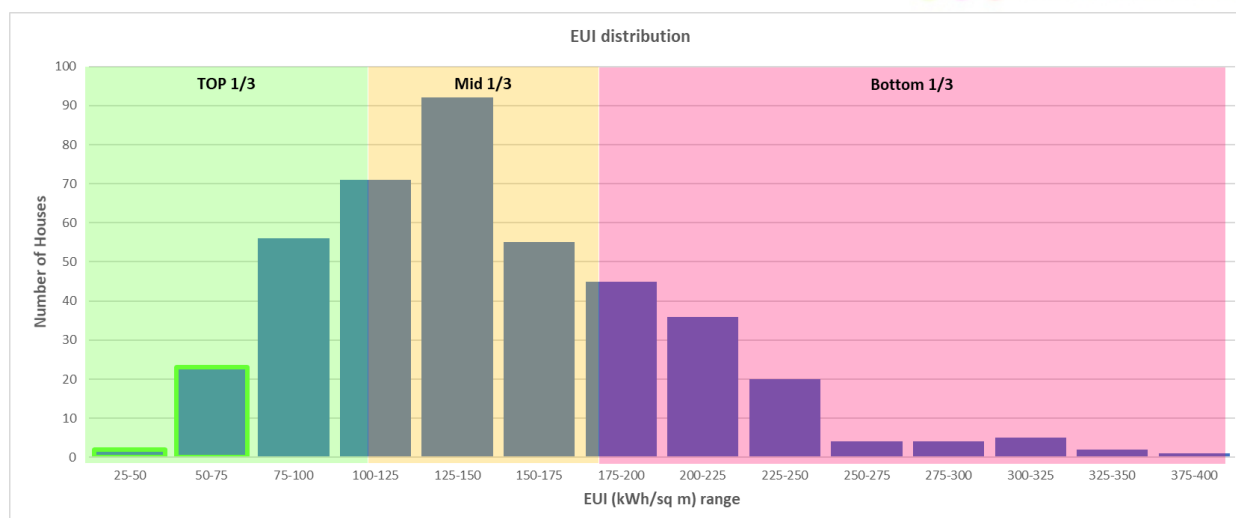


Figure 10: Tertile analysis to identify the homes that have the least electricity consumption.

The top one-third performing homes in terms of EUI demonstrated significantly low electricity usage of less than 121kWh/m². Many of these top performers were larger homes, with a mean of 193 square meters (2,076 sq. ft.) and max of 534 square meters (5,750 sq. ft.) The mean area for the whole sample was 159 square meters (1710 sq. ft.) with a standard deviation of 61 square meters (658 sq. ft.). Because the top 1/3rd tier has larger homes it benefits from the normalization of EUI by area. A notable portion of these homes also utilize non-electric heating energy sources such as cord wood/pellets and propane either as primary (N=5) or secondary (N=28) source.

Table 8 presents the descriptive statistics for each of the tertiles. We examined the top 26 performing homes, and among these, 15 have an area greater than 219 square meters (2,368 sq. ft., mean + 1 SD). Additionally, 8 out of these 26 homes use a wood pellet stove as a secondary heating source, and one home utilizes it as the primary heating source.

Table 8. Descriptive statistics of tertiles.

Tertiles	Floor Area (sq. ft)			
	Mean	Median	Min	Median
Top 1/3 rd	2076	1941	866	1941
Middle 1/3 rd	1,705	1,618	952	1,618
Bottom 1/3 rd	1,349	1,260	541	1,260

Although EUI is a useful measure of energy use in homes, its limitations are exposed in the above analysis by the fact that non-electric heating sources in some of these homes skew them to lower EUI. The true measure of energy efficiency in homes should be determined using more comprehensive metrics that account for both the total energy consumption from all sources. We can use EUI as an outcome measure in studies of energy efficiency measures in homes, together with predictor variables from a variety of sources.

4.5 Household load profiles by dwelling types

The household energy profiles categorized based on the type of dwelling structure are depicted in Figure 11. During the winter season, the energy use peaked in the morning hours, typically between 7:00 a.m. to 9:00 a.m., due to increased heating demands. Detached homes, which form the majority of the

dataset (N=375), reached their peak energy consumption around 8:00 a.m., averaging 4.88 kW and peaking again at 4.63 kW at 6 p.m.

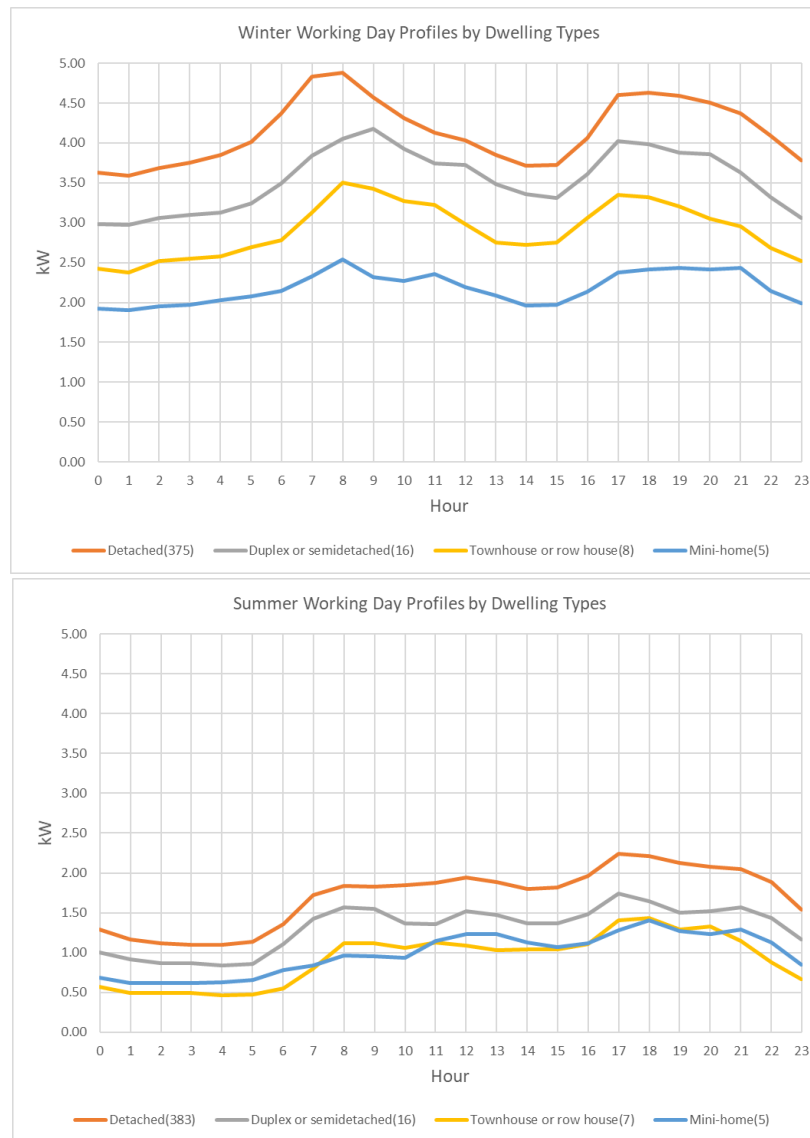


Figure 11. Winter and summer whole house load profiles by dwelling structure based on smart meter data.

During the summer season, peaks were observed later in the day, between 5:00 p.m. and 7:00 p.m. This pattern is evident in Detached homes and Duplex or Semi-detached homes, while Mini-homes and Townhouses show slightly lower peaks due to their smaller size.

4.6 Load profiles by heating system types

4.6.1 Winter workday load profiles

Winter load profiles, irrespective of type of heating system, reflect the increased energy consumption for heating during colder mornings. The winter working day load profiles for various heating system types in Figure 12 show that systems with electric radiant heating exhibited the highest peak in the early morning hours compared to other systems. This peak occurred around 8 a.m. Central furnaces or boilers had the second highest peak and had the most consistent load throughout the day. Central heat pumps also had high loads in the morning and evening, but were more variable. Dwellings that either used MSHP or EB as the primary heating system had similar profiles with low morning peaks without much variability during the day. Note that most homes that were categorised with EB as primary heating system also had a heat pump so it is not surprising to see the two profiles being similar and close to each other.

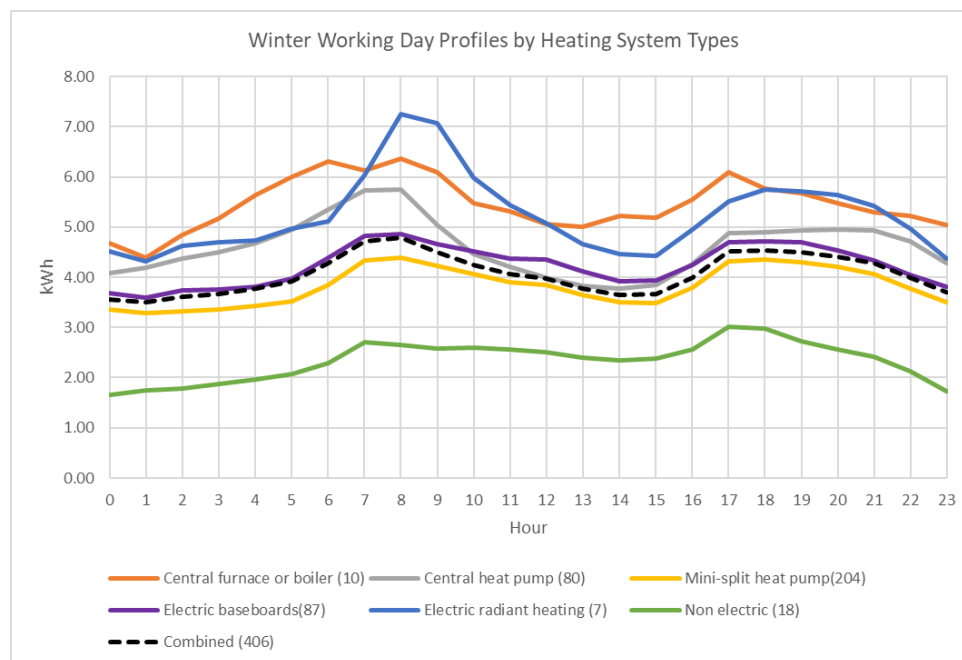


Figure 12. Winter household load profile by heating system type based on smart meter data.

4.6.2 Seasonal load differences

Winter profiles showed consistently higher loads across all heating types due to increased heating demand, with noticeable peaks in the morning and evening. Summer profiles generally had lower loads, with peaks typically occurring in the afternoon (Figure 13).

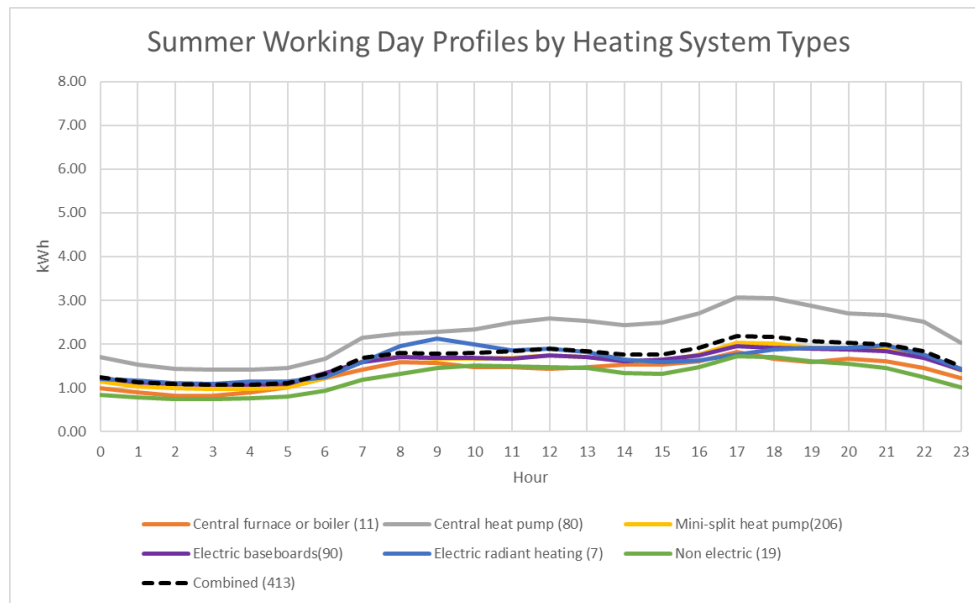


Figure 13. Summer household load profile by heating system type based on smart meter data.

4.7 Peak demand

In New Brunswick, the electric peak demand is characterized by two distinct types: daily morning peak demand between 7 a.m. – 9 a.m. and super peak events. The daily morning peak demand occurs routinely as residents and businesses begin their day, leading to increased electricity usage for heating, lighting, and operation of appliances. This peak typically aligns with the early morning hours when activity levels rise sharply. On the other hand, the super peak is less predictable and usually coincides with periods of extremely cold temperatures. During these times, the demand for electricity surges as heating systems work harder to maintain comfortable indoor temperatures, placing additional strain on the power grid. Understanding these demand patterns is crucial for effective energy management and planning, ensuring reliable electricity supply during critical periods.

4.7.1 Daily morning peak

Table 9 provides the maximum average peak demand in kilowatts (kW), derived from the aggregated daily demand across all dwellings in the sample for each season. Note that the peak demand during the summer occurred early in the evening. The peak demand in winter was nearly 2.6 times higher than that in the summer, as illustrated by the comparative data in the table.

Table 9. Average peak demand in kW by seasons for the baseline period.

Season	Date	Time	Average Demand (kW)
Summer	2021-06-08	5:30 p.m.	2.81
Fall	2021-11-29	5:30 p.m.	4.61
Winter	2022-01-12	8:15 a.m.	7.42
Spring	2022-03-04	7:15 a.m.	6.78

4.7.2 Super peak events

4.7.2.1 2022 events

This section examines the energy performance of dwellings during the super peak events of 2022. One major contributing factor to these peaks was the extremely cold weather conditions. NB Power identified the following dates as super peak days for 2022: January 11, 12, 16, 19, 21, 22, 24, 25, 27, 31; February 1, 2, 6, 14, 15, 16; and, March 1, 4. Figure 14. Outdoor temperatures corresponding to the super peak events from January 1, 2022 to March 4, 2022 .Figure 14 illustrates the timeline of super peak events along with the corresponding outdoor temperatures on those dates.

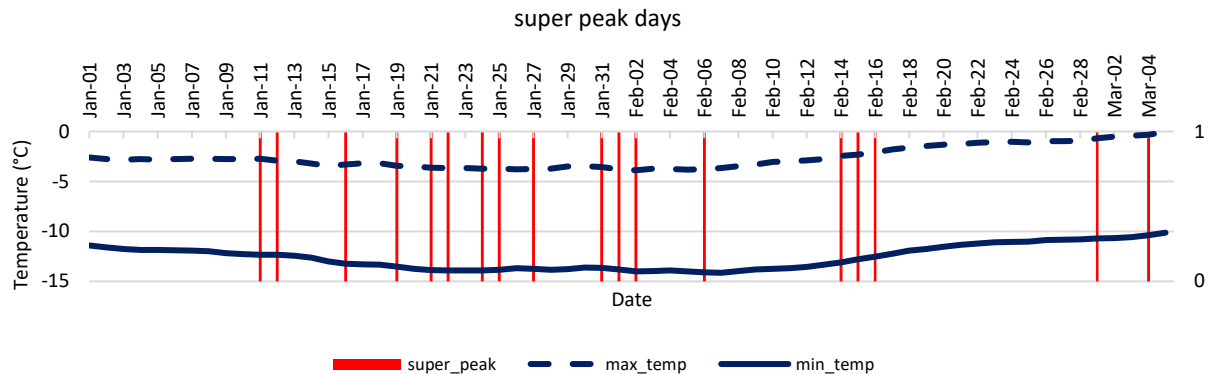


Figure 14. Outdoor temperatures corresponding to the super peak events from January 1, 2022 to March 4, 2022 .

Average load profiles, categorized by dwelling type, for 18 super peak days were compared to the average profiles from January 1 to March 5, 2022, as illustrated in Figure 15.

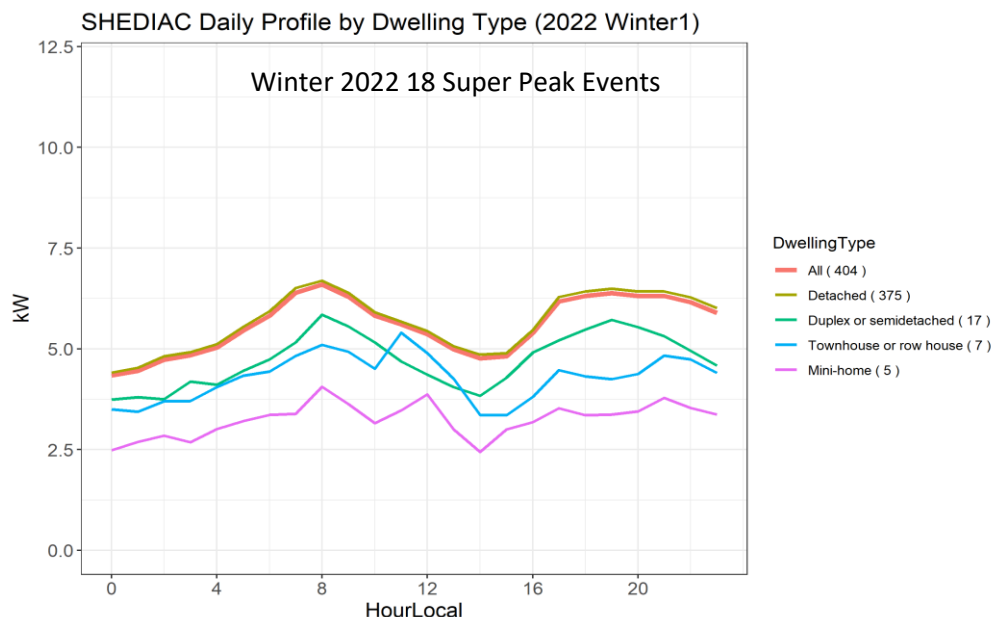


Figure 15. Average load profile for Winter 2022 on super peak days from January 1, 2022 to Mar 5, 2022.

The morning peak at 8 a.m. on super peak days reached nearly 6.5 kW, which is significantly higher than the average of 3.75 kW for the same timeframe on non-super peak days as shown in Figure 16. The

mini-home and townhouse or row house categories displayed in Figure 15 had a lower electricity use as compared to the detached homes. The average winter profile in Figure 16, including the super peak days, exhibited a flatter trend, with a slightly late peak between 9 a.m. and 12 p.m.

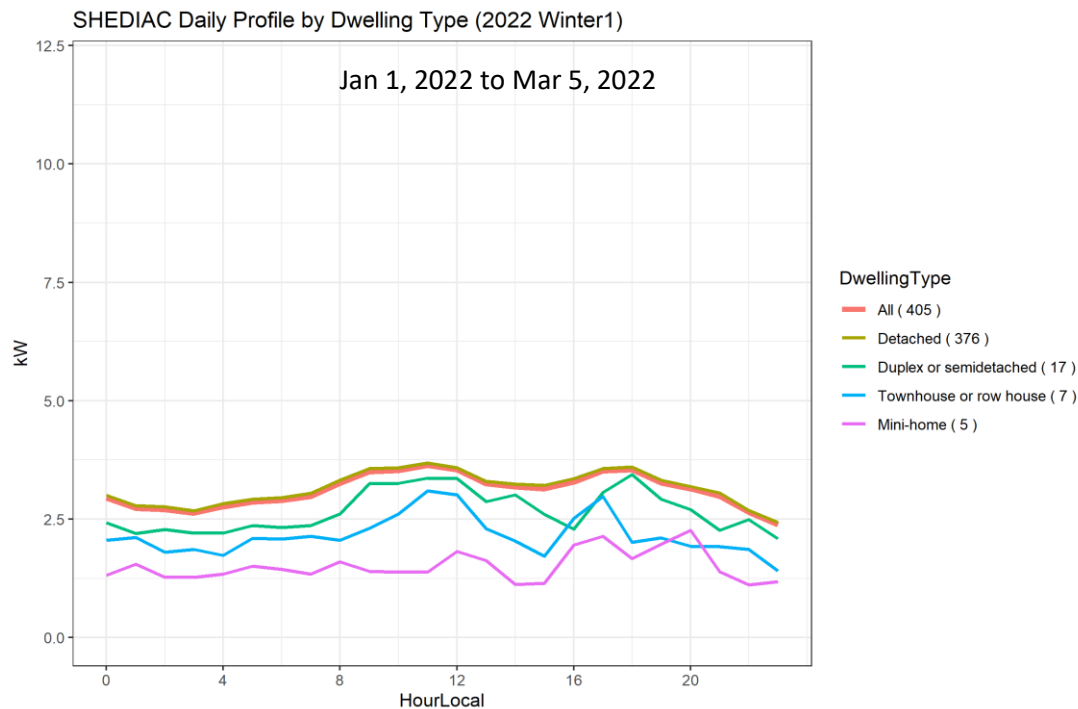


Figure 16. Average load profile for Winter 2022 from January 1, 2022 to Mar 5, 2022 (non-super peak days).

Four charts on Figure 17 depict average load profiles, segregated by dwelling type, corresponding to a sample of four super peak days to show variations in peak demand, time of peak demand, and profiles. Morning peak demand reached nearly 7.5 kW whereas the evening peak demand was slightly more than 5 kW. The average load profile, depicted as thick orange line plots labeled "All," represents the mean load profile across all dwellings. However, because most dwellings in the sample (and most homes in Shediac, see Veitch et al. [2025]) were categorized as "Detached," this average is dominated by the load profiles typical of detached homes. Detached homes generally feature larger floor areas, higher ceilings, and increased exterior exposure due to numerous large windows, resulting in a high window-to-wall ratio. Consequently, their heating demand tends to be higher compared to other dwelling types in the sample, such as duplexes, townhouses, or mini homes.

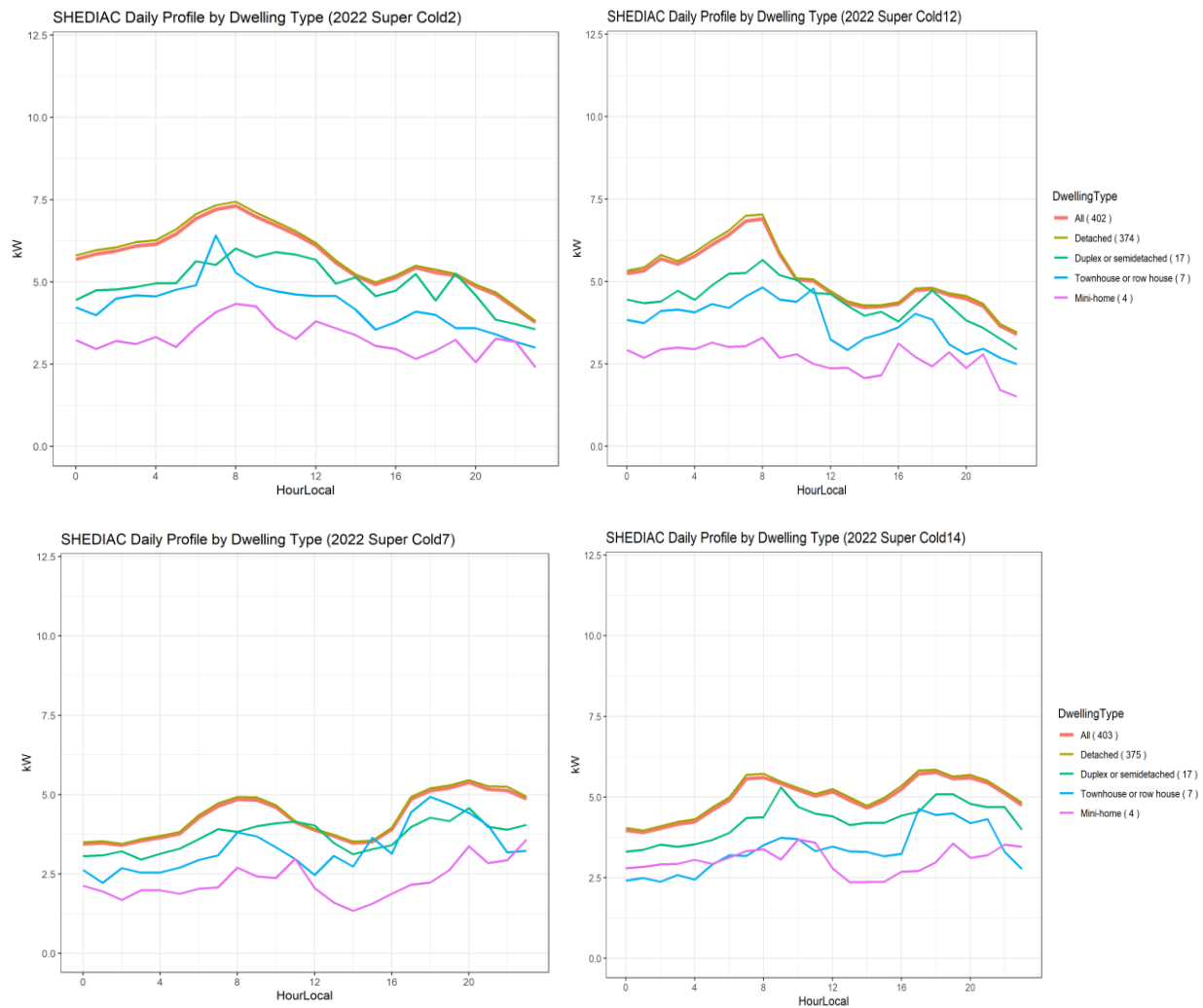


Figure 17. Average load profiles, segregated by dwelling types, corresponding to the four super peak days.

4.7.2.2 Cold weather snap of February 4, 2023:

While the previous sections in the report focused on the baseline period of May 2021 to April 2022, this section provides an analysis of the impact of a cold weather snap, which occurred on February 4, 2023, on household energy use and the subsequent impact on the grid. Table 10 and Figure 18 illustrate the significant effect of extremely cold weather on system demand, primarily driven by heating loads. Although the coldest day was on February 4th, the chart begins from February 2nd to help visualise the lag between the outdoor temperature changes, household energy use, and subsequent increase in system demand. On February 4, 2023, outdoor temperatures remained below -28 °C from 2 a.m. to 7 a.m., resulting in a system demand increase to 3,394 MW by 10 a.m. This demonstrates the time lag in grid demand response, as the NB Power grid demand profile mirrors the heating loads but with some delay. Notably, heating loads from 378 participant dwellings in Shediac rose to 3,176 kW, as detailed in Table 10.

Table 10. Effect of extremely cold temperature on peak demand during this cold snap.

Date	Avg. Daily Outdoor Temp.	24-hr Usage (kWh)	Peak Load (kW)	Peak Load Time
2023-02-02	-10.7	40,143	2,119	06:00:00
2023-02-03	-12.0	41,537	2,779	23:00:00
2023-02-04	-23.1	66,633	3,176	08:00:00
2023-02-05	-11.1	49,828	2,547	08:00:00
2023 Winter Avg.	-3.8	32,961		

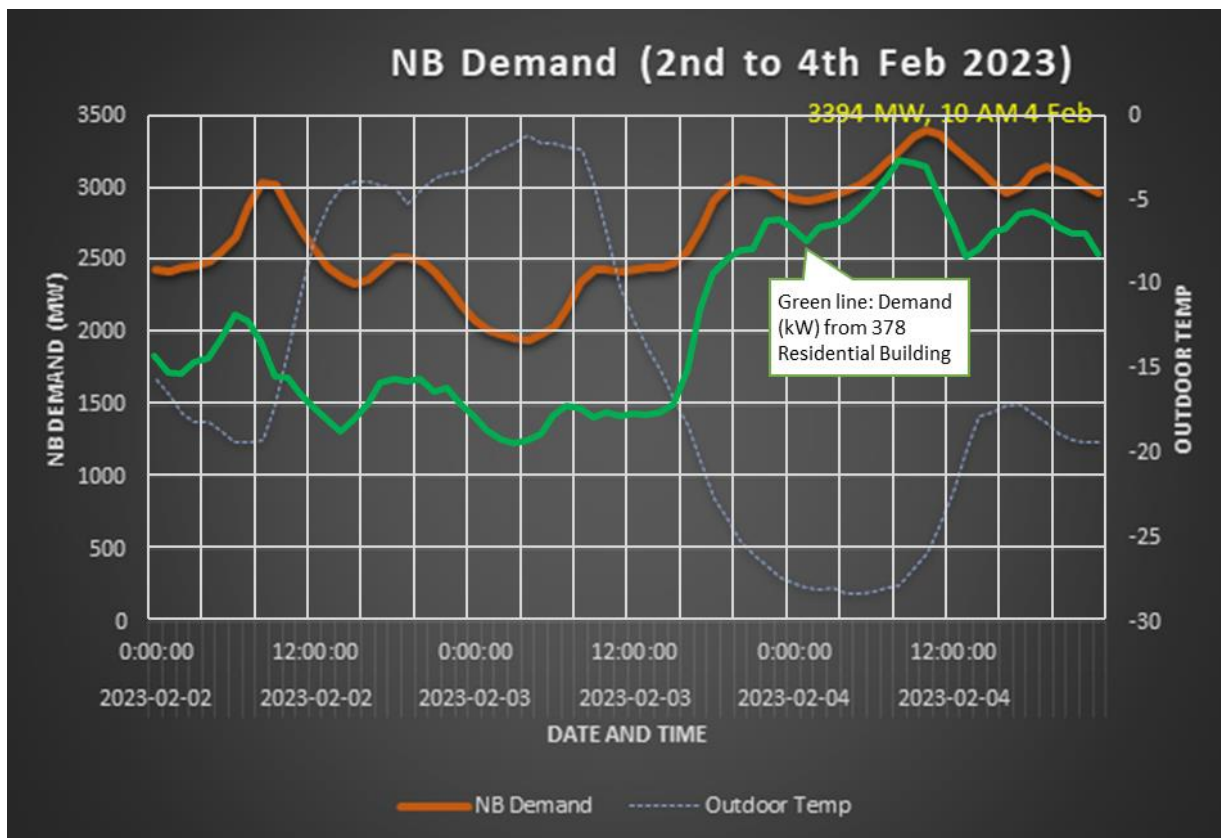


Figure 18. The impact of extreme cold weather on system demand driven by heating loads of 378 participant dwellings.

4.8 Cluster analysis

We used hierarchical clustering to group electricity use profiles into clusters based on their similarity. This algorithm is unsupervised to build a hierarchy of clusters by initially treating each data point as its own cluster and then merging the closest pairs until all data points form a single cluster or meet specific criteria. When analyzing energy use profiles, the correlation between profiles was used as the distance metric to determine similarity, allowing for a more nuanced understanding of patterns in household energy use.

The clustering algorithm revealed five distinct clusters shown in Figure 19. Cluster 1, "no peak," showed consistent energy consumption throughout the morning. Cluster 2, "peak early," experienced a sharp increase starting at 4 a.m., peaking around 6 a.m. Cluster 3, "on peak," represented the largest group with a gradual increase peaking between 7 a.m.-8 a.m. Cluster 4, "peak late," had a delayed peak starting around 8 a.m. Lastly, Cluster 5, "peak time drop," displayed an initial increase followed by a decline beginning at 5 a.m., indicating reduced activity after an early peak.

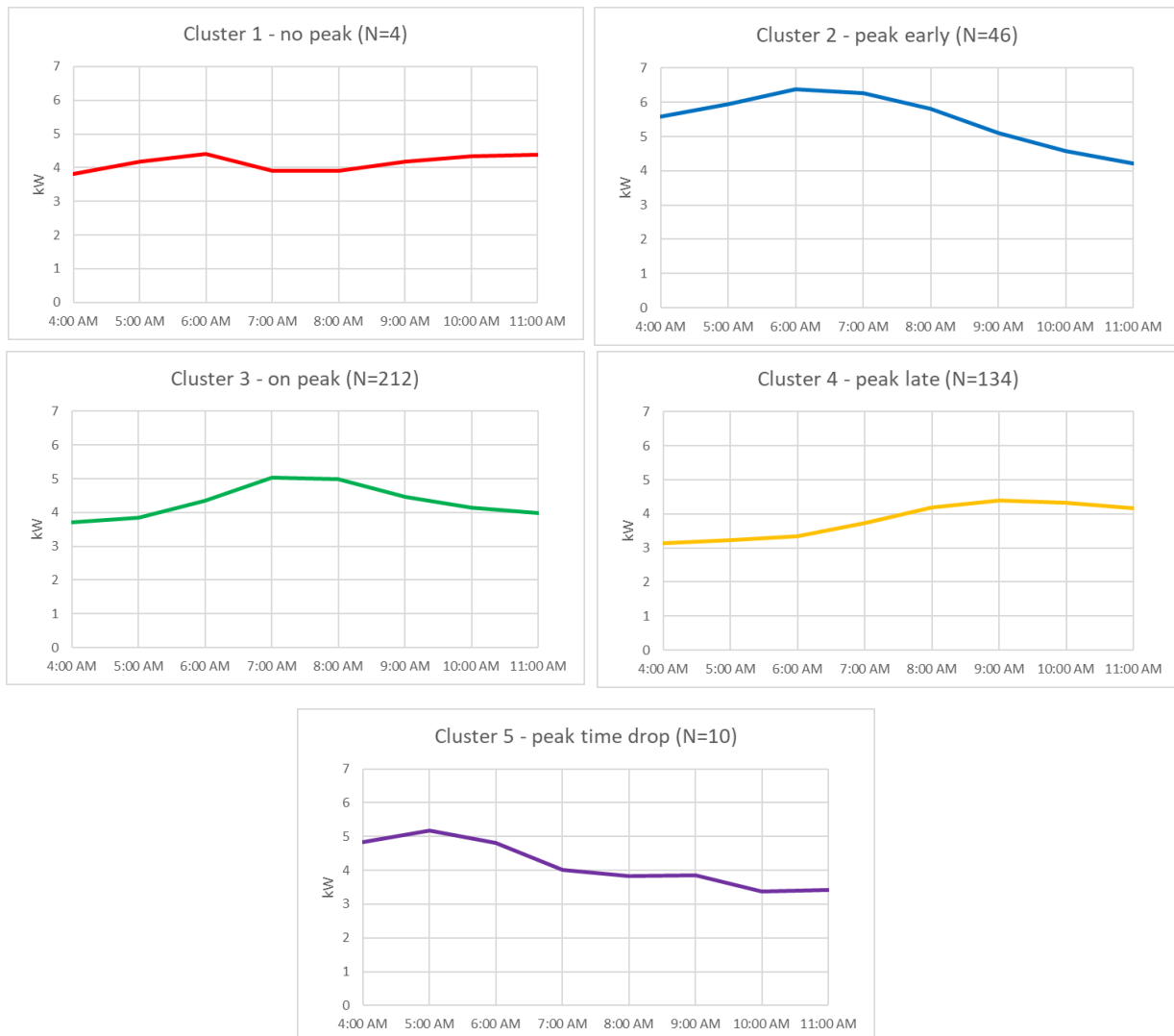


Figure 19. Cluster profiles for the Shediac sample based on daily use in winter 2021, during the baseline period.

The clusters were used for balancing the time-of-day, solar and battery storage, and cold-climate MSHP research groups as described by Veitch et al. (2025).

5 Conclusions

This report from Shediac Residential Energy Study reports analyses of energy use characteristics across nearly 500 dwellings by leveraging a unique combination of data sets, including smart meters, smart thermostats, occupancy levels, and household characteristics along with weather data. Through various data analytic techniques, the study uncovered insights into energy use patterns and peak demand, highlighting the influence of building characteristics on energy use.

The analysis revealed significant seasonal variations, with increased energy demand during colder months due to increased heating needs. The study examined domestic hot water usage, finding a seasonal pattern in electricity use for water heating.

Cluster analysis segmented households into distinct energy consumption patterns, providing valuable insights for targeted energy efficiency retrofits and demand response strategies. By including these patterns in the variables to be balanced in research group assignments, we controlled for unwanted variability in the interventions that could have confounded the interpretation of other results in this study. The potential remains for future analyses to consider the behavioural, household, and dwelling characteristics that might explain these daily patterns.

In addition to seasonal patterns, extreme weather can cause sudden increases in energy use; to examine these events, we examined the 18 super peak days from January 1, 2022, to March 5, 2022, to assess their impact on household demand. During these super peak days, electricity demand surged, with average peak loads reaching nearly 6.5 kW, compared to an average of 3.75 kW on non-super peak days. Understanding the dynamics and timing of these super peak events is crucial for energy providers like NB Power to maintain grid stability and optimize energy distribution.

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Chapter 5: Performance and Perception Evaluations of Solar Photovoltaics and Battery Energy Storage Systems

Natalia Cooper, Hadia Awad, Jennifer A. Veitch, and Ajit Pardasani

Executive Summary

This report addresses one part of the Shediac Residential Energy Study (described in detail in other project reports), the solar energy intervention. Seventy-five households in Shediac, New Brunswick received rooftop solar photovoltaic panels and battery energy storage systems (SOL) at no charge and agreed to participate in an evaluation of the system operation and performance in parallel with surveys concerning the occupants' perceptions of system performance, their attitudes towards renewable energy technologies, and their satisfaction with the project. The study included over 400 other participants who did not possess the SOL technology.

The SOL intervention was combined with a test of time-of-day (TOD) electricity rates, the participants being randomly divided into two groups (TOD and no-TOD). The batteries were operated in resiliency mode for the no-TOD group, always maintaining a full charge, but in the time-based control (TOD) group the batteries discharged during the morning peak period and recharged from the grid from daytime production and overnight during the low-rate period. Regardless of the battery mode, electricity production during the day served the home's demand first, and excess production (if any) was sent to the electricity grid. Participants received a solar energy credit of \$0.0487 per kWh for energy sent to the grid. TOD participants received a bill credit if their electricity bill calculated using TOD rates was lower than the usual flat-rate electricity charge.

Attitudes and perceptions

The survey results revealed that the majority of SOL participants experienced high satisfaction with the overall project processes, including satisfaction with the installation process, technology performance, and the information about the technologies that were provided for them. The majority of participants were satisfied with the project overall, and many noted that they appreciated NB Power's support for renewable energy projects and valued the opportunity to participate in the study.

The lower environmental impact, higher energy efficiency, and increased resiliency that SOL technologies afforded were often cited as the main benefits of these technologies. However, concerns regarding high initial costs, technology complexity, and maintenance needs were also raised and likely contributed to some skeptical views about these technologies. The perception of solar panels varied over time, with initial excitement giving way to skepticism about perceived benefits and energy consumption. The availability of backup power was important to most participants, many of them citing its reliability during outages, protection of essential appliances, and peace of mind as the main advantages.

The overall willingness to pay for these technologies was higher among participants who received them, but most participants agreed that investing in renewable energy would provide financial benefits. Participants indicated that they would be willing to pay \$1001-\$5000 (regardless of whether they had already received a SOL system). Given the price of the system installed in this project, this would mean that participants seek incentives or rebates on the order of 75%. Without a reduction in the prices of the SOL system tested here, widespread adoption is unlikely.

Participants in the SOL group were able to view their solar energy credit details through the reports on a bespoke website. Those who did tended to be satisfied with the information provided, although not all participants took advantage of accessing these reports.

System performance

The time-based control battery mode of operation (TOD group) showed significant demand reduction during peak times as a result of battery discharge and on-site solar energy use. However, it also created a new peak during off-peak hours when the battery recharged. This rebound effect was addressed during the study by the battery vendor by either reducing the charging rate or by staggering the start time for batteries to charge.

Excess energy generated by the solar panels and exported to the grid was higher in the no-TOD group compared to TOD group. For the TOD group, excess solar energy was used to charge the battery, while for the no-TOD group, the battery was set to 100% backup reserve and rarely discharged, so excess solar was exported. Energy consumption savings were associated with the amount of solar energy generated on site, and therefore, were most significant in summer due to the high solar output.

Participants in the TOD group saved \$840 per year, while those on the no-TOD rate structure saved \$460 per year. However, given the cost of these systems (~\$45,000), the simple payback period for a customer even under a TOD rate scenario would be 54 years. A substantial reduction in the overall prices of such technologies, or generous incentive programs, will be necessary to facilitate adoption.

The total cost to NBP of the TOD and SEC credits for the SOL intervention was ~\$16,100. In practice, this cost would be offset by savings in fuel and power purchases, depending on the precise mix of electricity sources over the study period. Homes with solar generation also save utility costs because of avoided electricity generation, which for these 75 homes amounted to \$20,520 per year.

GHG emissions were reduced through both on-site use of renewable energy and export to the grid. The study estimated monthly GHG emissions reduction for both backup reserve and time-based control modes. Overall, the annual estimated GHG emissions reduction per household is 1,384 kg CO₂e/year for the no-TOD group and 1,444 kg CO₂e/year for the TOD group. On average, the monthly energy generation from the 5 kW solar panels ranged from 127 kWh in Dec. to 738 kWh in May, with an average annual yield of 1,013 kWh/kW. Battery round-trip efficiency was found to be 87.4% for basement installations and 87.5% for garage installations.

The resilience of households equipped with SOL was assessed during Hurricane Fiona (Sept 24, 2022) for the continued supply of electricity. During the hurricane, 80% of participant households lost grid power for more than 12 hours on the event day. The next day, by the end of the recovery period, 96% of households were reconnected to the grid. Solar energy generation increased from 3% during the event to 73% during the recovery stage. Post event, all solar panels were back to normal. Regarding the battery storage systems, pre-event, during the preparedness stage, all batteries were held at 100% State of Charge (SOC) by the battery vendor based on the weather forecast. During the event, they were programmed to discharge to provide critical load support. By the end of the event, batteries were at 60% SOC. No signs of physical damage to any of the solar panels or batteries were observed.

Conclusion

By addressing factors such as user motivations, adoption practices, and perceived benefits and challenges, stakeholders can enhance overall satisfaction and increase the adoption of these technologies. The study confirmed that SOL system significantly reduced grid dependency, GHG emissions, and electricity bills. The findings provided valuable insights into the pathways to net-zero

communities. Also, it served as a demonstration case to inform stakeholders about incentive programs, subsidy options, and electricity rate structures.

1 Introduction

The transition toward renewable energy sources has gained significant momentum in recent years, driven by the urgent need to mitigate climate change and reduce dependency on fossil fuels. Among the various renewable energy options, solar panels have emerged as a prominent solution to reduce carbon footprint and lower energy bills. The combination of solar panels with battery storage systems (SOL thereafter) has gained new traction among homeowners, driven by the benefits of reducing energy costs, increasing energy independence, and enhancing resiliency.

Following the COP28 climate change conference, more than 130 countries agreed to triple the world's installed renewable energy capacity from the 2022 levels to at least 11,000 GW by 2030 (IEA, 2024). Globally, in 2023, solar panel installations alone accounted for three-quarters of renewable capacity additions worldwide (IEA, 2024). Moreover, it is forecast that by 2028, the share of solar photovoltaics and wind in global electricity generation will double to 25% (IEA, 2024). Hence, with anticipated high grid penetration due to distributed renewable energy sources, the congestion problem at the transmission grid level should be addressed through, for example, curtailment (Millstein et al., 2021), battery energy storage (Talent & Du, 2018; Zhang et al., 2023), and demand side management (Xie et al., 2021). In Canada, the adoption of solar energy systems has been steadily increasing, supported by government incentives and a growing awareness of environmental sustainability.

To cope with the intermittent and fluctuating nature of renewable energy production and the increasing space heating and cooling demand, the implementation of battery storage systems is a common solution (Talent & Du, 2018). Systems combining lithium-ion batteries coupled with solar panels in buildings show considerable potential for demand side management (DSM) in buildings, reducing the anticipated risks of grid penetration (Zhang et al., 2023), and thus enhancing grid stability (He et al., 2021) and resilience (Xie et al., 2021). Moreover, solar panels and battery storage systems allow electricity consumers to become electricity prosumers (Barbour & González, 2018).

However, the success of government initiatives and the overall adoption of such technologies largely depend on users' perceptions and satisfaction with these technologies, which are critical for their widespread adoption and long-term success (Prabatha et al., 2020; Agu et al., 2023). Several studies have highlighted the importance of understanding user perceptions to enhance the adoption rates of renewable energy systems, noting that investigation of the main motivational factors that influence homeowners' decision-making processes is essential to support the future adoption of these technologies and optimize their benefits (Alipour et al., 2022). The investigation of the field performance of commonly deployed distributed energy sources, such as SOL is essential to quantify the effects of these technologies locally from the technical, environmental, economic, as well as resilience perspectives (Dong et al., 2020b; Koskela et al., 2019). This report provides this combined perspective: system performance and citizen perceptions.

1.1 Influences on adoption

1.1.1 Perceptions and attitudes

Both personal and contextual factors can influence individual intentions and behaviors toward the adoption or non-adoption of innovative technologies (Hai et al., 2017). Positive attitudes and pro-environmental values have widely been considered as the reasons for an individual's decision to adopt renewable energies, while perceived risks, costs, and fear about new technologies can cause resistance to adopting or changing energy sources (Hai et al., 2017; Sovacool et al., 2022). Parkins et al. (2018) proposed that the adoption of solar technology may depend to some degree on the observed adoption

behavior within an individual's social network, specifically individual knowledge and awareness, the engagement within the community, and the visibility of the renewable energy infrastructure.

The perceptions of homeowners about energy consumption and cost savings are pivotal in shaping their overall satisfaction with SOL. The perceived economic benefits, such as reduced electricity bills and potential return on investment, were found to be primary motivators for adopting these technologies (Hannan et al., 2021; Al-Shahri et al., 2021). However, discrepancies between expected and actual savings can lead to dissatisfaction if homeowners are initially motivated by the promise of cost savings, but those expectations go unmet (Zaidan et al., 2022).

Homeowners' willingness to pay (WTP) for renewable technologies influences adoption. Economic considerations, such as initial investment costs, long-term savings, and available incentives, play a significant role in decision-making processes, especially when financial incentives, such as tax rebates and subsidies, make these technologies more affordable and attractive (Zakeri et al., 2021; Duan et al., 2020). The perceived long-term cost savings and the potential for increased property value can also motivate such investments (Gillingham et al., 2024).

The perceived benefits of SOL extend beyond financial considerations. Homeowners often cite environmental benefits, such as reducing greenhouse gas emissions and reliance on fossil fuels, as key drivers for adoption. A comprehensive review emphasized that environmental concerns increasingly influence consumer behavior toward renewable energy technologies (Wall et al., 2021; Maduku, 2024). Additionally, the reliability and resilience provided by battery storage systems, particularly during power outages, are valued benefits that enhance overall satisfaction (Rana et al., 2022). However, some homeowners also considered the environmental impact of these technologies, including their production and disposal, which can pose environmental challenges (Tawalbeh et al. (2021). Mehedi et al. (2022) highlighted the need for sustainable practices in producing and recycling these technologies to minimize their ecological footprint.

The installation process of SOL was also found to be critical in influencing homeowners' overall satisfaction. Studies found that factors such as the installation team's professionalism, the installation's duration and timely completion, and the clarity of communication regarding the process and expected outcomes play crucial roles (Bao et al., 2020; Rigo et al., 2022).

1.1.2 System factors

SOL technologies play a critical role in reducing stress on the electricity grid. Alramlawi et al. (2018) studied the impact of using SOL to overcome grid-scheduled blackouts and explored the potential benefits of applying economic model predictive control to optimize the operation of hybrid SOL, maximizing battery lifetime. Their objective was to maximize load match and minimize the total cost of grid-imported energy. In order to overcome the lack of field testing of SOL, some studies addressed this issue by introducing a simple energy storage degradation model (Dong et al. 2020a).

Key performance indicators (KPIs) of SOL found in the literature included technical KPIs such as self-consumption and load match (or self-sufficiency) (Dong et al., 2020b), and peak load shifting (Zhang et al., 2023), whereas the economic KPIs can be assessed through multiple parameters such as simple payback time, levelized cost of energy for solar panels, and levelized cost of storage for batteries (Dong et al., 2020a). The environmental KPIs found in the literature include CO₂ emissions reductions (Liu et al., 2022) and CO₂ emission payback time, which is the number of years of system operation (avoidance) to offset its manufacturing (cradle-to-use) CO₂ emissions (Dong et al., 2020a).

Tsianikas et al. (2019) studied the trade-off between resilience and cost by running simulations of SOL with input from measured load profile data of a hospital. The authors emphasized the need for installing

relatively large batteries for critical systems (such as hospitals) to ensure resilience. Masrur et al. (2021) examined the technical and economic performance of a grid-tied airport microgrid consisting of a solar PV system, a battery, and a diesel generator, with a focus on the hybrid and standalone configurations feeding critical loads. Critical loads are systems or devices that, if they lose power, could lead to significant risks, such as endangering the well-being of occupants, compromising security, or disrupting crucial operations. Then, resilience benefits over the system life cycle were evaluated. The study indicated potential financial benefits as well as a significant number of hours of power supply during grid outages over the system lifespan. Chowdhury et al. (2023) simulated grid outages in a hypothetical healthcare center located in a refugee camp in Rohingya, including the healthcare center load, a 643 kW solar PV system, and a 102 kW battery. Two modes of operation were examined, resilience mode and financial mode, resulting in CO₂ emission reductions of 69% and 44%, respectively, over the system lifespan.

1.2 Research gaps

The review of scientific literature identified that several challenges can have a negative effect on homeowners' satisfaction with these technologies. These included technical issues, such as the efficiency and reliability of the systems, the maintenance needs, and the complexity of the installation and integration of these systems into existing home infrastructure (Al-Shari et al., 2021; Rana et al., 2022). Nevertheless, other studies have found that personal drivers such as self-sufficiency and grid independence can also have a strong influence on SOL preferences. Agnew et al. (2017) showed that most respondents indicated preferences for buying medium or large battery systems despite higher costs and longer payback periods. Around 70% of respondents in this survey indicated that they hope to completely disconnect from the existing centralized electricity supply network.

On the other hand, the literature lacks studies that demonstrate SOL performance under real conditions and the use of these data to make informed decisions. Furthermore, there is a lack of understanding of how these technologies perform at the community scale and interact in extreme events such as blackouts, severe storms, severe cold or hot days, etc. The study reported here is unique in having a large, long-term set of field data on SOL, which we used to evaluate their performance under various conditions, along with participant surveys to capture their perceptions throughout the study period.

1.3 Objectives

This report describes the results of one intervention in the Shediak Residential Energy Study: a field test of the performance of a system, identified in this report as SOL, consisting of a 5-kW rooftop solar photovoltaic panel array and a solar inverter with 13.5 kWh battery energy storage (maximum 5 kW charge or discharge rate). Veitch et al. (2025) have described the entire study in detail.

The objectives of the SOL intervention were:

- To characterize the system performance over an extended period (more than one year), in terms of peak electricity demand, overall energy consumption, energy provided to the electrical grid, and CO₂ emissions reductions associated with the system.
- To contrast the performance of two modes of operation: time-based control (time-of-day, or TOD) and resilience (no-TOD).
- To assess perceptions and attitudes towards the SOL technology and the TOD intervention among the homeowners who received SOL systems and others in the same community who did not. Among the concepts assessed were satisfaction, performance expectations, perceived benefits, the importance of resilience to outages, and willingness to pay for SOL systems.

2 Method

2.1 Participants

Of the original 529 participants in the full study, 75 were enrolled in the SOL research group and received the intervention. See Veitch et al. (2025) for the detailed protocol of home assessments and consent procedures leading to the SOL installations. Table 1 summarizes the selected characteristics of the SOL participants and the others who did not receive this intervention. Although survey participation rates were high (~75%), not every participant completed every survey, and no questions in any survey were mandatory, resulting in missing data affecting every analysis.

Table 1. Characterization of SOL and no-SOL participants participating at the end of the study and their homes. Totals do not sum to 75 because of varying responses to survey questions.

	SOL N	SOL %	No-SOL N	No-SOL %
Respondent sex				
Male	39	63.9	107	56.9
Female	22	36.1	81	43.1
Respondent age (end of study)				
21-30	3	4.9	2	1.1
31-40	8	13.1	18	9.7
41-50	15	24.6	40	21.5
51-60	15	24.6	36	19.4
61-70	12	19.7	52	28.0
71-80	7	11.5	30	16.1
81+	1	1.6	7	3.8
Prefer not to say			1	0.5
Household Income				
<\$20k			4	2.0
\$20k<\$40k			18	9.1
\$40k<\$60k	6	10.2	27	13.6
\$60k<\$80k	5	8.5	24	12.1
\$80k<\$100k	7	11.9	24	12.1
\$100k<\$150k	16	27.1	40	20.2
\$150+k	21	35.6	44	22.2
Don't Know	4	6.8	17	8.6
Heating System				
No heat pump	7	9.3	106	23.3
Heat pump at start	60	80.0	285	62.8
Heat pump purchased during project	8	10.7	40	8.8
Heat pump given by project	0	0	23	5.1

2.2 Surveys

Participants completed seven surveys between January 2020 and March 2024. See Veitch et al. (2025) for the contents of each survey. For this report, we selected questions related to satisfaction with the project, perceptions of the technology, attitudes toward utility interventions, the importance of resilience, and willingness to pay for renewable technologies. Some of these had been asked on one occasion only; others had been repeated so that comparisons between initial attitudes and those with experience could be made. Survey questions are described in their related results sections.

2.3 Interventions and system data

The SOL system comprised a 5 kW rooftop solar photovoltaic panel array and a solar inverter with 13.5 kWh battery energy storage (maximum 5 kW charge or discharge rate) (Veitch et al., 2025). Households were randomly assigned to one of two battery control modes (although the battery energy management system could also support other modes): (1) time-based control (TOD) and (2) backup reserve (no-TOD). Participants were not permitted to switch between the two modes. Depending on the home configuration, the battery energy storage units were installed either in a heated garage or in a basement utility room.

Regardless of the battery control mode, solar energy served the home's demand first. Excess energy was sent to the grid. Participants were billed monthly for their actual consumption at the authorized flat rate. They received a solar energy credit (SEC) of \$0.0487 per kWhr, shown each month as a line on their NB Power bill and reported in detail on a SEC report downloadable from a bespoke energy portal. Participants in the SOL-TOD group also received a TOD credit if the calculation of their electricity bill using TOD rates resulted in a lower amount than the regular bill charge (see Pardasani et al., 2025b, for more detail about the TOD intervention generally).

The systems were installed and commissioned between June 2022 and Dec. 2022 at varying installation dates for each system. The number of installed and commissioned units are shown below:

Month	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22
Num Operational	1	10	23	57	62	72	75

For the principal performance analyses, we selected Dec. 1, 2022 as the start date. Data collection ended on Mar. 31, 2024. Telemetry data from 67 SOL systems (TOD N=32 and no-TOD N=35) systems were available for these analyses. Eight out of the 75 installations were excluded. The top three reasons for the exclusion were (1) data quality/anomalies, (2) major data gaps, and (3) voluntary upsizing of the solar system by the homeowner.

Utility Dispatch of DERs: Battery Energy Storage– In addition to evaluating the time-based control (TOD) and resilience mode of operation (no-TOD), utility dispatch of battery energy storage was conducted using DER test signals by Siemens Canada to assess their effectiveness in managing electrical grid load. However, the analysis of these interventions is beyond the scope of this report. For a detailed explanation, refer to Veitch et al. (2025).

Dispatch signals were sent on occasion between Dec 1, 2022, to Jan 31, 2023, targeting both TOD and no-TOD groups. Siemens Canada is responsible for the analysis of the data concerning DERs interventions. To ensure an unbiased analysis of peak demand reduction from SOL, we excluded days on which utility dispatch events occurred.

Hurricane Fiona– The unique occurrence of Hurricane Fiona and associated power outages in September 2022 enabled separate analyses of system performance for resilience between Sept. 18 and 30, 2022. Data from 46 systems that had been commissioned before Sept. 18 were available for these analyses.

Data Sources–

- telemetry data at hourly intervals from the batteries (electric power grid draw, solar power generation, grid export, battery charge/discharge, and state of charge);
- 15-minute interval smart meter data (electric power draw, averaged to hourly intervals) (see Pardasani, 2025a, for details);

- outdoor temperatures from the nearest weather station (Environment Canada #50309, Greater Moncton Int'l Airport, 22 km inland from Shediac).

2.4 SOL data processing

This subsection presents a description of field data processing and the mathematical formulation of the SOL telemetry data. Time series data includes values from the battery, solar panels, and the grid. Other parameters such as household load, on-site use, source of power for battery charge, and source of power for on-site use were not measured but rather derived. Table 2 lists the nomenclature used in the current study.

Table 2. Nomenclature and abbreviations used in this report.

Short term	Description
<i>DER</i>	Distributed energy resources. In this study, DER refers to SOL system (i.e., solar panels and battery energy storage system)
B_{min}	Minimum battery energy storage value (kWh)
<i>DoD</i>	Maximum depth of discharge of battery (%)
$Q_B(t)$	Energy stored in battery at time (t) (kWh)
<i>SOC</i>	Battery state of charge (%)
SOC_i	Initial battery state of charge (%)
$S(t)$	Power generated by solar PV array at time (t) (kW)
$L(t)$	Household load at time (t) (kW)
$L_{peak}(t)$	Household load at time (t) (kW) during on-peak durations (7:00 am -8:59 am on weekdays)
$B(t)$	Battery charge and discharge amount at time (t) (W). Here, a negative value indicates charge, positive indicates discharge, and 0 indicates no flow
$B_{ch}(t)$	Battery charge portion at time (t), extracted from $B(t)$, negative values (-kW)
$B_{dch}(t)$	Battery discharge portion at time (t), extracted from $B(t)$, positive values (+kW)
$G(t)$	Meter grid power for a given dwelling at time (t) (kW). A negative value indicates export, positive indicates draw, and 0 indicates off-grid.
$G_{peak}(t)$	Meter grid power for a given dwelling at time (t) (kW) during on-peak durations (7:00 am -8:59 am on weekdays)
$G_{imp}(t)$	Grid import portion at time (t), positive values (kW) extracted from $G(t)$
$G_{exp}(t)$	Grid export portion at time (t), negative values (kW) extracted from $G(t)$
$G_{off}(t)$	Off-grid occurrence at time (t), zero or null values extracted from $G(t)$
$LM(t)$	Load match. The portion of household load ($L(t)$) met on site by DER (solar and battery) (kW)
$LM_s(t)$	Load match from solar panels only (kW)
$DER_{av}(t)$	Available DER at time (t) (kW)
<i>SBT</i>	Subscript indicating PV/battery inclusion in the calculation method
<i>ST</i>	Subscript indicating PV inclusion in the calculation method
<i>NT</i>	Subscript indicating the no-tech scenario (No-SOL)
<i>rate</i>	Refers to the electricity purchase rate at timestep (t) (\$/kWh)
<i>Bill</i>	Refers to the aggregated bill (monthly, annual). It is the aggregated product of the energy consumption and rate at timestep (t) (\$)
<i>SEC</i>	Solar Energy Credit (\$/kWh)
$Change_{grid}(t)$	Impact of implementing PV/battery on grid draw as opposed to NT
$Change_{bill}(t)$	Impact of implementing PV/battery on customer's bill as opposed to NT
<i>GHG</i>	Greenhouse gas emissions: The carbon dioxide equivalent emissions from various greenhouse gases based on their time-integrated global warming potential as compared to emissions of an equal mass of carbon (kg CO ₂ e) (Emerson et al., 2023)
GHG_{offset}	The amount of GHG emissions reduction (kg CO ₂ e) as a result of on-site renewable energy generation
$GHG_{offset, on-site}$	The amount of GHG emissions reduction (kg CO ₂ e) as a result of self-use of on-site renewable energy generation
$GHG_{offset, exp}$	The amount of GHG emissions reduction (kg CO ₂ e) as a result of exporting renewable energy generation
GEF_{imp}	Greenhouse gas emissions factor by energy form for imported energy from the utility grid (NB = 0.275 kg CO ₂ e/kWh)

Eq. 1 through Eq. 5 below formulate processing of the data. Household load $L(t)$ was determined by adding up the solar $S(t)$, battery $B(t)$, and grid $G(t)$ values for each time instance. Battery charge/discharge portions (Eq. 1) as well as the grid import/export portions (Eq. 2) were disaggregated to calculate on-site use (load match) $LM(t)$ (Eq. 4) and available DER $DER_{av}(t)$ (Eq. 5).

Effects of DER implementation on customers' energy consumption and bill are expressed in Eq. 6 and Eq. 10, respectively. Monthly energy consumption reduction $Change_{Grid}(t)$ was quantified by the arithmetic difference between the monthly net-grid consumption with SOL $G_{SBT}(t)$ and the baseline represented by the monthly household load $L(t)$ (Eq. 6). Peak demand reduction, between 7:00 am and 8:59 am on weekdays is determined from the arithmetic difference between the peak-time net-grid $G_{peak}(t)$ and the baseline represented by the peak-time loads $L_{peak}(t)$ as in Eq. 7.

Eq. 8 and Eq. 9 describe the customer's bill calculation method. Two scenarios for each dwelling were analysed: (1) baseline scenario: customer's bill without SOL (household loads only) $B_{NT}(t)$ and (2) actual scenario: customer's bill with SOL installation $Bill_{SBT}(t)$. Bill saving $Change_{Bill}(t)$ is represented by subtracting the baseline scenario (no-SOL) from the actual scenario (SOL). Bill saving includes export credits, savings due to on-site use, and peak shifting (energy arbitrage) (Eq. 10).

SOL can mitigate GHG emissions (Eq. 12, Eq. 15) in two ways: By directly offsetting the use of grid electricity by clean energy generated on-site $GHG_{offset, on-site}$ (Eq. 13), and by exporting renewable electricity to the grid $GHG_{offset, exp.}$ (Eq. 14) (Emerson et al., 2023). As per ANSI ASHRAE 228-2023 (Emerson et al., 2023), a GHG emission factor GEF_{imp} of 0.295 kg CO₂e/kWh was used for New Brunswick. In the present, the hourly GHG emission factors are not available; hence could not be applied to this study. However, we anticipate that peak demand reduction, particularly for time-based control SOL should contribute to additional GHG emissions reductions. It should be noted that GHG emissions factors depend entirely on jurisdiction and on the energy source mix.

$$B(t): \begin{cases} B_{Ch}(t), B(t) < 0 \\ B_{Dch}(t), B(t) > 0 \end{cases} \quad (1)$$

$$G_{SBT}(t): \begin{cases} G_{IMP, SBT}(t), G_{SBT}(t) > 0 \\ G_{EXP, SBT}(t), G_{SBT}(t) < 0 \\ G_{OFF, SBT}(t), otherwise \end{cases} \quad (2)$$

$$L(t) = S(t) + B(t) + G_{SBT}(t) \quad (3)$$

$$LM(t) = L(t) - B_{Ch}(t) - G_{IMP, SBT}(t) \quad (4)$$

$$DER_{AV}(t) = S(t) + B_{Dch}(t) \quad (5)$$

$$Change_{Grid}(t) = G_{SBT}(t) - L(t) \quad (6)$$

$$Change_{peak\ demand}(t) = G_{peak}(t) - L_{peak}(t) \quad (7)$$

$$Bill_{NT}(t)(\$) = L(t) \times rate_{purchase}(t) \quad (8)$$

$$Bill_{SBT}(t)(\$) = G_{IMP, SBT}(t)(kWh) \times rate_{purchase}(\$/kWh) - G_{EXP, SBT}(t) \times rate_{SEC} \quad (9)$$

$$Change_{Bill}(\$) = Bill_{NT}(\$) - Bill_{SBT}(\$) \quad (10)$$

$$LM_S(t) = S(t) - G_{EXP}(t) \quad (11)$$

$$GHG_{offset} \text{ (kg CO}_2\text{e)} = S \text{ (kWh)} \times GEF_{imp} \text{ (kg CO}_2\text{e/kWh)} \quad (12)$$

$$GHG_{offset,on-site} \text{ (kg CO}_2\text{e)} = LM_S \text{ (kWh)} \times GEF_{imp} \text{ (kg CO}_2\text{e/kWh)} \quad (13)$$

$$GHG_{offset,exp} \text{ (kg CO}_2\text{e)} = G_{EXP,SBT} \text{ (kWh)} \times GEF_{imp} \text{ (kg CO}_2\text{e/kWh)} \quad (14)$$

$$GHG_{offset} \text{ (kg CO}_2\text{e)} = GHG_{offset,on-site} \text{ (kg CO}_2\text{e)} + GHG_{offset,exp} \text{ (kg CO}_2\text{e)} \quad (15)$$

Round trip efficiency of the battery (U.S. Energy Information Administration, 2021) was calculated by comparing the ratio of charge to discharge for garage and basement battery installations separately. We predicted that garage battery installations would have lower efficiency during winter because of thermal conditioning at temperatures below 0°C. Batteries should not be located in areas colder than 10°C unless those areas are heated. On the other hand, the issue of locating the battery is important because some jurisdictions require the battery to be separate from the occupied areas of the home as a fire safety measure. It was also hypothesized that the discrepancy, if any, between round-trip charge and discharge amounts would be approximately 10%, reflecting the manufacturer's round-trip loss factor.

3 Results

3.1 Feelings and attitudes

3.1.1 User experiences

3.1.1.1 System satisfaction

The SOL group provided feedback about their experience with the SOL installation process, living with the technology, and the project overall. These survey questions were answered on 5-point scales from very dissatisfied (0) to very satisfied (4). Table 3 summarizes these results, showing average ratings (M) (scale 0-4) and standard deviation (SD) for each question. Graphs in Figure 1 show a breakdown across the scale in percentages across all questions. The majority of participants were satisfied with all aspects of the project and the technology.

Table 3. SOL participants' satisfaction with their technology and project experiences (scale 0-4).

Satisfaction with...	Mean	SD	N
Information received about the technology when first offered (Dec. 2022)	3.4	0.7	69
The installer (Dec. 2022)	3.5	0.8	69
Information received during the installation (Dec. 2022)	3.4	0.8	69
Technology performance (Dec. 2022)	3.5	0.8	68
System performance (Mar. 2024)	3.1	1.0	58
SEC reports are clear and understandable (June 2023)	2.9	0.8	46
Project team communication (Dec. 2022)	3.3	0.8	69
Project team communication (Mar. 2024)	3.2	0.8	58
Overall project satisfaction (Mar. 2024)	3.3	0.9	46

Figure 1 shows data collected from SOL participants at the end of the project (March 2024) asking them to report their satisfaction with the project team's communication and overall project satisfaction. The

results show that many SOL participants reported high satisfaction with team communication and the project.

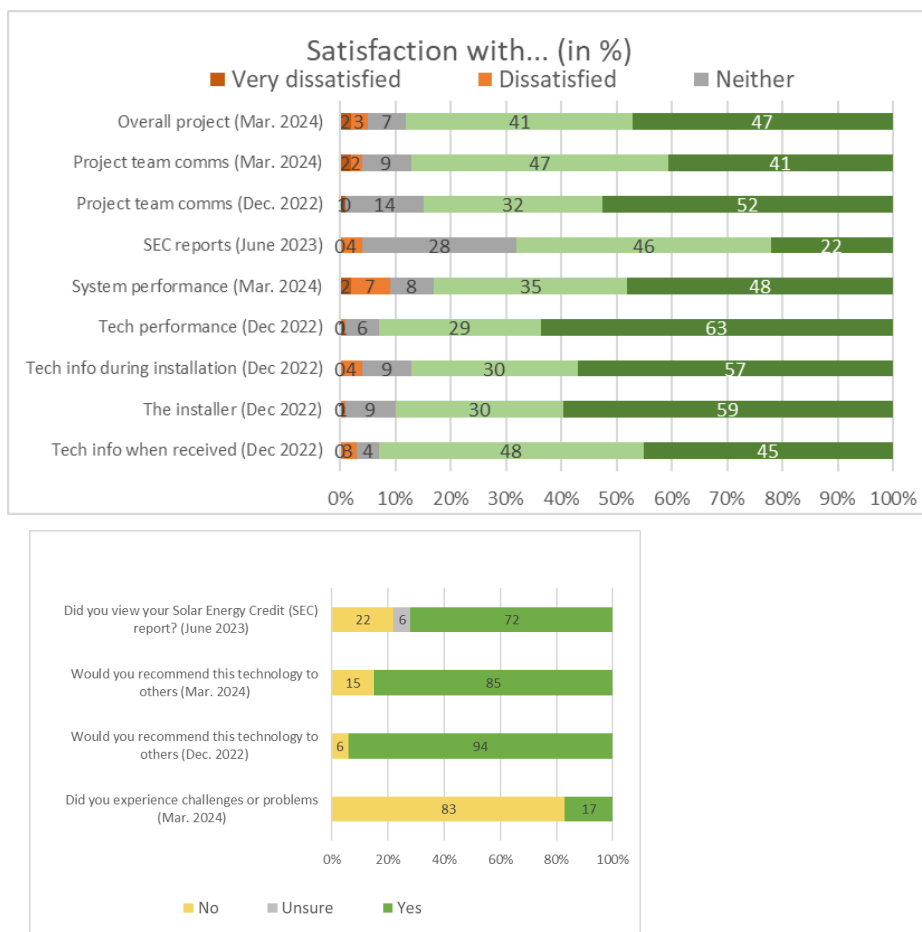


Figure 1. Satisfaction and agreement/disagreement ratings across a series of questions between December 2022 and March 2024, numbers indicate percentages (SOL = 58-69)

It is relevant to point out that the participants' willingness to recommend the technology to others was higher when they first received the technology (Dec 2022) than at the end of the project (March 2024). The difference amounts to five people with lower willingness. This change could be due to several reasons:

- **Experience** – In Dec 2022, the SOL system was seen as a new and exciting technology that participants received without any financial cost or prior experience. By the end of the project, participants were much more familiar with the technology and, as such, could have experienced some issues with its performance.
- **Technical issues** – During the project, some participants experienced technical difficulties with technology performance, which might have contributed to the participant's lack of confidence in technology reliability and effectiveness.
- **Expectations** – Participants' expectations about technology usability and possible payback might have been different when they first received the technology. By the end of the project, these expectations might not have been met, creating discontent with technology capabilities.

- **Lack of control** – The nature of the project meant that participants were not permitted to control the battery operation, which might have contributed to their frustration and negative perceptions of the SOL system.
- **Social environment** – By communicating with other project participants and comparing their system to that of their neighbors, some participants might have experienced feelings of inadequacy or dissatisfaction, which could have led to negative perceptions of this technology.

Qualitative feedback from 64 participants in the SOL group after several months of experience with the technology revealed details about the features they liked and did not like. Table 4 summarizes the themes of these responses.

Table 4. The most liked and most disliked features of the technologies, and numbers of comments for each.

Most Liked	N	Most Disliked	N
Backup power	16	High cost and ROI concerns	12
Increased awareness and energy efficiency	13	Technical issues and reliability	6
Low environmental impact	10	Limited customer support and information	6
Cost savings	8	Complexity and usability	5
Convenience and control	6	Limited impact on energy savings	5
Educational value	3	Initial low familiarization	3
Technological usability	3	Unclear savings/environmental benefits	2

The results showed that the ability to have backup power during outages was a significant benefit for many participants, as it provided peace of mind, a sense of security, and reliability. Participants liked the energy efficiency provided by the technology, which aligned with their desire to be more energy-friendly. The capability to track and monitor energy production and consumption was also noted as a favorite feature as it increased their awareness and encouraged more efficient energy use. Specific features like the vendor app and the solar array were particularly appreciated for their utility and ease of monitoring, adding convenience and flexibility to their energy management. Participants liked the potential for cost savings on their electricity bills, even though some noted that the initial investment was high (note: there was no initial cost for these participants; the SOL system was provided to them and would be their property after the project).

Responses to other open-ended questions revealed that a few participants experienced problems with the technology such as the battery overheating or problems with keeping the charge. These were warranty matters. Other participants reporting feeling that they had limited understanding and felt unsure about how to use the battery to get its full advantage.

3.1.1.2 Utility interventions

NB Power and its partner, Siemens Canada, adjusted battery operations during the project through DER test signals to evaluate the potential for using residential battery energy storage units to support grid stabilization. These interventions were intended not to be noticeable to participants.

Most participants (59.3%) reported not noticing these adjustments. Participants (3 comments) mentioned that they noticed these adjustments through the vendor app, through which they could see the system operation but not alter it. The system behaviours that they noticed are summarized in Table 5 below.

Table 5. Comments about noticed battery adjustments in solar TOD and solar no-TOD groups

SOL Groups	Reason for Noticing Battery Adjustments	N	Examples
TOD			
	Visual observation in app	3	"Only visually within the App"
	Different discharging times	3	"I noticed I was paying from the grid to charge the battery system"
	Charging behaviour	2	"The battery begins getting charged from the grid at 10 pm and discharges when it is high peak times"
	Control and settings	2	"The battery was not kept charged before storms"
No-TOD			
	Cost efficiency concerns	4	"I noticed I was paying from the grid to charge the battery system"
	Inability to use battery advantageously	3	"I could not use the battery to my advantage"
	Operational anomalies	3	"I noticed my battery being discharged at various times during the day."
	Storm-related observations	2	"I noticed during the storm forecast"

Although the response frequency was not high, the comments related to the “cost efficiency concerns” suggest areas for improvement in communication, and user education to better meet participant expectations and enhance the perceived value of the battery storage interventions.

3.1.2 Attitudes towards renewable energy technologies

All participants responded in surveys to questions concerning their attitudes towards renewable energy technologies, the perceived benefits and challenges, and their willingness to pay for such technologies. Here, we contrast the responses from the SOL (maximum N=75) and no-SOL groups (maximum N=258). Note that the sample sizes changed for each survey because participation rates varied and because of attrition. These attitudes were measured after SOL installations had been in place for between 6-12 months (June 2023) and once at the end of the project, nine months later (Mar. 2024).

Another set of questions concerning attitudes about the SOL technology were assessed by SOL participants in both December 2023 and March 2024, and by both groups in March 2024. These questions focused on the perceived value of having solar panels, energy bill and consumption, aesthetics, environmental benefits, and attitudes toward utility intervention with battery storage. The survey questions varied for the SOL and the no-SOL groups to reflect whether participants had or did not have SOL installed. For example, for the no-SOL group, the survey question was: *A solar panel and battery energy storage system would increase the overall value of my home*; and for the SOL group, the question was: *A solar panel and battery energy storage system have increased the overall value of my home*.

The results in Table 6 show that over time, the attitudes towards renewable energy sources and solar PV systems dropped for most questions. One exception was the question about the cost of the technologies, for which both groups continued to agree that the financial investment in these technologies would be quite high.

Note that some questions in the survey were worded positively and some were worded negatively. This was done deliberately to avoid response bias, which occurs when respondents tend to agree with statements regardless of their content. By including both positively and negatively framed questions, we encouraged participants to carefully read each item and provide more thoughtful and accurate responses, reducing the likelihood of automatic or habitual answering. This technique also helps in identifying inconsistencies in responses, further enhancing the reliability of the survey data (Moroney & Cameron, 2019).

The values in the table show an average rating across all received responses - values of 0-1 indicate disagreement with the statement, a value of 2 indicates neutral opinion, and values of 3 and 4 indicate agreement with the statement. The arrows in the column indicate how the responses changed over time – an arrow pointing upward indicates that the overall sentiment of the question has increased over time in a desirable way, and an arrow pointing downward indicates that the overall sentiment of the question has decreased over time (to a less desirable condition). Only questions with significant differences (refer to Table 7) have arrows in the corresponding cell. A dash in a cell in the table indicates that the question was not asked in that survey.

Table 6. Perceptions about renewable technology and backup power, showed as mean and standard deviation M(SD) for June 2023 and March 2024.

	SOL			no-SOL		
	June 2023	Mar. 2024	Direction	June 2023	Mar. 2024	Direction
Perceptions about renewable technologies (Disagree strongly to agree strongly, 0-4)						
If I invest in renewable energy sources (e.g., by installing solar panels), I will personally receive financial benefits.	3.7 (0.8)	2.8 (0.9)	↓	2.9 (0.8)	2.7 (0.9)	↓
If I do not invest in renewable energy sources (e.g., by installing solar panels), I will personally incur financial costs.	2.6 (0.9)	2.2 (1)	↑	2.4 (0.9)	2.2 (1)	↑
If I reduce my at-home energy consumption, I will have to give up some comfort and convenience.	1.9 (0.9)	1.8 (0.9)		1.8 (0.9)	1.7 (1)	
If I personally invest in renewable energy sources, it will cost me money.	2.9 (0.8)	3 (0.8)		3.1 (0.8)	3 (0.9)	
One down side to installing renewable energy sources like solar panels is that they can make the home look unattractive.	2.7 (1)	2.5 (1)		2.6(1)	2.6(1.1)	
Having renewable energy sources like solar panels would make me more likely to invest in battery energy storage.	3.4 (0.7)	-		3.1 (0.8)	-	
Perceptions about backup power (Disagree strongly to agree strongly, 0-4)						
Having a source of backup power to keep important electrical devices running during a power outage is important to me.	3.4 (0.7)	3.5 (0.6)		3.3 (0.8)	3.2 (0.8)	
If incentives were available, I would be willing to invest in energy storage that would provide backup power for my home if there was a grid outage	3.5 (0.7)	3.2 (0.9)	↓	3.3 (0.7)	3.2 (0.8)	
Perceptions about SOL technologies (Disagree strongly to agree strongly, 0-4)	Dec. 2023	Mar. 2024	Direction		Mar. 2024	Direction
Solar panels and battery storage increase the value of a home.	3.2 (0.7)	3.1 (0.9)		-	2.8 (0.9)	
Solar panels (with or without battery storage) reduce electricity bills.	-	2.8 (1.2)		-	2.9 (0.8)	
I believe the solar panels increased my overall energy consumption.	1.1 (1.2)	1.2(0.9)		-	1.4 (1.1)	
Having rooftop solar panels reduces my energy consumption.	3.2 (0.9)	2.3 (1.1)	↓	-	2.5 (1)	
The solar panels on the roof make my home look less attractive.	1.7 (0.1)	2.7 (1)	↓	-	2.7 (1.1)	
There is an environmental benefit to solar energy.	4 (0.2)	3.4 (0.7)	↓	-	3.2 (0.7)	
Perception about battery during a power outage						
It is reassuring to know that the battery can power some of my home, if there is a power outage.	3.7 (0.6)	3.7 (0.5)		-	3.2 (0.7)	

Perception about utility interventions	Dec. 2023	Mar. 2024	Direction		Mar. 2024	Direction
It is (it would be) acceptable for the utility to adjust the battery operation to maintain a stable electrical system for New Brunswick.	3.2 (0.8)	2.1 (1.2)	↓	-	2.5 (0.9)	

In social science research, inferential statistical tests are used to examine the associations between variables and to make decisions about their probable causes. We used *t*-tests to compare the changes over time within the SOL and no-SOL participants, as shown in Table 5, to judge whether differences were large enough to be caused by their experiences during the intervening time. We also include effect size to show the magnitude of the effects, which is an indicator of their practical importance.

The *t*-test is a statistical test used to compare the means of two groups to determine the likelihood of observing these results if there were no differences between them (the *null hypothesis*). The *t* statistic tells us how much the means of the two groups differ relative to the variation within the groups. There is a known probability distribution for this statistic based on the size of the sample. From this, we can determine the probability (*p*) of the *t* for this comparison. If the probability *p* is lower than the criterion we set, then we conclude that we can reject the null hypothesis and infer that the difference we observed was caused by the variable that differs between the groups (in this case, the SOL intervention) (Kerlinger & Lee, 2000).

An effect size is a measure of the strength or magnitude of the difference between two groups. Unlike the *p*-value, which supports a probabilistic decision about causality (“statistical significance”), the effect size describes how large the difference is (“practical significance”). Here, we use a common measure of effect size, Cohen's *d*, which quantifies the size of the difference between two means in terms of standard deviation units. A larger effect size indicates a more meaningful or substantial difference. We use Cohen's rules of thumb, defining a small effect as *d* = 0.2; a medium effect as *d* = 0.5, and a large effect as *d* = 0.8). (Cohen, 1988).

We used paired comparison *t*-tests within the SOL and no-SOL groups to examine whether attitudes had changed over time for questions with two times of asking. The sample sizes for these tests differed from the overall results above because the tests required that participants have answered both surveys. Table 7 summarizes these results. The pattern of statistically significant results shows a general negative trend, with attitudes that changed becoming less agreeable over time.

Table 7. Paired *t*-test results examining change in attitudes over time (June 2023 to March 2024) within the SOL and no-SOL groups. The column names: *t* = *t*-test statistic, *df* = degrees of freedom, *p* = probability given *df*, *d* = effect size (Cohen's *d*).

	SOL				no-SOL			
	<i>t</i>	<i>df</i>	<i>p</i>	<i>d</i>	<i>t</i>	<i>df</i>	<i>p</i>	<i>d</i>
Perceptions about renewable technologies								
If I invest in renewable energy sources (e.g., by installing solar panels), I will personally receive financial benefits.	2.63	52	<0.05	0.4	3.1	166	<0.005	0.2
If I do not invest in renewable energy sources (e.g., by installing solar panels), I will personally incur financial costs.	2.11	52	<0.05	0.3	2.36	166	<0.05	0.2
If I reduce my at-home energy consumption, I will have to give up some comfort and convenience.	1.63	52	0.11	0.2	0.57	166	0.57	0.1
If I personally invest in renewable energy sources, it will cost me money.	-1.24	52	0.22	-0.2	-0.62	167	0.53	-0.1
One down side to installing renewable energy sources like solar panels is that they can make the home look unattractive.	1.81	52	0.07	0.2	1.356	167	0.178	-0.1

	SOL				no-SOL			
	t	df	p	d	t	df	p	d
Perceptions about backup power								
Having a source of backup power to keep important electrical devices running during a power outage is important to me.	-0.41	52	0.69	-0.1	1.48	167	0.14	0.1
If incentives were available, I would be willing to invest in energy storage that would provide backup power for my home if there was a grid outage	2.68	52	<0.05	0.4	0.99	167	0.32	0.1
Perceptions about SOL technologies								
Solar panels and battery storage increase the value of a home.	-0.24	39	0.81	-0.04	-	-	-	-
I believe the solar panels increased my overall energy consumption.	-0.39	39	0.701	-0.1	-	-	-	-
Having rooftop solar panels reduces my energy consumption.	6.91	26	<0.001	1.33	-	-	-	-
The solar panels on the roof make my home look less attractive.	9.52	39	<.001	-1.5	-	-	-	-
There is an environmental benefit to solar energy.	6.87	17	<.001	1.6	-	-	-	-
Perception about battery during a power outage								
It is reassuring to know that the battery can power some of my home, if there is a power outage.	-1	39	0.32	-0.2	-	-	-	-
Perception about utility interventions								
It is (it would be) acceptable for the utility to adjust the battery operation to maintain a stable electrical system for New Brunswick.	7.33	33	<.001	1.3	-	-	-	-

In summary, there is a notable decrease in perceived financial benefits from June 2023 (3.7) to March 2024 (2.8), suggesting uncertainties regarding personal financial gains from solar investments. Both groups consistently perceived that investing in renewables will cost money, reflecting a common concern about the upfront financial commitment required. Both groups consistently valued having a backup power source during outages, with high agreement levels (3.4-3.5), highlighting the importance of reliability and energy security. Acceptance of utility interventions on the battery (a question only relevant to the SOL group) decreased significantly from 3.2 to 2.1, indicating growing concerns or resistance to external control over personal energy resources. This highlights the need for better communication and understanding of the benefits and rationale behind such adjustments.

3.1.3 Financial considerations

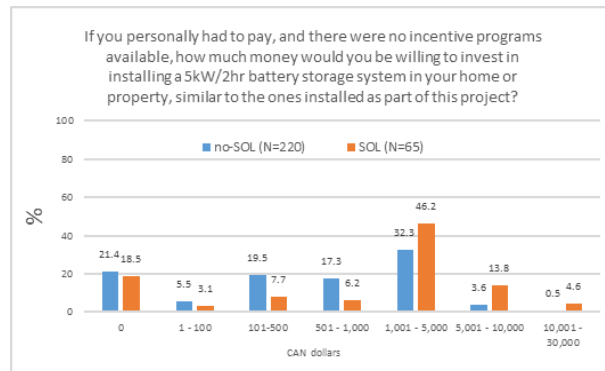
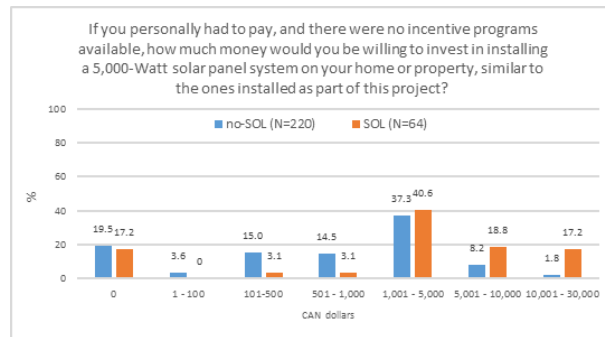
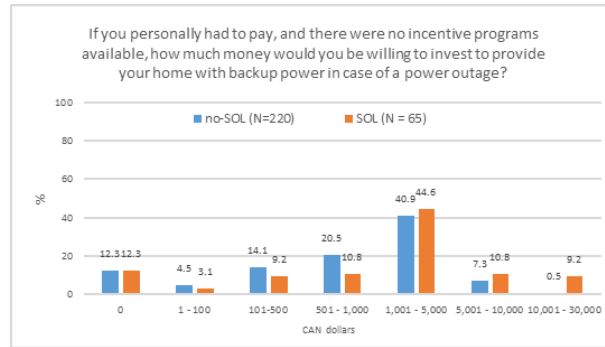
The willingness to pay for a technology is an indicator of technology acceptance and also a guide to program and policy developers. In June 2023, we asked what participants would be willing to invest if there were no incentive programs to encourage adoption. In March 2024, we asked what level of incentive would be required for them to participate in an incentive program. Figure 2 shows the results. On the left are results for all participants in June 2023, and on the right are related questions asked of the no-SOL group only in March 2024. The SOL group already had these technologies so the hypothetical questions were not relevant to them.

The approximate cost for the SOL system (solar PV and battery energy storage) installed as part of this project was \$40,000-45,000 per home. This included \$15,000 for solar panels, \$20,000-25,000 for the battery, plus \$2000-3000/home for site-specific work such as running cables from garage to basement, etc.

The pattern of results for the willingness to pay shows that the SOL group (which had the technology and had not needed to pay for it) was more willing to pay for these systems. They might see more value

in these systems because of their experience with one, but this might also reflect their overall slightly higher income than the no-SOL participants. Looking to the March 2024 questions put to the no-SOL participants, we see that their willingness (or possibly their ability) to pay for these technologies is considerably lower than their total cost, and the level of incentives they would expect to receive in order to afford these technologies was high. The modal incentive level was 50% of the cost, and half of the sample would need an incentive greater than 50%. Interestingly, approximately 80% of the no-SOL participants expected that if they did purchase a solar PV system, the payback time would be 10 years or more.

June 2023



March 2024 (no-SOL only)

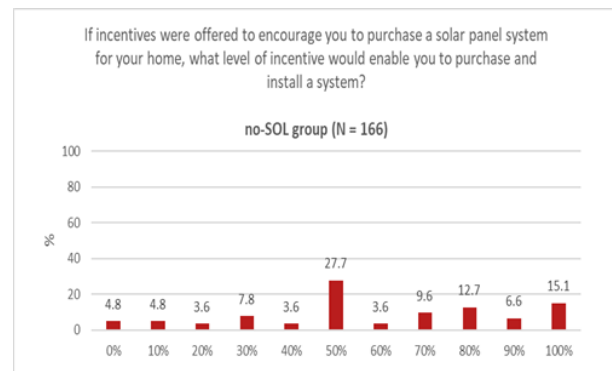
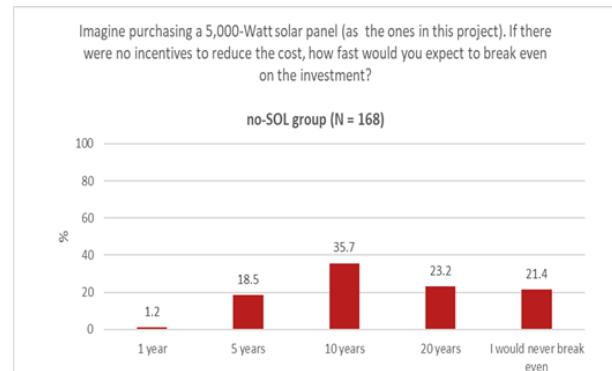
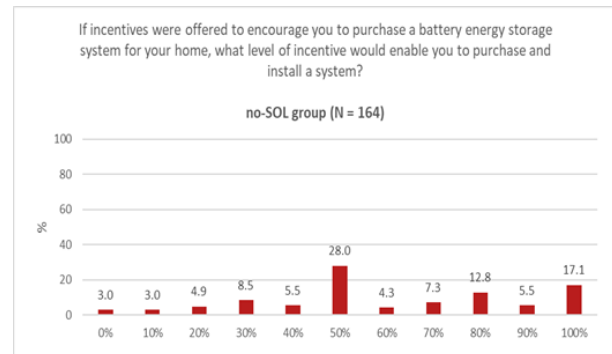
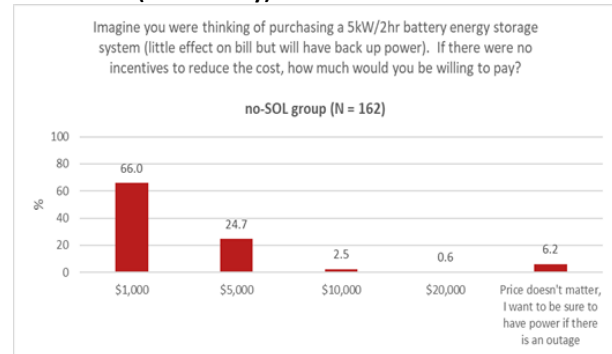


Figure 2. Financial considerations in SOL system adoption, contrasting results without and with incentives.

3.1.4 Resilience

3.1.4.1 Qualitative indications

The attitude data made clear that having backup power available was important to all participants, and that this did not change throughout the project. Open-ended questions provided insight into participants' opinions about the benefits to having backup power and the challenges to obtaining it.

Responses came from 213 participants in the no-SOL group and 64 participants in the SOL group. Not all participants commented on all topics. The main themes from the comments were grouped to give an overview of the frequencies of specific comments related to that theme. Table 8 shows the overview of the responses about the benefits and challenges of backup power, extracted through qualitative analysis of responses provided by all participants. Appendix A includes quotations from participants.

Table 8: The main benefits and challenges with backup power from SOL and no-SOL groups

Research Group	Main Benefits of Backup Power		Main Challenges with Backup Power	
	Main themes	N	Main themes	N
Sol	Reliability and functionality during power outages	18	Installation and maintenance	11
	Safety, security, and comfort	15	Cost and financial impact	9
	Peace of mind for essential appliances and services	10	System management and performance	7
	Cost savings	5	Integration with a home system	3
	Environmental benefits	3		
No SOL	Reliability and functionality during power outages	35	Cost and financial concerns	38
	Peace of mind and security	27	Maintenance and operations	27
	Prevention of food spoilage	15	Installation complexity	25
	Maintains comfort	11	Fuel and noise	12
			Environmental concerns and emissions	10
			Availability and market issues	10

The perceived benefits for having a backup power system were similar for both groups (SOL and no-SOL). The main benefits included the reliability during power outages, protection of essential appliances and services, perceived safety, and overall security that this technology offers. SOL participants liked the fact that the battery storage system provides a safer alternative to generators, as it reduces risks associated with fuel-based systems. In the no-SOL group, many participants reported having generators or wood burners as their backup power.

All participants were able to elaborate further and indicate how easy or difficult they thought it would be to acquire backup power. Table 9 shows the overview of the responses about the ease and difficulty of acquiring backup power, extracted through qualitative content analysis of responses provided by all participants. The principal differences lie in the increased difficulty and maintenance of obtaining backup power in the no-SOL group. Relatively fewer SOL participants commented, likely because they already had backup power, and it had been provided by the project. Appendix A includes quotations from participants.

Table 9. Perceived easiness and difficulty of obtaining backup power in SOL and no-SOL groups

Research Group	Easiness Perceptions	N	Difficulty Perceptions	N
	Main themes		Main themes	
SOL	Smooth acquisition and installation process	10	Cost and financial impact	15
	Maintenance, support, and guidance	8	Challenges in acquisition and installation	12
	User-friendly systems	6	System performance and efficiency	10
			Usability and management	8
			Support and communication	6
No-SOL	Easy	23	Cost and financial impact	35
	Not difficult	5	Installation and maintenance issues	25
	Fairly easy	2	Awareness and complexity	22
			Noise and emissions	10
			Availability of fuel	10

3.1.4.2 Resilience experience

The arrival of Hurricane Fiona in New Brunswick on Sept. 22, 2022, demonstrated the practical value of resilience against a major power outage. Fifty-two of the SOL systems had been installed and commissioned. At the next survey, in Dec. 2022, we asked those participants about their experiences.

In the SOL-TOD group, 91% of the 47 reporting households reported experiencing power outages during and after the hurricane, whereas 67% of households in SOL-no-TOD reported having noticed an outage. Participants were also asked whether they noticed that the energy storage battery provided power in their home during this outage, to which 91% of participants in the SOL-TOD group and 79% of participants in the SOL-no-TOD group reported that they indeed noticed this capability. The majority of participants responding to this survey had felt reassured by having an energy storage battery during Hurricane Fiona (SOL-TOD = 69.5%, SOL-no-TOD = 75%). Concerning their satisfaction with the availability of backup power from a battery energy storage system, the majority of the participants reported being completely happy, and this was higher in the SOL-TOD group (96%) than in the SOL-no-TOD group (71%) (Figure 3).

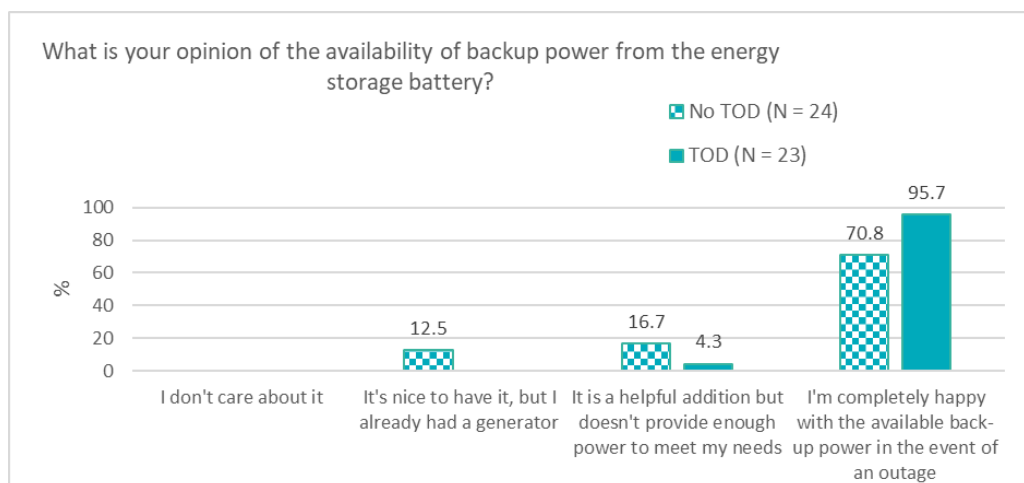


Figure 3. Opinions about the availability of backup power from the battery energy storage unit after Hurricane Fiona, for SOL participants by TOD group.

3.2 System performance evaluation

In this section, the SOL system performance results are summarized, including the performance of the solar panels, grid export, the effects of SOL systems on peak demand, load profiles, monthly grid energy

consumption, GHG emissions reduction, and customers' bills as calculated from telemetry data. Battery round-trip efficiency was also studied for both installation locations: garage and basement, and summarized in the section. The time-series data from the household smart meter, solar PV inverter, and battery energy management system were shared by NB Power with the NRC and are described by Pardasani (2025a, 2025b) in separate reports.

SOL telemetry data (from the solar inverter and battery energy management system) and 15-minute interval smart meter data were analyzed to characterize month-by-month solar generation, grid draw, and battery use. The data were categorized by TOD groups, aggregated at the monthly interval, and averaged over all households. These statistics are presented in Table B.1 in Appendix B. Table B.2 presents the effects of SOL installations on weekday and weekend peak demand, monthly grid energy use, bills, and GHG emissions, under the two battery modes of operation. This section reports each set of outcomes in turn.

3.2.1 Solar panel performance

In Table 10, statistics for the monthly energy generation from the solar panels are summarized. The standard deviation values indicate the relatively high variation in the monthly output from one system to another. Several factors can cause variations in the monthly aggregated generation, demonstrating the stochastic nature of solar aggregated energy:

- **Solar panel layout & configuration:** Although all the solar panels were the same size, the tilt and azimuth angle varied depending on the largest available rooftop area of each dwelling and its layout and configuration.
- **Effect of microclimate:** The dwellings equipped with the SOL system were scattered throughout the town of Shediac. Therefore, local cloud cover could impact the aggregated solar energy generation in one area but not in another.
- **Shading elements:** Nearby objects such as trees, adjacent buildings, or soiling elements could affect the system's efficiency, leading to varying losses in solar energy generation.
- **Miscellaneous factors:** Issues such as system malfunctions or inverter problems could also contribute to variations in solar energy generation.

Note that the energy generation from the solar panels was not influenced by the TOD grouping, so the summary in Table 10 combines data from both the TOD and no-TOD groups. Additionally, the data show that there was higher solar output or more favorable solar conditions in 2024 compared to 2023, particularly in the winter months.

Table 10. Statistics on the monthly output of rooftop solar installations (kWh) for Shediac residential study participants covering the period from Dec. 2022 to March 2024

Month	Year	Mean	SD	Median	Min	Max
		kWh				
Dec.	2022	107	32	103	0	175
Jan.	2023	122	43	126	0	237
Feb.	2023	257	95	251	0	453
Mar.	2023	326	99	334	0	516
Apr.	2023	615	97	631	0	720
May	2023	728	102	742	0	818
June	2023	524	37	532	413	585
July	2023	719	51	731	572	793
Aug.	2023	549	49	559	423	619
Sep.	2023	481	57	491	345	565
Oct.	2023	327	67	329	94	435
Nov.	2023	227	53	220	99	320
Dec.	2023	147	43	139	63	263
Jan.	2024	151	72	143	19	318
Feb.	2024	271	61	275	139	486
Mar.	2024	405	67	396	308	773

The average final yield calculated in the field is 1,013 kWh/kW_p per year. Table 11 provides a statistical summary that includes the mean, standard deviation, median, minimum, and maximum values.

Table 11. Summary of the annual solar energy generation and final yield of solar panels located in Shediac, NB

	Unit	Mean	STD	Median	Min	Max
5 kW PV system	kWh/year	5,065	522	5,087	3,984	6,004
Annual yield	kWh/kW _p /year	1,013	104	1,017	797	1,201

3.2.2 Grid export

The energy generated by the solar panels that was not used on-site and was exported to the grid is illustrated in Figure 4. The grid export from no-TOD households is significantly higher than that of the TOD households. This is because TOD households' time-based control mode of battery operation maximized the solar energy generation self use. In the time-based control mode of operation (TOD), excess solar energy is used to charge the battery, while in no-TOD, the battery is set up to maintain 100% backup reserve, and the battery is rarely discharged.

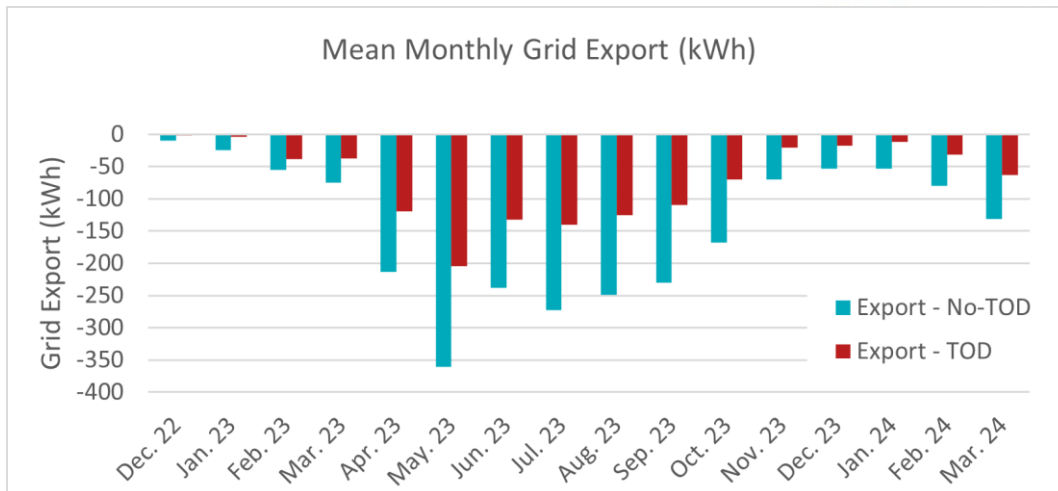


Figure 4. Average monthly grid export after SOL system implementation for the no-TOD and TOD groups.

3.2.3 Effect of SOL on peak demand and load profile

Table 12 summarizes the influence of the SOL installations on household peak demand $G_{peak}(t)$ (i.e, 7:00 am – 8:59 am) for the TOD and No-TOD groups.

To accurately assess the peak demand reduction, the following data filtering approach was followed for this specific analysis (thus does not apply to the rest of the report):

- Peak demand period: 7:00 am to 8:59 am for both TOD and No-TOD groups.
- Weekdays and weekends were separated into two subgroups. The batteries were programmed differently for weekends.
- Stat holidays were removed
- Battery dispatch events that took place during peak demand periods were removed, since they caused bias in the overall peak reduction analysis.
- Note: in Winter 2022, all batteries were programmed for solar self-use. Time-based control and Backup reserve modes of operation were introduced later in Summer 2023.

In winter 2022 and Winter 2023 the weekday peak demand of the TOD group was reduced by 3.4 kW and 3.1 kW, respectively, compared to the same group of participants modeled without solar and battery storage. For the No-TOD group, weekday peak demand was reduced by 1.6 kW for both Winter 2022 and Winter 2023.

Table 12. Average peak demand (kW) (7:00 – 8:59), summarizing grid draw, net grid, load, and peak demand reduction (kW and %) (subtraction of load and net grid)

	Grid Draw				Net Grid (Import-Export)				Load			
	TOD		No-TOD		TOD		No-TOD		TOD		No-TOD	
Weekday/ end	WD	WE	WD	WE	WD	WE	WD	WE	WD	WE	WD	WE
Winter 2022	1.11	4.10	4.35	4.24	1.10	4.10	4.33	4.24	4.20	4.20	4.50	4.30
Summer 2023	0.24	1.27	1.59	1.41	0.23	1.27	1.51	1.35	2.08	1.86	2.01	1.81
Winter 2023	1.01	3.76	3.83	3.98	1.01	3.76	3.69	3.98	4.00	3.86	4.24	4.04
Average Dec. 2022-Mar. 2024	0.72	2.63	3.09	2.83	0.72	2.63	3.03	2.81	3.19	2.96	3.39	3.04

	Peak Demand Reduction (kW) (Load – Net Grid)				Peak Demand Reduction (%) (Load – Net Grid) / Load			
	TOD		No-TOD		TOD		No-TOD	
Weekday/ end	WD	WE	WD	WE	WD	WE	WD	WE
Winter 2022	3.10	0.10	0.17	0.06	74%	2%	4%	1%
Summer 2023	1.85	0.59	0.50	0.47	89%	32%	25%	26%
Winter 2023	3.00	0.09	0.55	0.06	75%	2%	12%	1%
Average Dec. 2022- Mar. 2024	2.47	0.33	0.36	0.23	80%	15%	12%	11%

The implementation of SOL and the battery mode of operation influenced household load profiles. To evaluate these effects, we studied the effect of the two battery operation modes on the load profile before and after the SOL implementation, categorized by the primary heating system.

Figure 5 illustrates the average weekday 24-hour profile of household loads (in red), which can be considered independent of the SOL system, and the post-SOL system net-grid loads (in black) for dwellings. The figure includes data for both (a) backup reserve mode (no-TOD) and (b) time-based control mode (TOD). The profiles are organized by primary heating system (rows) and season (columns). The term “Battery Location=Any” indicates that the data were not categorized by the battery installation location (e.g., garage or basement), as we did not observe any significant effect of battery location on peak demand.

Under time-based control mode (TOD), demand reduction was most significant during: (1) the peak-time window (7:00 am– 8:59 am) due to battery discharge, and (2) during peak solar generation periods, especially in summer, due to on-site use.

Under backup reserve mode (no-TOD), demand reduction resulted from solar output being used on-site, especially in summer. Furthermore, because backup reserve batteries were fully charged at all times, excess solar generation was fully exported to the grid.

Under the time-based control mode (TOD), on-peak and mid-peak demand were significantly reduced due to maximized on-site use with DER, using the battery if necessary. On the other hand, during off-peak hours (between 10:00 pm and 06:59 am next day), grid draw increased, especially between 10:00 pm and 01:00 am next day (3–4 hours were required to fully recharge the battery). That created a new peak, exceeding the original morning peak value. To elaborate on the new nighttime peak due to recharging the battery, a summary of the change in demand during the first 4 hours of the off-peak periods is presented in Table 13. The summary is grouped by season. Between Winter 2022 and Fall 2023, the increase in demand was most significant at 22:00 and trended down in the following hours. Then, between Winter 2023 and Spring 2024, the increase in demand was most significant at 11:00 pm. Overall, the average increase in peak was 3.55 kW, 3.49 kW, 2.12 kW, and 1 kW at 10:00 pm, 11:00 pm, 0:00 am, and 1:00 am, respectively.

(a) Mean weekday grid/load profiles for No-ToD participants, Battery location=Any
Season

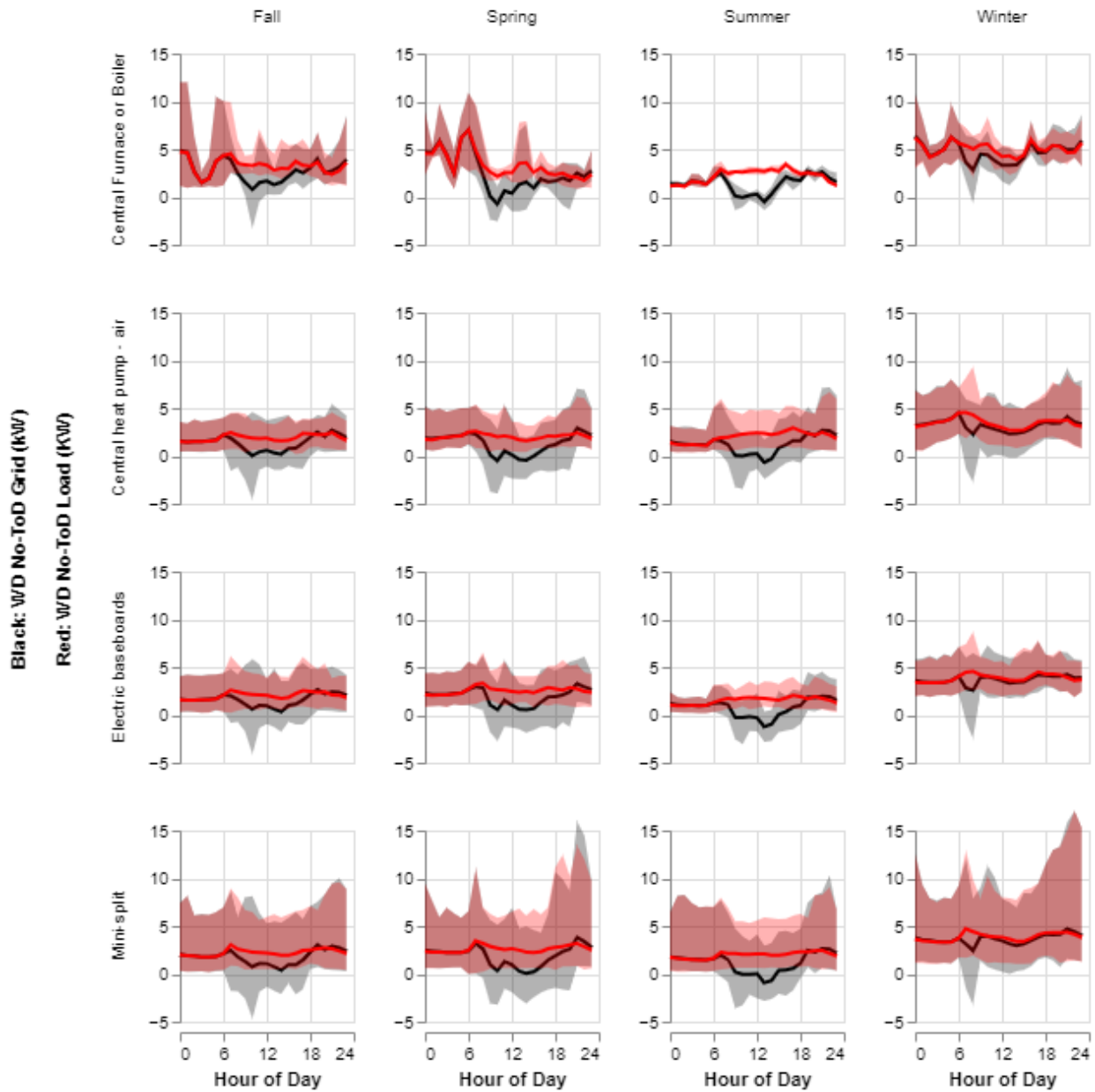


Figure 5 (a). Mean weekday grid/load profiles: The summary of the effect of SOL systems on the grid load (kW) under backup reserve mode (no-TOD). The solid line represents the mean and the upper and lower boundaries of the area (range) represent maximum and minimum. The data are grouped by primary heating type (rows) and season.

(b) Mean weekday grid/load profiles for TOD participants, Battery location=Any
Season

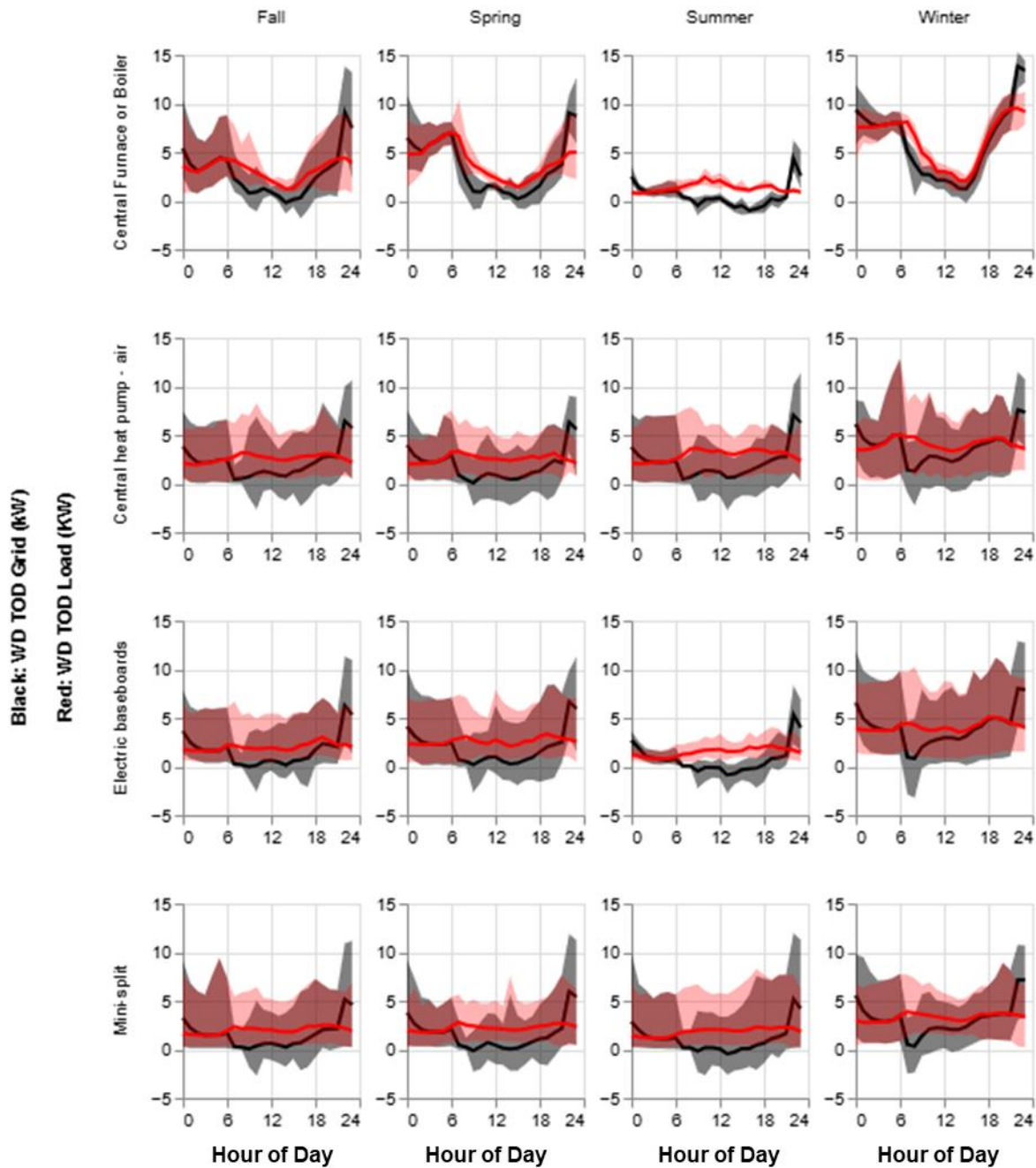


Figure 5 (b). Mean weekday grid/load profiles: The summary of the effect of SOL systems on the grid load (kW) under time-based control mode (TOD) on weekdays. The solid line represents the mean and the upper and lower boundaries of the area (range) represent maximum and minimum. The data are grouped by primary heating type (rows) and season.

Table 13. Change in demand during off-peak periods.

Season	Hour	Grid Draw	Load	Demand Increase (kW)	Peak Demand Reduction (%)
				(Load – Net Grid)	(Load – Net Grid) / Load
Winter 2022	10 pm	7.24	3.83	3.41	89%
	11 pm	6.99	3.62	3.37	93%
	0 am	6.4	3.22	3.18	99%
	1 am	4.54	3.15	1.39	44%
Spring 2023	10 pm	6.45	2.73	3.72	136%
	11 pm	5.59	2.54	3.05	120%
	0 am	4.24	2.29	1.95	85%
	1 am	3.15	2.21	0.94	43%
Summer 2023	10 pm	5.61	2.2	3.41	155%
	11 pm	4.58	1.86	2.72	146%
	0 am	3.12	1.55	1.57	101%
	1 am	2.2	1.41	0.79	56%
Fall 2023	10 pm	6.47	2.45	4.02	164%
	11 pm	5.74	2.19	3.55	162%
	0 am	3.66	1.95	1.71	88%
	1 am	2.54	1.77	0.77	44%
Winter 2023	10 pm	8.06	3.98	4.08	103%
	11 pm	8.29	3.82	4.47	117%
	0 am	5.33	3.46	1.87	54%
	1 am	4.19	3.24	0.95	29%
Spring 2024	10 pm	4.46	3.51	0.95	27%
	11 pm	7.69	3.42	4.27	125%
	0 am	6.27	3.28	2.99	91%
	1 am	4.55	3.04	1.51	50%
Average Dec. 2022-Mar. 2024	10 pm	6.62	3.07	3.55	116%
	11 pm	6.33	2.84	3.49	123%
	0 am	4.66	2.54	2.12	83%
	1 am	3.4	2.4	1	42%

The charge rate was influenced by two main parameters:

- **Battery SOC%:** The charge rate was maximized when the battery SOC is between 25% and 85%. Additionally, during the summer, solar energy generation was at its peak due to longer daylight hours. This abundance of solar energy allowed the battery to reach a high SOC%. As a result, during off-peak periods in the summer, batteries generally drew less energy from the grid and charged at a slower rate compared to the winter and shoulder seasons.
- **Battery energy management system programming:** The maximum charge rate was observed to change multiple times throughout the study.

Figure 6 presents a histogram showing the charge rate (kW) for the TOD group during each time step between 22:00 and 1:00, for weekdays between December 1, 2022, and March 31, 2024. The x-axis represents the charge rate bins. The y-axis indicates the frequency of occurrence for each bin. The dataset consists of 1,892 instances, 473 instances for each timestep. This histogram analysis can be used to calculate the probability, or likelihood, of different charge rates at each time step.

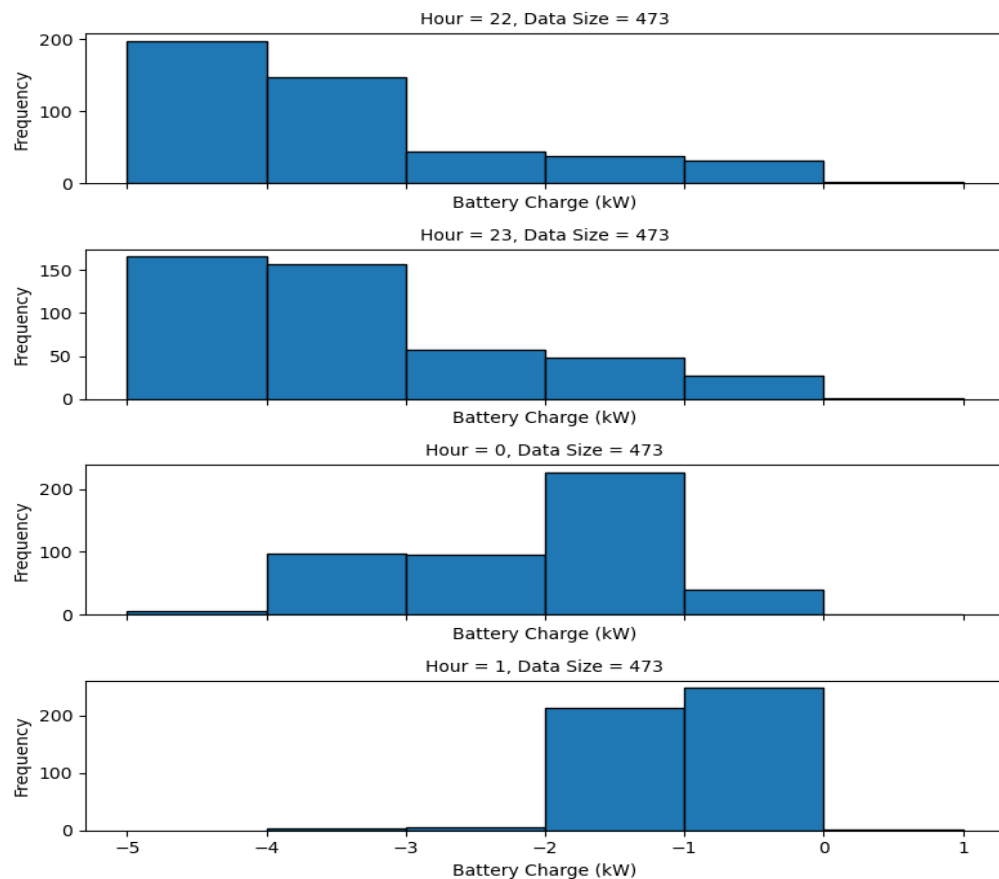


**Figure 6. Histogram indicating the battery charge rate (kW) for each time step between 10:00 pm and 1:00 am.
Data size = 1,892. Battery charge is expressed in negative values.**

3.2.4 Effect of SOL on electricity usage

Figure 7 illustrates the monthly household grid draw with SOL systems. The teal bars show the average monthly grid draw without SOL (i.e., the energy used in the home assuming no SOL on that home), while the red bars show the actual household grid draw with SOL. The difference between the two measurements reflects the effect of SOL systems on grid draw. The top and bottom charts represent no-TOD and TOD households, respectively.

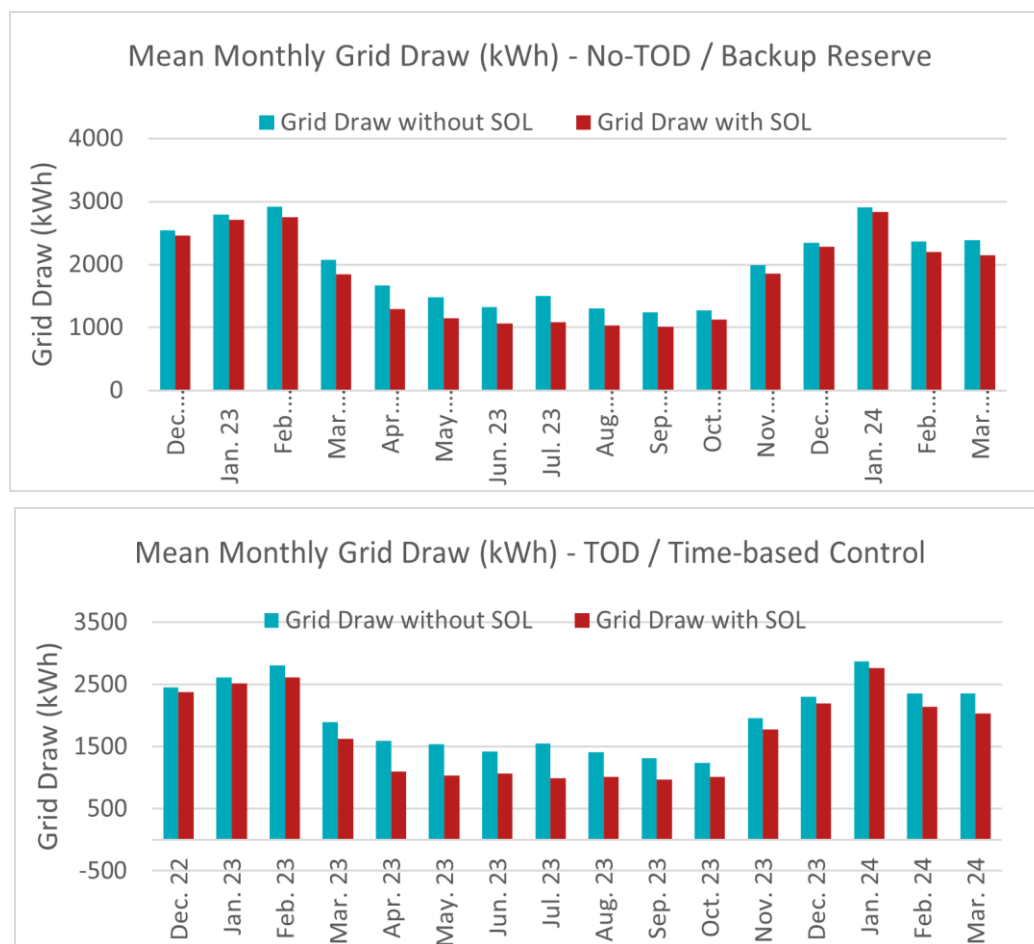


Figure 7. Average monthly grid draw with SOL system and average monthly household energy consumption without SOL (assuming no-SOL). The effect on the grid due to SOL systems is indicated by the avoided grid energy consumption. The top and bottom charts represent no-TOD and TOD households, respectively.

Energy consumption savings were most pronounced in summer months because of summer-peaking solar output. The reduction in aggregated electricity draw was primarily due to the solar generation. The batteries contributed to peak reduction, bill savings, and electrical power resilience, but they might not directly reduce aggregated energy usage.

3.2.5 Effect of battery location on round-trip efficiency

The study involved 42 battery installations in the mechanical rooms of basements and 25 in insulated garages. Initially, there were concerns that the round-trip efficiency of the garage installations could suffer in cold temperatures. Figure 8 presents scatterplots of weekly aggregated data, showing the relationship between charge (x-axis) and discharge (y-axis) for (left) for batteries installed in basements (left) and garages (right).

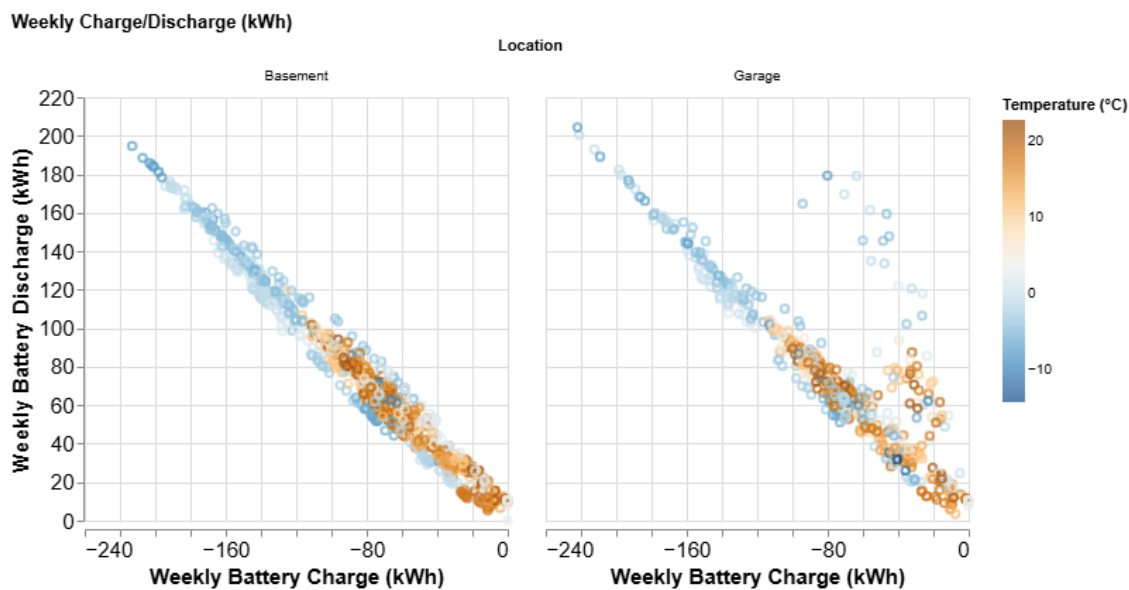


Figure 8. Scatterplots illustrating weekly in-situ battery charge (x-axis) and discharge (y-axis) performance. The color gradient represents outdoor temperature. Each plot is grouped by location of battery install: (left) basement and (right) garage

An Ordinary Least Squares (OLS) linear regression fit for the weekly aggregates (Figure 8) was conducted for basement and garage installations and the coefficients of regression were extracted and summarized in Table 14, where $Discharge = K + M \times Charge$. Our analysis reveals that the weekly round-trip efficiency calculations are more reliable than the daily ones. The weekly round-trip efficiency was found to be 87.4% for basement installations and 87.5% for garage installations.

Table 14. Round-trip efficiency calculation summary

	Basement	Garage
Intercept (K) kWh	2.5026	2.4731
Round-trip efficiency (M) %	87.38	87.46
R^2	0.975	0.975
No. observations (n. SOL)	1250 (n=42)	657 (n=25)

Overall, battery installations in garages performed comparably to those in basements in terms of round-trip efficiency.

3.3 Effect of SOL on electricity bills

For customers, the most salient evidence of system performance is seen on their monthly electricity bills. We calculated these effects in two ways: (1) using telemetry data for the 67 installations with clean data and (2) examining the actual bill settlement data for the full sample of 75 homes.

3.3.1 Telemetry data calculations

This section analyzes the financial results based on the bi-directional smart meter and solar inverter data. Both time-based control (TOD) and backup reserve (no-TOD) modes of operation, along with solar panels, were assessed for their impacts on monthly bills. Figure 9 shows the estimated monthly bill with the SOL system (in red) and another scenario for the same household's bill without the SOL system (in teal). Figure 9a shows this for the no-TOD households, and Figure 9b for the TOD households. The difference between the two scenarios reveals the average monthly bill consequences of the technology implementation (the cost of technology is out of scope). Below the plot is a data table summarizing the solar credit, TOD credit, on-site use savings, as well as the total savings (including solar credit, on-site use of solar energy, and energy arbitrage). Energy arbitrage applies to the TOD group only. The total savings is the net difference between the bill with- and without- the SOL system. It represents the savings from all three benefits mentioned above. Customer bill savings were also aggregated at seasonal resolution, shown in Table 15.

The calculations of bill impact presented in this sub-section were solely dependent on the product of the time-series telemetry data and the given rate structures, including solar credits (see the Methods section above). This method is a simplified translation of energy currency into dollar currency without considering bill settlements, transmission and distribution fees, etc. This method can play a role in making informed decisions about future energy pricing without having to obtain historical utility bills. Nevertheless, the most accurate indication of electricity bill savings would come from actual bills reported below.

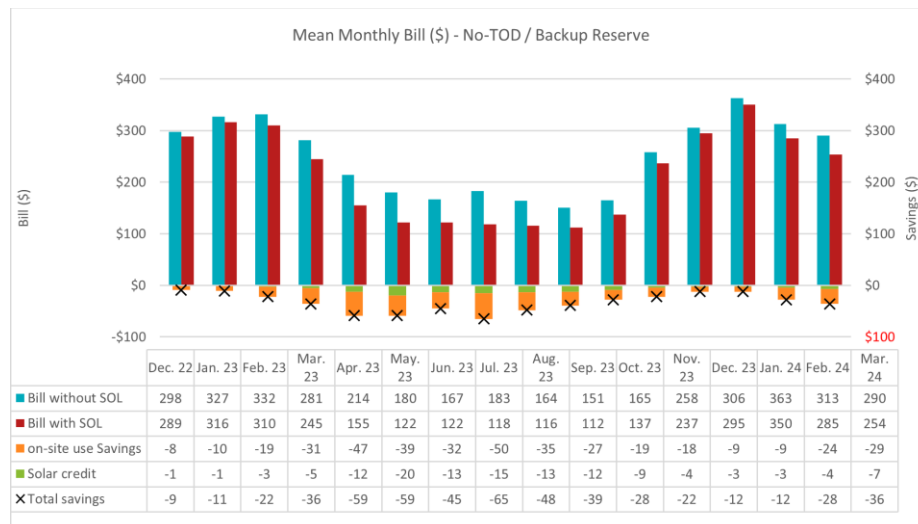


Figure 9a. Average monthly bill with and without SOL system, accounting for SEC credits for no-TOD households.

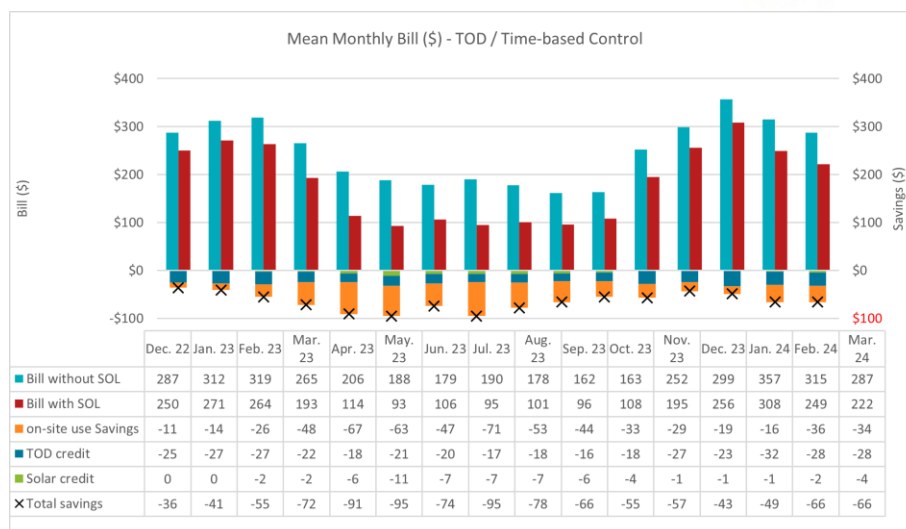


Figure 9b. Average monthly bill with and without SOL system, accounting for SEC and TOD credits for TOD households.

Table 15. Summary of customer bills for usage by season with and without SOL and TOD and subsequent bill savings (negative values indicate customer pays less).

Battery mode Of operation	Season	Seasonal (3-month) aggregate (\$) per household				Total savings per season, all sources
		Bill without SOL	Solar credit	Bill with SOL	TOD Credit	
Backup reserve / No-TOD	Winter 2022	957.1	-4.5	914.5	0	-42.6
	Spring 2023	675.5	-34.0	521.3	0	-154.1
	Summer 2023	514.0	-38.3	356.0	0	-157.8
	Fall 2023	574.6	-24.4	485.1	0	-89.5
	Winter 2023	982.1	-10.2	930.5	0	-51.7
Time-based control / TOD	Winter 2022	917.1	-2.2	784.8	-79.3	-132.4
	Spring 2023	658.5	-18.9	400.8	-61.2	-257.7
	Summer 2023	547.5	-20.0	301.7	-55.2	-245.9
	Fall 2023	576.5	-10.3	398.5	-60.4	-178
	Winter 2023	971.2	-3.3	813.0	-83.2	-158.1

3.3.2 Bill settlement data

Data were available each month for participants' electricity usage, associated customer bill charges, solar energy production, associated solar energy credit (SEC) amounts, and calculated time-of-day electricity credits through monthly bill settlement files from NB Power. The fields in the settlement files are described in a separate report by Pardasani (2025b). The data reported here are from three groups encompassing all of the participants, including those without SOL systems.

- SOL-TOD: This group has rooftop solar and is on time-of-day (TOD) rates.
- SOL-No-TOD: This group has rooftop solar but is not on TOD rates.
- NO-SOL: This group does not have rooftop solar.

Table 16 provides insights into electricity usage and associated costs for these groups for five seasons, from winter 2022 (starting Dec. 1, 2022) through winter 2023 (ending Feb. 29, 2024). The amounts shown are monthly averages in each season. Figure 10 visualizes these numbers. Overall conclusions to be drawn are:

- Overall usage and the associated bill charges are roughly equivalent for the three groups.
- The SOL-TOD group benefited from both solar installations and TOD pricing, which helped to lower their overall electricity bills compared to the other groups (see also Figure 9 and Table 15).
- The SOL-No-TOD group benefited from solar installations but missed out on additional savings from TOD pricing, see also Figure 9 and Table 15.
- The NO-SOL group had the highest costs, highlighting the economic benefits of integrating solar panels and considering TOD pricing.
- Although the no-TOD group exported more solar energy to the grid than the TOD group and thus received a larger solar energy credit, the TOD group received the TOD credit, more than mitigating the financial effect of the difference in battery operation.

Table 16. Average monthly electricity usage and associated billing charges for three research groups over seasons from Winter 2022 to Winter 2023, (M = Average; SD = Standard Deviation; SEC = Solar Energy Credit; TOD = Time-of-Day)

		M (SD)				
		Winter 2022	Spring 2023	Summer 2023	Autumn 2023	Winter 2023
SOL-TOD	Usage (kWh)	2,702 (1,141)	1,373 (739)	1,058 (855)	1,540 (1,110)	2,509 (950.43)
	Bill charges (\$)/Month	313.68 (132.49)	164.76 (87.44)	128.54 (103.82)	187.16 (134.84)	304.81 (115.48)
	Solar Export (kWh)/Month	24 (32.78)	167 (132.19)	191 (156.60)	73 (80.85)	37 (47.43)
	SEC Credit (\$)/Month	1.16 (1.60)	8.10 (6.44)	9.28 (7.62)	3.52 (3.94)	1.80 (2.31)
	TOD Credit (\$)/Month	30.03 (9.73)	17.33 (8.88)	11.74 (7.62)	20.91 (15.28)	32.32 (10.32)
SOL-No-TOD	Usage (kWh)	2,878 (1,324)	1,574 (1,574)	1,139 (709.68)	1,624 (913)	2,754 (1,272)
	Bill charges (\$)/Month	335.34 (154.75)	188.76 (112.44)	138.35 (86.23)	197.26 (111.95)	334.64 (154.49)
	Solar Export (kWh)/Month	44 (55)	269 (138)	292.27 (97.10)	152 (97)	82 (56)
	SEC Credit (\$)/Month	2.16 (2.68)	13.10 (6.69)	14.23 (4.73)	7.39 (4.70)	4.01 (2.73)
	TOD Credit (\$)/Month	0	0	0	0	0
No-SOL	Usage (kWh)	2,689 (1,037)	1,650 (691)	1,210.61 (679)	1,489 (736)	2,523 (975)
	Bill charges (\$)/Month	312.32 (120.48)	198.16 (81.54)	147.08 (82.57)	181.04 (89.48)	307 (118.57)

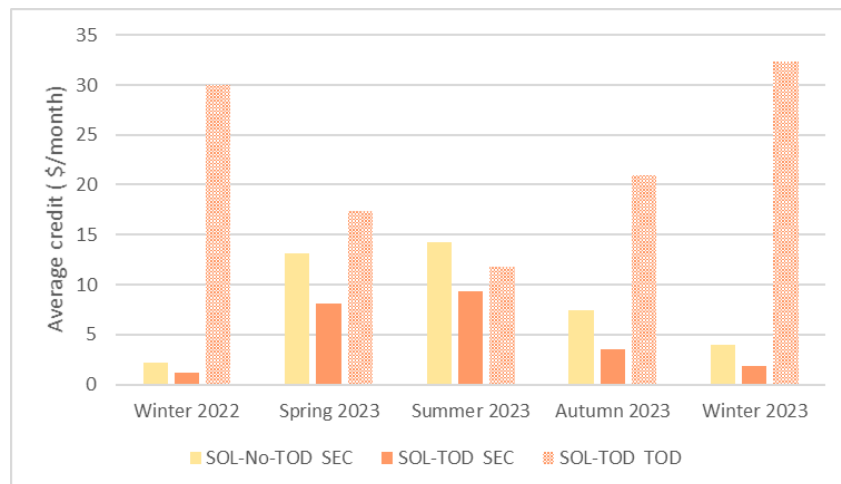
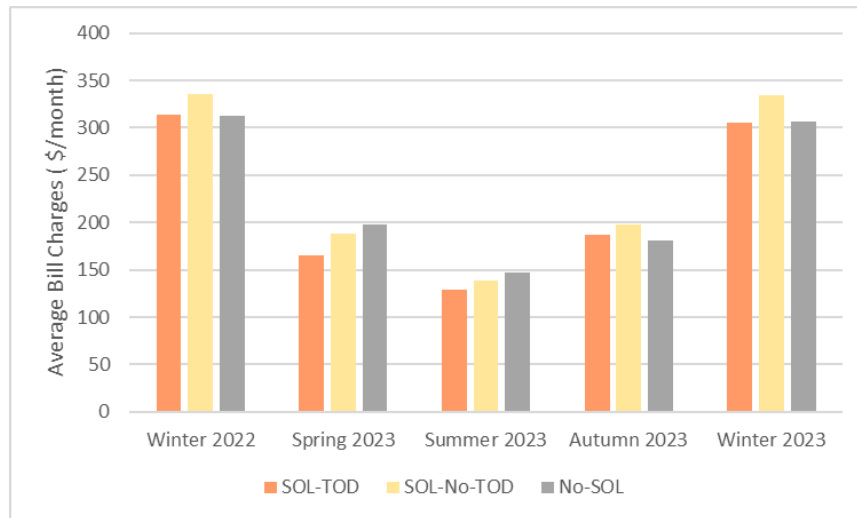
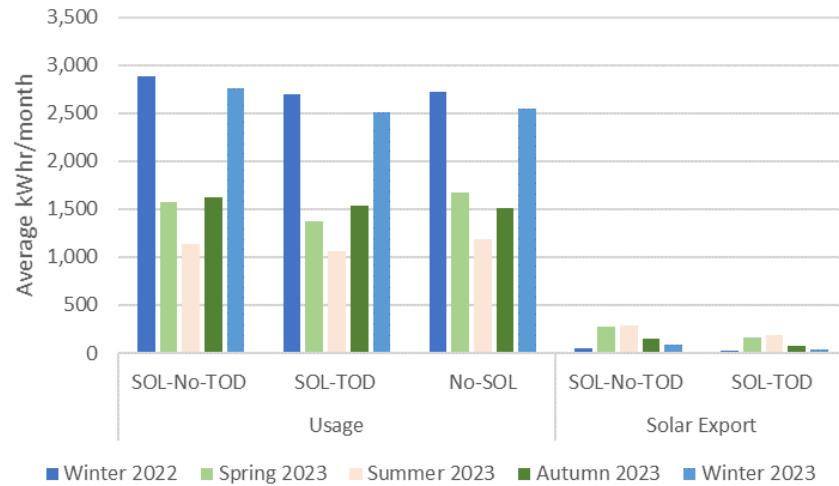


Figure 10. A visualization of the average of the average monthly usage, bill charges, and credits for the SOL-no-TOD, SOL-TOD, and no-SOL groups, based on Table 16.

3.3.3 TOD rates applied to backup reserve mode

For all SOL participants (both TOD and no-TOD), we present the distribution of TOD credits (or losses) calculated from smart meter data. Figure 11 illustrates the hourly distribution of estimated TOD credits for the TOD group, which uses time-based control logic, and the no-TOD group, which employs backup reserve control logic. The calculation for the no-TOD group is hypothetical because TOD credits were not offered to the no-TOD participants, but this analysis provides comparative insight into the potential distribution of credits if NB Power were to consider extending TOD credits (or applying a TOD rate structure) in their future programs to SOL customers whose batteries are programmed for resilience.

Positive values on the y-axis indicate that participants would receive credit due to the TOD rate, which occurs during off-peak periods when the TOD rate is lower than the flat rate. A zero value denotes neutrality, observed during mid-peak periods on weekdays (12 hours a day) and throughout weekends and holidays when the mid-peak rate equals the flat rate. Consequently, neutrality is seen in nearly 50% of the data sample. Negative values appear during the 2-hour on-peak period, indicating that participants incur additional costs with the TOD rate. For the TOD participants, this is outweighed by the positive values in the off-peak rates period, but for the no-TOD participants, with batteries programmed for resilience, the TOD rates result in an overall cost.

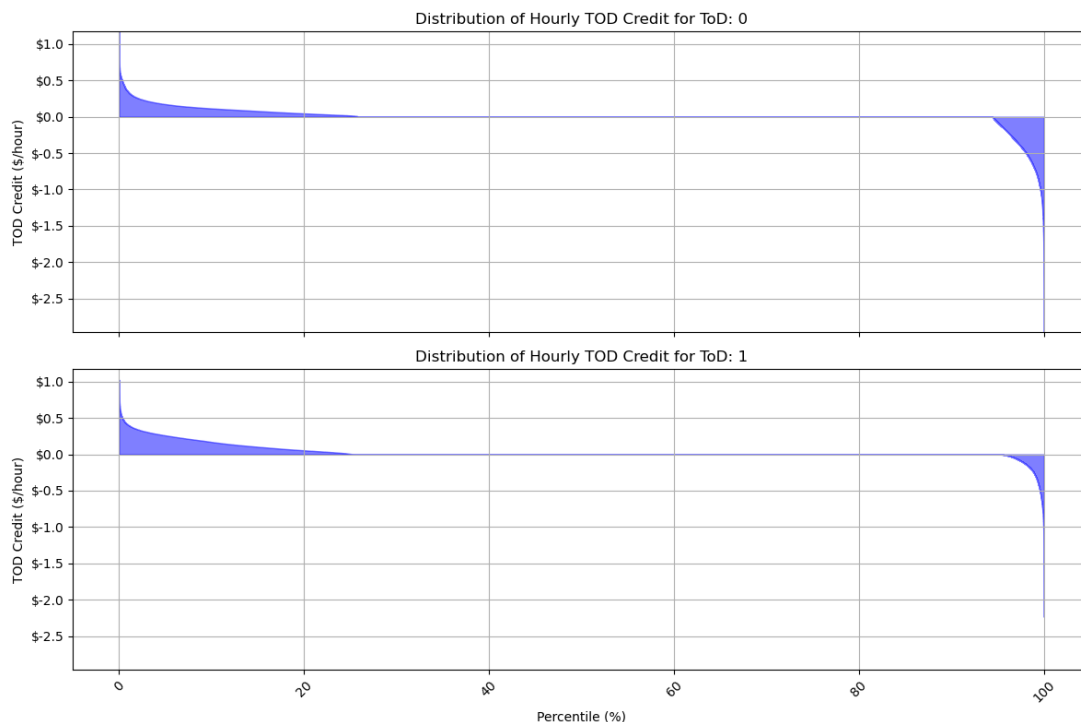


Figure 11. Distribution of estimated hourly TOD credit (or loss) for the SOL no-TOD (TOD = 0, top panel) and SOL TOD (TOD = 1, bottom panel) groups.

The data plotted in Figure 11 highlights a noticeable difference in TOD credits between the TOD and no-TOD groups, attributed to the programming of their batteries. The time-based control algorithm for the TOD group effectively reduced on-peak demand and enabled battery recharging during off-peak periods. This synchronized behavior, aligned with TOD pricing, maximized the benefits of TOD credits. In

contrast, the no-TOD group's load profile is typical of a dwelling with only solar PV installation, resulting in lower TOD credits (or a net cost to their bill).

3.4 Cost and benefits for NB Power

3.4.1 Utility cost savings

Utility cost savings from SOL arise from the avoidance of energy consumption or reduced peak demand, both of which lead to avoided costs for generation, transmission, and distribution of electricity. The savings can accrue in multiple ways: 1) Self-use of solar energy, 2) Load shifting due to battery systems for time-of-day (TOD) participants, which are programmed to optimize the daily morning peak reduction to maximise TOD credits, and 3) Dispatch signals from NB Power on critical peak days to discharge the batteries, thereby reducing household load.

Given the intricate nature of distinguishing between avoided energy (self-use) and energy shift components within the SOL model, especially with the battery functioning as a buffer, this section concentrates on the avoided costs associated with generating electricity through solar self-use.

The avoided generation of electricity corresponds to the solar PV energy produced and utilized on-site (self-use). Self-use is quantified as the difference between on-site solar energy generation and the energy exported to the grid, represented by the equation: solar self-use = solar energy generation – solar export (kWh) (refer to Eq. 11). It is important to note that battery discharge is excluded from self-use calculations in this context.

The avoided cost of electricity is calculated by multiplying the amount of solar on-site use (kWh) by the avoided cost of generation (\$0.077/kWh). Seasonal variations in monthly utility cost savings are detailed in Table 17, while aggregated annual utility cost savings are presented in Table 18.

Additionally, Appendix C outlines the utility cost savings arising from shifts in grid draw during periods of peak hourly demand on extremely cold days, utilizing day-ahead pricing from the Independent System Operator New England (ISO New England).

Table 17. Seasonal variation of the monthly utility cost savings through self-use of solar energy generation, grouped by battery mode of operation/TOD rate structure.

Battery Mode	Season	Monthly Average per household		
		Solar energy generation	Solar on-site use	Solar on-site use utility cost savings (\$0.077/kWh)
		kWh/month/household		\$/month/household
Backup reserve / No-TOD	Winter 2022	153.90	124.40	\$9.58
	Spring 2023	539.72	323.55	\$24.91
	Summer 2023	589.24	336.13	\$25.88
	Fall 2023	340.23	184.06	\$14.17
	Winter 2023	181.85	120.08	\$9.25
Time-based control / TOD	Winter 2022	170.77	156.22	\$12.03
	Spring 2023	572.84	452.41	\$34.84
	Summer 2023	605.15	472.62	\$36.39
	Fall 2023	350.05	283.46	\$21.83
	Winter 2023	197.17	176.96	\$13.63

Table 18. Annual utility cost savings through self-use of solar energy generation per household, grouped by battery mode of operation/TOD rate structure (top) and for all 75 homes (bottom).

Battery mode of operation	Year	N.homes	Monthly Average per household		
			Solar energy generation	Solar on-site use	Solar on-site use utility cost savings (\$0.077/kWh)
			kWh/year/household		\$/year/household
Backup reserve / No-TOD	23/24	38	5,035	2,917	\$224.62
Time-based control / TOD	23/24	37	5,251	4,207	\$323.91
			kWh/year/75 households		\$/year/ 75 households
Total	23/24	75	385,622	266,494	\$20,520.06

3.4.2 NB Power costs for bill credits

Although TOD and Solar Energy Credit programs help electric utilities to manage energy demand, promote renewable energy, and enhance customer satisfaction, there are costs to develop, design and roll out these programs. These include the infrastructure and technology for smart meters, billing system updates, customer support, marketing and education, regulatory compliance, program management, and incentives. These program costs were outside the scope of this project, but would factor into any utility decision to proceed with new programs.

The TOD rate structure applied in this project was designed to be revenue-neutral (Pardasani et al., 2025b) in comparison to the approved flat rate for New Brunswick. However, these calculations did not take into account the battery energy storage units or other automated off-peak loads (e.g., vehicle charging). We analysed the credits for the period from the entire period starting with the first install in June 2022 until the end of the study in March 2024.

- Total TOD credit paid by NB Power to SOL-TOD participants from June 1, 2022, to March 31, 2024: \$13,540
- Total solar energy credit paid by NB Power to SOL participants from June 1, 2022, to March 31, 2024: \$2,640.

3.5 Effect of SOL on GHG emissions

Figure 12 shows the estimated monthly GHG emissions reductions as a result of the SOL system implementation for (a) backup reserve mode (no-TOD) and (b) time-based control mode (TOD), grouped by month and source of reduction, represented by the negative bars in the bar charts below. New Brunswick's electricity grid's GHG emissions factor GEF_{imp} has a value of 0.275 kg CO₂e/kWh at present. SOL contributed in reducing GHG emissions in the following two ways:

- On-site use of renewable energy sources (Eq. 13)
- Export of renewable energy to the grid (Eq. 14)

GHG reduction estimates summarized in this report are not comprehensive; other factors could further reduce GHG emissions at scale. For example, DERs may reduce the peak demand, thus reducing the need for expanding grid capacity. They can also reduce dependency on high-emitting fuel sources to meet the peak demand. Because hourly and seasonal emission factors are not available for New Brunswick, more granular GHG reductions from DERs for peak shaving, load shifting, and demand response could not be estimated.

Overall, the annual estimated GHG emissions reduction per household with a 5kW solar PV system is 1,384 kg CO₂e/year for the no-TOD group and 1,444 kg CO₂e/year for the TOD group. For the entire SOL group, consisting of 75 SOL systems, the annual GHG emissions were reduced by 106 tCO₂e per year.

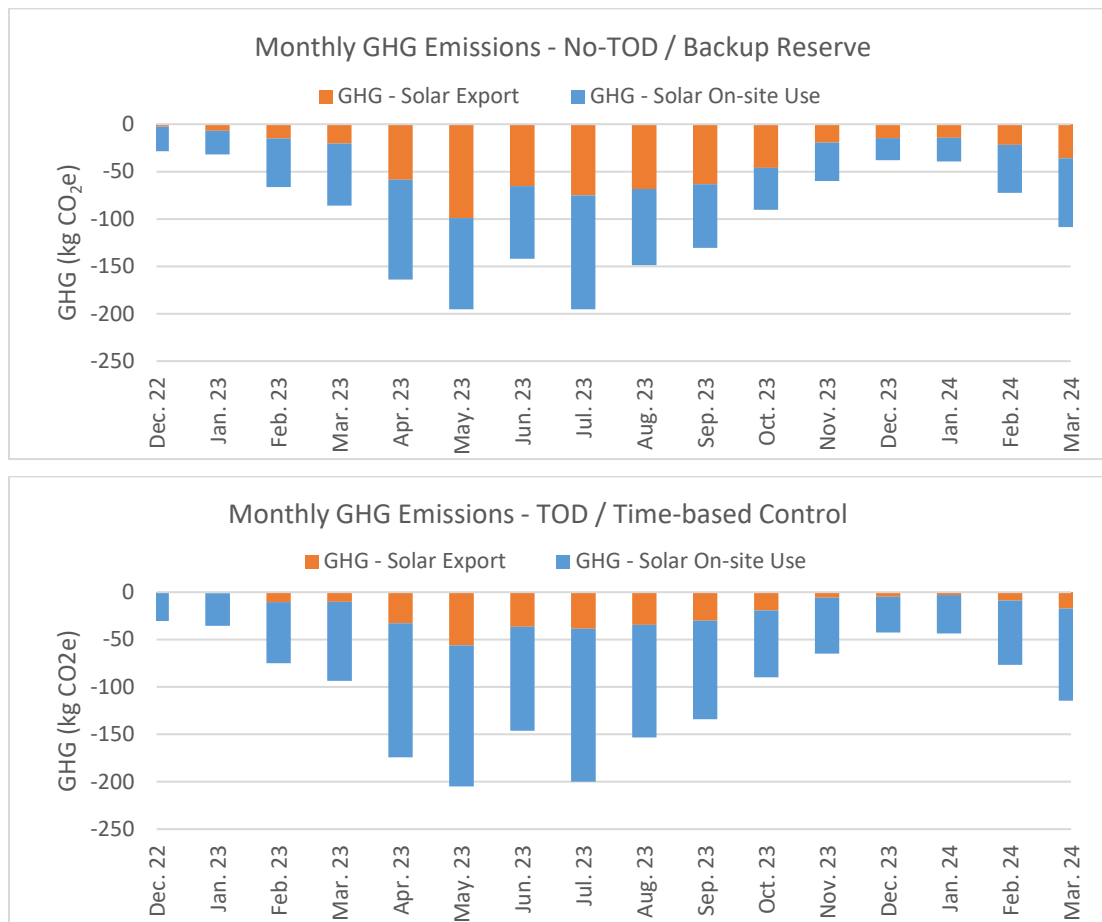


Figure 12. Average monthly GHG emissions reduction as a result of the SOL system implementation for (a) backup reserve (no-TOD) mode and (b) time-based control (TOD) mode, grouped by month and source of reduction, represented by the negative bars.

3.6 System resilience

Resilience, as defined by the Argonne National Laboratory, is the ability of a system “to withstand specific threats, minimize or mitigate potential impacts, and to return to normal operations if degradation occurs” (Petit et al., 2013). Power outages can occur because of extreme weather conditions such as high winds and freezing rain, which cause physical damage to powerlines, as well as during heat waves and cold snaps, which can overload the electrical power system (Canadian Red Cross, 2023).

We examined the energy performance of 46 residential buildings equipped with SOL systems during their response to a power outage caused by Hurricane Fiona, which hit Shediac on Sep. 24-25, 2022. In preparation for the hurricane, seeing the weather forecast, the battery vendor set the batteries to backup reserve mode to hold the batteries at 100% SOC in preparation for the storm.

3.6.1 Resilience Measurement Index (RMI)

For critical infrastructures, Carlson et al. (2012) defined resilience as the “*ability of a facility or asset to anticipate, resist, absorb, respond to, adapt to, and recover from a disturbance*” (Carlson et al., 2012). Out of these six elements, Petit et al. (2013) identified four major elements for RMI components known as *preparedness, mitigation measures, response capabilities, and recovery mechanisms*. We followed the RMI approach by identifying the four RMI components that are relevant to this study.

The performance during the hurricane was compared to a baseline period: one week prior to the event. Table 19 summarizes the selected RMI components and examples that are applicable to the performance of the SOL systems during a power outage. Four components are identified as follows:

- **Preparedness:** the period prior to the occurrence of a predicted event. Hurricane Fiona was forecasted to arrive at Atlantic Canada on or around Sep. 24, 2022. The preparedness stage was thus proactively initiated on the afternoon of Sep. 22, 2022. Batteries were manually switched to backup reserve mode. Hence, batteries were fully charged and held at 100% SOC until an outage occurred. Once the battery detected an outage it switched to the islanding mode and started to discharge to meet the demand. Only limited (critical) loads are allowed during an outage for SOC longevity. Homeowners were informed of the possible consequences of the hurricane.
- **Mitigation measures:** The availability of solar power during an outage and the limiting of the loads were considered as methods of risk mitigation.
- **Response capabilities:** This category characterizes both the capacity of response and absorption during the event occurrence. Response capabilities could be either on-site or off-site (Petit et al., 2013); however, in this study, we are interested only in on-site response capabilities. Indicators of response capabilities are identified as the duration of power availability from the SOL system during the disruptive event, and the user’s behavior in conserving energy.
- **Recovery mechanisms:** Post-event, on Sep. 25, 2022, the behavior of SOL system after switching back from islanding mode to grid interaction and solar self-use.

Table 19. Components of RMI Applicable to local SOL system performance during a power outage

Component	Applicable components of RMI		
	Day (of Sep. 2022)	Example	KPI
Preparedness	22,23	Switch to backup reserve mode. Inform homeowners.	SOC, charge/discharge rate.
Mitigation measures	22,23,24	Reduce electrical loads.	Household loads, SOL system self-use.
Response Capabilities	24	SOL energy available onsite Automated detection of outage and switch-over to islanding mode.	Available energy from SOL system for self-use.
Recovery Mechanisms	25	Post-event grid interaction (Power flow to and from each energy component) Automated detection of power restoration and switch back to the grid connected operation.	Battery discharge, household loads, grid import/export. Capability of battery system to detect utility power.

3.6.2 Hurricane Fiona

At the time of the hurricane, only 46 SOL systems had been commissioned in Shediac. Hence, data from these 46 households were collected for the period between September 18 and 30, 2022, during which Hurricane Fiona occurred on September 24. Table 20 summarizes the number of households (out of the 46) affected by a power outage and the duration of the outage as a result of the hurricane.

Before the event, during the preparedness stage, all households had a normal electricity supply. During the event, 80% of SOL households were affected by the outage for more than 12 hours, while 20% did not experience power failure. In the recovery stage, 72% of households regained grid connection, 11% were disconnected for more than 12 hours, and 17% were disconnected for less than 12 hours. Post-event (48 hours following after the hurricane), 96% of the households had regained grid power, while the remaining 4% - representing only two households - continued to experience power outages. It is important to note that typical consequences of a hurricane can include physical damage to properties, large trees, power lines, and major infrastructures. Therefore, households that continued to experience interrupted grid power supply after major events may be linked to these occurrences.

Table 20. Summary of power outage duration and population of affected households as a consequence of the event

Event phase	Date in September	# Households with power outage levels			% Households with power outage levels		
		≥ 12 hrs	< 12 hrs	No outage	≥ 12 hrs	< 12 hrs	No outage
Preparedness	22-23	-	-	46	-	-	100%
Event	24	37	-	9	80%	-	20%
Recovery	25	5	8	33	11%	17%	72%
Post-event	26	2	-	44	4%	-	96%

3.6.3 System performance during and after Hurricane Fiona

Net grid effects: Although not applicable to the Shediac study with its relatively small number of systems during Fiona, emergency preparedness for a large number of batteries could potentially cause new peak demand: (a) when all batteries are switched to backup reserve mode at the same time; or (b) post-event, aggressive recovery to charge battery storage and meet pent up demand for heating. This event lasted for only 24 hours. If the event had continued longer, the battery storage might have drained, and a new post-event peak could have occurred upon power restoration. Also, signs of grid penetration were observed post-event (Figure 13).



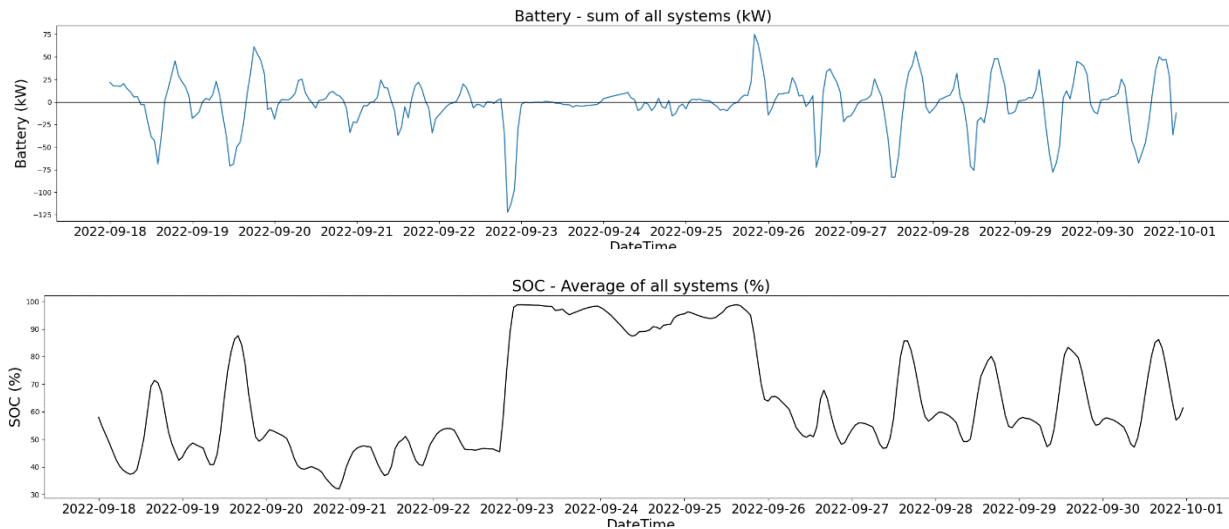


Figure 13. In order from top: Total Net grid, solar energy generation battery flow, and mean battery SOC views from all 46 households summed up between September 18 and 30.

We observed that upon restoration of power, when batteries reverted to the solar self-consumption mode (time-based control mode had not been set up yet for the TOD participants) a significant amount of solar energy was exported to the grid due to the high SOC of the batteries. Additionally, during the recovery period and post-event, the clear-sky index was substantially higher for most days. This resulted in increased solar output, and thus a greater probability to meet and exceed the household demand, particularly since the batteries were nearly fully charged.

Solar generation: Furthermore, because the event occurred during the end of summer/beginning of fall in a high latitude region, the solar energy output was high because of relatively longer daylight hours as compared to winter months. For solar generation evaluation, a baseline was needed for comparison. We selected the day with the highest aggregated solar energy within the study period (September 18-30, 2022) as the baseline which was September 30, the last day of the period.

Using September 30, 2022 as a baseline for solar generation, daily solar energy generation declined by 88% during the preparedness stage, 97% during the event, 27% during the recovery, and 45% post event. The maximum clear-sky solar generation for September was 33 kWh/day, but during the hurricane, it dropped to just 1 kWh/day.

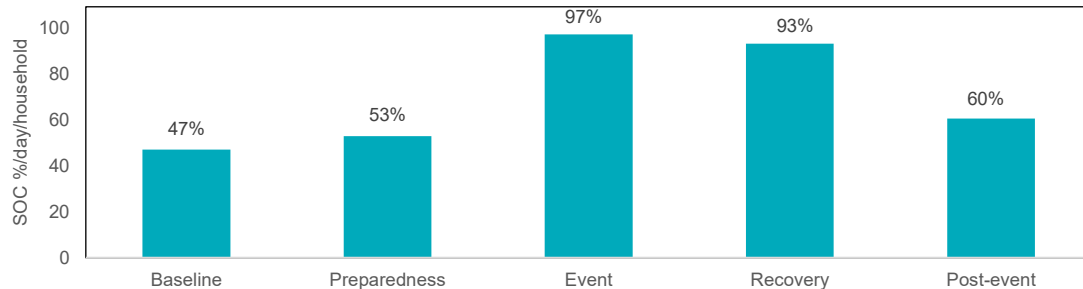
Battery and SOC: Figure 13 depicts the battery flow and SOC, respectively. Pre- and post- event (on the far left and far right of the plot), the 24-hour charge/discharge cycle is clearly visible, showing charging from excess solar energy during the daytime and discharging during the nighttime. During the event and recovery period, the discharge rate was minimal, given that 80% and 28% of households experienced power outages during the event and recovery, respectively.

Figure 13 provided a clear interpretation of the battery SOC. During the preparedness stage, all batteries were charged and maintained at 100%. During the event and recovery, a slight discharge was observed. However, recharging also occurred due to the availability of excess solar energy generation.

Battery performance was further analysed in terms of SOC and energy flow, as shown in Figure 14 (a). The average SOC was 97% at the start of the event, slightly dropping to 93% during the recovery, before settling back to the baseline levels as batteries resumed normal operation. In Figure (b), a breakdown of the actual released energy by the battery is presented. On average only 0.3 kWh per household was

discharged during the event, while 6 kWh per household was discharged from the battery during the recovery period, indicating minimal battery usage during the power outage.

(a) Average daily values for State of Charge %



(b) Average daily battery reserve per household
Energy stored in battery and discharged energy

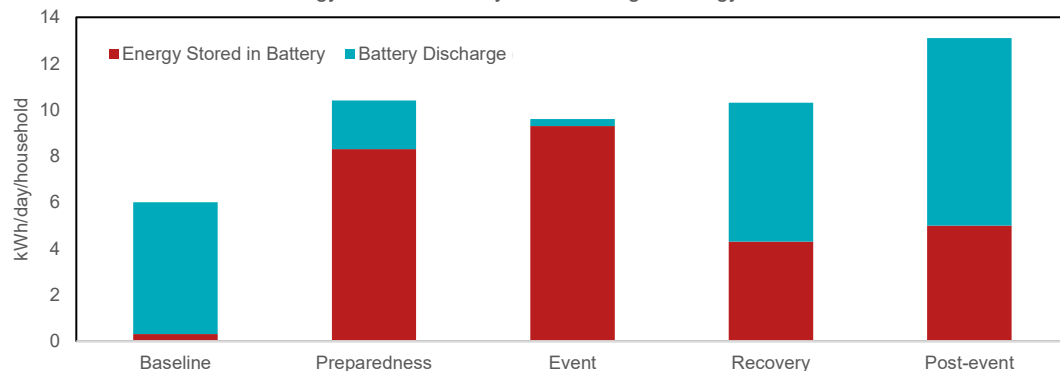


Figure 14. (a) Average battery state of charge for all batteries during the various event stages.

The baseline is the mean SOC for all batteries between Sep.18-21.

(b) a breakdown of the mean daily energy stored in the battery and the amount of daily energy discharge (kWh).

Grid energy dynamics: Grid energy dynamics were also evaluated as depicted in Figure 15. The baseline grid import and export were 22 kWh/day/household and 1 kWh/day/household, respectively. During preparedness, the grid import increased by 12 kWh/day/household and grid export declined by 0.99 kWh/day/household below the baseline. During the event, because 20% of households were connected to the grid and 80% were reconnected at a later time of the day, we could still observe grid supply, but much lower than the baseline. In recovery, grid import exceeded the baseline by 3 kWh/day/ household, while export was 9 kWh/day/household higher than the baseline, reflecting the restored grid connectivity, higher SOC, and higher solar generation.

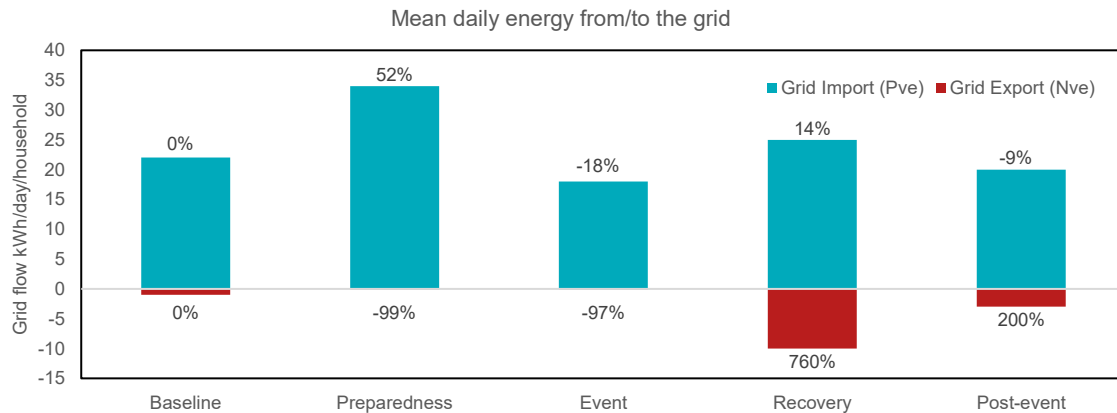


Figure 15. Mean grid energy (import and export) (kWh) of all SOL systems during the various event stages. Two peaks were noticed, the import peak during preparedness and the export peak during recovery.

Overall, the key findings include:

- **Preparedness:** Batteries were switched to 100% backup reserve, resulting in increased grid import with no outages.
- **Event:** Solar operated at 3% capacity, batteries maintained SOC between 97%-100%, and critical loads were prioritized, with 80% of households losing power for over 12 hours.
- **Recovery:** Solar returned to 73% capacity, aiding battery recharge alongside partial grid reconnection; grid export peaked at a 760% increase.
- **Post-Event:** Most households regained grid power, with solar performance dependent on weather conditions.

Overall, this unanticipated occurrence during the Shediac Residential Energy Study has highlighted the resilience and performance dynamics of SOL systems in managing energy during a significant weather event.

4 Discussion

4.1 Feelings and attitudes

Overall, most SOL participants were very satisfied with the technology they received and with the project. Most participants reported that they would recommend these technologies to others. Participants were satisfied with the information they received about the technology before the installation, as well as the overall installation process. These findings align with previous research indicating that professionalism and clarity of communication during the installation process significantly increase homeowners' satisfaction with technologies (Bao et al., 2020; Rigo et al., 2022).

Lower environmental impact, improved energy efficiency, and resilience (the availability of backup power during an outage) were reported as the main benefits of having such technologies. However, many participants also raised concerns regarding these technologies, such as perceived high initial cost, technology complexity, and maintenance needs, as well as low awareness of energy savings, specifically regarding expected vs actual savings. Over time (nine months for most variables), attitudes on these variables became slightly more negative. Over those same nine months, the monthly averages for the SEC credits on participants' electricity bills were under \$15, which might have been less than participants had expected, although for the SOL-TOD group the TOD credits were as high as ~\$30 in a

month. The savings attributable to on-site usage of the electricity generated by the system were less visible unless participants compared their year-over-year bills. These findings are consistent with previous literature that showed that discrepancies between expected and actual savings lowered overall satisfaction levels with technologies (Hannan et al., 2021; Al-Shahri et al., 2021; Zaidan et al., 2022).

Another reason for the decline in attitudes during the project might have been the fact that the project team purposefully limited participants' interactions with these technologies to enable meaningful comparisons between experimental groups. Previous research has found that limited interactions with technologies contribute to lower satisfaction and diminish future adoption of renewable technologies (Parking et al., 2018). As such, these ratings may be influenced by some of these restrictions, as participants often noted that they would like to interact with the technologies and learn more about them.

Existing studies about battery storage systems have shown that the reliability and resilience they provide are seen as their main benefits and greatly contribute to overall satisfaction (Rana et al., 2022; Agnew et al., 2017). Similarly, in this study, the overall perceptions of battery energy storage systems were very positive, especially among those who had experienced their use during Hurricane Fiona. Having backup power in case of a power outage was very important to most participants, with many reporting having backup power before they participated in this project (generators). Resiliency, lower energy consumption, self-sufficiency, and grid independence were all seen as the major benefits of having access to backup power, which is consistent with previous research that indicated that some homeowners are willing to invest in backup power even with higher cost and longer payback periods (Agnew et al., 2017; Al-Shari et al., 2021; Rana et al., 2022).

The utility adjustment of the battery energy storage systems occurred on several occasions during the project without warning to participants, most of whom did not notice. Those who reported noticing changes mentioned that this was mainly through the visual information in the battery app, noticing changes in battery controls and settings, as well as different discharge times. Some participants felt that the utility adjustment limited their ability to use the battery storage system more advantageously (although participants were locked out of making changes to their systems, and this was unrelated to the DER interventions). This was reflected in the lower satisfaction ratings for the acceptability of utility companies making these adjustments.

Overall willingness to pay for these technologies was slightly higher for participants in the SOL group, as they reported being willing to pay higher prices for both the solar panels and the battery energy storage than participants who did not receive these technologies (no-SOL group). However, around 20% of participants in both groups (SOL and no-SOL) reported not being willing to invest in these technologies (despite the fact that SOL participants had received their systems at no cost).

The attitudes concerning renewable energy technologies and battery storage systems were also collected from participants who did not receive these technologies as part of this project (No-SOL group). A large incentive (50% or more of the purchase price) would be needed to enable most participants to buy such a system, as their willingness (or ability) to pay more than \$1000 was very limited. Conversely, a few participants indicated that having backup power made price almost irrelevant.

4.2 System performance

4.2.1 Resilience

During Hurricane Fiona, which provided a resilience case study, participant households were properly prepared for the forecasted event, from the energy backup viewpoint. Before the event, the battery

vendor activated the storm watch feature by setting the batteries to 100% backup reserve mode and holding the SOC until an outage was detected (islanding mode).

Data show that during the event on Sep. 24, all batteries were held at an initial SOC_i of 100%, where only critical loads were permitted. By the end of the event day, the average SOC was 93% and continued to discharge slowly until the end of the recovery stage. Solar energy, as well as intermittent grid connectivity, helped the battery to recharge slightly during the event. That said, if the event had lasted for longer, the SOL systems could have sustained and continued to provide power to supply critical loads for at least 2-3 days in a row.

One concern is the possibility of a new peak in demand occurring because of the switch to backup reserve mode, if there were a larger number of systems connected than the 46 in Shediac. During the event, the battery energy reserve was available for use onsite, but only for critical loads; other sources of energy supply, such as solar and intermittent grid power, were also slightly present. During recovery, similar to the new import peak mentioned earlier, the new export peak could be a subject of concern for scalable DERs due to grid penetration, which occurred right after a major event. A staggered switch between battery modes of operation can be an affordable solution. Post-event, the entire system successfully returned to normal operation with no sign of physical damage.

4.2.2 SOL performance

The SOL systems have proven to reduce the households' grid dependency. The rooftop installed 5 kW_p solar PV panels generated monthly, on average, somewhat between 127 kWh/month in Dec. and 738 kWh/month in May (the peak month for solar energy generation in NB). The solar panels' productivity varied according to multiple factors (layout configuration, shading, soiling, micro-climate, etc.). On a yearly basis, an average of 5 MWh was generated per solar PV system.

The TOD group (with time-based control of the battery energy storage unit) demonstrated a significant peak demand reduction (between 7:00 am and 8:59 am), especially in the winter. On average, in Winter 2022 and Winter 2023, peak demand in SOL(TOD) households was reduced by 3.1 kW (74%) and 3.0 kW (75%), respectively.

Load profiles were considerably influenced by SOL implementation. In addition to peak demand reduction, early in the project a new peak (rebound effect) was created at 10:00 pm when the off-peak period started, as all TOD group battery systems automatically switched to "charge" mode. This phenomenon was noted and battery systems were programmed to charge at lower rates.

The no-TOD group had not been expected to contribute to peak demand reduction. However, due to the excess solar energy export, especially in summer, the no-TOD group contributed to a significantly reduced demand during summer daytime. Moreover, grid penetration can be expected in cases of relatively larger solar PV systems per household.

Battery roundtrip efficiency was calculated based on the weekly battery cycle for both garage and basement installations. The two locations had very similar round-trip efficiency factors of 87%. Future studies with more detail, longer term investigation, and larger sample size would enable a more robust recommendation about the desirable battery location.

4.2.3 Financial considerations

4.2.3.1 Participant bills

Electricity bills were reduced in three ways: (1) on-site use, (2) solar export credit, and (3) for the TOD group, energy arbitrage. The no-TOD group has benefitted more from the export credit while the TOD group had the most economic benefit from energy arbitrage. Self-use saving was almost equal in both

TOD and no-TOD, but slightly higher in the TOD group (excess solar energy was often used to charge the battery). Participants in the TOD group saved \$840 per year, while those on the no-TOD rate structure saved \$460 per year.

It is noteworthy to mention the discrepancies that we observed between the attitudes toward technology adoption (section 4.1) and the actual cost and benefits. Participants felt that their savings were not as high as they had expected, despite having received the technology for free and saving hundreds of dollars per year.

4.2.3.2 Cost-benefit calculations for homeowners

Many participants saw the benefits of having solar technology and the value of having backup through a battery storage system. However, participants in both SOL and no-SOL groups also expressed concerns about upfront financial commitment, including the high cost of the technology purchase and maintenance, and uncertain return on investment. Participants expressed a desire to be reimbursed for at least 50% of the cost for them to consider paying for such technologies.

A simple payback period calculation showed that it would take a minimum of 54 years to recover the initial cost of the solar panels and battery energy storage system (~\$45,000), based on the savings of ~\$840/year under the TOD rate structure. This suggests that a substantial reduction in the overall prices of such technologies is necessary to facilitate their adoption. Government incentives, such as tax credits, rebates, or grants, could play a significant role in reducing the financial burden and encouraging more widespread adoption. These incentives could help lower the effective cost of investment, making solar energy an attractive option.

4.2.3.3 Utility costs and benefits

The total cost to NBP of the TOD and SEC credits for the SOL intervention was \$16,180. In practice, this cost would be offset by savings in fuel and power purchases, depending on the precise mix of electricity sources over the study period.

In total, the annual utility cost savings through avoided electricity generation for these 75 homes amounted to \$20,520. The analysis of battery operation modes indicates that the implementation of a time-based control strategy has significantly enhanced solar on-site usage, resulting in a 1.44-fold increase in utility cost savings (\$224.62/year for the no-TOD (backup reserve) group and \$323.91/year for the TOD (time-based control) group).

Concerning the TOD rate structure specifically, it appears that for the SOL participants, it was not revenue-neutral for NB Power, as it had been designed for a general load profile in the province. Considering the substantial costs associated with the TOD program and the dispatch signaling of battery energy storage units, it may be beneficial to develop a new rate structure specifically for devices such as electric vehicles and household battery energy storage units that charge during off-peak hours.

4.2.4 GHG emissions reduction

GHG emissions were reduced in two ways: (1) the onsite use of renewable energy sources and (2) the export of renewable energy to the grid. Overall, the estimated annual GHG emissions reduction per household is 1,384 kg CO₂e/year for the no-TOD group and 1,444 kg CO₂e/year for the TOD group. The size of the solar PV system significantly influences the amount of GHG emissions reduction. In this report, the effect of peak management from the battery was not considered due to the unavailability of GHG emissions factors at an hourly granularity.

4.3 Lessons learned and recommendations

Battery mode of operation – The TOD group, using a time-based control mode of operation, is intended to minimize GHG emissions, reduce customer bills, and decrease peak demand. On the other hand, the no-TOD group aimed for resilience, making its fully charged battery a better candidate in principle for utility dispatches. This project had a limited scope to explore these issues.

- **Recommendation** – To achieve optimal results from utility dispatch events, it is important to ensure that the batteries are fully charged before each dispatch. This requires effective communication between the vendor and the utility operator.
- **Recommendation** – To develop a successful utility intervention program for battery energy storage systems under the normal conditions in which owners control their technologies, extensive and specific stakeholder consultations and program evaluation will be needed. Such an evaluation was beyond the scope of this project.

The rebound effect – At the beginning of the study, TOD participants' battery energy storage units recharged at maximum capacity (5 kW) once the off-peak signal was sent. Subsequently, the battery energy management system operators adjusted the charge rate to 3.45 kW, instead of 5 kW, and implemented a randomization algorithm to prevent a new peak.

- **Recommendation** – Further investigations into peak management are needed, particularly when SOL systems are deployed at a larger scale.

Battery installation location – The study revealed that both battery installation locations (i.e., garage and basement) exhibited very similar round-trip efficiency factors of 87%.

- **Recommendation** - Although attached garage spaces are usually unheated, they are transitional spaces between the indoor and outdoor environment. They inherit heat lost through the adjacent walls of the house, and often remain relatively warm. Future studies with more detail, such as monitoring the battery ambient temperature, longer-term investigation, and larger sample size, would help to understand the best location for these technologies.

Communication – The black box control approach and lack of openness about the control strategies from the battery energy management system vendor were issues in the project, especially because the battery mode of operation influences other decisions pertaining to DER events and management of resources.

- **Recommendation** – Future applications of solar PV and battery systems to maximise utility benefits require more openness about the control strategies and better communication between vendors and grid operators.

4.4 Future work

Scenarios and options analysis - The parametrized data-driven simulations developed in this study can be used to create scenarios and evaluate control strategies. By adjusting key parameters, such as system size, capacity, orientation, rate structure, and Time-of-Day (TOD) scheduling, the solar PV and battery energy storage system simulation model can be run to explore various scenarios. Additionally, these models can be scaled up to the district level for broader analysis and planning.

5 Conclusion

The Shediak Residential Energy Study evaluated the performance and user perceptions of solar photovoltaic and battery energy storage systems (SOL) in 75 homes, revealing significant benefits and challenges associated with these technologies. SOL participants reported high satisfaction with the project communication processes and their participation in the project. This satisfaction was largely attributed to bill savings, the system's ability to reduce grid dependency and greenhouse gas emissions, as well as resilience during power outages, such as those experienced during Hurricane Fiona.

The SOL systems demonstrated a substantial peak demand reduction for participants on TOD and reduced grid draw with bill savings for all, though the savings were higher for the TOD group as compared to the no-TOD. While Time of Day (TOD) and Solar Energy Credit programs provide significant benefits in managing energy demand, promoting renewable energy, and enhancing customer satisfaction, they also incur various costs. Specific programs targeting automated devices that can charge at off-peak hours would ensure financial viability while achieving generation targets.

Despite these positive outcomes, the study also highlighted challenges for owners, such as the perceived high initial costs and complexity of the systems, which deter broader adoption. Although most participants reported positive attitudes toward renewable technologies and valued their benefits, the calculated savings might not provide enough motivation to enable other customers to acquire such systems. Addressing these concerns through improved incentives and education could enhance user satisfaction and increase adoption rates. The insights gained from this study would be valuable for stakeholders and policymakers aiming to develop net-zero communities, develop DER incentive programs, explore subsidy options, and electricity rate structures.

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Appendix A - Open-ended responses about resilience

Some of the examples of responses were as follows:

"It is very comforting to know that I have that backup system. Also, I was never really comfortable with the idea of a generator; it can be dangerous. I prefer our Tesla battery." (SOL participant)

"Peace of mind and with climate change there are more power outages! We feel that we need to be better customers and with a safer power system!" (SOL participant)

"Gas generator provides some power for sump pumps, fridge, and freezer, lighting, and heat." (no-SOL participant)

"I have a 2200 W generator that provides me with peace of mind that I can have some energy for household essentials." (no-SOL participant).

For participants in both groups (SOL and no-SOL), some of the main challenges mentioned were the cost and financial impact, mainly related to installation, maintenance, system management, and efficiency. In the SOL group, participants reported some issues with improper installation, and some difficulties with regular maintenance requirements to ensure system reliability. They noted some limitations in the duration of backup power and the potential need for additional systems, like generators. Financial affordability was seen as one of the main challenges, due to possible high initial investment and ongoing maintenance costs. Other challenges included difficulties with integrating the system into existing home infrastructure and space requirements, performance issues, and the need for ongoing support and maintenance services.

In the no-SOL group, other challenges associated with backup power included regular maintenance of generators to ensure functionality, noise, and emissions generated by gas-powered generators, as well as fuel availability during extended power outages. The installation complexity and the need for professional assistance were also mentioned frequently as one of the main challenges, including the technology availability on the market.

Some of the examples of responses were as follows:

"Before being part of the project, we did not have backup power systems. The only difficulty that we would have is to financially afford any system. We would have to go with the cheaper system." (SOL participant)

"It provides a backup power. The challenge is that you have to be at home when the power goes out to manage the distribution of power..." (SOL participant)

"The cost of obtaining such a device would make it difficult at this time, but would definitely be worth it. We live in an area where power outages and brown-outs are quite common." (no-SOL participant)

"Gas-powered generator has proven useful in outages. However, it's loud and emits odors." (no-SOL participant)

Ease of acquiring backup

When talking about the easiness of acquiring backup power, the SOL group participants mainly reflected on the installation process with the backup power technology they received as part of this project. The SOL group appreciated the professional and smooth installation process, particularly, that the process was straightforward and hassle-free, and involved clear communication and minimal disruption. They were happy with the support and guidance throughout the process, with the prompt responses to inquiries and comprehensive maintenance services that contributed to their positive experience. Solar participants found the backup power system easy to use and manage, as the automated switching, user-friendly interfaces, and clear instructions contributed to perceived ease of use. The potential cost and financial impact of having such technology, specifically related to the high initial investment, the justification for the investments, and ongoing maintenance were reported as the main difficulties of this technology. The overall complexity of the systems, together with limited knowledge and support were also mentioned as the main challenges when acquiring backup power.

In the no-SOL group, some participants mentioned that they thought it would be relatively 'easy' and 'straightforward' to acquire and set up a backup power system. The main difficulties associated with this process were related to financial cost and investment, the limited knowledge about technologies, the complexity of the technologies, including the installation process and assistance, ongoing maintenance and support services, as well as environmental impacts (noise, emissions).

Some of the examples of responses about the easiness of acquiring backup power were as follows:

"I have the Tesla battery that comes with the solar panels from the Shediac community project. The installation was seamless and didn't disrupt our daily routine." (SOL participant)

"During outages, I can maintain an internet connection and cook hot meals. It is basically challenge-free" (SOL participant)

"I have a portable generator which I use to power my sump pump, freezer, and fridge. I had no challenges in acquiring this." (no-SOL participant)

"Depending on availability but should be relatively easy." (no-SOL participant)

Some of the examples of responses about difficulties with acquiring backup power were as follows:

"Integrating into the house electrical system was more complex than expected... you have to have adequate space in your garage for the batteries" (SOL participant)

"It gives you a short-term peace of mind when you have minor power outages. Obviously, long-term outages, I will have to use my generator." (SOL participant)

"When power out I have a 4200watts gas generator, its always a trouble to get the cord out! And generator is not strong enough to run the stove, heat, water heater but we always manage..." (no-SOL participant)

"I believe we could purchase a generator for \$500-\$1000 but it is not currently in our budget." (no-SOL participant)

Appendix B - Summary tables for SOL system telemetry

Table B.1. Summary of the average monthly telemetry data for households equipped with SOL systems. Impacts of SOL systems on demand, energy, bill, and GHG emissions reduction

Battery mode	Year	Month	Monthly Average from all households								
			Solar energy generation*	Household load	Grid draw	Net grid	Grid export	Battery charge	Battery discharge	Solar/battery on-site use	Battery - SOC
			kWh								
Backup reserve / No-TOD	2022	Dec.	107	2,539	2,547	2,451	-9	-87	73	166	93
	2023	Jan.	122	2,795	2,792	2,687	-25	-114	107	197	94
		Feb.	257	2,920	2,844	2,696	-55	-148	131	317	93
		Mar.	326	2,077	1,918	1,773	-75	-7	0	237	100
		Apr.	615	1,669	1,368	1,083	-213	-30	20	402	99
		May	728	1,481	1,204	788	-361	-127	110	459	97
		June	524	1,327	1,113	822	-238	-101	90	368	97
		July	719	1,505	1,116	814	-273	-109	91	528	97
		Aug.	549	1,305	1,081	781	-248	-121	105	397	97
		Sep.	481	1,236	1,063	779	-230	-110	94	337	97
		Oct.	327	1,275	1,171	960	-168	-98	85	245	98
		Nov.	227	1,991	1,964	1,789	-70	-117	102	249	93
		Dec.	147	2,345	2,432	2,224	-53	-122	106	190	94
	2024	Jan.	151	2,905	3,025	2,784	-53	-198	176	265	93
		Feb.	271	2,365	2,368	2,118	-79	-133	118	301	95
		Mar.	405	2,390	2,316	2,016	-131	-135	116	379	96
Time-based control / TOD	2022	Dec.	107	2,453	2,423	2,376	-2	-311	278	386	56
	2023	Jan.	122	2,616	2,556	2,515	-4	-312	286	409	56
		Feb.	257	2,812	2,676	2,572	-38	-351	319	553	59
		Mar.	326	1,890	1,694	1,589	-37	-324	286	588	64
		Apr.	615	1,589	1,149	982	-120	-358	332	845	73
		May	728	1,535	1,075	832	-204	-410	369	909	69
		June	524	1,426	1,088	931	-132	-346	310	708	68
		July	719	1,553	994	857	-140	-365	334	921	69
		Aug.	549	1,414	1,031	886	-125	-350	322	754	67
		Sep.	481	1,315	992	862	-109	-347	313	691	69
		Oct.	327	1,238	1,079	943	-70	-315	285	540	66
		Nov.	227	1,964	1,782	1,760	-20	-315	283	498	61
		Dec.	147	2,299	2,216	2,173	-18	-285	258	394	59
	2024	Jan.	151	2,867	2,770	2,750	-11	-302	262	408	57
		Feb.	271	2,352	2,151	2,105	-32	-287	256	502	61
		Mar.	405	2,361	2,042	1,973	-63	-359	332	684	61

*Note that solar generation is calculated based on the average output of all solar panel systems. The TOD and no-TOD do not affect solar energy generation.

Table B.2. Calculated impacts of the solar panels and battery storage systems on household performance – Summary of average effects on the monthly granularity

Battery mode	Year	Month	Average demand reduction from all households		Monthly average from all households									
			Peak demand reduction/ Weekday	Peak demand reduction/ Weekend	Monthly grid energy consumption savings	Bill without SOL	Solar energy credit	TOD credit	On-site use savings	Bill with SOL	Monthly total savings incl. SEC, TOD, on-site use	Monthly GHG emissions reduction - export	Monthly GHG emissions reduction - on-site use	Monthly GHG emissions reduction - Total
			kW		kWh				\$				kg CO ₂ e	
Backup reserve / No-TOD	2022	Dec.	0.100	0.029	-88	298	-1	0	-8	289	-9	-4	-49	-53
	2023	Jan.	0.250	0.024	-108	327	-1	0	-10	316	-11	-8	-58	-66
		Feb.	0.086	0.127	-224	332	-3	0	-19	310	-22	-20	-94	-114
		Mar.	0.108	0.221	-305	281	-5	0	-31	245	-36	-27	-70	-97
		Apr.	0.328	0.466	-586	214	-12	0	-47	155	-59	-71	-119	-190
		May	0.555	0.593	-693	180	-20	0	-39	122	-59	-115	-135	-250
		June	0.461	0.339	-505	167	-13	0	-32	122	-45	-76	-109	-184
		July	0.468	0.546	-691	183	-15	0	-50	118	-65	-86	-156	-242
		Aug.	0.337	0.332	-524	164	-13	0	-35	116	-48	-79	-117	-196
		Sep.	0.204	0.234	-457	151	-12	0	-27	112	-39	-73	-99	-172
		Oct.	0.081	0.075	-314	165	-9	0	-19	137	-28	-54	-72	-126
		Nov.	0.216	0.119	-202	258	-4	0	-18	237	-22	-25	-73	-99
		Dec.	0.034	0.046	-121	306	-3	0	-9	295	-12	-18	-56	-74
	2024	Jan.	0.024	0.012	-120	363	-3	0	-9	350	-12	-19	-78	-97
		Feb.	1.163	0.121	-248	313	-4	0	-24	285	-28	-26	-89	-115
		Mar.	0.282	0.070	-374	290	-7	0	-29	254	-36	-44	-112	-155
Time-based control / TOD	2022	Dec.	2.885	0.093	-77	287	0	-25	-11	250	-36	-1	-114	-115
	2023	Jan.	2.851	0.083	-101	312	0	-27	-14	271	-41	-2	-121	-123
		Feb.	3.550	0.124	-240	319	-2	-27	-26	264	-55	-14	-163	-177
		Mar.	2.948	0.299	-301	265	-2	-22	-48	193	-72	-12	-173	-186
		Apr.	2.339	0.664	-607	206	-6	-18	-67	114	-91	-38	-249	-287
		May	2.257	0.873	-703	188	-11	-21	-63	93	-95	-64	-268	-332
		June	1.873	0.531	-495	179	-7	-20	-47	106	-74	-41	-209	-250
		July	1.851	0.699	-695	190	-7	-17	-71	95	-95	-44	-272	-315
		Aug.	1.815	0.527	-529	178	-7	-18	-53	101	-78	-40	-222	-262
		Sep.	1.723	0.412	-453	162	-6	-16	-44	96	-66	-34	-204	-238
		Oct.	1.881	0.363	-295	163	-4	-18	-33	108	-55	-24	-159	-183
		Nov.	2.647	0.174	-203	252	-1	-27	-29	195	-57	-8	-147	-155
		Dec.	2.724	0.089	-126	299	-1	-23	-19	256	-43	-6	-116	-123
	2024	Jan.	2.939	0.033	-117	357	-1	-32	-16	308	-49	-4	-120	-125
		Feb.	3.314	0.159	-247	315	-2	-28	-36	249	-66	-11	-148	-159
		Mar.	1.830	0.130	-388	287	-4	-28	-34	222	-66	-22	-202	-224

Appendix C - Utility cost savings using ISO NE pricing

This section is associated with Section 3.4.1 and serves as an extension to the utility cost savings in the context of applying the day ahead Independent System Operator New England (ISO NE) pricing.

For this exercise, we examined the utility cost savings from application of day ahead ISO NE pricing to days during the winter 2022 with “highest hourly demand” (see Table C.1). The savings were calculated using SOL participants energy data. The days with “highest hourly demand” typically occurs during extremely cold weather when there is a high demand for electricity to heat buildings (Pardasani et al., 2025a).

The ISO NE prices are credible, publicly accessible, and a reasonable proxy for marginal energy costs in New Brunswick. The dates for “highest hourly demand” and “Day Ahead New England USD” prices converted to Canadian dollars were shared by NB Power with the NRC. We focused exclusively on the marginal savings from load shifting as a result of the technology and the TOD intervention.

Table C.1. Days with “highest hourly demand” between Dec. 1, 2022 and March 1, 2024 provided by NB Power

Index	Date	Index	Date	Index	Date
1	2022-12-12	15	2023-02-24	29	2024-01-19
2	2022-12-28	16	2023-02-25	30	2024-01-22
3	2023-01-11	17	2023-02-26	31	2024-01-24
4	2023-01-12	18	2023-02-27	32	2024-01-30
5	2023-01-25	19	2023-02-28	33	2024-01-31
6	2023-02-01	20	2023-03-02	34	2024-02-08
7	2023-02-02	21	2023-12-06	35	2024-02-09
8	2023-02-03	22	2023-12-08	36	2024-02-16
9	2023-02-04	23	2023-12-22	37	2024-02-20
10	2023-02-05	24	2024-01-06	38	2024-02-21
11	2023-02-06	25	2024-01-07	39	2024-02-22
12	2023-02-07	26	2024-01-08	40	2024-03-01
13	2023-02-15	27	2024-01-09		
14	2023-02-23	28	2024-01-18		

To assess the impact of SOL systems in helping to reduce utility power purchase costs, a side-by-side comparison was conducted for each dwelling. For each dwelling with SOL, a baseline was established representing the same dwelling without SOL. We then compared each dwelling to its baseline, applying ISO New England rates to both scenarios. The difference in costs between the baseline and actual SOL dwelling reflects the savings or penalties due to SOL deployment.

$$Cost_{SOL,NE} = Grid(t) * rate_{NE}(t) \dots \dots (16)$$

$$Cost_{BL,NE} = Load(t) * rate_{NE}(t) \dots \dots (17)$$

$$Diff_{Cost,NE} = Cost_{SOL,NE} - Cost_{BL,NE} \dots \dots (18)$$

Equation 16 calculates the cost of electricity for a given SOL dwelling using the ISO New England rates. Equation 17 calculates the cost of electricity for the same dwelling under the baseline (BL) scenario, where the SOL system is isolated. To elaborate, the baseline scenario accounts for only household electricity usage and does not have any grid interaction with the SOL components (i.e., solar PV, and battery charge and discharge). Hence, the BL scenario provides a reference to quantify the change in grid draw resulting from the SOL deployment. More detail can be found in Section 2.4. Equation 18 calculates the cost savings of the SOL scenario in comparison to the BL scenario.

Utility cost savings are achieved due to the shift in grid draw. In case of SOL deployment, the household energy use remains unchanged; instead, battery energy storage acts as a buffer, controlling when and how much energy is drawn from the grid. The shift in grid draw occurs due to battery programming, which discharges the battery system during peak periods and recharges it during off-peak times. Additionally, battery dispatches also shift the grid draw.

Solar self-use is normally regarded as avoided grid draw rather than a shift in household energy usage. Its contribution to the utility cost savings can be evaluated at the full purchase price for the prevailing hour, rather than the differential between the SOL and BL scenarios. For example, shifting 100 kWh of energy from an hour with a market price of \$50/MWh to an hour with the price of \$40/MWh creates \$1 in savings. However, if the energy is avoided rather than shifted, the value or savings is \$5, determined by the price of the hour.

In Table C.2, we have summarized the shift in grid draw per household per day for days with the “highest hourly demand”. The 40-day dataset is categorized based on TOD group assignment (TOD and no-TOD), type of day (weekday or weekend), and dispatch status (dispatch or regular day). This categorization allows us to analyze the influences of various parameters on grid draw and utility savings under different conditions and timeframes.

The results indicate that the effect on grid draw is most significant during regular (non-dispatch) days for both TOD (9.89 kWh/household/day) and no-TOD (9.82 kWh/household/day) groups. Conversely, utility savings in dollar amounts are highest during dispatch days for both no-TOD (CDN \$1.12/household/day) and TOD (CDN \$1.10/household/day) compared to regular days.

The higher savings observed in the no-TOD group during dispatch days can be attributed to their backup reserve mode of operation. This mode allows batteries to receive dispatch signals when they are at full state of charge (100% SOC), whereas the TOD group's batteries may be partially charged due to discharging during on-peak periods. This difference is further supported by the utility savings observed during regular weekdays, where the TOD group's savings exceed those of the no-TOD group.

Table C.2.. Shift in grid draw and associated utility savings on selected days per household per day, grouped by TOD status, dispatch status, and day type

TOD Status	Dispatch Status	Day Type	N. Days	Shift in Grid Draw (kWh/Household/Day) M (SD)	Utility Savings (CDN\$/Household/Day) M (SD)	N. Participants	Total 40-day utility Savings from ALL SOL (CDN\$)
TOD	Dispatch Day	Weekday	19	-5.48 (6.64)	-\$1.10 (\$1.04)	37	-\$1,296
	Regular	Weekday	15	-9.89 (7.86)	-\$0.63 (\$0.61)		
	Regular	Weekend	6	-5.81 (4.26)	-\$0.86 (\$0.91)		
No-TOD	Dispatch Day	Weekday	19	-6.23 (6.04)	-\$1.12 (\$0.95)	38	-\$1,315
	Regular	Weekday	15	-9.82 (7.48)	-\$0.49 (\$0.53)		
	Regular	Weekend	6	-4.76 (3.79)	-\$0.91 (\$1.05)		
Total number of days			40		Total number of participants	75	-\$2,610

Chapter 6: Effect of Time-of-Day Electricity Rates

Ajit Pardasani, Jennifer A. Veitch, Yitian (Vera) Hu, Hadia Awad, and Natalia Cooper

Executive Summary

The Shediac Residential Energy Study examined the effects of various smart energy technologies on residential energy consumption, peak electrical demand, and participant attitudes. One of its interventions was a test of Time-of-Day (TOD) electricity rates. This intervention study aimed to provide insights into the efficacy of TOD pricing as a tool for demand management and energy conservation. The study also included cold-climate mini-split heat pumps (CC-MSHP) and rooftop solar photovoltaic panels paired with battery energy storage (SOL). Participants who did not receive either of these technologies formed the no-Tech group.

The Shediac Residential Energy Study was a quasi-experiment in a field setting, involving 529 households at the beginning in 2019, and 333 remaining in the project at its conclusion in 2024. Most of the attrition occurred because of participants selling their homes and moving. Data were collected through smart meters, smart devices such as smart thermostats, home assessments, surveys, and monthly bills.

TOD methodology

Participants were divided into TOD and non-TOD (no-TOD) groups using stratified random assignment. We used data from May 1, 2021 – May 21, 2022 for the baseline period. The TOD intervention commenced on May 22, 2022 and continued until March 31, 2024. During the intervention period, participants in the TOD group received information from the project about how to take advantage of TOD electricity rates. The TOD rates are shown in Table ES.1. Participants were billed using the regular flat rate for electricity, which was equivalent to the mid-peak rate in the table. If applying the TOD rates to their pattern of electricity usage would have resulted in a lower bill, the difference was paid to them as a TOD credit on their monthly bill. They could not be penalized; if the difference would have resulted in a higher bill, the TOD credit for that month was \$0. All participants could see their electricity usage in almost real time on a bespoke energy portal; TOD participants could also download a shadow report that detailed their TOD electricity use and credits, if any.

Table ES.1 The TOD electricity rates (\$/kWh) tested in this trial.

	Weekdays		Weekends and holidays	
	May 2022 – Mar. 2023	Apr. 2023 – Mar. 2024	May 2022 – Mar. 2023	Apr. 2023 – Mar. 2024
On-peak 7:00 – 9:00	\$ 0.2564	\$ 0.2752	\$ 0.1138	\$ 0.1215
Mid-peak 9:00 – 22:00	\$ 0.1138	\$ 0.1215		
Off-peak 22:00 – 7:00	\$ 0.0738	\$ 0.0784		

The analysis of energy data employed a Difference-in-Differences (DiD) statistical approach to compare changes in energy use between the baseline and the experiment periods, with TOD as the experimental group, and no-TOD as the control group, while accounting for outdoor temperature. Both energy consumption and peak electricity demand were outcomes of interest.

Participant attitudes were recorded before, during, and at the end of the TOD trial using online surveys. Where appropriate, the TOD and no-TOD groups were compared using t-tests.

TOD key findings

Peak Demand Reduction: The introduction of TOD rates led to a reduction in average morning peak demand across dwellings, although the savings depended on the type of heating system and sample size. For example, the no-Tech (all dwellings that did not receive solar PV and battery storage or cold climate mini-split heat pumps) group saw a 3.3% reduction in winter 2022, though this effect was not statistically significant in winter 2023. The existing MSHP group (participants whose homes were heated with mini-split heat pumps not provided by the project), reduced their average demand by 5.4% in winter 2022 and 3.0% in winter 2023.

Energy Conservation: While TOD rates primarily target load shifting, this study observed that they also unintentionally led to energy conservation. The existing MSHP group achieved a 3.4% reduction in daily energy usage during the winter 2022. Additionally, the central heat pump group achieved a 4.3% reduction in the winter 2022 and 3.9% reduction in the winter 2023.

Bill Effects: Analysis showed that TOD billing resulted in small favourable bill effects, with most participants experiencing some bill savings.

During the TOD experiment from June 2022 to March 2024, no-Tech TOD participants received an aggregated sum of \$4,645 in bill credits. Without protection against penalties, their total billing would have increased by \$5,538 (a difference of \$893 across all participants). The peak reduction resulted, on average, in small financial benefits for participants, but only during the winter months. The variability in TOD credits was very large. Some participants could have experienced bill increases on the order of \$60 monthly in a season had there been bill penalties.

Participant Behaviour and Attitudes: Surveys indicated improved knowledge and awareness of TOD rates among participants. Most reported efforts to adapt to TOD pricing, despite minimal financial rewards. There was a high level of interest in participating in a TOD rates program in future if one were offered.

Conclusion

The TOD rates intervention successfully caused small reductions in average morning peak electricity demand and (somewhat unexpectedly) total daily energy use. The effect of the intervention on shifting electricity usage away from the daily morning peak was observed to be dependent on the type of heating system being used. Despite the meagre financial benefits of this intervention, participants reported very favourable attitudes towards TOD rates provided that making the behavioural changes were convenient and maintained their comfort.

Challenges and limitations

The study faced limitations due to small sample sizes and attrition, reducing statistical power. Additionally, the complexity of participant schedules and limited energy literacy posed challenges to maximizing the benefits of TOD rates.

Recommendations

Enhanced Communication: Clear messaging and education about TOD benefits and strategies are essential for maximizing participant engagement and energy savings.

Technology Integration: Increased adoption of smart technologies could further improve the effectiveness of TOD rates.

Tailored Approaches: Customizing TOD programs to align with participant demographics and behaviours may enhance acceptance and impact.

The study underscores the potential of TOD pricing as an effective tool for modern grid management, leveraging economic signals to optimize fuel consumption, purchased power, and capacity costs.

1 Introduction

Societal responses to the urgent need to reduce carbon emissions pose challenges for electric utilities. The pressure to reduce carbon emissions – for example, by adopting electric vehicles to replace gas combustion engines – adds to rising electrical demand at the same time as utilities seek to reduce their own carbon emissions by adding renewable energy sources to the grid. The need to maintain grid stability can mean that it is as important to reduce peak demand as to improve efficiency. Using smart internet-connected technologies and obtaining customer permission to manage electrical loads through distributed energy resources (DERs) can help utilities to address peak demand.

Another method is to adopt variable electricity rates based on demand. Peak demand generally follows a regular pattern in any given area, with the peak occurring around the same time on most days. Therefore, many utilities use a price signal to motivate changes in the time of day at which customers use electricity, charging a higher rate at the time of day when demand is usually highest. Such time-of-day (TOD) pricing is an essential tool in modern grid management, offering a cost-effective solution to enhance grid reliability and stability without the immediate need for substantial infrastructure upgrades.

This report is one of a family of reports from the Shediak Residential Energy Study, focusing in this instance on a trial of TOD electricity rates and their effects on peak electrical demand, overall energy use, participant energy use behaviours and attitudes towards the TOD intervention. Details concerning the study as a whole are provided by Veitch et al. (2025).

1.1 Background

TOD electricity rates are designed to reflect the varying cost of generating and delivering electricity at different times. These rates can vary significantly depending on the region and the local utility company. Here is a generic sample of how these rates might be structured:

On-Peak Hours: This is when electricity demand is highest, typically during the afternoon for summer peaking (e.g., 11 a.m. to 5 p.m. on weekdays in Ontario) and early morning for winter peaking regions (as is usually the case in New Brunswick). Rates are usually highest during these hours to encourage reduced consumption.

Mid-Peak Hours: These are times when electricity demand is moderate, such as during the morning and early afternoon (e.g., 7 a.m. to 11 a.m. and 5 p.m. to 7 p.m. on weekdays in Ontario). Rates are typically in between peak and off-peak rates.

Off-Peak Hours: Rates are usually lowest during these hours. These are periods when electricity demand is lower, often during the night (e.g., 7 p.m. to 7 a.m. weekdays, in Ontario) and all day on weekends and holidays.

Newsham (2019) reviewed the literature on TOD rates with a focus on the energy use and customer billing outcomes of studies conducted in locations in North America and Europe with electric heating and very cold winters. The majority of TOD deployments have occurred in summer-peaking regions, aiming to reduce air conditioning load during periods of peak system-wide demand, where the primary winter heating fuel is natural gas. Thus, most deployments have limited direct relevance to the situation in New Brunswick, and studies focusing on winter-peaking regions are scarce. Utilities, he found, typically design TOD rates to be revenue-neutral, ensuring that on average customers who do not change their behaviour do not incur higher bills than under standard fixed rates. TOD programs almost always resulted in a reduction in average peak period usage, although the reduction was sometimes only a few percent. There was also sometimes a small overall conservation effect. However, certain

customer profiles may lead to bill increases, necessitating the provision of bill protection mechanisms for low-income households.

The following regions around the world have deployed Time-of-Day rates (Faruqui, Sergici, & Lam. 2020):

- Ontario, Canada
- France
- Great Britain
- Italy
- Arizona (APS, SRP)
- California (PG&E, SCE, SDG&E, SMUD)
- Colorado
- Michigan (Consumers Energy)

Xcel Energy began transitioning its Colorado residential customers to Time-of-Day (TOD) rates in 2022, with plans to complete the transition by October 2025 (XcelEnergy, 2025). Customers have the option to opt-out and instead remain on the flat rate plan. Initially, Xcel Energy implemented a three-tier rate system consisting of on-peak (3 p.m. to 7 p.m.), mid-peak (1 p.m. to 3 p.m.), and off-peak (all other times, including weekends and holidays) rates. However, in February 2025, they received regulatory approval to eliminate the mid-peak rate and adjust the on-peak period to later in the evening, from 5 p.m. to 9 p.m..

Hydro-Québec's dynamic pricing, while not time-of-day (TOD) pricing, deserves mention because both Quebec and NB Power are winter peaking systems. Hydro-Québec offers lower electricity pricing during the winter through critical peak rebate and critical peak pricing options under their demand response program (Doonan, 2022). Customers are notified the day before about upcoming events, typically on very cold days, to help them manage their energy use. An average curtailment of 1 kW per dwelling was observed in 2021, which is similar to the results observed by the NRC during the 567-home demand control study (Pardasani et al., 2020).

An analysis of TOD rates in Ontario from 2009 to 2014 found that these rates reduced summer peak usage by 3.3% before 2012, 2.3% in 2012, 2.0% in 2013, and 1.2% in 2014. Winter load shifting impacts were lower and also decreased each year. No electricity conservation was observed (Faruqui & Bourbonnais, 2020). Ontario is a summer-peaking province because of cooling loads and natural gas is the prevalent mode of heating, although electric heating is more prevalent in the north. The segmented winter results from the sub-sample of customers in the northern part of the province (N=12,401), which had the coldest winters and had a higher proportion of electric heating, showed usage reductions of 2.55% and 2.17% during the morning and evening winter peak periods, respectively, in the pre-2012 period. These reductions decreased to 0.97% and 0.50% by 2014 (Faruqui et al. 2016).

The implementation of TOD rates has generally resulted in measurable, but modest, reductions in peak period usage, ranging from a few percent to slightly higher in some cases. The effectiveness of TOD rates in reducing peak demand is often correlated with the ratio between peak and off-peak prices, with higher ratios leading to greater reductions. When combined with enabling technology such as smart thermostats, battery energy storage, the effect is stronger.

The design of TOD rates keeps evolving to keep pace with change in customer load profiles. Increasing adoption of solar photovoltaics is prompting some utilities with a high penetration of solar generation to rethink the structure of residential TOD rates. For example, California is delaying the start of the peak period by five hours; the new peak period in San Diego will be from 4 p.m. to 9 p.m., whereas it previously began at 11 a.m. (Faruqui, Hledik, Sergici, 2019).

Engaging customers in a TOD rate program requires awareness and education (Yang et al., 2018), starting from the recognition that many customers lack a clear understanding of how their electrical bills are calculated (Design, 2019). People are not straightforward rational economic decision-makers who choose to act based only on the simple balance of costs and benefits; personal attitudes, values, social and moral norms, as well as risk or loss perceptions, all influence the acceptance of TOD rates (Rabin, 2002).

Nobel-prize-winning research into risk perception has established that people care twice as much about avoiding losses than receiving gains (also called loss aversion) (Kahneman and Tversky, 1979, Tversky and Kahneman, 1991), even when the losses are not financial. This risk aversion carries over into decisions about participating in TOD programs; for example, a UK study found that participants would be willing to adapt their household practices to price changes as long as the changes did not negatively affect their quality of life (Ozaki, 2018). Conversely, however, other investigations have emphasized price incentives as the most efficient strategy to achieve reductions in household electricity consumption, either by charging higher prices during peak times or providing a lump sum as an incentive to reduce consumption (Nilsson et al., 2018, Ito et al, 2018; Ito et al., 2023).

Program design influences uptake, with programs that make TOD rates the default showing greater success in reducing demand than those requiring customers to opt in (Fowlie et al., 2021; Faruqui and Bourbonnais, 2020; Nicolson et al., 2018). Nonetheless, messaging and framing strategies will influence acceptance and TOD program success, especially when tailored to the characteristics of the population. Environmentally conscious respondents may accept a TOD program with a lower benefit to themselves (i.e., a smaller discount for off-peak use) when the environmental and system benefits of the TOD program are explained to them, and the more so when the time-shifting behaviours were seen as easy (Buryk et al., 2015). In other contexts, the societal or national benefits of grid stability can motivate participation (Parag, 2021).

Making TOD uptake easy by using smart, internet-enabled technologies is receiving increasing research attention. Automated thermostats that change setpoints according to TOD rates can substantially increase the success of TOD pricing programs (Blonz et al., 2023). Smart thermostats reduced peak usage by 11% for every 10% increase in the peak-to-off-peak price ratio, compared to 6.5% for those without such technologies (Faruqui and Bourbonnais, 2020). A higher willingness to shift behaviours was also found in owners of electric vehicles (Nicolson et al., 2017). Moreover, customers on TOD rates may be more likely to adopt other efficient technologies including solar photovoltaics (Liang et al., 2020).

In summary, successful implementation of TOD rates requires an understanding of the values and attitudes of customers; a straightforward, easy-to understand plan; messaging tailored to the customer base; and a sufficiently large spread between high and low rates that customers can detect the price signal and act to avoid the loss incurred by high usage during the peak rate period. The ease of the behavioural change required to reduce peak usage will influence TOD program success, and this can be facilitated using smart technologies.

1.2 Objectives

The TOD trial in the Shediak Residential Energy Study addressed the following questions:

- What is the impact of TOD on daily energy use?
- What is the impact of TOD on winter peak demand?
- What is the impact of TOD on participants' bills?
- What are the perceptions of participants about the TOD rates?
- What is the satisfaction and acceptance level of participants regarding the TOD rates?

- What actions did participant take to benefit from TOD rates?

2 Method

2.1 Participants

Participants in the TOD intervention were part of the larger study. The details concerning recruitment, as well as collection of demographics, electricity use, and dwelling data are described in Veitch et al. (2025). Demographic information was collected by online surveys (survey #1 in particular), and dwelling data came from an in-person home assessment in winter 2020 (HA1), immediately prior to the COVID-19 pandemic. Smart electricity meters were installed in participant homes in winter 2020 to provide 15-minute average electricity use data. The pandemic forced a lengthy pause in the study while direct participant contacts were not permitted.

Participants were assigned by the NRC in December 2021 to the research groups for TOD (who received the intervention) and no-TOD (who received no intervention). The assignment was assisted by an internally developed automated tool to achieve equality in the two groups on the following variables:

8. 2020 electricity load profile based on the smart meter data;
9. Shift in peak demand in 2021 from 2020, based on the smart meter data, addressing the effect COVID-19 on the energy use profile;
10. Daily occupancy schedule of participants as reported in survey #1;
11. Primary heating system type (from HA1);
12. Dwelling type (e.g., detached, semi-detached, from HA1);
13. Floor area (from HA1);
14. Household income as reported in survey #1.

The assignment procedure also took into account the expected technology group assignments, so that the homes that would be offered either heat pumps or solar + battery energy storage systems included half TOD and half no-TOD participants. (See Cooper et al., 2025; Hu et al., 2025, and Veitch et al. 2025 for more detail on these technologies.) Unfortunately, the final technology group assignments (which were made following a second home assessment after the TOD group assignments) left an imbalance between TOD and no-TOD for the cold-climate mini-split heat pump (CC-MSHP) group (see Table 1).

Of the 427 active participants in spring 2022, half were assigned to the TOD group (N=211) and half to the no-TOD (N=212) group. Four participants for whom there was no data on any or all of these attributes did not receive any TOD intervention materials and their energy use, billing, and survey data were excluded from all further TOD analyses.

For the present report, data from the participants who received solar + battery energy storage systems (SOL) were excluded because their electricity use pattern differed dramatically from the rest of the sample. The TOD results for the SOL group have been reported in Cooper et al. (2025). The present report includes survey data from all participants except the SOL group and the four excluded cases.

Table 1 shows the demographic characteristics of the participants and dwellings represented in the survey data discussed in this report. We report age, sex, and household income as reported in survey #1. Daily occupancy patterns did change because of the pandemic; we have reported the occupancy pattern from June 2022, which are the data closest to the start of the TOD trial in May 2022. Concerning the heating systems, we report the data as of the end of the study. Uptake of heat pumps was high in this community even at the start of the project (over 60% of the full sample) and several participants

acquired them at various times during the project. For those who independently purchased heat pumps during the project, it is uncertain exactly when they came into use and what capacity they had.

Table 1. The characteristics of the TOD and no-TOD groups whose data are reported here.

	TOD N	TOD %	no-TOD N	no-TOD %
Survey respondent sex (Winter 2020)				
Male	96	57.1	103	61.3
Female	70	41.7	65	38.7
Survey respondent age (Winter 2020)				
21-30	5	3.3	8	5.3
31-40	26	17.3	29	19.1
41-50	41	27.3	33	21.7
51-60	32	21.3	35	23.0
61-70	24	16.0	31	20.4
71-80	20	13.3	9	5.9
81+	1	0.7	5	3.3
Prefer not to say	1	0.7	2	1.3
Household Income (Winter 2020)				
<\$20k	3	1.8		
\$20k<\$40k	17	10.1	13	7.8
\$40k<\$60k	28	16.6	21	12.6
\$60k<\$80k	24	14.2	22	13.2
\$80k<\$100k	23	13.6	20	12.0
\$100k<\$150k	45	26.6	45	26.9
\$150+k	23	13.6	30	18.0
Don't Know	6	3.6	16	9.6
Home area (SF) (HA1)				
0-1000	14	8.0	10	5.7
1000-2000	124	71.3	122	70.1
2000-3000	30	17.2	31	17.8
3000-4000	3	1.7	8	4.6
4000-5000	2	1.1	3	1.7
>5000	1	0.6	0	0.0
Daily Occupancy Pattern (Spring 2022)				
Someone always home	86	69.9	84	66.7
Someone home part of the day	24	19.5	26	20.6
Out all day, back in evening	13	10.6	16	12.7
Heating System (March 2024)				
No heat pump ever	22	12.6	29	16.7
Heat pump at start	114	65.5	120	69.0
Heat pump purchased during project	23	13.2	17	9.8
Heat pump given by project (CC-MSHP)	15	8.6	8	4.6

Although 423 participants were assigned to either the TOD or no-TOD groups, the sample sizes vary for the different analyses reported here. Surveys were voluntary and not every participant completed each survey. Technological problems resulted in data loss periodically from smart meters and smart thermostats. The project as a whole experienced attrition over its life from 2019 to 2024, primarily because of participants selling their homes and moving. A special instance of attrition that affected the TOD trial was the decision to extend the project for an additional nine months, changing the end of data collection to March 31, 2024 from June 30, 2023, primarily to ensure at least one full year of data collection for the technology group with solar panels and battery energy storage. Some participants chose not to extend their participation for the additional time. Analyses proceeded with the maximum data available.

2.2 Independent variables

2.2.1 Time-of-Day intervention

The TOD intervention began in May 2022 and continued until the end of March 2024. At all times, all participants received their regular monthly electricity bill and were charged for electricity use at the flat rates approved by the New Brunswick Energy and Utilities Board, which was a flat rate. During the TOD trial, participants in the TOD group were eligible to receive a credit on their electricity bill if the result of their electricity use with the TOD rates applied produced a lower charge than the regular flat rate. It was not possible for participants to be charged more for their electricity use than the regular flat rate, so there was no penalty for failing to shift the time of their electricity use in response to TOD rates.

The rate structure tested in this intervention was developed by NB Power with input from the NRC and was designed to be revenue-neutral to the utility in non-experimental settings. The TOD rates tested in this project are shown in Table 2. In New Brunswick, the system peak demand generally occurs in the morning between 7:00 and 9:00, with a smaller peak in the afternoon. The hourly total marginal costs, including fuel, purchased power, and capacity costs for NB Power, are on average higher during the morning peak. Therefore, this was the period designated for on-peak higher rates. The mid-peak rate was the flat rate charged to all New Brunswickers. The rates increased in the second year of the trial together with the general increase in the approved flat rate for electricity on April 1, 2023. The TOD rate structure did not change as a result of this increase.

Table 2. The TOD electricity rates (\$/kWh) tested in this trial.

	Weekdays		Weekends and holidays	
	May 2022 – Mar. 2023	Apr. 2023 – Mar. 2024	May 2022 – Mar. 2023	Apr. 2023 – Mar. 2024
On-peak 7:00 – 9:00	\$ 0.2564	\$ 0.2752	\$ 0.1138	\$ 0.1215
Mid-peak 9:00 – 22:00	\$ 0.1138	\$ 0.1215		
Off-peak 22:00 – 7:00	\$ 0.0738	\$ 0.0784		

Participants were provided with the opportunity to see their electricity consumption using a bespoke Participant Energy Portal developed for this study. All participants regardless of experimental group were provided with an opportunity to register on the portal starting in May 2021 (one year before the TOD trial started). The portal allowed them to see the time of their electricity use in close-to real time.

During the TOD intervention, each month the TOD participants received shadow reports corresponding to their billing periods. A sample shadow report is shown in Figure 1. These reports were delivered through the Participant Energy Portal, and participants received an e-mail notice when each month's report had been posted. The reports illustrated what their current bill would be under the TOD rate structure and reported any TOD bill credits that would appear on their monthly bill. The report was designed to help participants understand the consequences of their actions on their electricity usage and the potential bill savings of shifting their usage to different times of day. If their performance had led to a bill credit, it appeared on their next month's bill against a short text identifying the credit as being a "Shediac Smart Community Project – Time-of-Day Credit".

THIS IS YOUR SHADOW REPORT – SHEDIAC SMART ENERGY COMMUNITY PROJECT – AND IS FOR INFORMATION PURPOSES ONLY.

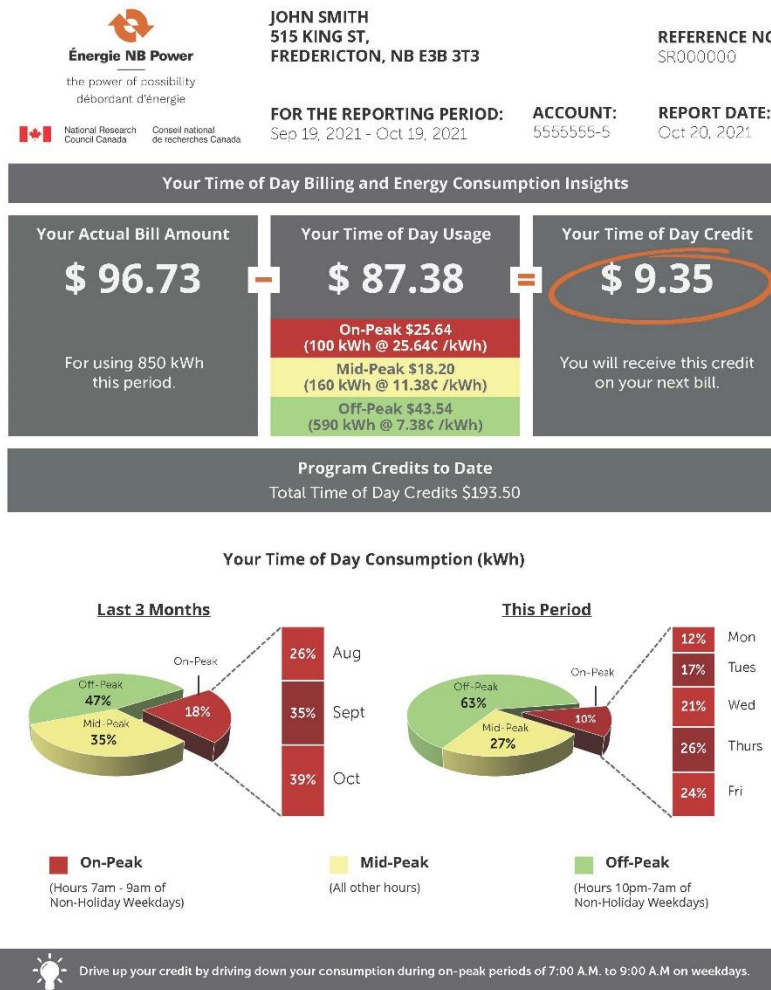


Figure 1. This is a mock-up of a shadow report showing how TOD performance was communicated to participants each month.

TOD participants were given instructions on how to take advantage of the TOD program. The program launch was introduced with a paper brochure mailed to each participant in April 2022. This was followed with a correction in June 2022 after a misprint had been found. Appendix A.1 shows the brochure.

More detailed instructions for TOD actions were provided using the Participant Landing Page (a different web site from the Participant Energy Portal). In summer 2022 there were instructions for the cooling season (Appendix A.2). For winter 2022, participants were informed by e-mail in mid-December that they could find information on the Participant Landing page specific to their home heating system (Appendix A.4). There were five variations of the information, but each participant saw only the one specific to their primary heating system as it had been identified in the Home Assessment 1 in winter 2020. A notable feature for homes without heat pumps was instruction on a night-time setback with a preheat setting before the morning peak hours and a setback during the peak hours. Prior research had shown that this strategy could be effective to reduce the morning peak in homes with electric baseboard heating (Pardasani et al. 2018).

Analysis of the results for the first year of the intervention, with a particular focus on winter 2022 (December 2022-February 2023) showed that homes that had set back their temperature settings overnight had a higher peak electricity demand than those which had maintained a stable temperature without a night-time setback⁴. This phenomenon was also observed in previous studies that evaluated peak shift strategies using smart thermostats in occupied homes in New Brunswick (Pardasani et al., 2017). The team decided on a simplified message for winter 2023: “Choose a comfortable temperature setpoint for your heating system and leave the thermostat at that setting: Set it and forget it.” All TOD participants were invited to attend an in-person information session between October and December 2023. This provided an opportunity to hear feedback from them, but its main purpose was to deliver this TOD message concerning the best way to take advantage of TOD rates that winter. At the same time, the “TOD tips” pages on the Participant Landing Page were updated to the single message, regardless of heating system type (Appendix A.40).

Thus, the intervention consisted of a rate structure; quasi-real-time electricity use visibility; monthly performance reports (‘shadow reports’); monthly TOD credit line on the electricity bill; e-mail reminders about the program; summer and winter tips for TOD participants available online; and an in-person workshop with instructions and an opportunity to provide feedback, in the second year of the intervention.

2.2.2 Heating system type

With electricity being the principal fuel for space conditioning (heating and cooling) in New Brunswick, space conditioning was the largest single electricity use in participant homes. Different heating system types have different load profiles and were expected to deliver different outcomes depending on how participants used them.

Results for cold-climate mini-split heat pumps (CC-MSHP) are based on the 23 homes that received these units from the project. The results for these homes are reported by Hu et al. (2025).

For homes that did not receive complex technologies from the project (no-Tech), home assessment data (HA1; see Veitch et al., 2025) was used to create subsets of data with which to better understand the effects of the TOD rates on homes with varying heating system types, while maintaining adequate sample sizes for each group:

- Dwellings that use mini-split heat pumps (MSHP) as primary source of heating and electric baseboards (EB) as secondary. This subset could have multiple-head or multiple MSHPs and dwelling could have multiple thermostats.
- Dwellings that use a central heat pump as the primary heating source.

2.3 Data sources and preparation

2.3.1 Surveys

Seven surveys were conducted during the study, all administered online. These are described in detail in Veitch et al. (2025). This report includes results of questions pertinent to the TOD objectives described above:

- Understanding of their electricity bills;

⁴ The 2022 Energy Planning Survey by NBP revealed that most New Brunswickers lower their thermostats at night and when nobody is at home; 68% of New Brunswickers report using this method for conserving energy [New Brunswick Power, 2023].

- Expectations of their ability to change the timing of their electricity-use behaviours and, for TOD participants, their experiences of the ease of this change;
- Expectations of the possible financial benefits of a TOD program;
- For TOD participants, satisfaction with the TOD program;
- Participants' reports of the times at which common electricity use actions take place.

2.3.2 Project event log

The NB Power team maintained a calendar of events for the town of Shediac in form of a spreadsheet that logged the following data throughout the project:

- COVID-19 related health related phases
- School closures
- Statutory holidays
- Major storms
- Planned outages
- Unplanned outages and power outage data
- Major public events
- Major project related events

The data from the project event log was used to understand the cause for missing smart meter data and anomalies in energy usage profiles. For instance, data from days with major storms and unplanned outages could be excluded from the analyses.

2.3.3 Electricity use data

As described elsewhere, smart electricity meter data provided electricity demand data for each house, with values for 15-min averages delivered and ingested into the NRC SQL data warehouse (Pardasani, 2025).

Ensuring the integrity and reliability of this data through validation is crucial for accurate analysis and meaningful results. The data validation was a two-step process. The first step involved the application of Validation, Estimation, and Editing (VEE) rules on the smart meter data by NB Power. The data received at the NRC had undergone the VEE process, and was further subjected to a data quality check and cleaning.

VEE rules are procedures used by utility companies to ensure the accuracy and completeness of smart meter data. These rules involve performing rigorous checks to validate the data, raising flags if values lie outside the expected bounds, and identifying any anomalies or gaps that need attention. When data is flagged for estimation due to missing or erroneous values, the VEE process steps in to fill these gaps with estimated values, particularly for short time intervals (refer to Appendix B for a list of VEE Rules).

The NRC conducted a thorough data completeness check on the smart meter data received from NB Power. This process involved assessing the presence and continuity of data points within the period of analysis. If the data for any period or any smart meter was found to be missing beyond the predetermined threshold (50% of expected data points), we excluded that period or that meter from our analysis. Figure 2 shows the percent data completeness for the period May 2021 to March 2024.

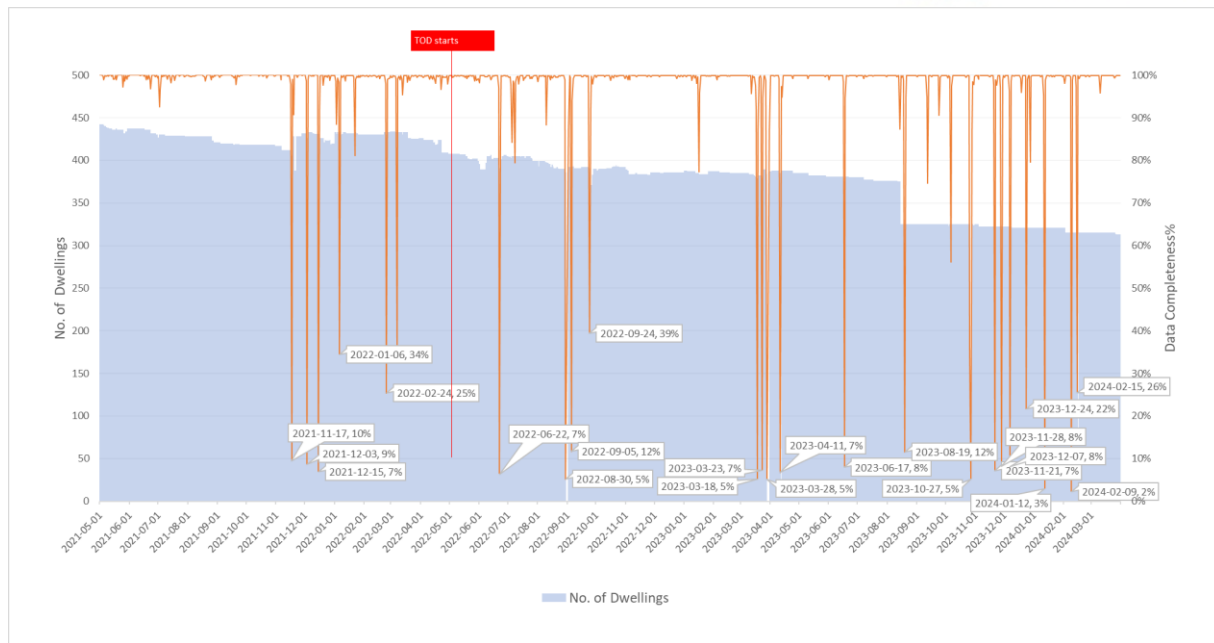


Figure 2. Percent data completeness for a period May 2021 to March 2024.

Two outcome measures were derived:

- Average peak demand (kW) was the average of the 15-min data for each house between 7:00 a.m. and 9:00 a.m. on each weekday. Weekends and holidays were excluded. The outcome measure for analyses reported below is the average daily morning peak demand for the experimental groups, no-TOD and TOD. That is, the house-level data for each day for all participants in one experimental group was averaged to give a single score for that group for that day. Regression analyses then paired this daily group average with the weather data for that date.
- Total energy use (kWh) for the day was the sum of the 15-min energy use data for each house on that weekday. Weekends and holidays were excluded. The outcome measure for the regression analyses below is the average total energy use per day for the experimental groups, no-TOD and TOD. That is, the house-level data for each day for all participants in one experimental group was averaged to give a single score for that group for that day. Regression analyses then paired this daily group average with the weather data for that date.

The usable dataset progressively decreased over time from 2019 to 2024 due to attrition and periodic technological issues with smart meters and other devices. For these analyses, we used data from May 1, 2021 – May 21, 2022 for the baseline period. We focused on winters for the intervention periods, and did so with two analyses: winter 2022 (dataset A, N=421) and winter 2023 (dataset B, N=322). The cases in dataset B are also present in dataset A. The drop in cases arose from people who chose not to stay in the project for the nine-month data collection extension, as illustrated in Figure 3.

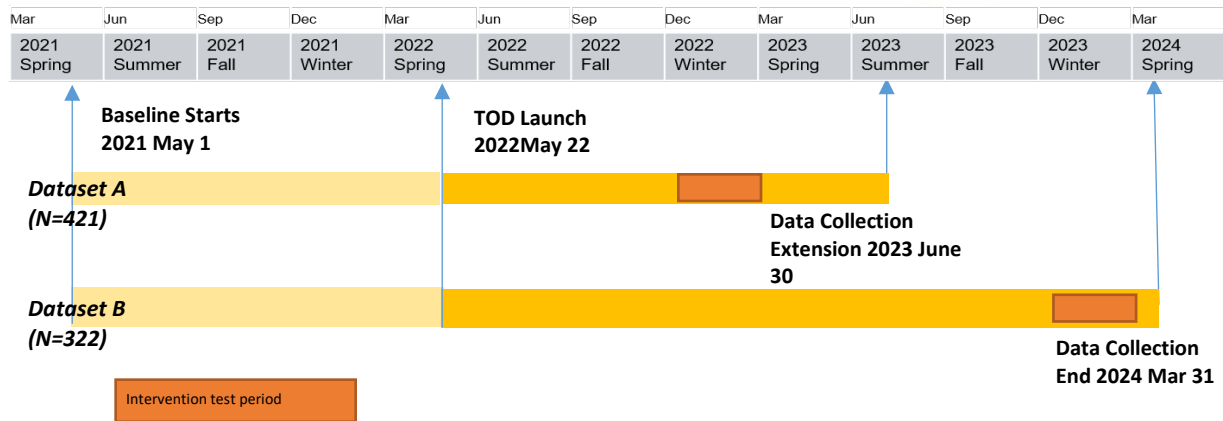


Figure 3. The smart meter dataset has two subsets: Dataset A and Dataset B. B is a subset of A. The dark orange boxes mark the time periods of data used for the intervention period in the regression analyses.

2.3.4 Electricity bill data

Starting in April 2022, monthly bill settlement data was delivered to the NRC data warehouse. These data showed the regular bill amount, the total electricity usage, the usage per billing rate period (off-peak, mid-peak, and on-peak) and the TOD bill credit, if any. Bill data was not available prior to the start of the TOD intervention.

2.3.5 Weather data

Heating and cooling demand vary seasonally and across years depending on the weather, and these are factored into the electricity use analyses. Hourly outdoor temperature data was downloaded from the Environment Canada weather station #6918 (Bouctouche weather station) until October 3, 2021 (when it stopped reporting data). From October 4, 2021 onward data was obtained from station #50309 (Greater Moncton International Airport).

The weather data were used to calculate heating degree days (HDD) and cooling degree days (CDD). These are calculated based on the difference between the daily average outdoor temperature and a base temperature. A cooling day is one with an average outdoor temperature above the base temperature, and a heating day is one with an average outdoor temperature below the base temperature. The choice of base temperature is critical because it represents the threshold beyond which heating or cooling is needed. Common choices are 15°C or 18°C, but these may not suit every region or application. The choice of base temperature can significantly influence the accuracy of energy consumption predictions, as an incorrect base temperature may fail to accurately reflect actual energy usage patterns. We chose a base temperature of 12.5°C to optimize the model's predictive accuracy. This adjustment was made considering the local climate and the fact that all buildings in the study were residential, mostly with zone heating. A rationale is provided in Appendix C.

2.4 Data analyses

2.4.1 General

As noted above, this report excludes the SOL group because the technology dramatically altered the pattern of electricity use and masked any behavioural changes. For the electricity use data and bill data analyses, this report also excluded the CC-MSHP group because there is a separate report about the performance of this technology. The survey data, however, included the CC-MSHP participants because this technology would not be expected to change their electricity use behaviours or attitudes.

2.4.2 Survey data

Most of the survey questions reported here yielded categorical data that we report descriptively with the frequency or percentage of responses in each category. Some questions were ratings on Likert-type ordinal scales and these are also categorized with descriptive statistics (means, standard deviations, etc.). Where relevant, we have conducted either independent-groups *t*-tests to compare responses between TOD and no-TOD participants, or paired *t*-tests to compare responses from two points in time, generally within one of the TOD groups. In all cases these inferential tests examined the likelihood that the observed difference would have occurred if, in fact, there were no difference between the two comparators (two groups or two time points). If the probability of the observed effect was 5% or less ($p < 0.05$) then we concluded that the difference had occurred because of a causal effect.

2.4.3 Regression method

The logic of comparisons for both the survey and energy data is described by the Difference in Differences (DiD) method. This is a statistical technique used for estimating the causal effect of a treatment by comparing the changes in outcomes over time between the experiment group that is exposed to the treatment and the control group that is not (Torres-Reyna, 2015). Both the groups are subjected to the same (potentially variable) external conditions (e.g., weather) with the only difference being that the experiment group receives the treatment and control group does not. This method is particularly relevant for the Shediach residential study, which was a field quasi-experiment with many variables that could not be controlled (Cook & Campbell, 1979). The TOD group was subject to the treatment at the TOD launch in May 2022 and the control group continued with the standard rate.

The rationale behind DID is that if the experiment group did not receive the treatment, the differences between treatment and control groups should stay the same over time, as illustrated in Figure 4.

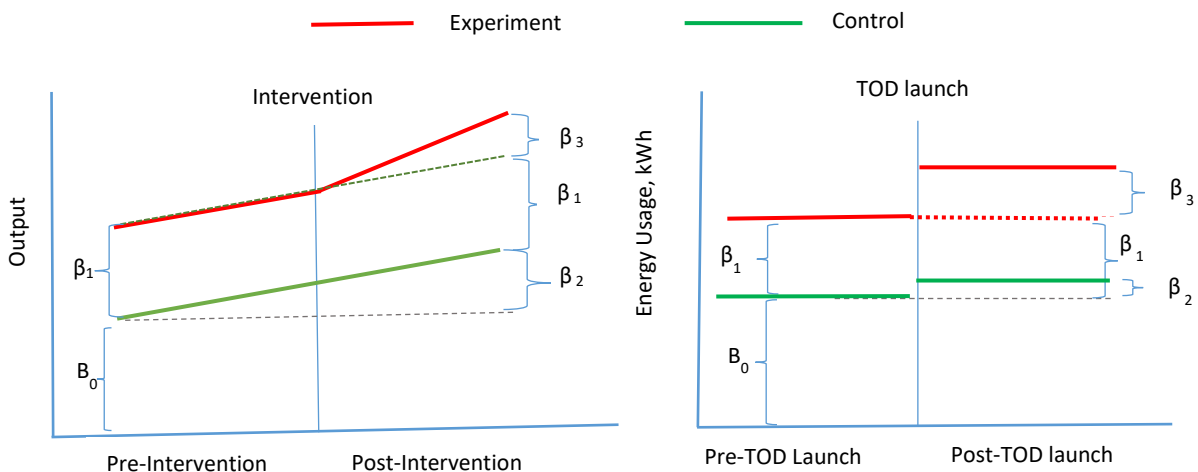


Figure 4. The chart on the left illustrates the general concept of DiD where the control and experiment variables change over time. The chart to the right illustrates the application of DiD in which the experiment group may experience a step change with the launch of TOD. Although the no-TOD group is not expected to experience a direct change in energy usage due to the experimental treatment, participating in a study may motivate some change.

β_0 is the average energy use for the baseline period. β_1 is the comparison of energy use between the two groups. β_2 is the change in energy use over time (before and after the intervention began). It is assumed that the difference between the two groups would have remained constant through the observation period in absence of the treatment. β_3 is the interactive variable modelling the effect of intervention over the time on the experiment group.

In simplest form the energy use for the experiment groups is estimated by the following equation:

$$y = \beta_0 + \beta_1 \text{TreatmentVariable} + \beta_2 \text{TimeVariable} + \beta_3 \text{TimeVariable} * \text{TreatmentVariable}$$

The above equation does not take into account the impact of weather on the energy use. Adding the heating degree days (HDD) and cooling degree days (CDD) to the above equation:

$$y = \beta_0 + \beta_1 \text{TreatmentVariable} + \beta_2 \text{TimeVariable} + \beta_3 \text{TimeVariable} * \text{TreatmentVariable} + \beta_4 * \text{HDD} + \beta_5 * \text{CDD}.$$

In the DiD method, we seek particularly for a statistically significant interaction term (β_3), which tells us that the two experimental groups showed diverging outcomes after the intervention than before.

3 Results

3.1 Surveys

3.1.1 Knowledge and attitudes

Three surveys contributed information about participants' knowledge and attitudes relating to TOD electricity pricing: November 2021 (before the TOD launch, but about six months after the launch of the Participant Energy Portal for all participants), November 2022 (about six months after the TOD launch) and March 2024 (the end of the study, nearly two years after TOD launch). For the first of these, no one had experienced the TOD intervention and everyone received the same questions. For the other two surveys, some questions were presented again but in two forms: the original, hypothetical wording for the no-TOD group, and reworded to refer to actual experiences for the TOD group (see Veitch et al., 2025).

The responses to questions in this section are categorical. The number of responses in some categories was very small even though some of the samples were greater than 100 participants. Although there are nonparametric statistical tests for categorical data, they are generally not stable with small cell (samples in each group) sizes; therefore, we have assessed these results qualitatively rather than attempting statistical tests.

Noting that successful TOD programs require understanding of how electricity is used and priced, we asked questions about participants' understanding of their electricity bills and their estimated electricity consumption in both winter and summer. Figures 5 and 6 show the results for these three questions.

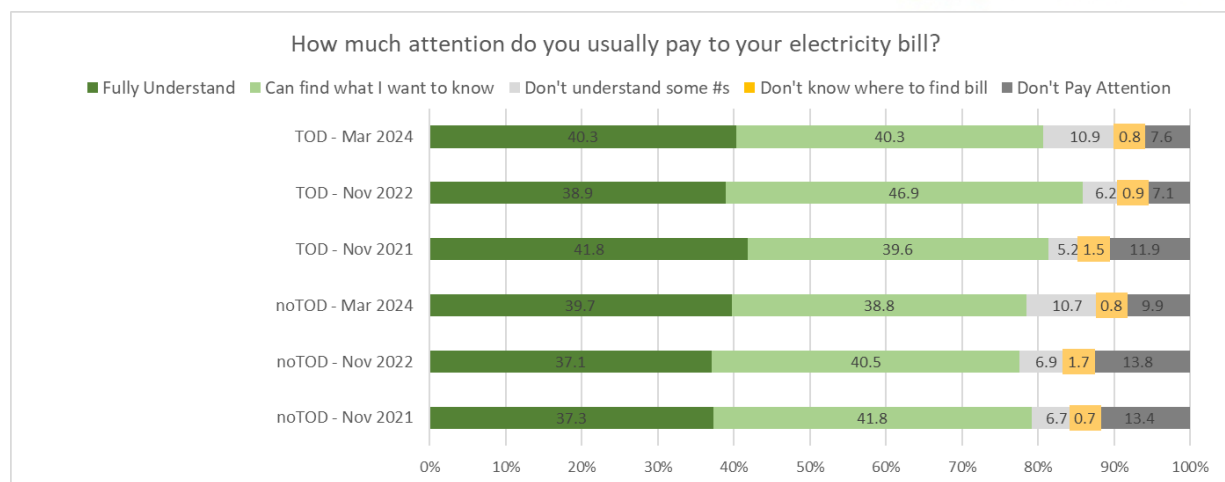


Figure 5. Participants reported understanding of their electricity bills, by TOD group and time.

Figure 5 reveals that over 80% of respondents have the ability to understand their electricity bills at least well enough to find what they want to know. Interestingly, there was a small increase in the number of people who reported not understanding some of the numbers on the bill, with nearly 11% of both the TOD and no-TOD groups reporting this in March 2024. We at NRC wonder if there was some other change to the bills of which we are unaware. The good news for this TOD trial is that there appears to be a decrease in the TOD group in the number of respondents who reported not paying attention to their electricity bills after the TOD intervention began (Nov. 2022 and March 2024).

Figure 6 shows the participants' estimated monthly electricity consumption in both winter (top panel) and summer (bottom panel). The most notable finding is that the most frequent response for both groups was "don't know". This does not suggest a high degree of energy literacy among this sample. For reference, in winter 2022, the average monthly total electricity usage based on settlement data ranged from a low of 61 kWh to a high of 23,908 kWh, with the median (50th percentile) value for both groups being approximately 2,487 kWh. The 75th percentile was just under 3,244 kWh, meaning that 25% of respondents consumed more electricity than that per month. Similarly, in summer 2022 the median monthly usage in the settlement files was 1,106 kWh, but under 4.2% reported usage greater than 1000 kWh. Neither group showed a good awareness of their electricity consumption, and this did not change over the course of the TOD trial.

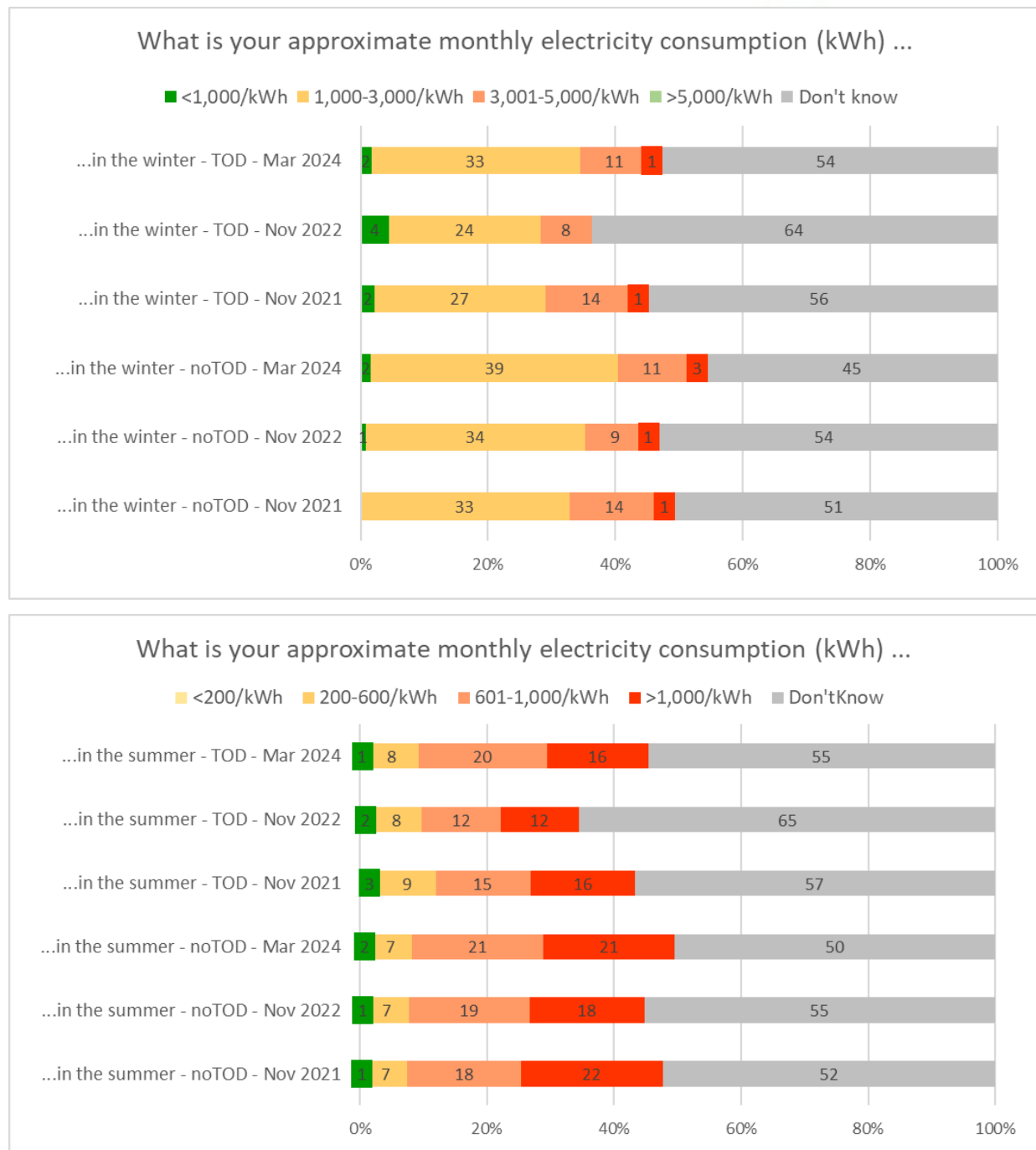


Figure 6. Participants' estimates of their monthly electricity consumption. Top panel: Estimated winter electricity consumption. Bottom panel: Estimated summer electricity consumption.

To better understand participants' energy literacy, in November 2022 we also asked participants to report the top three energy-using technologies in their homes. The heating system, water heater, and dryer were the top three choices for the most energy-consuming technology for both the no-TOD and TOD groups. Table 3 shows the frequencies with which various devices were chosen. Heating, clothes drying, and water heating were (correctly) identified as the biggest users by most participants in both

the TOD and no-TOD groups, but there was variability and a few individuals reported that what are relatively small uses in homes were among their top consumers.

Table 3. Participants identified what they believed to be the top three energy-consuming devices in their homes in November 2022. This shows the frequency with which each was identified as #1, #2, or #3, by TOD group.

	#1		#2		#3	
		%		%		%
no-TOD	Heating System	39	Dryer	28	Dryer	24
	Dryer	24	Water Heater	20	Water Heater	14
	Water Heater	12	Heating System	16	Heating System	9
	Air Conditioning	7	Air Conditioning	6	Electric Range	9
	Electric Range	6	Electric Range	6	Refrigerator	9
	Refrigerator	4	Dishwasher	5	Air Conditioning	8
	Washer	3	Separate Freezer	5	Dishwasher	8
	Swimming Pool	2	Refrigerator	3	Washer	5
	Hot Tub	1	Washer	3	Separate Freeze	3
	Separate Freezer	1	Swimming Pool	2	Swimming Pool	3
	TV	1	Other	2	Hot Tub	2
	Other	1	Auto Block Heater	1	Lighting	2
			Electric Car	1	TV	2
			Hot Tub	1	Personal Electronics	1
			Personal Electronics	1	Other	1
TOD	Heating System	41	Dryer	22	Dryer	20
	Dryer	27	Water Heater	19	Water Heater	14
	Water Heater	16	Heating System	17	Refrigerator	9
	Dishwasher	6	Electric Range	13	Separate Freezer	9
	Air Conditioning	3	Air Conditioning	7	Heating System	7
	Electric Range	3	Refrigerator	6	Washer	6
	Hot Tub	2	Dishwasher	5	Dishwasher	5
	Washer	1	Washer	4	Electric Range	5
	Personal Electronics	1	Separate Freezer	3	Lighting	5
	Refrigerator	1	Lighting	2	Swimming Pool	5
	Other	1	Fireplace	1	Air Conditioning	4
					TV	4
					Personal Electronics	3
					Electric Car	2
					Auto Block Heater	1
					Hot Tub	1

Participants' ratings of their knowledge of TOD pricing revealed the effect of the intervention (Figure 7). There is a clear pattern in that the no-TOD group mostly reported little to no knowledge about TOD pricing at all time points, but the TOD group greatly increased its knowledge during the intervention.

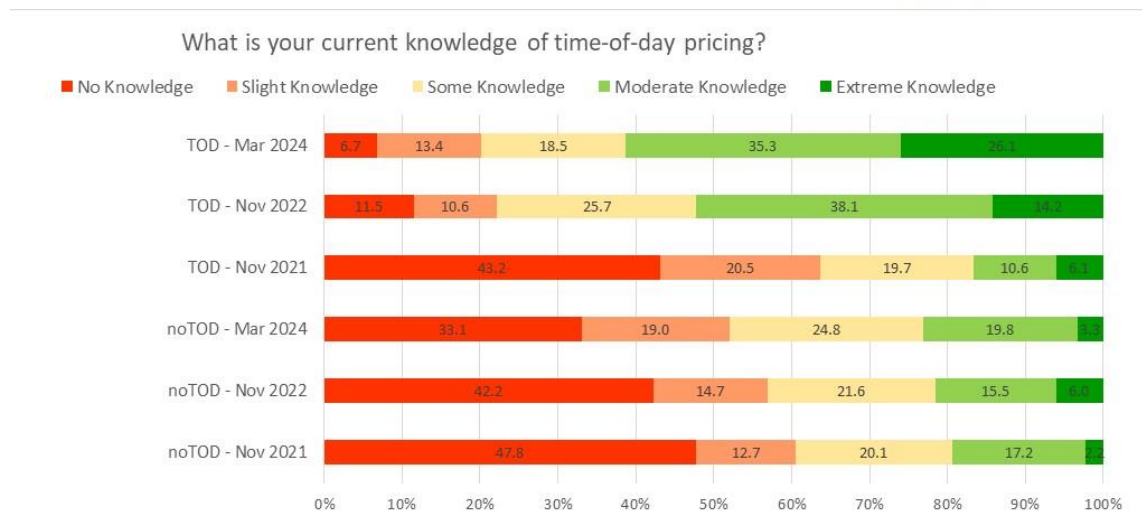


Figure 7. Participants in the TOD group clearly acquired knowledge about TOD pricing during the intervention.

At the three survey times we asked participants to report which of several possible effects might be the main benefits of TOD pricing (Figure 8). There was broad agreement that lower electricity bills would be the main benefit, and this was unaffected by TOD group or time. However, there was more volatility among members of the TOD group in the frequency of choosing “lower energy consumption”, and a marked drop in this choice at the end of the study. Perhaps encouragingly for the utility, the frequency of choosing “higher utility revenues” was persistently low.

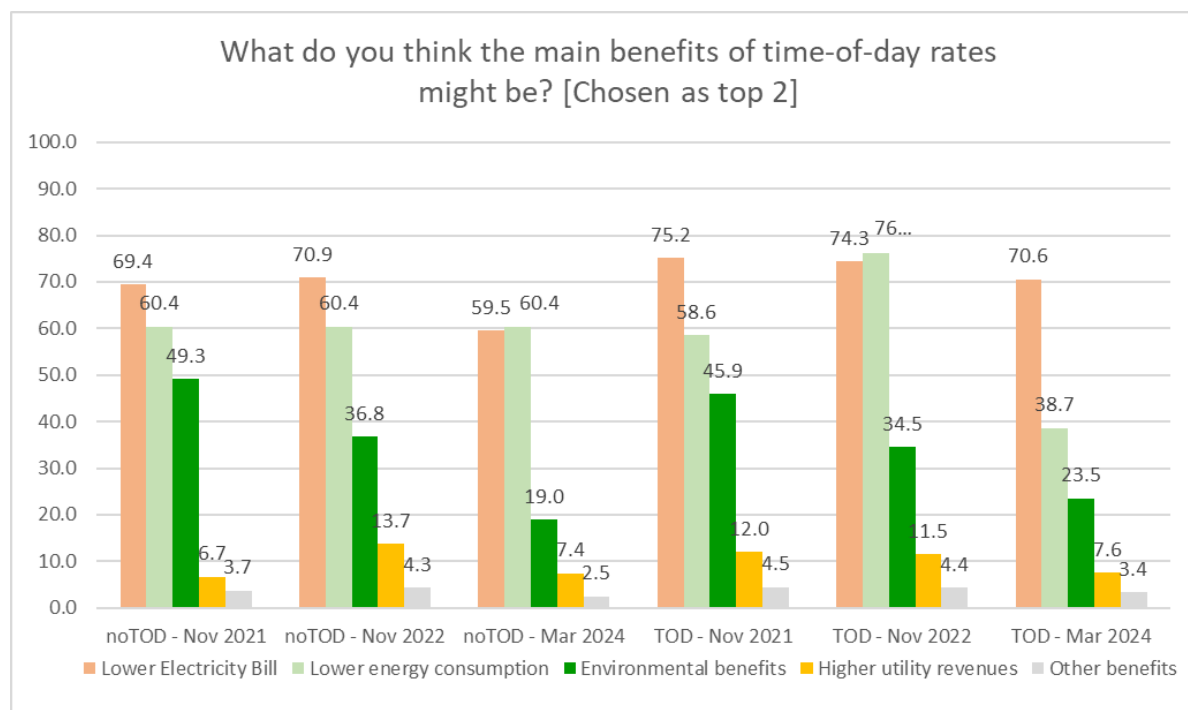


Figure 8. Respondents' choices of the top two benefits of TOD pricing.

On the first two occasions we asked participants “How much do you think you could save on energy consumption if you were being charged time-of-day rates for the electricity you use?”. The implication of this question was bill savings. Responses to this question showed the effect of being in the TOD group. The no-TOD group showed little change from 2021 to 2022. The TOD group response, however, was substantially changed six months into the TOD intervention, with fewer people reporting being unsure and more people reporting that they would not experience any savings, or only small savings (Figure 9). (Actual outcomes are reported below.)

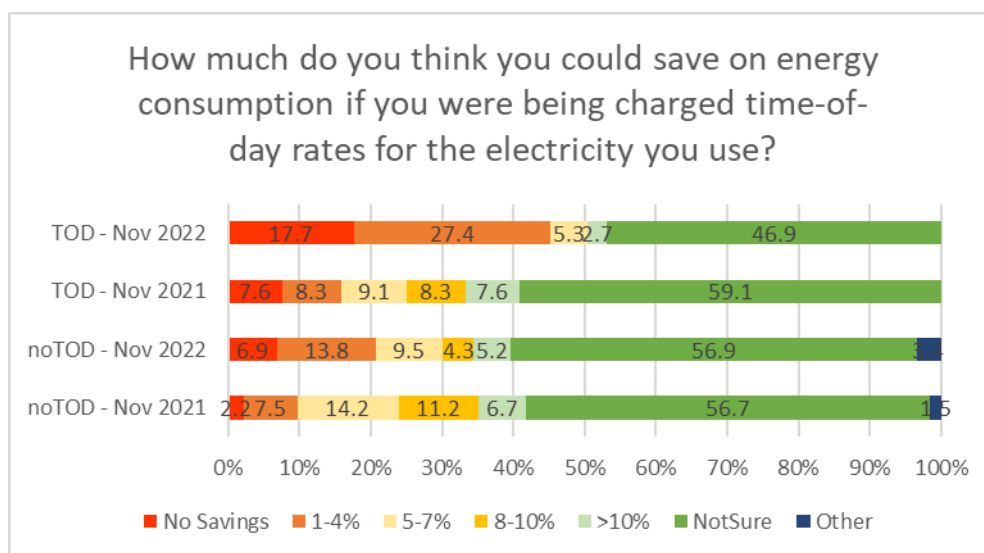


Figure 9. Participants estimated their possible energy consumption savings under TOD rates.

3.1.2 Energy behaviours and timing

In order to take advantage of TOD rates, people need to be mindful of their electricity use and its timing. Several questions probed participants’ energy use habits and their ability to change the timing of their major energy using behaviours.

When asked at what time their peak electricity usage occurred, the majority of participants responded that it occurred overnight (between 10 p.m. and 6. a.m.) (Figure 10). The TOD program does appear to have changed responses to this question, with TOD participants having increased the frequency of responding “morning” and decreased the frequency of responding “night time” as compared to the baseline in November 2021. The no-TOD group showed little change over time on this question.

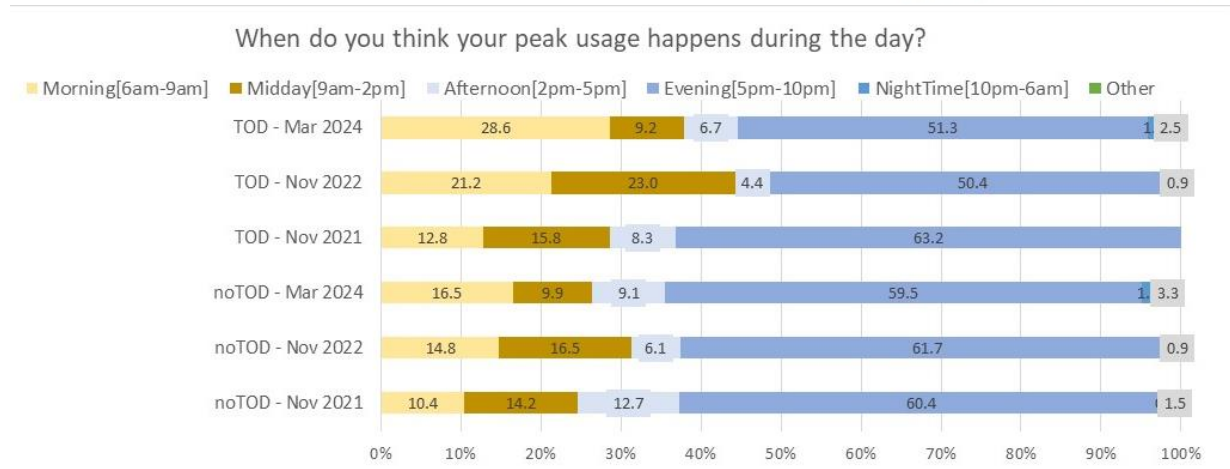


Figure 10. The reported time of participants' peak daily electricity usage.

Apart from space conditioning, washing and drying clothes can be significant energy-using behaviours. We asked when participants did these chores (Figure 11). Unfortunately, we gave incorrect times for the morning period and muddled off-peak and on-peak times into one category. This makes it difficult to interpret the results in light of the TOD intervention. It does appear, however, that there was a small shift in the TOD group to doing these chores between 9 and 11 p.m.

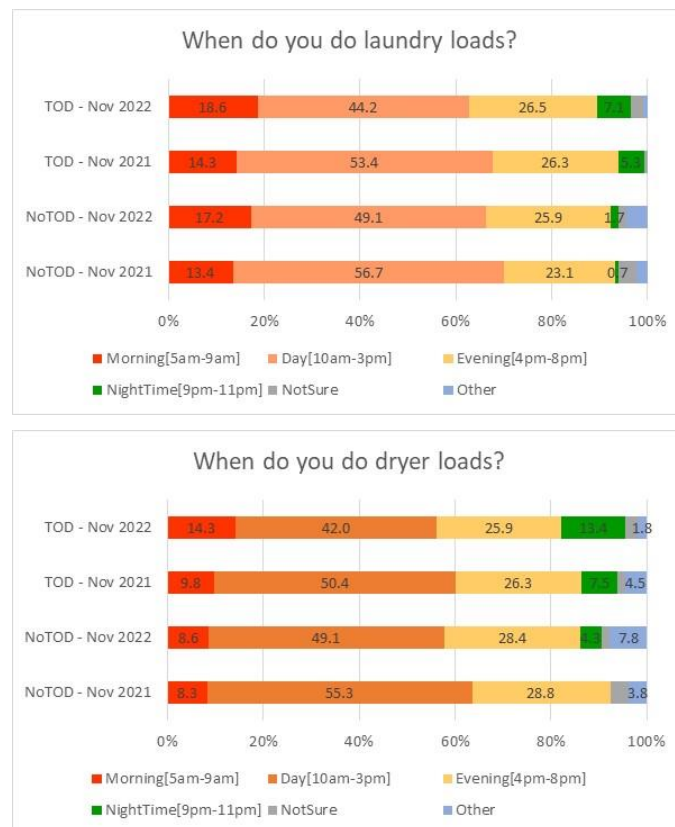


Figure 11. The reported time of participants' washing and drying loads.

Participants were asked which actions they thought they might be able to change the timing of in order to take advantage of TOD rates, choosing the top three. Figure 12 shows these responses. Doing laundry or running a dishwasher in the evening were frequent choices. For the no-TOD group, night-time temperature setbacks were popular choices in both years. For the TOD group, night-time setbacks were not as common a choice in 2022, likely reflecting the TOD intervention. A night-time setback would reduce their energy use but would not shift it away from peak time. It also appears, however, that the possible benefit of a morning preheat (during off-peak time) was not well understood, as it was chosen less often after the intervention than before.

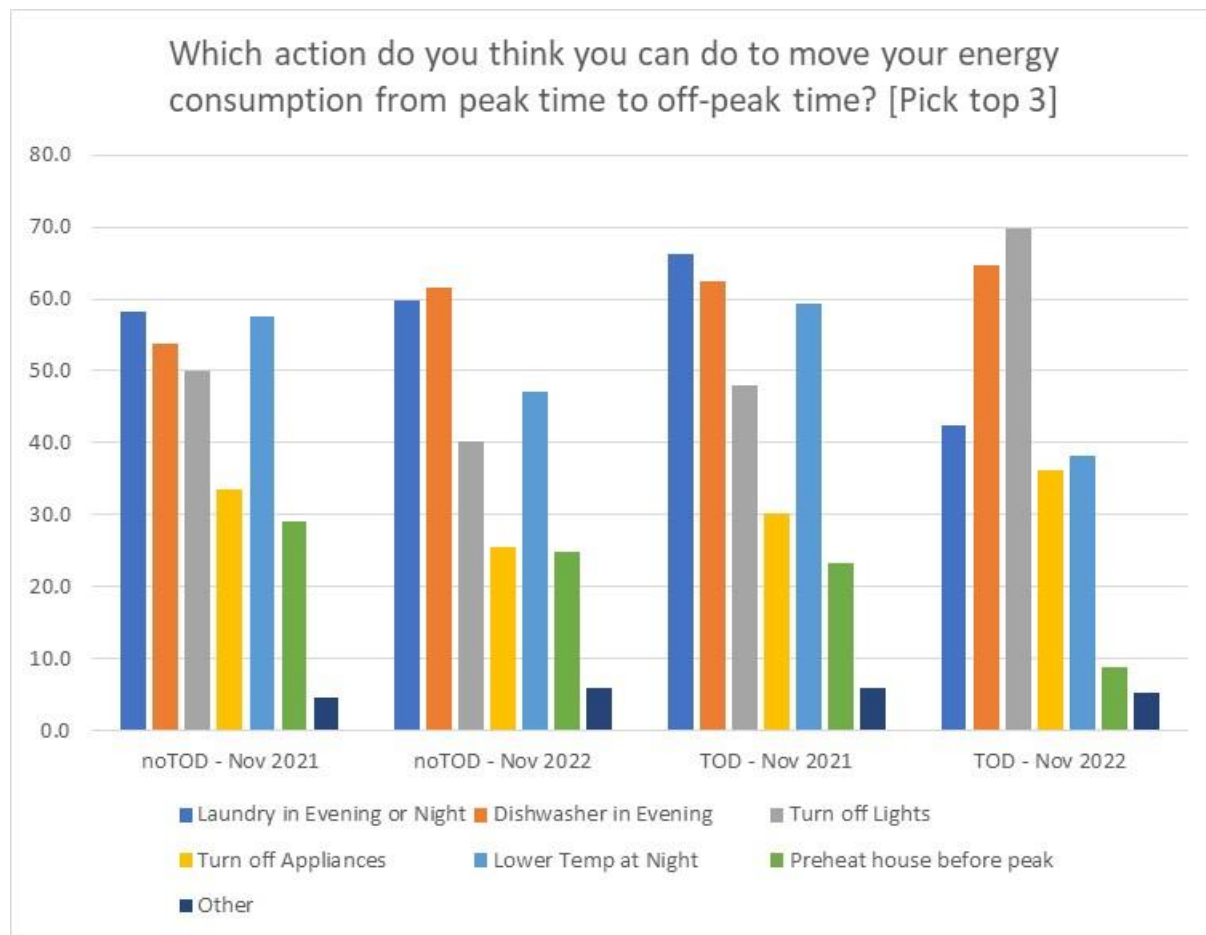


Figure 12. Different behaviours are amenable to timing changes.

As concerns how often participants could do these actions (or did do them, for the TOD group in 2022 and 2024), the TOD intervention had a somewhat surprising result (Figure 13). There was optimism for the no-TOD group and the TOD group before the intervention, with over 40% reporting they would be able to shift the timing of their electricity use every day. After the TOD intervention began, however, the TOD group became less likely to report doing the behaviour daily and much more likely to say they did this 2-4 times weekly. By the end of the study in March 2024 there were fewer people unsure about their ability to shift their energy behaviours, and more who reported that they thought they would be unable to do so. This might reflect difficulty that TOD participants experienced in making sufficient change to generate sizeable TOD credits (see below).

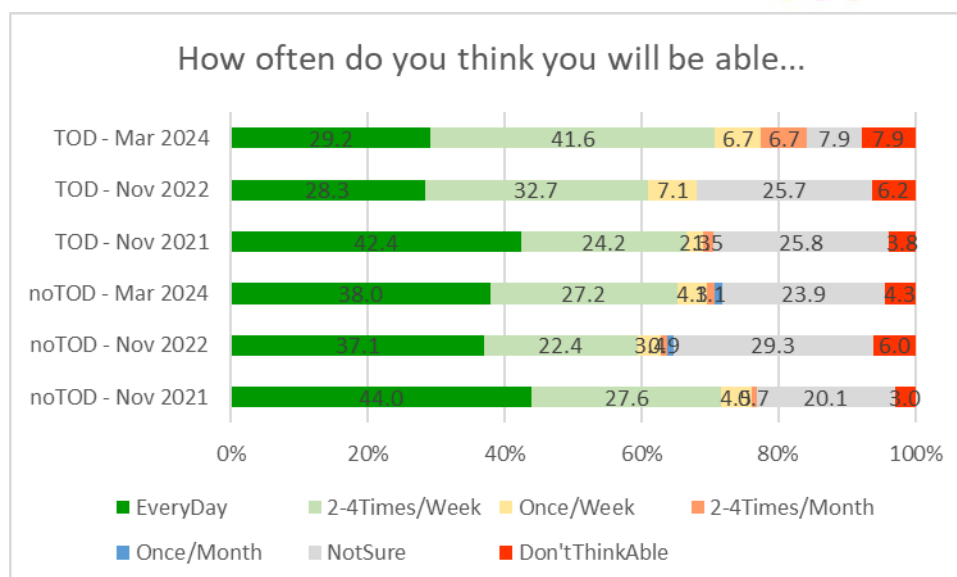


Figure 13. The frequency with which participants expected to be able, or were able, to change the timing of energy behaviours.

In March 2024 we asked more specific questions about household activities and their timing. The general patterns of broad categories of activities are similar between the no-TOD and TOD groups (Table 4). The frequency of working from home was similar between the two groups (Figure 14). However, the specific energy-using activities list in Table 5 shows a difference between the groups. For all but one of the activities, a smaller percentage of the TOD group than the no-TOD group reported performing that activity between 7:00 a.m. and 9:00 a.m.; however, this difference was statistically significant only for the frequency of doing laundry in the morning peak hours (Fisher's exact test = 5.404 ($df = 1$), $p < 0.025$). For only one behaviour, "use home office equipment for work or schoolwork" is the percentage higher for the TOD group during the morning peak.

Table 4. The percentage of no-TOD and TOD participants who reported each category of activity taking place in their homes in morning, afternoon, and evening.

	Morning		Afternoons		Evenings	
	No-TOD %	TOD %	No-TOD %	TOD %	No-TOD %	TOD %
House work	42.6	49.5	31.9	35.5	42.6	39.8
Office work	48.9	46.2	41.5	39.8	14.9	19.4
Homeschooling	1.1	0.0	1.1	1.1	2.1	5.4
Hobbies	9.6	14.0	29.8	20.4	53.2	44.1
Computer gaming	7.4	4.3	18.1	3.2	45.7	35.5
Socializing	7.4	4.3	18.1	3.2	45.7	35.5

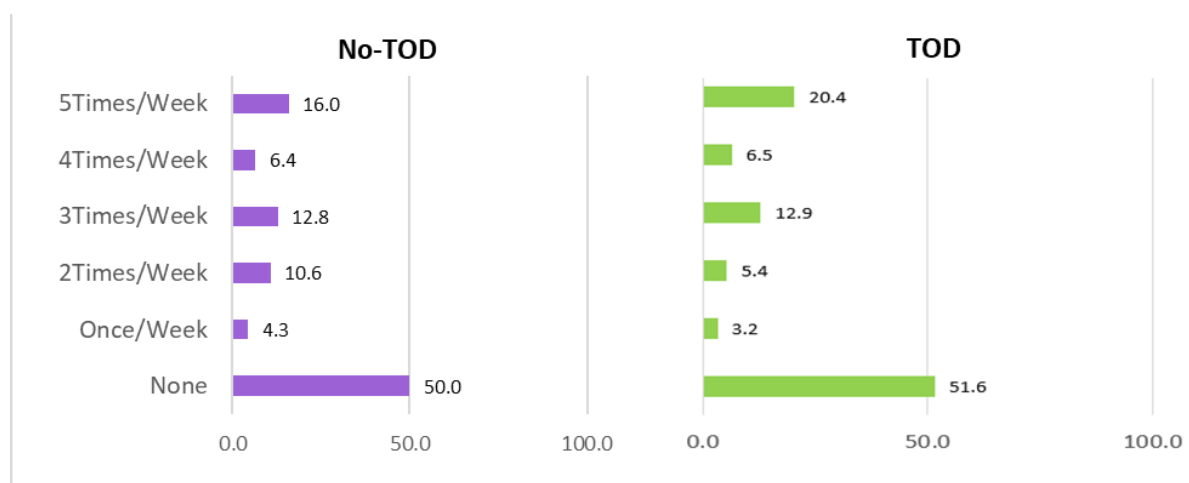


Figure 14. The frequency (%) of participants in the no-TOD and TOD groups who worked from home showed a similar pattern in the two groups.

Table 5. The percentages of no-TOD and TOD participants who perform selected energy-using behaviours in morning or evening peak periods.

	7:00 a.m. – 9:00 a.m.		5:00 p.m. to 9:00 p.m.	
	No-TOD %	TOD %	No-TOD %	TOD %
Cooking	52.4	46.3	85.5	87.8
Shower or bathe	64.5	55.3	29	34.1
Laundry	36.3*	22.8*	38.7	41.5
Get ready for school/work	66.1	64.2	3.2	3.3
Increase temperature	26.6	22.8	13.7	13
Dishwashing	21	14.6	61.3	53.7
Charge EV	0	0.8	3.2	4.1
Gaming system	4.8	4.9	23.4	24.4
TV on	42.7	30.9	78.2	77.2
Use home office equipment	48.4	55.3	34.7	40.7
Other	2.4	1.6	2.4	1.6

Throughout the study we asked participants if they had felt that their household routine had to change in order to participate in the research project. This too showed a difference between the no-TOD and TOD groups. Before the TOD trial began, the two groups were both at a low level of agreement with this question (under 4%). The TOD group showed a continued increase in the percentage agreement with this question (but still not a high level, with a maximum of 14%); the no-TOD group showed no real increase (Figure 15).

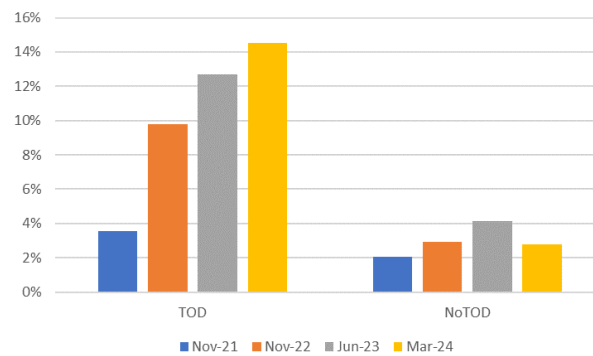


Figure 15. The percentages of TOD and no-TOD participants reporting that they had felt they had to change their household routines in order to participate in the research project, at four survey times.

3.1.3 Program experiences

Key elements of the TOD intervention were the Participant Energy Portal (which was available to all participants) and, for the TOD group only, the communications tools.

The Participant Energy Portal recorded total visits by each user and the date of the last visit. Table 6 shows summary statistics about its use. We cannot explain the data showing that one no-TOD participant visited the site 601 times; despite this, it is evident that usage of the site was far more frequent for the TOD group. Most of the no-TOD group stopped visiting it before the TOD intervention began. When asked in November 2022 whether they had visited the Participant Energy Portal, only 15.5% of no-TOD participants reported that they had (58.6% no, 26.9% unsure), whereas 54% of TOD participants reported that they had (42.5% no, 3.5% unsure). Of the TOD participants, 43.4% reported that they had viewed or downloaded their Shadow Reports (44.2% no, 12.4% unsure).

Table 6. The usage of the Participant Energy Portal

	Last visit before April 2022	Last visit after April 2022	Mean total	SD	Median	Min	Max
no-TOD	49	10	4.31	45.6	0	0	601
TOD	13	93	5.75	8.45	2	0	43

TOD participants were asked about their satisfaction with the various modes of communication. The dominant response was ‘neither satisfied nor dissatisfied’ (Figure 16).

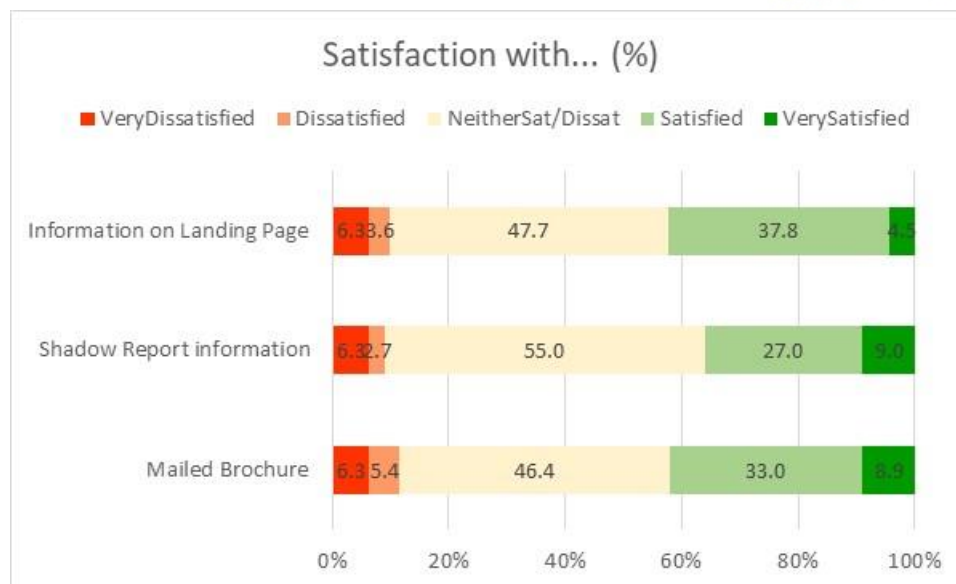


Figure 16. TOD participants' satisfaction with program elements.

At the end of the project, in March 2024, we inquired whether TOD participants had engaged with the program. Most had. Of those that had not, the most commonly chosen reasons for not having tried were convenience, too little reward, and lack of understanding (Table 7).

Table 7. Participant engagements, and reasons against it.

	Did you try to take advantage of the TOD rates during this project?	Why not? Too much effort	Why not? My daily schedule is complicated enough without changing it	Why not? Too inconvenient	Why not? Too little reward	Why not? I think it would only benefit the utility	Why not? I didn't understand how it worked	Why not? Other, please specify:
%	87.4% = Yes	0.0%	40.0%	20.0%	33.3%	0.0%	33.3%	0.0%
N	104	0	6	3	5	15	5	

3.1.4 Future intentions

All participants were asked at the end of the study if they might participate in a TOD rate program if one were offered. No details were provided about what the offering might be because pretesting within the team determined that the possible questions were too complex. Willingness to participate was high (see Table 8). Of the reasons given for not participating, the most common was that it would be incompatible with their daily schedule. The size of the possible reward was another barrier, as was a suspicion that such a program would only benefit the utility.

Table 8. Participants' future intentions if there were a TOD program, and reasons against participating.

	If NB Power offered a Time-of-Day rate program in the future, would you sign up for it?	Why not? Too much effort	Why not? My daily schedule is complicated enough without changing it	Why not? Too inconvenient	Why not? Too little reward	Why not? I think it would only benefit the utility	Why not? I don't understand how it would work	Why not? Other, please specify:
%	80.1 = Yes	10.8	44.7	23.4	31.9	27.7	19.1	14.9
N	236	5	21	11	15	13	9	7

To assess whether participants might be interested in future rate programs and participating in them, in survey #7 we asked three questions:

- How interested would you be to learn about choices for how you could be billed for the electricity you use?
- How likely is it that you would choose to be billed using a new billing option if it would allow you to lower your bill, even if it took some effort on your part?
- How likely is it that you would choose to be billed using a new billing option if it would allow you to lower your bill with some effort on your part, and the new system was more complicated for you to understand?

Figure 17 shows the results for these three questions. Interest in learning about rate options was high, with over 60% of respondents reporting interest in learning. As might be expected, interest in participation in a new billing option, although still high, dropped when considering that participation might require effort or be complex to understand.



Figure 17.27 Interest in learning about or participating in new billing programs.

3.2 Energy usage

Section 2.3.3 describes the data treatments for the peak demand and total energy use outcome variables reported here. As described above, two datasets were used to evaluate the effects of intervention through regression analysis. For dataset A, the baseline period was from May 2021 to May 2022 with a total N=421. The intervention test used this dataset from winter 2022 (Dec. 1, 2022 – Feb. 28, 2023) for regression analysis. For dataset B, the baseline period was from May 2021 to May 2022 with a total N=322 (a subset of dataset A) and the intervention test used the data from winter 2023 (Dec. 1, 2023 – Feb. 29, 2024).

This section presents the impact of TOD rates on the no-Tech sample as a whole and then for two non-overlapping subsets: 1) MSHP, and 2) central heat pumps. This division provides a better understanding of whether the type of heating system, along with its controlling smart thermostat, influences energy usage as a result of the TOD intervention. Tables 9 and 10 detail the sizes of the different heating system groups with and without TOD, and indicate whether the model outputs were statistically significant; the detailed results are in the following sections. (Note that there were too few homes with electric baseboard heating as the primary heating source to analyze them as a subgroup.)

Table 9. Model statistical significance for impact of TOD on peak demand using dataset A (winter 2022 comparison)

Group	TOD Group Size (N)	no-TOD Group Size (N)	Model statistical significance for average morning peak demand (7-9 a.m.)	Model statistical significance for average energy consumption
no-Tech	140	141	Yes	Yes
Existing MSHP	89	88	Yes	Yes
Central HP	28	33	Yes	Yes

Table 10. Model statistical significance for Impact of TOD on peak demand using dataset B (winter 2023 comparison)

Group	TOD Group Size (N)	no-TOD Group Size (N)	Model statistical significance observed for average morning peak demand (7-9 am)	Model statistical significance for average energy consumption
no-Tech	107	111	No	No
Existing MSHP	74	71	Yes	Marginal
Central HP	18	23	No	Yes

3.2.1 Effect of TOD on peak demand

3.2.1.1 no-Tech Group

This analysis used multivariate linear regression models that incorporated DiD coefficients. Average morning peak demand (kW) for the experimental group was the outcome variable. We shifted the time windows for HDD and CDD values (see Appendix D) to control for weather effects between 7 a.m. to 9 a.m.

Tables 11 and 12 present the outputs for regression models with DiD coefficients for datasets A (winter 2022) and B (winter 2023) respectively. The estimates reflect change in kW for a unit change in each predictor. The predictors TOD_GroupAssignment and ToDLaunch are Boolean: TOD_GroupAssignment assumes the value of 1 for the group under TOD rate and 0 for the no-TOD group. ToDLaunch assumes the value of 1 after the TOD program becomes active and 0 before.

The model level statistics (R^2) suggest a good fit for both datasets with over 96% of the variance explained and a statistically significant model ($p < 0.05$). The p -value for the interactive coefficient (TOD_GroupAssignment*ToDLaunch) meets our criterion for statistical significance for dataset A ($p < 0.05$) but not for dataset B ($p > 0.05$). Note that the statistically significant value for the predictor TOD_GroupAssignment shows that for dataset A the average morning peak demand was lower for the TOD group over this time period, regardless of the intervention.

Table 11. Model output for existing no- Tech group regression model of average morning peak demand based on dataset A (winter 2022 comparison).

Predictors	Unstandardized Regression Coefficient (kW)	Std. Error of the Estimate	<i>t</i>	<i>p</i>
Intercept	1.79	0.03	69.28	< 0.001
Shifted HDD	0.16	0.00	101.29	< 0.001
Shifted CDD	0.00	0.00	-0.70	0.49
TOD_GroupAssignment	-0.07	0.02	-2.62	0.01
TODLaunch	-0.05	0.04	-1.33	0.18
TOD_GroupAssignment*ToDLaunch	-0.14	0.05	-2.57	0.01
Model level statistics				
<i>df</i>	604			
R^2	0.964			
<i>p</i>	< 0.001			

The regression model based on the dataset B in Table 12 showed a higher average morning peak demand for the variable TOD_GroupAssignment by 0.09 kW; this applies to the whole period of dataset B. Conversely, the launch of Time-of-Day (TOD) rates was associated with a statistically significant decrease in peak demand (between the baseline period and the intervention period). However, the interaction between TOD_GroupAssignment and TODLaunch did not significantly impact peak demand, as indicated by the high p -value. One possible contributing factor to these different results could be possible bias in the sample from by the attrition (e.g., if for some reason households in the TOD group with lower morning peak demand were less likely to stay in the study after June 2023). It is also possible that the change to a ‘set it and forget it’ message to all participants (rather than only for MSHP owners, as in 2022) for winter 2023 contributed to enough changed behaviour to alter the model outcome.

Table 12. Model output for no-Tech regression model of average morning peak demand based on dataset B (winter 2023 comparison).

Predictors	Unstandardized Regression Coefficient (kW)	Std. Error of the Estimate	<i>t</i>	<i>p</i>
Intercept	1.72	0.03	68.65	< 0.001
Shifted HDD	0.16	0.00	101.83	< 0.001
Shifted CDD	-0.01	0.00	-1.76	0.08
TOD_GroupAssignment	0.09	0.02	3.59	0.00
TODLaunch	-0.13	0.04	-3.35	0.00
TOD_GroupAssignment*ToDLaunch	-0.05	0.05	-0.90	0.37
Model level statistics				
<i>df</i> :	594			
R^2	0.964			
<i>p</i>	< 0.001			

The regression model based on dataset A was then applied to the winter 2022 seasons data to calculate the estimated outcomes for the TOD group. The estimated reduction of 3.3% in average morning peak demand was observed for winter 2022 as shown in Table 13.

Table 13. Effect of TOD on winter morning average peak demand (7:00 – 9:00 a.m.) for the no-Tech group in winter 2022.

Season	Dataset	HDD	Temp.	Fit			95% CI - Upper		95% CI - Lower	
				Avg. TOD group Peak Demand (kW)	Predicted Demand w/o Intervention (kW)	Intervention effect (%)	Predicted Demand w/o Intervention (kW)	Intervention effect (%)	Predicted Demand w/o Intervention (kW)	Intervention effect (%)
2022 Winter	A	1470	-3.8	4.2	4.3	3.3%	4.4	5.5%	4.2	0.7%

3.2.1.2 Existing MSHP

This report covers the effect of TOD on existing MSHP using datasets A and B. The effect of TOD on CC-MSHP is covered in a separate report (Hu, et al. 2025).

The regression models (see Tables 14 and 15) were statistically significant for both datasets, and in both cases the statistically significant interaction term tells us that the no-TOD and TOD groups differed between the baseline and intervention periods, with the TOD group showing a lower average morning peak demand during the intervention period. The model explains 95% of the variance in peak demand ($R^2 = 0.959$ for dataset A, and 0.96 for dataset B). MSHP participants under the TOD rate structure reduced their demand by 0.22 kW (5.4%) in dataset A and by 0.12 kW (3%) in dataset B. Note that the TOD message to MSHP-owning participants was the same in both winters: “set it and forget it”.

Table 14. Model output for regression model of average morning peak demand based on dataset A for existing MSHP group.

Predictors	Unstandardized Regression Coefficient (kW)	Std. Error of the Estimate	t	p
Intercept	1.62	0.02	66.03	< 0.001
Shifted HDD	0.15	0.00	94.56	< 0.001
Shifted CDD	-0.01	0.00	-1.83	0.07
TOD_GroupAssignment	0.08	0.02	3.39	0.00
TODLaunch	0.03	0.04	0.72	0.47
TOD_GroupAssignment*TODLaunch	-0.22	0.05	-4.31	0.00
Overall model significance				
df:	604			
R^2	0.959			
p	< 0.001			

Table 15. Model output for regression model of average morning peak demand based on Set B for existing MSHP group.

Predictors	Unstandardized Regression Coefficient (kW)	Std. Error of the Estimate	t	p
Intercept	1.51	0.02	63.36	<0.001
Shifted HDD	0.14	0.00	95.68	<0.001
Shifted CDD	-0.01	0.00	-2.20	0.03
TOD_GroupAssignment	0.29	0.02	12.58	<.001
TODLaunch	-0.07	0.04	-1.96	0.05
TOD_GroupAssignment*ToDLaunch	-0.12	0.05	-2.42	0.02
Overall model significance				
df:	594			
R ²	0.96			
p	< 0.001			

Table 16 summarizes these findings with the estimated scores for both years calculated with the models for the respective years. The confidence intervals bracket the range of results with 95% probability; that is, the true value has a 95% likelihood of falling between these values.

Table 16. Comparing the effect of TOD for MSHPs for 2022 Winter and 2023 Winter.

Season	Dataset	HDD	Outdoor Temp.	Avg. TOD group Peak Demand (kW)	Fit		95% CI - Upper		95% CI - Lower	
					Predicted Demand w/o Intervention (kW)	Intervention effect (%)	Predicted Demand w/o Intervention (kW)	Intervention effect (%)	Predicted Demand w/o Intervention (kW)	Intervention effect (%)
2022 Winter	A	1470	-3.8	3.8	4.1	5.4%	4.2	7.7%	4.0	3.0%
2023 Winter	B	1421	-3.1	3.8	3.88	3.0%	4.0	5.5%	3.8	0.1%

3.2.1.3 Central heat pump

The model outputs are presented in Table 17 for winter 2022 and Table 18 for winter 2023, respectively. Both models fit the data well. The interaction term passes the criterion for statistical significance for dataset A (winter 2022) but not for dataset B (winter 2023). Note that the sample size of this group is small, so the group variability will be higher and statistical tests less powerful.

Table 17. Regression model output for the central heat pump group based on dataset A (winter 2022 comparison).

Predictors	Unstandardized Regression Coefficient (kW)	Std. Error of the Estimate	t	p
Intercept	1.75	0.02	70.83	< 0.001
Shifted HDD	0.15	0.00	96.61	< 0.001
Shifted CDD	-0.01	0.00	-2.59	0.01
TOD_GroupAssignment	-0.05	0.02	-2.31	0.02
TODLaunch	0.00	0.04	0.01	0.99
TOD_GroupAssignment*ToDLaunch	-0.16	0.05	-3.16	0.00
Overall model significance				
df:	604			
R ²	0.919			
p	< 0.001			

Table 18. Regression model output for the central heat pump group based on dataset B (winter 2023 comparison).

Predictors	Unstandardized Regression Coefficient (kW)	Std. Error of the Estimate	t	p
Intercept	1.66	0.02	69.30	< 0.001
Shifted HDD	0.15	0.00	97.52	< 0.001
Shifted CDD	-0.01	0.00	-3.21	0.00
TOD_GroupAssignment	0.11	0.02	4.76	0.00
TODLaunch	-0.11	0.04	-2.96	0.00
TOD_GroupAssignment*TODLaunch	-0.07	0.05	-1.29	0.20
Overall model significance				
df:	594			
R ²	0.90			
p	< 0.0001			

Table 19 summarises the findings for the central heat pump group, showing an estimated reduction in morning peak demand by 3.6% for winter 2022.

Table 19. The effect of TOD in winter 2022 morning average peak demand (7:00 – 9:00 a.m.) for the central heat pump group

Season	Dataset	HDD	Temp.	Avg. TOD group Peak Demand (kW)	Fit		95% CI - Upper		95% CI - Lower	
					Predicted Demand w/o Intervention (kW)	Intervention effect (%)	Predicted Demand w/o Intervention (kW)	Intervention effect (%)	Predicted Demand w/o Intervention (kW)	Intervention effect (%)
2022 Winter	A	1470	-3.8	4.5	4.7	3.6%	4.9	7.4%	4.5	-0.4%

3.2.2 The effect of TOD on daily energy use

Although TOD rates are primarily designed for load shifting rather than conservation, they offer the added benefit of encouraging users to modify their energy consumption patterns, thereby possibly enhancing energy efficiency. To assess the effect of TOD on total daily energy use, a regression model with DiD coefficients was used to compare daily energy use between the one-year baseline period and winters of 2022 (dataset A) and 2023 (dataset B). Additional models were calculated for the subsets of dwellings with existing MSHP and central heat pumps.

3.2.2.1 no-Tech Group

The output of the regression model, presented in Table 20, for the no-Tech group in winter 2022 is statistically significant overall ($p < 0.001$), with an R-squared value of 0.59, indicating moderate explanatory power. There are significant effects of heating and cooling on total daily energy use. Shifted HDD and CDD are strong predictors, with estimates of 3.34 and 0.69, respectively ($p < 0.01$). TOD_GroupAssignment, TODLaunch, and the interaction term does not meet the criterion for statistical significance.

Table 20. Regression model output for the effects on daily energy consumption in the no-Tech group based on dataset A (winter 2022 comparison).

Predictors	Unstandardized Regression Coefficient (kWh)	Std. Error of the Estimate	t	p
Intercept	34.86	0.53	65.71	< 0.001
Shifted HDD	3.34	0.03	98.30	< 0.001
Shifted CDD	0.69	0.09	8.09	0.00
TOD_GroupAssignment	-0.71	0.51	-1.39	0.16
TODLaunch	0.01	0.80	0.01	0.99
TOD_GroupAssignment*TODLaunch	-2.08	1.09	-1.92	0.06
Overall model significance				
df:	604			
R ²	0.59			
p	< 0.0001			

Table 21 presents the model output for winter 2023, which is overall a statistically significant model ($p < 0.001$), explaining 95.6% of the variance. Shifted HDD (estimate 3.28) and CDD (estimate 0.62) are strong predictors on the dependent variable, both show $p < 0.05$. TOD_GroupAssignment, TODLaunch, and the interaction term does not meet the criterion for statistical significance.

Table 21. Regression model output for the effects of daily energy consumption in the no-Tech group based on dataset B (winter 2023 comparison).

Predictors	Unstandardized Regression Coefficient (kWh)	Std. Error of the Estimate	t	p
Intercept	33.86	0.54	63.14	< 0.001
Shifted HDD	3.28	0.03	95.52	< 0.001
Shifted CDD	0.62	0.09	7.12	0.00
TOD_GroupAssignment	0.97	0.51	1.88	0.06
TODLaunch	0.11	0.83	0.14	0.89
TOD_GroupAssignment*TODLaunch	-1.74	1.13	-1.54	0.13
Overall model significance				
df:	594			
R ²	0.956			
p	< 0.0001			

3.2.2.2 Dwellings with existing MSHP

Table 22 presents the output of regression model with DiD coefficients for dataset A (winter 2022 comparison). Overall, the model is robust, with significant predictors primarily being heating degree days and the interaction term, indicating their substantial roles in influencing the daily energy usage. The interaction term is statistically significant, indicating that the TOD and no-TOD groups of dwellings with MSHP showed different daily energy consumption after the intervention.

Table 22. Regression model output for the effects on daily energy use for the existing MSHP group based on dataset A (winter 2022 comparison).

Predictors	Unstandardized Regression Coefficient (kWh)	Std. Error of the Estimate	t	p
Intercept	32.84	0.51	64.36	< 0.001
Shifted HDD	3.06	0.03	93.87	< 0.001
Shifted CDD	0.40	0.08	4.91	0.00
TOD_GroupAssignment	0.20	0.49	0.40	0.69
TODLaunch	0.95	0.77	1.24	0.22
TOD_GroupAssignment*ToDLaunch	-2.80	1.04	-2.68	0.01
Overall model significance				
df:	604			
R ²	0.957			
p	< 0.0001			

Table 23 presents the output of the regression model for dataset B (winter 2023 comparison). The regression model shows a strong fit, with an R-squared value of 0.953. Shifted HDD, Shifted CDD, and TOD_GroupAssignment significantly predict the daily energy usage. However, the interaction term TOD_GroupAssignment*ToDLaunch is not statistically significant for winter 2023.

Table 23. Regression model output for the effects on daily energy consumption for the existing MSHP group based on dataset B (winter 2023 comparison).

Predictors	Unstandardized Regression Coefficient (kWh)	Std. Error of the Estimate	t	p
Intercept	31.15	0.52	59.91	< 0.001
Shifted HDD	3.02	0.03	90.82	< 0.001
Shifted CDD	0.41	0.08	4.86	0.00
TOD_GroupAssignment	3.11	0.50	6.22	0.00
TODLaunch	0.21	0.80	0.26	0.79
TOD_GroupAssignment*ToDLaunch	-1.79	1.10	-1.63	0.10
Overall model significance				
df:	594			
R ²	0.953			
p	< 0.0001			

Table 24 presents estimated effect of TOD on total daily energy use in winter 2022 for the existing MSHP group. Corresponding to the average temperature of -3.8°C, the average actual total daily usage for the TOD group was 80.7 kWh. The predicted load without intervention was 83.5 kWh, resulting in a 3.4% reduction.

Table 24. The effect of TOD on total daily energy usage in winter 2022 shows energy conservation for the existing MSHP group.

Season	Dataset	HDD	Temp.	Fit		95% CI - Upper		95% CI - Lower	
				Avg. TOD group actual daily usage (kWh)	Predicted daily usage w/o intervention (kWh)	Intervention effect (%)	Predicted daily usage w/o intervention (kWh)	Intervention effect (%)	Predicted daily usage w/o intervention (kWh)
2022 Winter	A	1470	-3.8	80.7	83.5	3.4%	85.5	5.6%	81.4

3.2.2.3 Dwellings with central heat pumps

The model output in Table 25 for the central heat pump for winter 2022 shows overall statistical significance and a high percentage of explained variance (R^2). Both shifted HDD and shifted CDD were statistically significant influences on total daily energy use. The interaction term meets the criterion for statistical significance, indicating that the TOD group differed from the no-TOD group after the intervention.

Table 25. Regression model output for effects on total daily energy use for the central heat pump group based on dataset A (winter 2022 comparison).

Predictors	Unstandardized Regression Coefficient (kWh)	Std. Error of the Estimate	t	p
Intercept	36.06	0.74	48.97	< 0.001
Shifted HDD	3.74	0.05	79.44	< 0.001
Shifted CDD	2.16	0.12	18.16	< 0.001
TOD_GroupAssignment	-1.60	0.71	-2.27	0.02
TODLaunch	-1.02	1.11	-0.92	0.36
TOD_GroupAssignment*ToDLaunch	-3.97	1.51	-2.63	0.01
Overall model significance				
df:	604			
R^2	0.929			
p	< 0.0001			

The overall model in Table 26 for the central heat pump group for winter 2023 was statistically significant and explains a high percentage of variance. Both shifted HDD and shifted CDD on total daily energy use. The interaction of TOD group and intervention launch term meets the criterion for statistical significance, indicating that the TOD group and the no-TOD group differed after the intervention.

Table 26. Regression model output for effects on total daily energy use for the central heat pump group based on dataset B (winter 2023 comparison).

Predictors	Unstandardized Regression Coefficient (kWh)	Std. Error of the Estimate	t	p
Intercept	36.49	0.79	46.19	<0.001
Shifted HDD	3.68	0.05	72.92	<0.001
Shifted CDD	2.09	0.13	16.41	<0.001
TOD_GroupAssignment	-1.05	0.76	-1.38	0.17
TODLaunch	2.13	1.22	1.76	0.08
TOD_GroupAssignment*TODLaunch	-3.63	1.67	-2.18	0.03
Overall model significance				
df:	594			
R ²	0.918			
p	< 0.0001			

Table 27 shows that in winter 2022, the TOD intervention reduced daily usage in homes with central heat pumps by 4.3% (from 93.0 to 89.0 kWh). In winter 2023, the reduction was 3.9%.

Table 27. The effect of TOD on total daily energy usage in winter 2022 and 2023 shows energy conservation for the central heat pump group in both years.

Season	Dataset	HDD	Temp.	Avg. TOD group actual usage (kWh)	Fit		95% CI - Upper		95% CI - Lower	
					Predicted usage w/o intervention (kWh)	Intervention effect (%)	Predicted usage w/o Intervention (kWh)	Intervention effect (%)	Predicted usage w/o Intervention (kWh)	Intervention effect (%)
2022 Winter	A	1470	-3.8	89.0	93.0	4.3%	95.9	7.2%	90.0	1.1%
2023 Winter	B	1421	-3.1	90.1	93.8	3.9%	97.0	7.1%	90.5	0.4%

3.3 TOD effects on no-Tech participant bills

This section examines the effect of the TOD intervention on participant bills for the no-Tech research group, utilizing the data from monthly bill settlement files. Additionally, it presents S-curve based on smart meter data as a visual and analytical tool to understand the frequency of outcomes for individual homes.

3.3.1 Analysis of monthly bill settlements

Visual analysis of bill settlement data for the no-Tech group reveals that the TOD rate structure offered little reward for most TOD participants (Figure 18). Average monthly TOD credits were infrequently seen on participants' bills with the exception of the winter months. When the TOD calculation resulted in a negative value, there was no bill penalty for participants.

The wisdom of this choice for the project's success is evident from Table 28, which shows the descriptive statistics for the monthly average TOD credits in each season. Some participants would have seen substantial penalties had these been applied, as they used a large amount of electricity at on-peak rates. Throughout the TOD experiment period, spanning from June 2022 until March 2024, the no-Tech TOD participants collectively received \$4,645 as bill credits. Had negative values not been shielded, participants' total billing amount would have increased by \$5,538.

The TOD rate structure was intended to be revenue neutral for customers, meaning that the adjustments in electricity rates during peak and off-peak times were designed to balance out, so there were neither gains or losses for revenue overall. The overall mean of TOD credits for the duration of the experiment from June 2022 until March 2024 was \$3.18 for each of 151 participants and overall mean penalty for the same period would have been -\$3.88 for each of 147 participants.

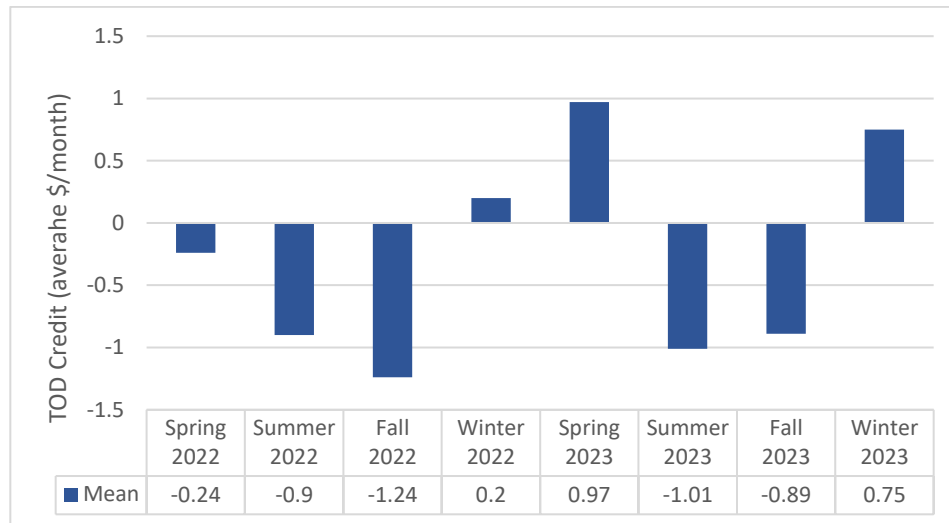


Figure18. Average monthly TOD credits (\$), averaged over seasons, from the start to end of the intervention.

Table 28. Summary statistics for the monthly average TOD credits by season. N is number of no-Tech participants on bill settlements for the season.

	Spring 2022	Summer 2022	Fall 2022	Winter 2022	Spring 2023	Summer 2023	Fall 2023	Winter 2023
N	161	158	157	152	149	124	123	123
Mean	-0.24	-0.90	-1.24	0.20	0.97	-1.01	-0.89	0.75
Median	0.28	-0.75	-0.73	1.41	1.28	-0.82	-0.26	1.62
SD	6.19	3.66	4.56	7.54	6.17	3.65	5.22	7.02
Minimum	-66.44	-15.34	-37.05	-53.37	-45.73	-20.21	-47.53	-58.03
Maximum	16.51	29.80	11.40	21.52	30.73	12.99	12.64	20.26

3.3.2 Understanding bill impact of TOD rates

Figure 19 shows the S-curve as a dashed line for the no-Tech TOD group during the baseline period (May 2021 to May 2022), and the same for the experiment period (January 2023 to December 2023) as a solid line for side-by-side comparison. The baseline period is a calculation of what would have happened had TOD rates been applied to the actual measured consumption during the baseline period.

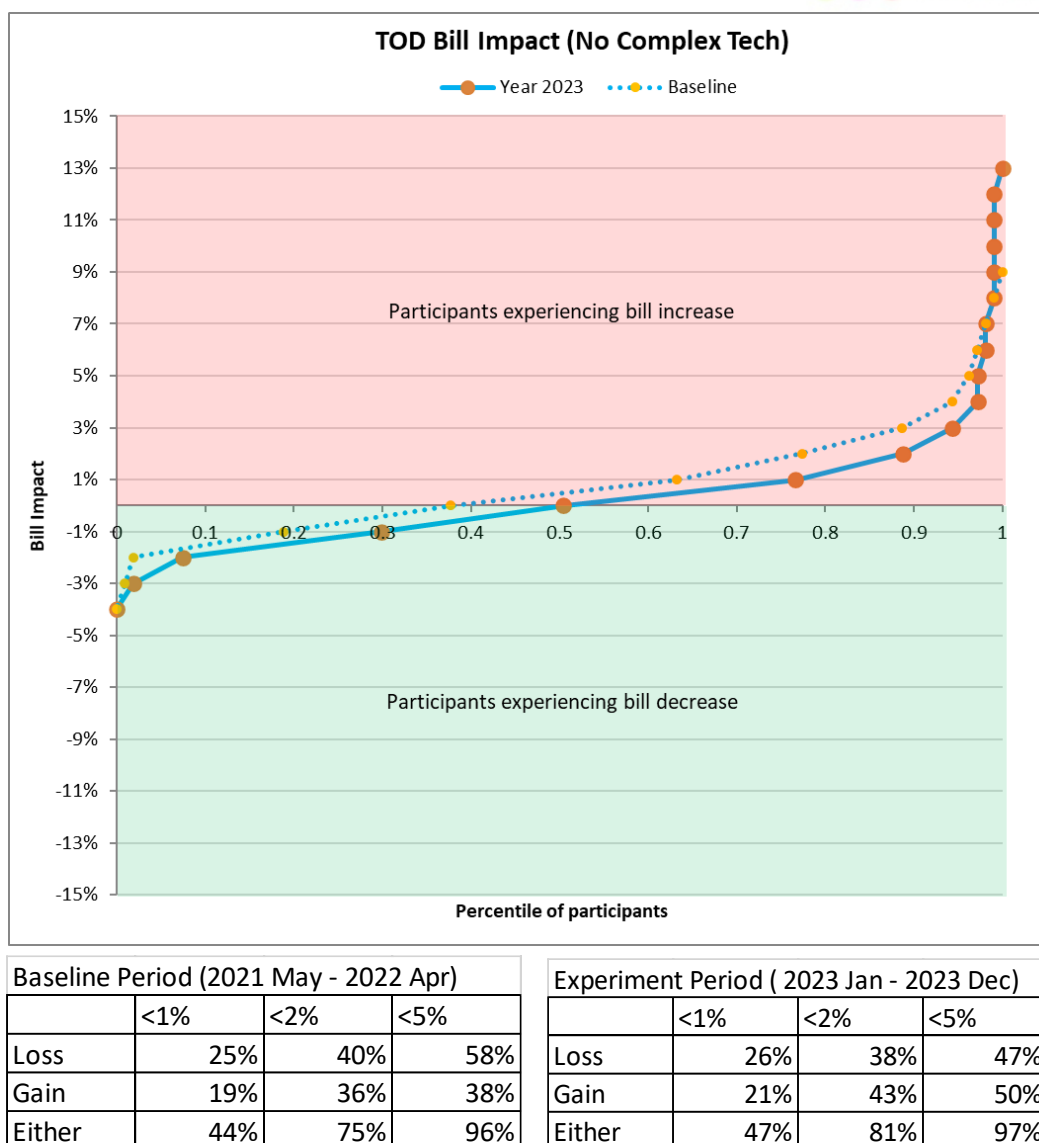


Figure 19. Distribution of bill changes across participants for the no- Tech TOD group.

After the introduction of TOD billing, the no-Tech TOD group's gains and losses shifted noticeably compared to the baseline period calculation:

Penalties: During the baseline period, 25% of the sample would have experienced penalties under 1% of the bill amount, 40% under 2%, and 58% under 5%. In the experiment period, these numbers slightly decreased to 26% under 1%, 38% under 2%, and 47% under 5%. This indicates a reduction in larger penalties after the introduction of TOD (i.e., the time of their electricity use shifted, but not enough to entirely avoid penalties). As mentioned earlier participants in the study are protected against the bill rise due to the TOD.

Savings: TOD credits under 1% of the bill amount would have increased slightly from 19% in the baseline to 21% in the experiment period. However, for gains under 2%, there was a significant increase from 36% to 43%, and under 5%, from 38% to 50%. This suggests that some customers experienced moderate credits with TOD billing compared to what would have occurred had there been TOD credits previously.

Overall Trend: The S-curve shifts towards a more balanced impact distribution with TOD rates. Overall, the introduction of TOD billing seems to have resulted in a more favorable balance of credits over penalties for the group, suggesting that TOD billing may have positively influenced customer energy costs for the no-Tech TOD group over time.

4 Discussion

4.1 Peak demand and energy conservation

The TOD rate intervention was primarily designed to shift the time of participants' electricity usage away from on-peak times to reduce the daily winter morning peak. The no-Tech group as a whole showed a 3.3% reduction in average daily morning peak demand in winter 2022. This effect is consistent with others, albeit on the lower end. Faruqui and Sergici (2013) analysed the effect of TOD by plotting the peak-to-off-peak price ratio from 40 studies. For a price ratio of 4:1, their scatter plot shows observed peak reduction ranging from nearly 3% to 10% without technology devices. The price ratio tested here was 3.47:1 and the duration of on-peak hours was only two hours.

Though no effect of the TOD rate intervention was observed on the morning peak demand for the winter of 2023 for the no-Tech group, its subset, the MSHP group, demonstrated a reduction of 3.0%. As previously noted, the effect of TOD rates in Ontario declined over years decreasing from 3.3% before 2012 to 1.2% in 2014. Initially, customers may respond to price signals by changing their energy use habits. However, over time, there is a risk of reverting to their previous habits if the savings no longer seem significant or if the effort to maintain the new behavior outweighs the perceived benefits. The long-term effectiveness of TOD rates relies on ongoing customer engagement, the integration of enabling technologies, and periodic adjustments to the rates to ensure they remain relevant and impactful.

Primary heating system moderated the effect of the TOD intervention. Dwellings with existing MSHPs responded to TOD rates with reductions of 5.4% in average daily peak demand in Winter 2022 and 3.0% in Winter 2023. Additionally, these dwellings demonstrated a notable conservation effect, achieving reductions of 3.4% in total daily energy use in winter 2022. Dwellings with central heat pumps showed a reduction of 3.6% in average daily peak demand in winter 2022 and reductions in total daily energy use of 4.3% in 2022 and 3.9% in 2023.

The conservation effect of the TOD intervention has been noted in other studies (Faruqui et al., 2016; Newsham, 2019). It could be attributed to increased consumer awareness of electricity usage patterns, leading to more mindful usage. Consumers may have adopted new habits, such as consistently turning off lights and unplugging devices, not just during peak periods. Additionally, social and community influences, driven by the behaviours of peers and neighbors, may further have encouraged energy conservation practices.

4.2 Financial considerations

The peak reduction resulted, on average, in small financial benefits for participants, but only during the winter months. The variability in TOD credits was very large. Some participants could have experienced bill increases on the order of \$60 monthly in a season had there been financial penalties. On average, each participant received \$3.18 in TOD credits, while potential penalties (that were not applied) averaged -\$3.88.

Although the rate structure was designed to be revenue-neutral, it could have resulted in a small increase in NB Power revenue had financial penalties been applied to customers' TOD bills. During the

TOD experiment from June 2022 to March 2024, no-Tech TOD participants received an aggregated sum of \$4,645 in bill credits. Without protection against negative values, their total billing would have increased by \$5,538 (a difference of \$893). Nonetheless, the introduction of TOD billing resulted in a more favorable balance of credits over penalties for the no-Tech TOD group, indicating a positive change in the time of electricity use during the intervention.

4.3 Attitudes

The survey results show that the TOD intervention did have an effect: Participants in the TOD group reported better knowledge about TOD rates after the intervention began and their estimates of the likely savings also changed, towards values that were closer to their experiences (mostly no TOD credits). Despite the relatively small payments, most participants reported having made efforts to take advantage of the TOD rates and would consider signing up for a TOD program if one were offered.

The literature review had found that participation in TOD programs requires clear communications and understanding, which this program largely achieved. It also requires, however, that changing the timing of energy behaviours be convenient and easy. The participants who reported not having made the effort to change their behaviours most often said that to do so was too complex given their schedules, or too inconvenient. However, this merits further investigation given the gaps in energy literacy revealed by the survey. It appears that many participants have a limited understanding of when their electricity demand is highest, which might mean that they incorrectly identified which changes they might make and how these might change their peak demand.

4.4 Limitations

Compared to utility intervention program evaluations (with thousands of customers enrolled), this was a small trial. This severely limited the statistical power, so that real effects might have been overlooked, especially for small subgroups of heating system types in the sample. As a field quasi-experiment, true experimental control was not possible. Nor could we control attrition, which resulted in a considerably smaller sample size at the end of the project.

5 Conclusion

This TOD rates intervention successfully caused small reductions in average morning peak electricity demand and (somewhat unexpectedly) total daily energy use. The effects were moderated by heating system type, being larger for MSHP than central heat pumps. Regrettably, the sample size was too small to test the effects on dwellings with electric baseboard heating. Despite the meagre financial benefits of this intervention, participants reported very favourable attitudes towards TOD rates provided that making the behavioural changes were convenient and maintained their comfort.

The Shediach study provides the evidence that heat pumps not only contribute to energy conservation but also help reduce demand during morning peak hours. In their 2025 study published by American Council for an Energy-Efficient Economy (ACEEE), Malinowski et al. emphasised the importance of utilities offering heat pump-specific electricity rate plans to encourage their adoption. Heat pumps typically use more electricity during nighttime off-peak periods, which align with the coldest temperatures and lower grid strain. When operated in a set-and-forget temperature setpoint mode, they present a smaller peak as compared to other heating systems (Pardasani et al. 2025). TOD rate structures can be designed to lower energy bills for consumers with heat pumps by offering reduced charges during these off-peak hours when heat pumps are most active. Furthermore, integrating heat

pump installations with energy efficiency envelope upgrades can further decrease electricity bills and peak demand.

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Appendix A - TOD instructions

A.1TOD Brochure

This brochure was delivered to the homes of all TOD participants as a printed document with a cover letter in May 2022. A second version with updated rates was delivered in June 2022. The second version is shown here.



Welcome to the Shediac Smart Energy Residential Study Time-of-Day Rate Plan!

You have been selected to participate in the Time-of-Day (TOD) research group in the Shediac Residential Energy Study.

Time-of-Day electricity rates can save you money if you change when you use electricity to times of day when energy is typically less expensive to generate. In New Brunswick this also produces fewer carbon emissions.

Changing when you use electricity is a great way to reduce your energy costs and help the environment!



What do Time-of-Day rates mean?

In New Brunswick, electricity generation is more expensive during weekdays when demand is the highest – in the morning when people are getting up and ready for their day, and in the evening when they are at home. These daily routines create peaks – periods of high energy demand – on the electricity system. Time-of-Day rates charge customers more for energy used during times of peak demand and less during times of low demand.

Why is the Shediac Residential Study researching Time-of-Day rates?

Time-of-Day electricity pricing gives customers more control over their bills by rewarding them if they use electricity when rates are lower. Time-of-Day rates can also help utilities manage peak demand by providing incentives for customers to change their energy use to off-peak hours. Electricity produced during off-peak hours

uses less fossil fuel and is better for the environment.

You are a partner in this important project! This research will inform NB Power about how Time-of-Day rates could work for New Brunswick in the future* – for the benefit of customers, the electricity system, and the environment.

Did you know?

Heating and hot-water systems account for the majority of the energy used by most homes in New Brunswick.



Shediac Smart Energy Residential Study Time-of-Day Rate Plan

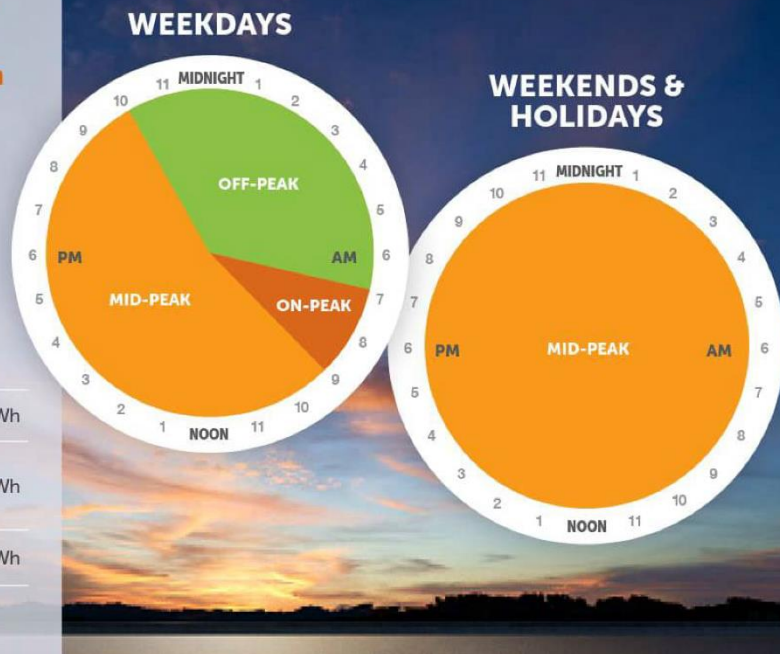
Timing is everything!

Time-of-Day rates for this project will vary depending on the time of day and day of the week. Off-peak, mid-peak and on-peak rates are shown below.

ELECTRICITY RATE /kWh

 OFF-PEAK 10pm-7am weekdays	7.38¢ /kWh
 MID-PEAK 9am-10pm weekdays plus weekends and holidays	11.38¢ /kWh
 ON-PEAK 7am-9am weekdays	25.64¢ /kWh

Rates as of April 1, 2022



Get to know your home's energy picture

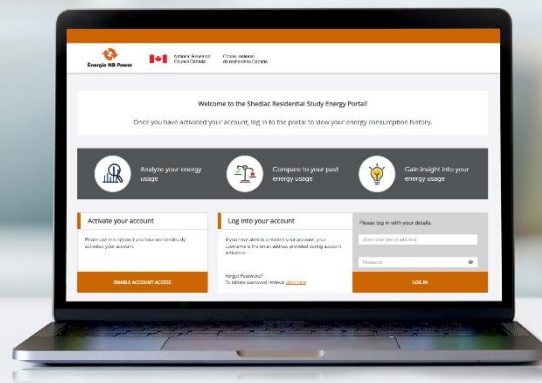
Energy use differs for every home depending on your lifestyle. You can learn more about your home's energy use by visiting your Participant Energy Portal.

If you have not activated your Portal account, please go to the Energy Portal home page to do so.

- Type this link into your browser:
<https://shediacproject.ecrportal.com/>,
- choose your **language preference**,
- then select **"Enable Account Access"** to proceed with the account activation steps.

Your Participant Landing Page at nbpower.com will have information that is specific to your home's situation about how you can change when you use energy to take advantage of your new Time-of-Day plan!

shediacproject.ecrportal.com/



How your Time-of-Day Plan participation looks to you!



You will still receive your monthly NB Power bill as you do Time-of-Day, showing charges calculated in the same way as they have always been.

As a Time-of-Day research participant, you will also have a 'Shadow Report' on your Participant Energy Portal. The Shadow Report will show you what your electricity bill would be when the rates shown above are applied to the times when you used electricity: off-peak, mid-peak or on-peak. If a large

enough portion of your electricity use is at times where energy rates are lower, the amount shown on the Shadow Report will be lower than your regular bill. You will receive a credit for that difference. The Shadow Report will show the credit, and you will see it on your regular bill in the next month. Changing your use so that an even larger portion is at times when rates are lower will increase the credit.

YOUR TIME
OF DAY USAGE:

WHAT THE CHARGE
WOULD HAVE BEEN USING
TIME-OF-DAY RATES FOR
THE ELECTRICITY YOU USED
ON YOUR MOST
RECENT BILL

YOUR
ACTUAL BILL
AMOUNT:

THE CHARGE FOR
ELECTRICITY YOU USED
ON YOUR MOST
RECENT BILL.

LAST
THREE MONTHS:

THE PERCENTAGE OF YOUR
ELECTRICITY USE WITHIN EACH TIME-
OF-DAY PERIOD OF THE LAST THREE
MONTHS

FOR EXAMPLE: 18% OF YOUR
ELECTRICITY IN THOSE THREE
MONTHS WAS ON PEAK.

**Don't be afraid of Time-of-Day,
it will help you use energy in a whole new way!**

shediaproject.ecrportal.com/

**NB Power has no plans to roll out time-of-day rates on a broad scale at this time but is exploring the potential benefits of time-of-day rates as part of this research study. All rate structures for NB Power must be approved by the Energy and Utilities Board (EUB) and any decision on applying for new rate options would only be made after foundational work is advanced further. Future time-of-day rates, if implemented, could be different from those being tested in the Shediac Smart Energy Community Project.*

NOTES

A.2 Summer 2022 - Cooling instructions

Welcome to the Shediac Smart Energy Residential Study Time-of-Day Rate Plan!

Recently, we mailed you an introduction to the Time-of-Day research group. For the rest of the Shediac Residential Energy Study, until June 30, 2023, your home will be part of this research group.

You can learn more about your home's energy use by visiting your Participant Energy Portal, where you will also find monthly Shadow Reports. Your Shadow Reports will show you what your electricity bill would be when the Time-of-Day rates are applied to the times when you used electricity: off-peak, mid-peak or on-peak. If a large enough portion of your electricity use is at times where energy rates are lower, the amount shown on the Shadow Report will be lower than your regular bill. You will receive a credit for that difference. The Shadow Report will show the credit, and you will see it on your regular bill in the next month. Changing your use so that an even larger portion is at times when rates are lower will increase the credit.

While home heating is a major energy use in New Brunswick winters, you can take advantage of Time-of-Day rates year-round. Here are some helpful tips for you to reduce your on-peak electricity use outside of the heating season:

- Did you know water heating is the second largest use of electricity in your home? Consider reducing your hot water usage between 7:00 – 9:00 in the morning by taking shorter showers or showering at a different time of day.
- Minimize your use of major appliances such as dishwasher, washer and dryer and oven during the peak hours.
- Unplug instant coffee makers that have a built-in hot water reserve and instead only use as much hot water as you need... but still have your morning tea/coffee as you start your day!
- Plan ahead! Prepare a breakfast that can be quickly reheated in the microwave, or have a cold breakfast to avoid using energy during peak hours. If you're really looking forward to a hot breakfast, use pans that match the burner size; using a pan or burner that is too big wastes energy.

You can also save energy in summer by reducing the amount of time you use air conditioning. Keep your home cool and comfortable without needing to turn on your heat pump or window A/C:

- Close your windows during the day when it is hot out and open them at night when it is cooler. A window open in the daytime will allow hot air and humidity to enter your home and force your air conditioner to work harder, but opening windows at night will let in fresh air while you sleep and cool your home at the same time.
- Keep your curtains closed to keep the sun from heating your home. (Do the opposite in the winter: keep your curtains drawn to get free heat from the sun!)

- Be sure to check cooling system filters every month and clean them as necessary. Dust, pollen, and other airborne debris can clog up your filters and reduce the amount of air that will flow through; this can cause your cooling system to overheat and work less efficiently.
- If you have ceiling fans, use them to circulate the air in your home and keep the upstairs from overheating. Hot air will rise, so turning on ceiling fans upstairs will help to push the heat back down and keep an even temperature throughout the home.
- Minimize the use of your oven, toaster and other cooking appliances in your home in the afternoons and early evenings. Try cooking with outdoor appliances such as a barbecue, or pre-cooking meals later in the evening or early in the morning and either serve them cold or re-heat in the microwave.

We hope you will use these tips to help reduce your energy consumption and lower your bills in the spring and summer. We'll send out more tips and seasonal advice in the fall.

If you have any questions about these tips or want to learn more about how you can take advantage of Time-of-Day rates, please contact us at Shediac@nbpower.com or drop by the project office.

A.3 Winter 2022 – Heating instructions

As detailed in the text, participants obtained an instruction sheet from their personal Participant Landing Page. They saw the one version that applied to the primary heating system as it was known to the project from Home Assessment 1.

A.3.1 Electric baseboards

Welcome to the Shediac Smart Energy Residential Study Time-of-Day Rate Plan!

Recently, we mailed you an introduction to the Time-of-Day research group. For the rest of the Shediac Residential Energy Study, until June 30, 2023, your home will be part of this research group.

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Home heating is a major energy use in New Brunswick, but the best way to change the timing of this energy use depends on what heating system is in your home. This document has been written specifically for the type of heating system you have.

Electric baseboard, electric furnace, electric boiler, electric radiant heating:

- Set your thermostat back by only 2 °C / 4 °F when you go to bed at night. For example, if you normally set your thermostat to 21 °C during the day, only turn it back to 19 °C at night – not more. This will keep your home a bit warmer, so that you don't need to re-heat your home as much in the morning. The TOD electricity rates are significantly lower at night, so your bill will be lower even though your heating system is set a bit higher than usual.
- Program your thermostat to turn on earlier so that it pre-heats your home before the peak hours start at 7 a.m. If you normally program your thermostats to 21 °C at 7 a.m., program them to 22 °C at 5 a.m. instead. Preheat your home by not more than 1 °C / 2 °F above your usual setpoint. This can save you money by heating when rates are lower and helps to reduce the peak demand during the hours when people are getting up.
- Turn down your thermostat by 1 °C / 2 °F during peak hours. A difference of just 1 °C on the coldest days of the year can reduce your energy consumption by up to 5%! If you usually set your thermostat to 21 °C for the daytime set it to 20 °C between 7-9 a.m. to reduce your peak energy use.

By implementing one or more of the above suggestions, you could see a big change in your peak energy use. And that means TOD cost savings for you, and lower GHGs for New Brunswick.

Here's what your thermostat programming schedule would look like based on the above suggestions:

Daytime setpoint	Nighttime 2 °C cooler	5:00-7:00 a.m. 1 °C above setpoint	7:00-9:00 a.m. 1 °C below setpoint
21 °C	19 °C	22 °C	20 °C
70 °F	66 °F	72 °F	68 °F

If your normal daytime setpoint is higher or lower than 21 °C, then add (if higher) or subtract (if lower) the difference from the numbers shown in the table.

Other Tips for Taking Advantage of Time-of-Day Rates

Here are some additional tips you can try to reduce your on-peak electricity use:

- Although electricity used to heat your home makes up the largest percentage of your bill, water heating is the second largest use of electricity in your home. Consider reducing your hot water usage between 7:00 – 9:00 in the morning by taking shorter showers or showering at a different time of day.
- Minimize your use of major appliances such as dishwasher, washer and dryer and oven during the peak hours.
- Unplug instant coffee makers that have a built-in hot water reserve and instead only use as much hot water as you need... but still have your morning tea/coffee 'cause you've gotta make it through the day!
- If the forecast calls for a cold night, plan ahead to prep a breakfast that can be quickly reheated in the microwave, or have a cold breakfast to avoid using energy during peak hours.

A.3.2 Mini-split heat pumps

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Mini-splits

- Mini-splits are more efficient and save the most energy when you “set it and forget it.” Set your heat pump to your desired room temperature and leave it there – no nighttime setbacks or lower temperatures when you are away from home.
- Electric baseboards or other back-up heating sources should be set 2 °C / 4 °F lower than your mini-split set point. If you normally heat your home to 21 °C with your heat pump, set your electric baseboard/backup thermostat to 19 °C. This will ensure that the backup only turns on when the mini-split can't keep the room warm on its own.
- Program your backup heat to turn on 2 hrs before you plan to get up. By using your back-up to pre-heat your home in the early morning when TOD prices are lower, you will reduce your on-peak energy consumption.

By implementing one or more of the above suggestions, you could see a big change in your peak energy use. And that means energy savings for you, and less GHGs for NB.

Here's what your thermostat programming schedule would look like based on the above suggestions:

Set your mini-split to 21 °C and leave it there.

For your electric baseboard or other electric back-up system:

Daytime setpoints	Nighttime setpoints	Morning pre-heat 5:00-7:00a.m.	On-peak 7:00-9:00a.m.
19 °C	19 °C	22 °C	19 °C
66 °F	66 °F	72 °F	66 °F

If your normal mini-split setpoint is higher or lower than 21 °C, then add (if higher) or subtract (if lower) the difference from the numbers shown in the table.

Other Tips for Taking Advantage of Time-of-Day Rates

Here are some additional tips you can try to reduce your on-peak electricity use:

- Although electricity used to heat your home makes up the largest percentage of your bill, water heating is the second largest use of electricity in your home. Consider reducing your hot water usage between 7:00 – 9:00 in the morning by taking shorter showers or showering at a different time of day.
- Minimize your use of major appliances such as dishwasher, washer and dryer and oven during the peak hours.
- Unplug instant coffee makers that have a built-in hot water reserve and instead only use as much hot water as you need... but still have your morning tea/coffee 'cause you've gotta make it through the day!
- If the forecast calls for a cold night, plan ahead to prep a breakfast that can be quickly reheated in the microwave, or have a cold breakfast to avoid using energy during peak hours.

A.3.3 Central air furnaces

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Central Air Source Heat Pumps:

- Set your heat pump to your desired room temperature and leave it there overnight. This will help your system to run efficiently and will keep your home a bit warmer so that you don't need to re-heat your home as much in the morning. Because the TOD electricity rates are significantly lower at night, your bill will also be lower even though your heating system is set a bit higher than usual.
- Program your thermostat to turn on earlier in the morning to preheat your home before the peak hours start at 7 a.m. If you normally program your thermostats to 21 °C at 7 a.m., program them to 22 °C at 5 a.m. instead. Preheat your home by not more than 1 °C / 2 °F above your usual setpoint. This saves you money by heating when rates are lower and helps to reduce the peak demand during the hours when people are getting up.
- Turn down your thermostat by 1 °C / 2 °F during peak hours. A difference of just 1 °C on the coldest days of the year can reduce your energy consumption by up to 5%! If you usually set your thermostat to 21 °C for the daytime set it to 20 °C between 7-9 a.m. to reduce your peak energy use.

Here's what your thermostat programming schedule would look like based on the above suggestions:

Daytime setpoint	Nighttime	5:00-7:00 a.m.	7:00 -9:00 a.m.
21 °C	21 °C	22 °C	20 °C
70 °F	70 °F	72 °F	68 °F

If your normal daytime setpoint is higher or lower than 21 °C, then add (if higher) or subtract (if lower) the difference from the numbers shown in the table.

Other Tips for Taking Advantage of Time-of-Day Rates

Here are some additional tips you can try to reduce your on-peak electricity use:

- Although electricity used to heat your home makes up the largest percentage of your bill, water heating is the second largest use of electricity in your home. Consider reducing your hot water usage between 7:00 – 9:00 in the morning by taking shorter showers or showering at a different time of day.
- Minimize your use of major appliances such as dishwasher, washer and dryer and oven during the peak hours.
- Unplug instant coffee makers that have a built-in hot water reserve and instead only use as much hot water as you need... but still have your morning tea/coffee 'cause you've gotta make it through the day!
- If the forecast calls for a cold night, plan ahead to prep a breakfast that can be quickly reheated in the microwave, or have a cold breakfast to avoid using energy during peak hours.

A.3.4 Geothermal heating

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Home heating is a major energy use in New Brunswick, but the best way to change the timing of this energy use depends on what heating system is in your home. This document has been written specifically for the type of heating system you have.

Geothermal heat pumps:

Congratulations for choosing the most efficient heating system on the market! Geothermal heat pumps use less energy than other heating systems, and also contribute less to morning peak, but there are things you can still do to help reduce your morning energy use:

- Set it and forget it. Don't turn your thermostat down at night before you go to bed; this will help your system to run efficiently and minimize your already low impact on peak.
- Although electricity used to heat your home makes up the largest percentage of your bill, water heating is the second largest use of electricity in your home. Consider reducing your hot water usage between 7:00 – 9:00 in the morning by taking shorter showers or showering at a different time of day.
- Minimize your use of major appliances such as dishwasher, washer and dryer and oven during the peak hours.
- Unplug instant coffee makers that have a built-in hot water reserve and instead only use as much hot water as you need... but still have your morning tea/coffee 'cause you've gotta make it through the day!
- if the forecast calls for a cold night, plan ahead to prep a breakfast that can be quickly reheated in the microwave, or have a cold breakfast to avoid using energy during peak hours.

By planning ahead and making little changes to our behaviour, we can have a big impact on our peak energy usage!

A.3.5 Non-electric heating

Welcome to the Shediac Smart Energy Residential Study Time-of-Day Rate Plan!

As you are aware, your home is part of the Time-of-Day research group. For the rest of the Shediac Residential Energy Study your home will be part of this research group.

You can learn more about your home's energy use by visiting your Participant Energy Portal, where you will also find monthly Shadow Reports. Your Shadow Reports will show you what your electricity bill would be when the Time-of-Day rates are applied to the times when you used electricity: off-peak, mid-peak or on-peak. If a large enough portion of your electricity use is at times where energy rates are lower, the amount shown on the Shadow Report will be lower than your regular bill. You will receive a credit for that difference. The Shadow Report will show the credit, and you will see it on your regular bill in the next month. Changing your use so that an even larger portion is at times when rates are lower will increase the credit.

Tips for Taking Advantage of Time-of-Day Rates for homes that do not heat with electricity.

Electricity used for home heating makes up the largest percentage of most New Brunswickers' monthly bills, but this is not the case for you if you don't heat with electricity. Here are some tips you can use to reduce your on-peak electricity use:

After space heating, electric water heating is the second largest use of electricity in most New Brunswick homes. If you have an electric water heater, consider reducing your hot water usage between 7:00 – 9:00 in the morning by taking shorter showers or showering at a different time of day.

- Minimize your use of major appliances such as dishwasher, washer and dryer and oven during the peak hours.
- Unplug instant coffee makers that have a built-in hot water reserve and instead only use as much hot water as you need... but still have your morning tea/coffee 'cause you've gotta make it through the day!
- If the forecast calls for a cold night, plan ahead to prep a breakfast that can be quickly reheated in the microwave, or have a cold breakfast to avoid using energy during peak hours.

A.4 Winter 2023 Heating

This was presented as a handout at in-person workshops for TOD participants, and also e-mailed to all TOD participants.

Shediac Smart Energy Community Project - Residential Energy Study

Save energy at peak times and take advantage of time-of-day rates

A simple winter heating strategy for Time-of Day (TOD) participants in the Shediac Residential Energy Study

This winter, consider setting your principal home thermostat(s) to the temperature your household finds most comfortable and leaving it there.

This strategy will help you save energy at peak times, avoid added 'on-peak' cost and protect the environment for future generations.

Why?

The common practice of turning down household heating sources at night and up again in the morning between 7 am and 9 am is a major contributor to peak load (the highest amount of electricity used in 24 hours).

Thanks to project participants in winter 2022 and 2023, here are things we have learned and what we recommend for you to do to take advantage of your time-of-day electricity rates:

Programming your thermostats to a lower temperature over night and increase in the morning can reduce energy use, but this strategy does not reduce the morning peak.

Homeowners who leave their household temperature the same all the time use less 'on peak' energy than those who turn heat sources down at night and up in the morning.

This is especially true for homes with mini-split heat pumps, which are designed to work efficiently when set at a constant temperature over 24 hours.

Advice for TOD participants in the Shediac Residential Energy Study:

1. Set your household thermostat(s) to a comfortable temperature
2. Leave it there for the winter heating season
3. Save 'on-peak' energy, avoid extra costs and protect the planet.

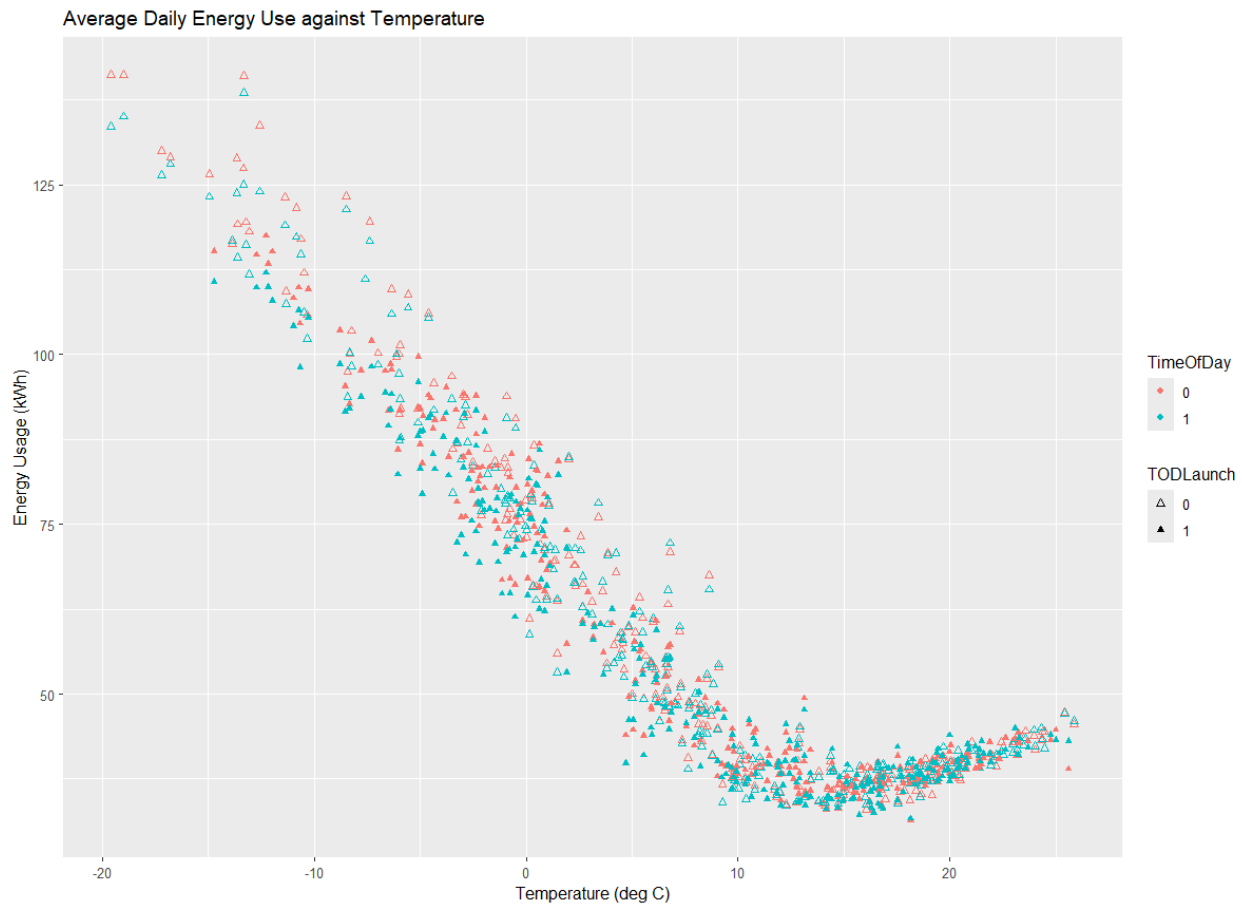
Thank you!

Appendix B - VEE flag matrix

VEE Flag	Name	Description	Threshold/Config	Notes
V0	VALID	No VEE operation performed on the interval	N/A	
V1	FAILED MAX DEMAND	Interval exceeded max demand threshold	10 kWh	NB Power to provide feedback on threshold value
V2	ESTIMATED	Interval value estimated using either Historic estimation or Class Load Profile estimation.	Historic Estimation (30 days)	• <u>Historic</u> estimation will be attempted first on interval and if unsuccessful <u>Class Load Profile</u> will be used for estimation ◦ Historic estimate for each interval is based on the average of valid intervals from a set number of Like Days that are comparable to the day for which the estimation is required. ◦ The Class Load Profile estimation routine will fill in missing intervals using intervals from a prototype class load profile.
V4	FAILED ESTIMATION	Historic and Class Load Profile estimation is unsuccessful for the interval	N/A	
V8	EDITED	Interval manually edited	N/A	• Where actual interval consumption data is not available and automated estimation processes have not been successful, UA may be required to manually inspect and approve interval consumption data or to edit the values. • Receiving meter read data with missing intervals would be extremely rare as UtiliSmart will only send meter read data when data is available (no gaps).

Appendix C - Choice of 12.5 °C as the base temperature for HDD and CDD

The following scatterplot illustrates the daily energy usage (kWh) in relation to the daily average outdoor temperature for households of no-Tech participants and includes both TOD and no-TOD participants. Notice the inflection point at the bottom, where daily energy use begins to rise at around 12.5°C, indicating the onset of the heating season. The flat valley at the bottom represents temperatures during the shoulder season, when there is neither heating nor cooling. The 12.5 °C was chosen as a base temperature for HDD and CDD for the best regression fit.



Appendix D - Shifted time windows for HDD and CDD

The impact of weather conditions on energy use in buildings is not always immediate. For instance, a drop in outdoor temperatures might not lead to an increased heating demand until later, as buildings have thermal inertia and retain heat. Similarly, a hot day might not cause an immediate spike in cooling load if a building is well-insulated or if occupants delay using air conditioning thermal discomfort sets in.

To account for this delayed impact, we shifted the 24-hour window used for HDD and CDD forward by 12 hours. This adjustment allowed us to better capture the lagged effect of temperature changes on energy consumption. Through several "what-if" scenarios, we determined that a 12-hour forward shift effectively encompassed the morning hours of interest and the preceding 19 hours. This technique is particularly valuable in predictive models, as understanding the temporal relationship between weather and energy use can lead to more precise forecasts and improved energy management strategies.

By plotting the average morning demand against the average outdoor temperature for the day (Figure D.1, left), and then against the outdoor temperature shifted 12 hours forward (Figure D.1, right), we observed a stronger linear relationship between demand and the shifted outdoor temperature. This stronger correlation underpins the use of shifted HDD and CDD in our regression models.

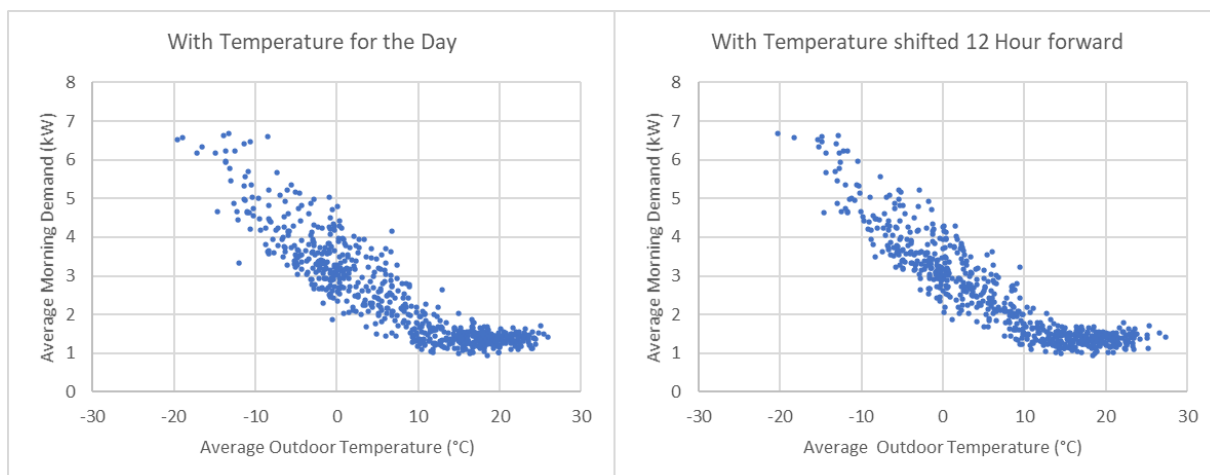


Figure D.1. Average morning demand (kW) in workings day during the study period against two ways of calculating average outdoor temperature.

Chapter 7: Technical and User Evaluation of Cold-Climate Mini-split Heat Pumps

Yitian (Vera) Hu, Ajit Pardasani, Jennifer A. Veitch, Natalia Cooper, and Hadia Awad

Executive Summary

The urgent need to mitigate climate change and reduce dependency on fossil fuels has led to governments incentivizing advanced energy technologies. Cold-climate mini-split heat pumps (CC-MSHP) show potential to reduce carbon emissions as well as to lower energy bills. Adoption of CC-MSHPs is steadily increasing, supported by advancements in technology and by government incentive programs. However, the continued success of these initiatives largely depends on the homeowners' perceptions and satisfaction with these technologies, as well as on evidence of satisfactory system performance.

The Shediak Residential Energy Study was conducted as part of New Brunswick Power's involvement in the Smart Grid Atlantic initiative. This report addresses one part of the Shediak Residential Energy Study (described in detail in other project reports), the CC-MSHP intervention. Twenty-three households in Shediak, New Brunswick received CC-MSHPs at no charge and agreed to participate in an evaluation of the system operation and performance in parallel with surveys concerning the occupants' perceptions of system performance, their attitudes towards the technology intervention, and their satisfaction with the project. The CC-MSHP intervention was combined with a test of a time-of-day (TOD) electricity rates experiment to encourage off-peak energy use. The participants were randomly divided into two groups for the TOD intervention. The participants in the TOD group were sent instructions as how to benefit from time-based rates and were credited for any resulting savings, whereas the participants in the no-TOD group did not receive such instructions and received no time-based financial incentives.

The study employed regression models and a Difference-in-Differences (DiD) approach to isolate the effects of the CC-MSHP installation and the TOD intervention on energy use. The analysis revealed that the installation of CC-MSHPs led to substantial energy savings and demand reduction, with up to 12% energy savings during winter, and a peak demand reduction of up to 16% during morning peak hours (7-9 am). The TOD intervention also contributed to additional savings, particularly in shifting energy use away from peak hours.

Project participants were invited to complete online surveys on seven occasions throughout the project. Overall, participants expressed high satisfaction with the technology, noting improved thermal comfort. The findings suggest that CC-MSHPs could play a crucial role in grid modernization and decarbonization efforts by boosting energy efficiency, reducing peak demand and enhancing user satisfaction.

1 Introduction

1.1.1 Background

The Shediac Residential Energy Study was initiated by New Brunswick Power (NBP) following a decision by the Town of Shediac to become “Atlantic Canada’s first smart energy community” as part of their participation in the Smart Grid Atlantic (SGA) initiative. The study evaluated several technological and behavioural interventions which, with successful integration, hold the promise to accelerate grid modernization and decarbonization. The objective of this study was to gain a deep understanding of each intervention by assessing both the technical and human aspects. The technology intervention evaluated in this report is high-efficiency cold-climate mini-split heat pumps (CC-MSHP). Other technologies and behavioural interventions are covered in separate reports. For more details on the background of the Shediac Residential Energy Study, please see Veitch, et al. (2025).

A mini-split heat pump (MSHP) is a versatile, duct-free heating and cooling system available in various capacities, making it a fast and tailored retrofit option for most existing buildings and homes that lack air ducts. As a type of air-source heat pump, an MSHP offers better energy efficiency than other zonal electric heating systems for residential buildings. At 8°C, the Coefficient of Performance (COP) of a typical air-source heat pump can range from 2.0 to 5.4 (Natural Resources Canada, 2022) while electric baseboard heaters cap their COP at 1. CC-MSHPs are a specialized type of mini-split heat pump designed to operate efficiently in extremely cold weather conditions. They maintain a higher COP at lower temperatures compared to standard MSHPs, which not only results in energy savings but also reduces the demand on the electricity grid during extreme cold days by meeting heating needs with less energy draw.

This study examined the performance of CC-MSHPs in real-world conditions, and was designed to better understand their impact on the grid and customer satisfaction, and to compare their effects to those of standard MSHPs. With more homes switching to MSHPs and CC-MSHPs, insights from this study will help inform grid planning and programs to address technology uptake.

Cold-climate mini-split heat pumps (CC-MSHP) were deployed to 23 participant dwellings by NBP in Fall 2022. The new CC-MSHP functioned as the primary heating system for these dwellings. Smart meter data was collected for energy performance analysis, while surveys were dispatched to study customer experience. These homes were also subject to a Time-of-Day (TOD) experiment, which was launched in May 2022, about five months earlier than the CC-MSHP deployment. The methods and results described in this report isolate the effect of this technology intervention and provide insights into its energy savings performance and its effects on winter peak demand and bills.

1.2 Objectives

The report addresses the following questions, which are a subset of those in the Shediac Residential Energy Study (Veitch, et al., 2025):

- What is the impact of the NBP-installed CC-MSHP on daily energy use?
- What is the impact of the NBP-installed CC-MSHP on winter morning (7-9 am) demand?
- What are the perceptions of participants regarding the CC-MSHP?
- What is the satisfaction and acceptance level of participants regarding the CC-MSHP?
- How does the performance of the NBP-installed CC-MSHP compare to those of existing MSHPs?

2 Method

2.1 Participants

Through a rigorous review process detailed in Veitch et al. (2025), 33 homes out of the original sample of 529 participants were identified as eligible to receive a thermal storage heat pump (TSHP). However, the chosen TSHP technology encountered a problem and was replaced with the CC-MSHP technology. At this point, 10 participants chose not to continue in the project, resulting in a reduction in the study group size to 23.

To be eligible to receive the TSHP technology at the start of study, a participant's home could not already have a heat pump. Since CC-MSHPs were only offered to the group that initially qualified for the TSHP option, all these homes were heated with electric baseboard heaters prior to this intervention.

In the overall initial sample of the study, many homes already had one or more existing mini-split heat pumps (MSHP) (N=226). Others chose to acquire MSHPs during the project (N=46). The four groups of participants whose data contributed to the analyses in this report are characterized in Table 1. For the analyses reported here, only participants who remained in the project until its end in March 2024 were included. One participant received a CC-MSHP but did not remain in the study to its end, and has been excluded from these analyses.

Table 1. Characterization of survey respondents and their homes in relation to heating system type for comparisons to CC-MSHP.

	Never_HP (N)	Never_HP (%)	HP_start (N)	HP_start (%)	HP_During (N)	HP_During (%)	CC- MSHP (N)	CC- MSHP (%)
Total size	58		226		46		22	
Respondent sex								
Male	28	60.9	128	58.7	22	47.8	12	57.1
Female	18	39.1	88	40.4	24	52.2	9	42.9
Respondent age (2020)								
21-30	3	7.0	7	3.6	3	6.8		
31-40	6	14.0	37	18.9	10	22.7	3	16.7
41-50	8	18.6	51	26.0	7	15.9	3	16.7
51-60	13	30.2	39	19.9	10	22.7	6	33.3
61-70	9	20.9	41	20.9	6	13.6	4	22.2
71-80	2	4.7	19	9.7	8	18.2	2	11.1
81+	1	2.3	2	1.0				
Prefer not to say	1	2.3						
Household Income (2020)								
<\$20k	1	2.2	2	0.9				
\$20k<\$40k	2	4.3	14	6.4	8	17.4	1	4.8
\$40k<\$60k	6	13.0	32	14.6	3	6.5	5	23.8
\$60k<\$80k	7	15.2	21	9.6	8	17.4	2	9.5
\$80k<\$100k	1	2.2	31	14.2	4	8.7	8	38.1
\$100k<\$150k	17	37.0	67	30.6	13	28.3	3	14.3
\$150+k	7	15.2	42	19.2	7	15.2	1	4.8
Don't Know	5	10.9	10	4.6	3	6.5	1	4.8

	Never_HP (N)	Never_HP (%)	HP_start (N)	HP_start (%)	HP_During (N)	HP_During (%)	CC- MSHP (N)	CC- MSHP (%)
Occupancy Pattern (at installation) (2022)								
Someone Always home	23	63.9	107	57.5	24	55.8	11	55.0
At home part of the day	8	22.2	48	25.8	13	30.2	6	30.0
Out all day, back in evening	5	13.9	31	16.7	6	14.0	3	15.0
Home area (SF)								
0-1000	2	5.3	6	2.7	4	8.7	2	9.1
1000-2000	13	34.2	109	48.2	25	54.3	15	68.2
2000-3000	15	39.5	54	23.9	8	17.4	1	4.5
3000-4000	4	10.5	33	14.6	1	2.2	1	4.5
4000-5000			13	5.8	3	6.5	1	4.5
>5000	1	2.6	4	1.8	2	4.3	1	4.5
Not Known	3	7.9	7	3.1	3	6.5	1	4.5
CC-MSHP Location								
Living room							19	87.0
Kitchen							3	13.0
CC-MSHP capacity								
9,000 BTU							1	4.4
12,000 BTU							18	82.6
15,000 BTU							3	13.0

**Totals do not sum equally because of varying responses to survey questions.*

2.2 Interventions

2.2.1 CC-MSHP intervention

The CC-MSHP selected for this project is rated with a COP of 2.13 at -25°C for the model with a capacity of 9,640 BTU/h. The CC-MSHPs were sized based on the heating demand of the dwelling and installed in one of the principal rooms of the home (usually the living room), with most homes receiving the 12,000 BTU capacity unit. The installations were carried out over a 6-day period between October 11-18, 2022. The heat pumps began operating immediately after installation, with the existing electric baseboards as secondary heat sources. Participants received a smart thermostat to control the CC-MSHP.

2.2.2 Time-of-Day intervention

The larger project included a Time-of-Day (TOD) electricity rate experiment, which included the CC-MSHP participants. Participants were randomly assigned to this intervention (Pardasani et al., 2025; Veitch et al., 2025), which began in May 2022. Participants in the TOD group were encouraged to shift electricity consumption away from the morning peak hours (7-9 am) using a differential rate structure, when electricity demand and production costs are high. The TOD rate used in the experiment is shown in Table 2 below. Participants in the no-TOD group were subject to a regular flat rate that is equivalent to the mid-peak/weekends and holidays rate for TOD group.

Participants assigned to the TOD group were given access to a Participant Energy Portal, which showed their energy usage and illustrated what their bill would be under the TOD rate structure for each billing cycle. The TOD group was billed for their electricity use at the regular flat rate but would receive credits if a lower amount were to be charged under the TOD rate. As a particular safeguard for the study, it was not possible for participants' bills to increase because of the TOD rates, although the project had access to accurate information about the cost implications of participants' time of electricity use. Additionally, instructions were provided to help participants take advantage of the TOD rate (Pardasani et al., 2025).

Table 2. TOD rate structure tested in this experiment.

	Weekdays		Weekends and holidays	
	May 2022 – Mar. 2023	Apr. 2023 – Mar. 2024	May 2022 – Mar. 2023	Apr. 2023 – Mar. 2024
On-peak 7:00 – 9:00	\$ 0.2564	\$ 0.2752	\$ 0.1138	\$ 0.1215
Mid-peak 9:00 – 22:00	\$ 0.1138	\$ 0.1215		
Off-peak 22:00 – 7:00	\$ 0.0738	\$ 0.0784		

The original TOD and no-TOD research groups that were initially assigned to receive thermal storage heat pumps were balanced using building characteristics and energy use characteristics. Because of the attrition following the change in heat pump technologies, the final test included 15 participants in the TOD group and 8 in the no-TOD group.

2.3 Data sources

2.3.1 Telemetry data

Data used in this report includes 15-minute interval smart meter data collected between January 2020 and March 2024. NBP implemented an automated data collection and sharing process with the NRC, enabling data to be securely stored at the SQL data warehouse at the NRC. Pardasani (2025) provided a detailed description of data capture and management.

Home assessment data and metadata on devices were recorded in CSV files and ingested into the NRC data warehouse. Hourly weather data from the nearest Environment Canada weather station was loaded into the SQL data warehouse.

Smart thermostats were provided to most homes in 2021, enabling some collection of thermostat settings for existing MSHP and electric baseboard heating systems. However, thermostat telemetry data is not available for the CC-MSHP units themselves.

2.3.2 Survey data

All project participants were invited to complete online surveys on seven occasions throughout the project (see Veitch et al., 2025). The present report includes a small subsection of questions. For the CC-MSHP participants only, this report includes responses concerning participants' satisfaction with the CC-MSHP, the installation process, and the project itself. These were answered on 5-point scales (from 0 to 4) from "very dissatisfied" to "very satisfied". "Yes" or "No" were the possible responses to a question about whether or not they would recommend these units to others.

For all groups, and when comparing the different heating system groups, thermal comfort was assessed in winter 2019 and winter 2023, both times using two questions. Thermal sensation was assessed using the ASHRAE scale (feeling from very cold to very warm on a 7-point scale) (American Society of Heating Refrigerating and Air-conditioning Engineers [ASHRAE], 2023). Thermal preference was rated on a three-point scale from wanting to be colder to wanting to be warmer (McIntyre, 1980).

Participants self-reported their household temperature settings for winter and summer: during waking time at home, when out of the house, and while sleeping; in winter 2019 (start of the project), winter 2022, and winter 2023. Given the absence of telemetry data for the thermostats on the CC-MSHP units, this was the best indicator of how this group used their new technologies. For this report we analyzed the winter 2022 and winter 2023 responses, to include only times when the CC-MSHP units were active.

2.4 Energy data analysis methodology

2.4.1 Timeline

The baseline period for this analysis was June 1, 2021 to May 21, 2022, covering a one-year period that should capture a variety of weather conditions and, therefore, load profiles. The Time of Day (TOD) intervention started on May 22, 2022, and continued until the end of the data collection period on March 31, 2024. The technology intervention started on October 19, 2022, when all 23 homes in this technology group switched to CC-MSHP as their primary heating source. Data during the installation period from October 11 to 18, 2022 was excluded from the analysis. A timeline with reference to meteorological seasons is shown in Figure 1 below.

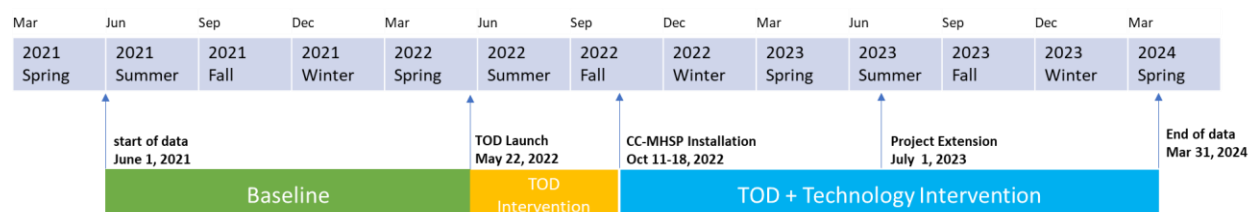


Figure 1. Timeline of baseline and interventions.

2.4.2 Energy data processing

For the energy conservation analysis, total energy use (kWh) for the day was the sum of the 15-min energy use data for each house on that weekday. Weekends and holidays were excluded. The outcome measure for the regression analyses below is the average total energy use per day for the experimental groups, no-TOD and/or TOD. That is, the house-level data for each day for all participants in one experimental group was averaged to give a single score for that group for that day. Regression analyses then paired this daily group average with the weather data for that date.

For the analysis of the morning peak demand, average peak demand (kW) was the average of the 15-min smart meter data for each house between 7:00 a.m. and 9:00 a.m. on each weekday. Weekends and holidays were excluded. The outcome measure for analyses reported below is the average daily morning peak demand for the experimental groups, no-TOD and/or TOD. That is, the house-level data for each day for all participants in one experimental group was averaged to give a single score for that group for that day. Regression analyses then paired this daily group average with the weather data for that date.

Days with more than 2 hours of missing data were excluded prior to aggregation. Only data from working days (non-weekend and non-holiday) were used in downstream analysis.

2.4.3 Analytical method

This technology group received two interventions concurrently, therefore there is a need to isolate the effects of each intervention. To address this, the following two approaches were explored:

1. The first approach analysed data exclusively from the no-TOD group, which comprised seven homes with complete data until the end of the experiment. This group served as the control group for the TOD intervention and, therefore, only received the technology intervention. The baseline data for this approach ranges from June 1, 2021 to October 10, 2022.
2. The second approach considered both interventions together, using data from both the TOD and no-TOD groups. The Difference-in-Differences (DiD) model used for the TOD analysis was modified with an additional dependent variable to isolate the effect of the technology intervention. For this approach, the baseline data spans from June 1, 2021 to May 21, 2022.

Regression models were developed for each approach, with the dependent variable being either daily energy usage in kWh or morning peak hour (7-9 am) demand in kW.

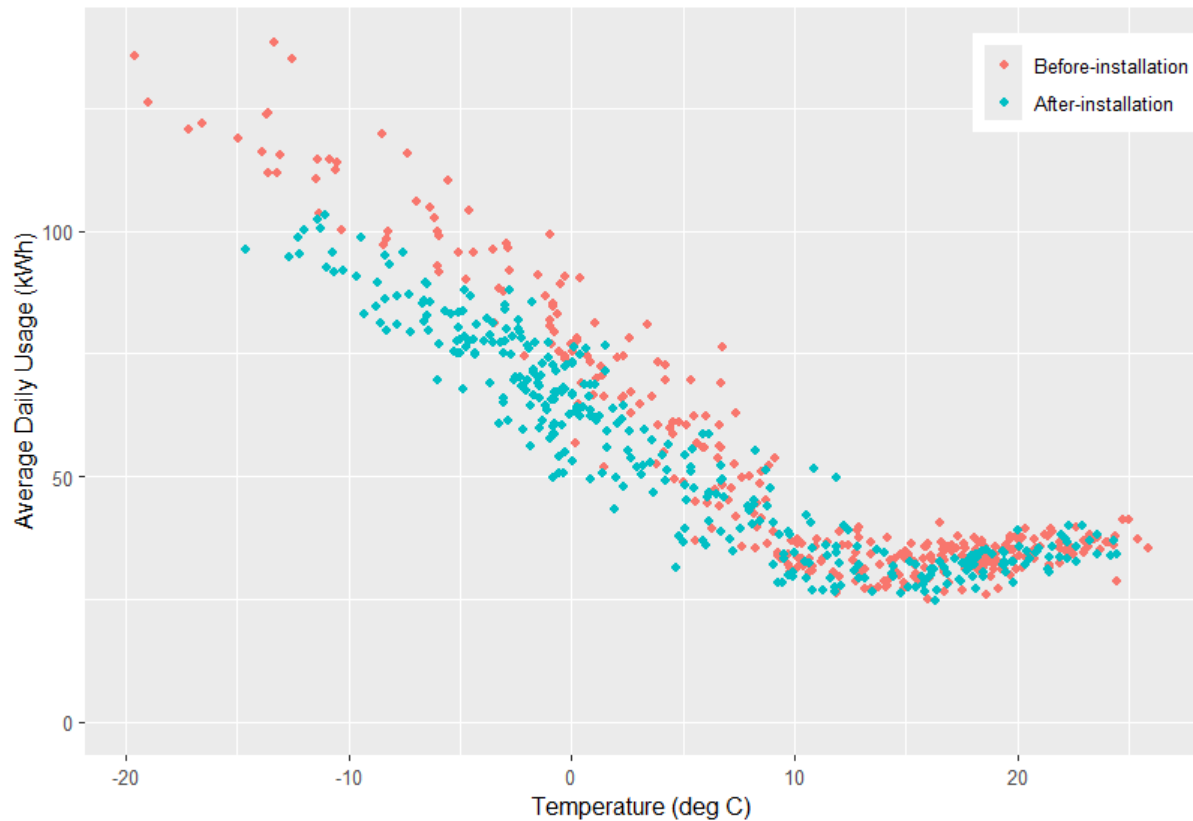


Figure 2. Average daily energy use before and after CC-MSHP installation (working days only).

An exploratory analysis was initially conducted to help construct a meaningful regression model. Figure 2 visualizes the dataset by plotting the average daily usage of the entire CC-MSHP group against outdoor temperature, with data points labeled separately for before and after installation. Strong correlations are observed between usage and outdoor temperature for both the cooling and heating seasons, with the correlation being much more prominent in the heating season. The breakpoint between cooling and heating is around 12.5 degrees and is then used for the calculation of Heating Degree Days (HDD) and Cooling Degree Days (CDD).

2.4.3.1 Regression model for daily energy use

This model is applied only to the no-TOD group for estimating the effect of the technology intervention, i.e., the installation of CC-MSHPs. The regression model is represented by the equation below

$$\text{DailyEnergy}_i = \beta_0 + \beta_1[\text{Installation}_i] + \beta_2[\text{HDD}_i] + \beta_3[\text{CDD}_i] + \beta_4[\text{HDD}_i] \times [\text{Installation}_i] + \beta_5[\text{CDD}_i] \times [\text{Installation}_i] \quad (1)$$

The energy use averaged for the no-TOD group for day i is modeled as a dependent variable with the following independent variables and interaction terms:

- Installation Status for day i , Installation_i (IF CC-MSHP has been installed, 1, otherwise 0)
- Heating Degrees Days for day i , HDD_i (IF average outdoor temp for day i < 12.5° C, 12.5° C – average outdoor temperature for day i , otherwise 0)

- Cooling Degrees Days for day i , CDD_i (IF average outdoor temperature day $i > 12.5^\circ \text{C}$, average outdoor temperature for day $i - 12.5^\circ \text{C}$, otherwise 0)
- Interaction of Heating Degrees Days and Installation Status for day i , $HDD_i \times Installation_i$
- Interaction of Cooling Degrees Days and Installation Status for day i , $CDD_i \times Installation_i$

The inclusion of two weather-dependent interaction terms is necessary because a comparison of the energy usage between the baseline and intervention periods for the no-TOD group (see blue line in Figure 3) indicates that the intervention affects energy use in the heating and cooling seasons differently. Specifically, during the intervention period, daily energy use reduced for the winter, while no significant change was observed for the summer.

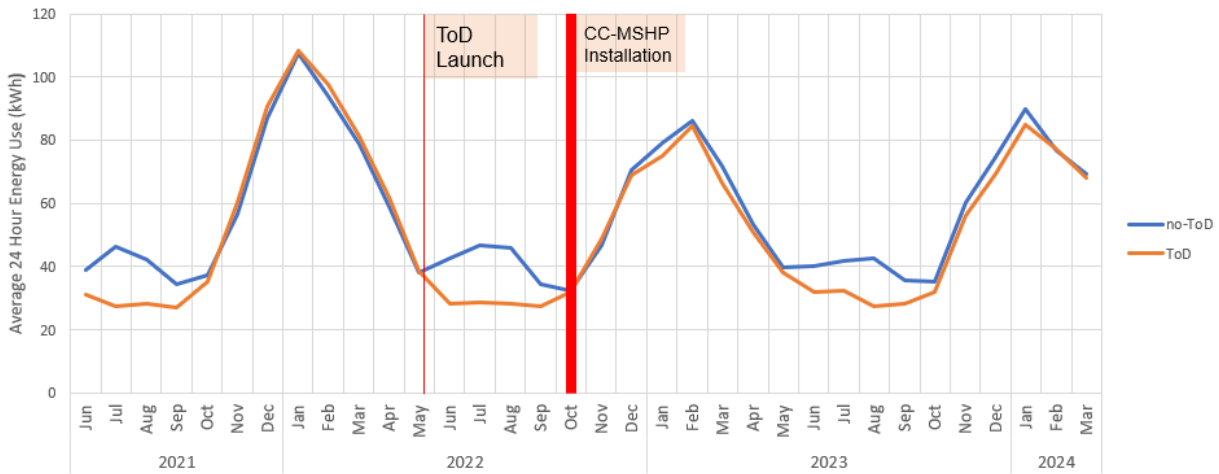


Figure 3: Monthly average 24-hour energy usage for TOD and no-TOD group.

2.4.3.2 Regression model with DiD for daily energy use

This model was applied to both the TOD and no-TOD groups and was used to estimate the effects of the technology intervention and the TOD intervention separately. The model is a hybrid version of the model described in section 2.4.3.1 and the DiD regression model for TOD analysis (Pardasani et al., 2025). The regression model is represented by the equation below:

$$\begin{aligned}
 \text{DailyEnergy}_{i,\text{group}} &= \beta_0 + \beta_1 [Installation_i] + \beta_2 [HDD_i] + \beta_3 [CDD_i] + \beta_4 [HDD_i] \times [Installation_i] \\
 &+ \beta_5 [CDD_i] \times [Installation_i] + \beta_6 [TODAssignment_{\text{group}}] + \beta_7 [TODLaunch_i] \\
 &+ \beta_8 [TODAssignment_{\text{group}}] \times [TODLaunch_i] + \beta_9 [CDD_i] \times [TODAssignment_{\text{group}}]
 \end{aligned} \tag{2}$$

The average energy use for the entire no-TOD group or TOD group for day i was modeled as a dependent variable with the independent variables and interaction term from section 2.4.3.1 and the following additional terms:

- TOD group assignment, $TODAssignment_{\text{group}}$ (IF assigned to TOD group, 1, otherwise 0)
- TOD status for day i , $TODLaunch_i$ (IF ToD rate in effect for TOD group, 1, otherwise 0)
- Interaction of TOD group assignment and TOD status for day i , $TODAssignment_{\text{group}} \times TODLaunch_i$
- Interaction of Cooling Degrees Days for day i and TOD group assignment, $CDD_i \times TODAssignment_{\text{group}}$

The TOD group assignment term explains the pre-existing differences between the TOD and no-TOD groups. An additional weather-dependent interaction term $CDD_i \times TODAssignment_{group}$, was included because this pre-existing difference was much more pronounced during the cooling season than the heating season. As seen in Figure 3, the orange line for the TOD group aligns closely with the blue line for the no-TOD group during the heating season, but sits higher in the cooling season, indicating a significant cooling load in the no-TOD group.

The TOD and no-TOD groups were not fully balanced partly due to the small group size. Although the groups were originally balanced during the assignment for TSHPs, this balance was disrupted when several participants left this research group after encountering technical issues with the TSHPs. The interaction term $TODAssignment_{group} \times Installation_i$ isolates the true effect of the TOD intervention, while the installation-related terms capture the effect of the technology interaction. This model assumes there was no interaction between the two interventions, i.e., TOD rate and CC-MSHP.

2.4.3.3 Regression model for Morning (7-9 am) Demand

With morning (7-9 am) demand as the outcome, a similar regression model applied to the no-TOD group was created, as per the equation below

$$\begin{aligned} MorningDemand_i &= \beta_0 + \beta_1 [Installation_i] + \beta_2 [HDD_i] + \beta_3 [CDD_i] + \beta_4 [HDD_i] \times [Installation_i] \\ &+ \beta_5 [CDD_i] \times [Installation_i] \end{aligned} \quad (3)$$

The morning demand from 7 to 9 am was averaged for the no-TOD group for day i and was modeled as a dependent variable with the following independent variables and interaction terms:

- Installation Status for day i , $Installation_i$ (IF CC-MSHP has been installed, 1, otherwise 0)
- Shifted Heating Degrees Days for day i , HDD_i (IF average shifted outdoor temp for day $i < 12.5^\circ C$, $12.5^\circ C - \text{average outdoor temperature for day } i$, otherwise 0)
- Shifted Cooling Degrees Days for day i , CDD_i (IF average shifted outdoor temperature day $i > 12.5^\circ C$, average outdoor temperature for day $i - 12.5^\circ C$, otherwise 0)
- Interaction of Heating Degrees Days and Installation Status for day i , $HDD_i \times Installation_i$
- Interaction of Cooling Degrees Days and Installation Status for day i , $CDD_i \times Installation_i$

To capture the weather conditions that influence electricity demand from 7-9 am, the 24-hour window for calculating the outdoor temperature was shifted 12 hours forward, i.e., from noon (12 pm) of day $i-1$ to 12 pm of day i . Refer to Appendix A for a detailed explanation.

To confirm the validity of the two interaction terms, similar graphs to Figure 3 were created for Morning (7-9 am) Demand. Again, it was observed that the technology intervention affects energy use in the heating and cooling seasons differently.

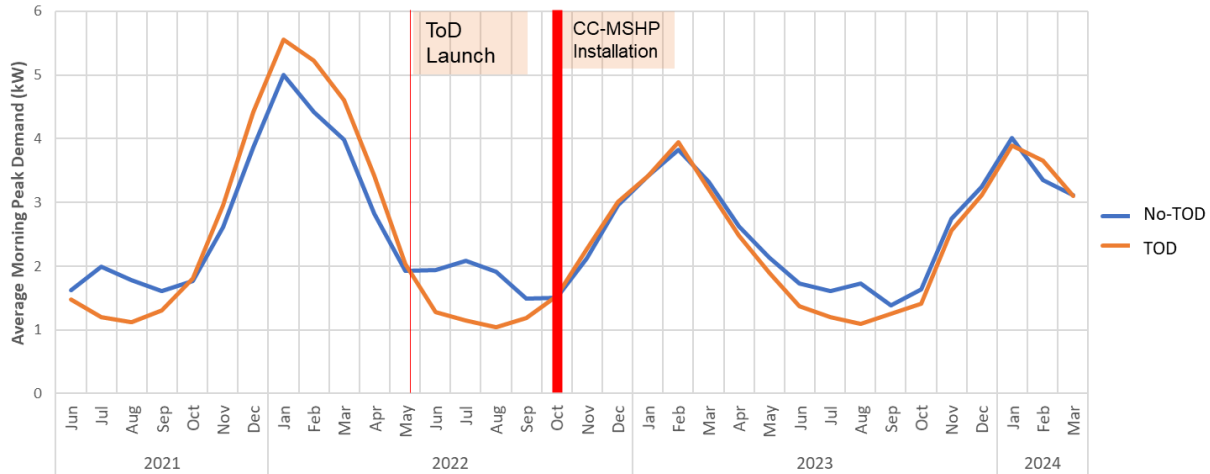


Figure 4. Monthly average morning (7-9 am) demand for TOD and no-TOD group.

2.4.3.4 Regression model with DiD for Morning (7-9 am) Demand

The DiD Regression model for Morning (7-9 am) Demand was represented by the equation below:

$$\begin{aligned} \text{MorningDemand}_{i,\text{group}} &= \beta_0 + \beta_1[\text{Installation}_i] + \beta_2[\text{HDD}_i] + \beta_3[\text{CDD}_i] + \beta_4[\text{HDD}_i] \times [\text{Installation}_i] \\ &+ \beta_5[\text{CDD}_i] \times [\text{Installation}_i] + \beta_6[\text{TODAssignment}_{\text{group}}] + \beta_7[\text{TODLaunch}_i] \\ &+ \beta_8[\text{TODAssignment}_{\text{group}}] \times [\text{TODLaunch}_i] + \beta_9[\text{CDD}_i] \times [\text{TODAssignment}_{\text{group}}] \end{aligned} \quad (4)$$

The average morning demand (7-9 am) for the entire no-TOD group or TOD group for day i was modeled as a dependent variable with the independent variables and interaction term from section 2.4.3.3 and following additional terms:

- TOD group assignment, $\text{TODAssignment}_{\text{group}}$ (IF assigned to TOD group, 1, otherwise 0)
- TOD status for day i , TODLaunch_i (IF ToD rate in effect for TOD group, 1, otherwise 0)
- Interaction of TOD group assignment and TOD status for day i , $\text{TODAssignment}_{\text{group}} \times \text{TODLaunch}_i$
- Interaction of Cooling Degrees Days for day i and TOD group assignment, $\text{CDD}_i \times \text{TODAssignment}_{\text{group}}$

The additional weather-dependent interaction term $\text{CDD}_i \times \text{TODAssignment}_{\text{group}}$, was again included because, as seen in Figure 4, the pre-existing difference between the TOD and no-TOD group was much more pronounced during the cooling season than the heating season.

3 Results

3.1 Seasonal energy usage change

Table 3 shows the output for the regression model (1) applied to the no-TOD group. The model level statistics suggest a good fit ($R\text{-squared} = 0.87$), further confirmed by the significant p -values (< 0.05) for all the independent variables and one interaction term. The “installation” term suggests that with the

installed CC-MSHP, there was a reduction of 3.06 kWh in average daily energy usage of homes in this group. For every 1 degree decrease in (daily average) outdoor temperature below 12.5°C, there was an additional reduction of 0.38 kWh in average daily energy usage, indicated by the interaction term between HDD and installation. However, the interaction term between CDD and installation was not statistically significant.

Table 3. Model output for regression model (1) showing the unstandardized regression coefficients for each term.

	Coefficient	Std. Error	t value	Pr(> t)
(Intercept)	33.52	0.81	41.26	<0.0001
HDD	3.21	0.07	46.91	<0.0001
CDD	1.32	0.14	9.25	<0.0001
installation	-3.06	1.25	-2.44	0.02
HDD: installation	-0.38	0.10	-3.75	0.00
CDD: installation	-0.16	0.23	-0.69	0.49
df:	673			
R ²	0.87			
p	<0.0001			

The model was then applied to each complete season in the intervention period, and the estimated savings from the installation of CC-MSHP are reported in Table 4. With this model, winter 2022 and winter 2023 showed average savings of 9.4% and 9.0% respectively, with a consistent 8-10% savings for all seasons.

Table 4. Energy saving calculation based on model (1).

	Winter 2022	Spring 2023	Summer 2023	Fall 2023	Winter 2023
Average Daily Energy Use (kWh) for no-TOD group (n = 7)	77.38	53.96	39.59	43.43	80.47
Estimated Saving (kWh) due to CC-MSHP Installation	9.13	6.43	3.78	5.48	8.97
% Saving due to CC-MSHP Installation	9.4%	9.7%	8.4%	10.3%	9.0%

Table 5 shows the output for the modified DiD regression model (2) applied to the entire technology group. The model level statistics again suggest a good fit, with a slightly better *R-squared* value (=0.91) than model (1). The coefficients of HDD and CDD are similar to those of model (1) indicating a strong and stable underlying dependency between weather and energy use. However, the main 'installation' term was no longer statistically significant. In contrast, the interaction term between installation and HDD has a greater effect. For every 1 degree decrease in outdoor temperature below 12.5°C, there was now an additional reduction of 0.57 kWh in average daily energy usage.

Regarding the terms related to the TOD intervention, the model suggests that there was no significant pre-existing difference between TOD and no-TOD groups, except during the cooling season. The no-TOD group used 1.42 kWh/day more energy for each 1 degree increases in (daily average) outdoor temperature above 12.5°C. This aligns with the discrepancy observed between the two groups observed in Figure 3. The interaction term of TOD launch and TOD group assignment estimates the true effect of

the TOD intervention, which was projected to result in a 2.18 kWh/day reduction in average energy use for the TOD group.

Table 5. Model output for regression model (2) showing the unstandardized regression coefficients for each term.

	Coefficient	Std. Error	t value	Pr(> t)
(Intercept)	31.83	0.67	47.78	<0.0001
HDD	3.40	0.05	74.44	<0.0001
CDD	1.40	0.11	12.85	<0.0001
installation	-1.27	0.93	-1.36	0.17
TimeOfDay	-0.70	0.70	-1.00	0.32
TODlaunch	0.01	0.81	0.01	0.99
HDD: installation	-0.57	0.07	-8.78	<0.0001
CDD: installation	0.02	0.15	0.15	0.88
CDD: TimeOfDay	-1.42	0.12	-12.23	<0.0001
TimeOfDay: TODlaunch	-2.18	0.82	-2.65	0.01
df:	1348			
R ²	0.91			
p	<0.0001			

The savings from both interventions by applying the model are reported in Table 6. With model (2), winter 2022 and winter 2023 report energy savings from technology intervention of 12.1% and 11.5% respectively, with a year-round savings estimated to be 9.5% (Mar. 2023-Feb.2024). For the TOD intervention, the winter savings are 2.5% and 2.4% respectively for years 2022 and 2023, with year-round savings at 3.9% (Mar. 2023-Feb.2024).

Table 6. Energy saving calculation based on model (2).

	Winter 2022	Spring 2023	Summer 2023	Fall 2023	Winter 2023
Avg. Daily Energy Use (kWh) for TOD group (n = 15)	75.05	50.79	30.01	38.41	77.14
Avg. Daily Energy Use (kWh) for no-TOD group (n = 7)	77.38	53.96	39.59	43.43	80.47
Estimated Saving (kWh) due to CC-MSHP Installation	10.62	5.94	1.35	4.29	10.33
% Saving due to CC-MSHP Installation	12.1%	10.1%	4.0%	9.6%	11.5%
Estimated Saving (kWh) due to TOD Intervention	2.18	2.18	2.18	2.18	2.18
% Saving due to TOD Intervention	2.5%	3.7%	6.5%	4.9%	2.4%

The year-round average savings based on the two models were very similar. The difference lies in how the savings were distributed throughout the year. In model (1), the savings were less weather-dependent, whereas in model (2), significant savings were realized in winter, with minimal savings in summer. This discrepancy was because the no-TOD group used for model (1) had a higher pre-existing cooling demand, which a more efficient CC-MSHP helped to reduce. In contrast, the TOD group had a lower initial cooling demand, and with the installation of CC-MSHP, the homes now had the means to meet cooling demand, potentially increasing their electricity use in summer.

The effect size of the TOD intervention was comparable to the result from TOD analysis (Pardasani et al., 2025). This adds to our confidence in the model (2)'s ability to separate the effects of the two interventions.

3.2 Winter morning (7-9 am) demand change

Table 7 presents the output for the regression model (3) applied to the no-TOD group. The model level statistics suggest a good fit, which was further supported by the significant p -values (< 0.05) for all the independent variables and one interaction term. The model suggested a reduction of 0.13 kW in average morning (7-9 am) demand and an additional reduction of 0.03 kW for each HDD.

Table 7. Model output for regression model (3) showing unstandardized regression coefficients.

	Coefficient	Std. Error	t value	Pr(> t)
(Intercept)	1.53	0.04	40.27	<0.0001
HDD(shifted)	0.16	0.00	48.89	<0.0001
CDD(shifted)	0.04	0.01	5.94	0.00
installation	-0.13	0.06	-2.16	0.03
HDD(shifted):installation	-0.03	0.00	-5.76	0.00
CDD(shifted):installation	-0.01	0.01	-1.31	0.19
df:	673			
R^2	0.88			
p	<0.0001			

The model was then applied to winter seasons during the intervention period, and the estimated savings from the installation of CC-MSHP are reported in Table 8. According to this model, winter 2022 and winter 2023 report demand reductions of 14.3% and 13.4%, respectively. The percentage reduction in morning demand was higher than the energy saving over 24 hours, indicating the demand during on-peak hours was lowered more than the demand during mid-peak or off-peak hours.

Table 8. Demand reduction calculation based on model (3).

	Winter 2022	Winter 2023
Average Morning Peak Demand (kW) for no-TOD group (n = 7)	3.39	3.59
Estimated Demand Reduction (kW) due to CC-MSHP Installation	0.57	0.56
% Demand Reduction due to CC-MSHP Installation	14.3%	13.4%

Table 9 shows the output for the modified DiD regression model (4) applied to the entire technology group. The model level statistics again suggest a good fit, with a slightly better R -squared value than model (3). For CC-MSHP related terms, the model suggested a reduction of 0.10 kW in average morning (7-9 am) demand across all seasons and an additional reduction of 0.04 kW for each additional HDD. The effect of the technology intervention in model (4) was shifted more towards the weather-dependent term compared to model (3), resulting in greater winter demand reduction reported in Table 10.

For terms related to the TOD intervention, the model suggests a significant pre-existing difference between the TOD and no-TOD groups; the morning demand of the TOD group was higher than that of the no-TOD group by 0.29 kW. However, during the cooling season, the morning demand of the no-TOD group was lowered by 0.08 kW for each additional CDD. The interaction term of TOD launch and TOD

group assignment estimates the true effect of the TOD intervention, which was projected to lower the morning demand by 0.34 kW.

Table 9. Model output for regression model (4) showing unstandardized regression coefficients.

	Coefficient	Std. Error	t value	Pr(> t)
(Intercept)	1.37	0.03	41.70	<0.0001
HDD(shifted)	0.17	0.00	77.62	<0.0001
CDD(shifted)	0.05	0.01	8.89	<0.0001
installation	-0.10	0.05	-2.03	0.04
TimeOfDay	0.29	0.03	8.50	<0.0001
TODlaunch	0.07	0.04	1.80	0.07
HDD(shifted):installation	-0.04	0.00	-12.33	<0.0001
CDD(shifted):installation	0.00	0.01	0.35	0.72
CDD(shifted):TimeOfDay	-0.08	0.01	-14.46	<0.0001
TimeOfDay:TODlaunch	-0.34	0.04	-8.32	<0.0001
df:	1348			
R ²	0.91			
p	<0.0001			

According to this model, winter 2022 and winter 2023 showed average demand reductions of 16.3% and 15.5%, respectively, caused by the technology intervention, and 7.5% and 7.3% because of the TOD intervention. The reductions from both interventions are 4-5% higher in the morning (7-9 am) than over 24 hours, indicating that both interventions helped to shift demand away from on-peak hours to mid-peak or off-peak hours.

Table 10: Demand reduction calculation based on model (4).

	Winter 2022	Winter 2023
Average Morning Peak Demand (kW) for TOD group (n = 15)	3.45	3.61
Average Morning Peak Demand (kW) for no-TOD group (n = 7)	3.39	3.59
Estimated Demand Reduction (kW) due to CC-MSHP Installation	0.74	0.72
% Demand Reduction due to CC-MSHP Installation	16.3%	15.5%
Estimated Demand Reduction (kW) due to TOD Intervention	0.34	0.34
% Demand Reduction due to TOD Intervention	7.5%	7.3%

3.3 Effect of CC-MSHP on electricity bills

With the average energy reduction reported in Table 6, for the period from March 2023 to February 2024, each household equipped with a CC-MSHP achieved an annual energy use reduction of 1,990.77 kWh and saved \$231.49 annually on electricity bills using the regular flat rate.

3.3.1 Effect on TOD billing for CC-MSHP Group

Table 11 illustrates the TOD credits for the CC-MSHP across different seasons. As previously noted, installations for CC-MSHP occurred from October 11 to 18, 2022, during the Fall season. The descriptive statistics reveal that the mean TOD credit was negative or negligible for most seasons except Spring 2023 and Winter 2023. On average, participants would have experienced a slight penalty instead of receiving credits under TOD rate structure; under the terms of this research project, there was no penalty.

The standard deviation varied across seasons, indicating differing levels of variability in TOD credits between participants. Winter 2023 had the highest SD (3.99), while Summer 2022 had the lowest SD (2.20), meaning greater consistency in the values.

Table 12 shows the total payments by NB Power for TOD credits to CC-MSHP participants. The amounts varied by season.

Table 11. TOD credits for CC-MSHP participants based on monthly bill settlement data averaged across seasons.

TOD Credit	Summer 2022	Fall 2022	Winter 2022	Spring 2023	Summer 2023	Fall 2023	Winter 2023
N	15	14	15	15	15	14	15
Mean/Month	-0.33	-0.88	0.08	0.74	-0.50	-0.37	0.66
SD	2.20	2.98	3.60	3.70	3.04	3.24	3.99
Minimum	-5.94	-7.08	-8.16	-13.07	-12.67	-11.15	-9.46
Maximum	4.62	4.24	7.03	7.06	4.46	3.65	6.37

Table 12. Total TOD bill credits paid out by season for all CC-MSHP TOD participants.

	Summer 2022	Fall 2022	Winter 2022	Spring 2023	Summer 2023	Fall 2023	Winter 2023
Total TOD Credit	30.18	30.36	63.70	78.33	34.09	39.93	88.20

3.3.2 Distribution of TOD bill credits and penalties

Figure 5 shows the distribution of bill credits and penalties as an S-curve as a dotted line for the CC-MSHP group during the one-year baseline period (May 2021 to May 2022), and the S-curve for the one-year experiment period (January 2023 to December 2023) is shown as a solid line for side-by-side comparison.

After the introduction of TOD billing, the CC-MSHP group's credits/gains and penalties/losses shifted as follows (Table 13):

Penalties: During the baseline period, 7% of the sample experienced penalties under 1%, 36% under 2%, and 64% under 5%. In the experiment period, these numbers increased to 14% under 1%, decreased to 29% under 2%, and decreased to 36% under 5%. This indicates an increase in smaller penalties and a reduction in larger penalties after TOD implementation.

Credits: Credits under 1% increased significantly from 21% in the baseline to 36% in the experiment period. For gains under 2%, there was a substantial increase from 29% to 57%, and under 5%, from 29% to 64%. This suggests that more customers experienced substantial gains with TOD billing.

Overall Impact: TOD billing led to noticeable changes in the distribution of financial outcomes for the group, with more credits and less severe penalties.

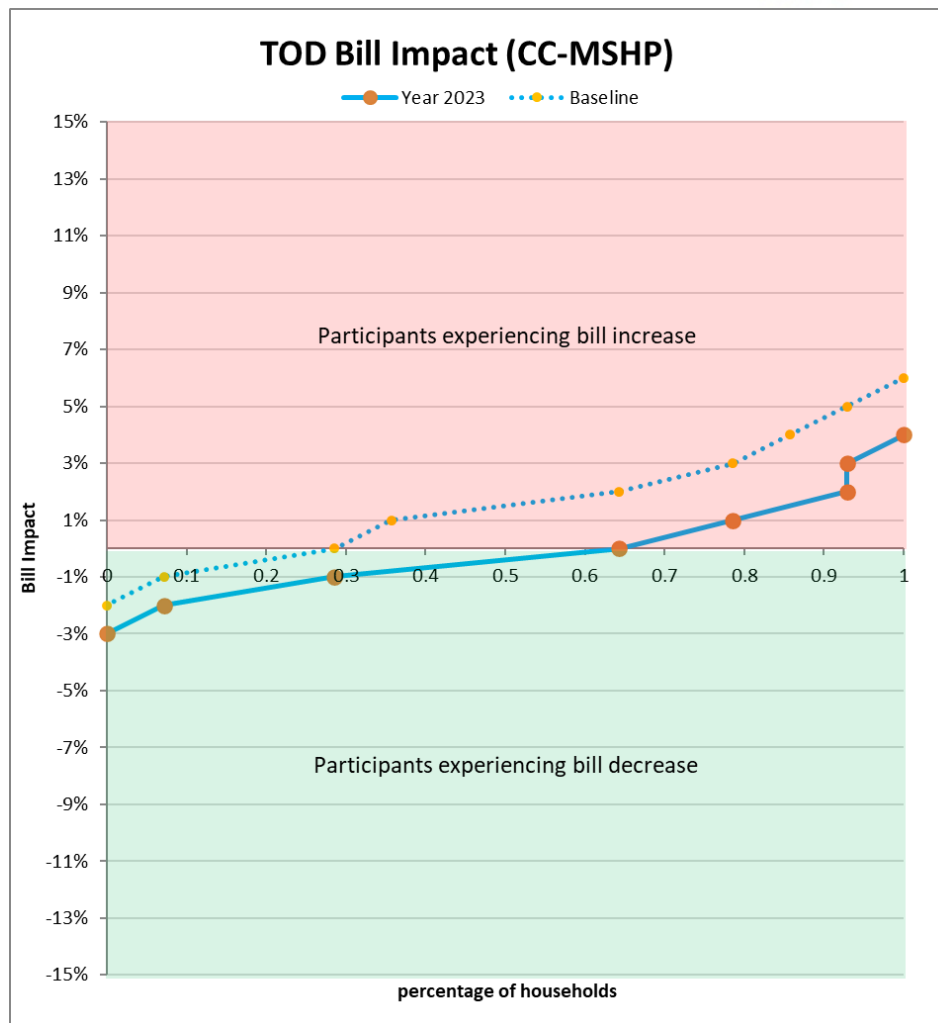


Figure 5: TOD impact on participant bills: distribution of credits/penalties for CC-MSHP group as compared to the baseline.

Table 13. Gain and loss distribution for CC-MSHP group.

	Baseline Period			Experiment Period		
	<1%	<2%	<5%	<1%	<2%	<5%
Gain	21%	29%	29%	36%	57%	64%
Loss	7%	36%	64%	14%	29%	36%

3.4 Benefit for NB Power

The NB Power installed CC-MSHP is rated with a COP of 2.13 at -25°C making it significantly more efficient than the electric baseboards that it replaces for space heating. The utility cost savings from CC-MSHP stem from reduced electricity usage for heating, leading to avoided costs associated with generation, transmission, and distribution of electricity. NB Power estimates the avoided cost of generation to be \$0.0770 per kWh. Table 14 shows the estimated average daily energy savings per household and Table 15 shows the corresponding avoided cost of generation.

Table 14. Estimated average daily saving (kWh) due to CC-MSHP installation per household

Winter 2022	Spring 2023	Summer 2023	Fall 2023	Winter 2023
10.62	5.94	1.35	4.29	10.33

Table 15. Utility cost savings due to the conservation effect of CC-MSHP per household

Season	Estimated energy savings for the CC-MSHP group kWh/household	Corresponding utility cost savings (@\$0.077/kWh) \$/household
Winter 2022	955.80	73.60
Spring 2023	546.48	42.08
Summer 2023	124.20	9.56
Fall 2023	390.39	30.06
Winter 2023	929.70	71.59

For the period from March 2023 to February 2024, households equipped with a CC-MSHP achieved an average annual energy use reduction of 1,990.77 kWh. This decrease led to annual utility cost savings of \$153.29 per household. Across all 23 CC-MSHP installations, the total utility cost savings amounted to \$3,525.65.

3.5 User experiences

Despite the disruption caused by the technology change from TSHP to CC-MSHP, participants in the CC-MSHP group were generally very satisfied with their technologies and their experiences in the project (Table 16). All of the survey respondents at the end of the study would recommend this technology to others, although one individual reported feeling very dissatisfied with their experience in the project as a whole.

Table 16. CC-MSHP participants' satisfaction with their technology and project experiences (scale 0-4).

Satisfaction with...	% very dissatisfied	% dissatisfied	% neither	% satisfied	% very satisfied	Mean	SD	N
Information received about the technology when first offered (survey Dec. 2022)			5.6	66.7	27.8	3.2	0.5	18
The installer (survey Dec. 2022)			5.6	22.2	72.2	3.7	0.6	18
Information received during the installation (survey Dec. 2022)		4.5	9.1	45.5	22.7	3.1	0.8	18
Technology performance (Mar. 2024)	16.7		5.6	44.4	33.3	2.8	1.4	18
Did you experience challenges or problems (survey Dec. 2023)	6.7	6.7	20	33.3	33.3	2.8	1.2	15
Would you recommend this technology to others (survey Dec. 2022)	No = 1 [5%]				Yes = 17 [95%]			18
Would you recommend this technology to others (survey Mar. 2024)					Yes = 18 [100%]			18
Project team communication (survey Dec. 2022)			11.8	29.4	58.8	3.5	0.7	17
Project team communication (Survey Mar. 2024)	5.9		5.9	41.2	47.1	3.2	1.9	17
Overall project satisfaction (Dec. 2022)			11.1	33.3	55.6	3.4	0.7	18
Overall project satisfaction (Mar. 2024)	5.6			44.4	50	3.3	1.0	18

3.6 Thermal comfort

We analyzed the thermal sensation and thermal comfort responses using separate analyses of variance (ANOVA). The model was a 4 (heating system group) by 2 (time) mixed between-within ANOVA with three planned comparisons. Each comparison tested the difference between the No-HP group (which had never had a heat pump) and one of the other groups (HP_start; HP_during; CC-MSHP). Alpha (the critical probability (p) value for deciding to reject the null hypothesis of no difference) was set at the conventional 0.05 or less.

Table 17 shows the estimated marginal means for thermal sensation, and Table 18 summarizes the ANOVA results. Thermal sensation was generally unaffected by the heating system, but did vary by season. Participants overall reported feeling warmer in their homes when asked in winter 2023. The weather in winter 2023 was warmer than in 2019.

Table 17. Estimated marginal means and standard errors for thermal sensation scores, by time and HP group.

	Winter 2019		Winter 2023		Overall HP Group	
	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
No_HP	0.18	0.20	0.29	0.21	0.23	0.17
HP_Start	0.32	0.08	0.47	0.09	0.39	0.07
HP_During	0.00	0.17	0.59	0.18	0.29	0.15
CC-MSHP	0.06	0.26	0.35	0.27	0.21	0.22
Overall Time	0.14	0.10	0.42	0.10		

Table 18. ANOVA results for Time x HP Group analyses of thermal sensation responses.

	<i>F</i>	<i>df</i>	<i>p</i>	Cohen's <i>d</i>
Time	7.55	1,245	0.000*	0.18
No_HP vs HP_start	0.74	1,245	0.392	0.05
No_HP vs HP_during	0.8	1,245	0.784	0.06
NO_HP vs CC-MSHP	0.01	1,245	0.926	0.01
Time x HP Group	1.65	3,245	0.179	na

The results for the ANOVA of thermal preference scores are in Table 19 and Table 20. They are consistent with the thermal sensation results. The only statistically significant effect was for time, and the means show that in winter 2019 participants wanted to feel warmer to a greater degree than in 2023 (for which the thermal sensation scores show that they did feel warmer than in 2019).

Table 19. Estimated marginal means and standard errors for thermal preference scores, by time and HP group.

	Winter 2019		Winter 2023		Overall HP Group	
	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
No_HP	0.38	0.10	0.17	0.10	0.28	0.08
HP_Start	0.32	0.04	0.22	0.04	0.27	0.03
HP_During	0.46	0.23	0.08	0.23	0.35	0.07
CC-MSHP	0.29	0.13	0.24	0.13	0.26	0.11
Overall Time	0.36	0.05	0.22	0.05		

Table 20. ANOVA results for Time x HP Group analyses of thermal preference scores responses.

	<i>F</i>	<i>df</i>	<i>p</i>	Cohen's <i>d</i>
Time	7.29	1,246	0.007*	0.17
No_HP vs HP_start	0.00	1,246	0.72	0.00
No_HP vs HP_during	0.43	1,246	0.51	0.04
NO_HP vs CC-MSHP	0.01	1,246	0.93	0.01
Time x HP Group	0.72	3,246	0.542	na

3.7 Self-reported winter thermostat settings

These analyses followed the same ANOVA model as for the thermal comfort data, although at different times. These comparisons were between when the CC-MSHPs were newly installed and when they had been in use for nearly 18 months including two winter seasons. Tables 21 and 22 summarize the results for the four times of day for which respondents reported their usual household thermostat settings (in deg C).

For daytime settings, the participants without any HP choose lower settings than those who started the project with a HP and those who purchased one during the project, but their settings are not different from that of the people with CC-MSHP. Moreover, there was an interaction of time and HP group, which

appears to relate to lower temperature settings in 2024 for the people without heat pumps (most of whom heat with electric baseboards).

Table 21. Estimated marginal means and standard errors for winter daytime at home thermostat settings, by time and HP group.

	Winter 2022		Spring 2024		Overall HP Group	
	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
No_HP	20.04	0.36	19.23	0.42	19.63	0.34
HP_Start	20.71	0.16	20.95	0.18	20.83	0.15
HP_During	21.05	0.29	20.74	0.34	20.90	0.28
CC-MSHP	20.06	0.45	20.38	0.53	20.22	0.43
Overall Time	20.46	0.17	20.32	0.19		

Table 22. ANOVA results for Time x HP Group analyses of winter daytime at home thermostat settings.

	<i>F</i>	<i>df</i>	<i>p</i>	Cohen's <i>d</i>
Time	0.64	1,213	0.423	0.06
No_HP vs HP_start	10.39	1,213	0.001*	0.22
No_HP vs HP_during	8.33	1,213	0.004*	0.20
NO_HP vs CC-MSHP	1.13	1,213	0.289	0.07
Time x HP Group	2.76	3,213	0.043*	Na

The results for the periods on winter days when people are out of the house (Tables 23 and 24) show lower temperatures for the No_HP group that meet the statistical significance criterion in comparison to those for HP_Start and HP_During, but not for CC-MSHP. The same pattern occurs for thermostat settings while sleeping in the winter (Tables 25 and 26).

Table 23. Estimated marginal means and standard errors for winter daytime out of house thermostat settings, by time and HP group.

	Winter 2022		Spring 2024		Overall HP Group	
	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
No_HP	17.42	0.55	17.54	0.58	17.48	0.49
HP_Start	18.80	0.23	19.33	0.24	19.06	0.21
HP_During	19.62	0.43	19.28	0.45	19.45	0.38
CC-MSHP	18.47	0.70	19.20	0.73	18.83	0.62
Overall Time	18.57	0.25	18.84	0.27		

Table 24. ANOVA results for Time x HP Group analyses of winter daytime out of house thermostat settings.

	<i>F</i>	<i>df</i>	<i>p</i>	Cohen's <i>d</i>
Time	1.0	1,208	0.319	0.07
No_HP vs HP_start	8.94	1,208	0.003*	0.20
No_HP vs HP_during	10.09	1,208	0.002*	0.22
NO_HP vs CC-MSHP	2.96	1,208	0.087	0.12
Time x HP Group	1.10	3,208	0.351	na

Table 25. Estimated marginal means and standard errors for winter sleeping thermostat settings, by time and HP group.

	Winter 2022		Spring 2024		Overall HP Group	
	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
No_HP	18.23	0.45	17.04	0.62	17.63	0.47
HP_Start	19.34	0.19	19.92	0.27	19.63	0.21
HP_During	20.08	0.36	20.10	0.51	20.09	0.39
CC-MSHP	18.56	0.57	18.44	0.79	18.50	0.60
Overall Time	19.05	0.21	18.87	0.29		

Table 26. ANOVA results for Time x HP Group analyses of winter sleeping thermostat settings.

	<i>F</i>	<i>df</i>	<i>p</i>	Cohen's <i>d</i>
Time	0.52	1,213	0.472	0.05
No_HP vs HP_start	14.90	1,213	0.000*	0.26
No_HP vs HP_during	16/21	1,213	0.000*	0.28
NO_HP vs CC-MSHP	1.279	1,213	0.259	0.08
Time x HP Group	3.35	3,213	0.020*	na

We calculated a night-time setback for each home by subtracting the sleeping temperature setting from the daytime setting. Note that manufacturer instructions and project instructions to the TOD participants directed people to “set it and forget it” because heat pumps are most efficient when set to a stable temperature. The results for the analyses of the overnight setbacks (Tables 27 and 28) show (a) that many participants with heat pumps continued to set back their thermostats at night; (b) the participants without heat pumps set back the most, and significantly more than the people who purchased heat pumps during the project; (c) the people with CC-MSHP set back equivalently to the people without heat pumps. Note that until they received CC-MSHP, this group also used electric baseboard heating, so it may be that their prior habits had not yet changed.

Table 27. Estimated marginal means and standard errors for winter overnight thermostat setbacks, by time and HP group.

	Winter 2022		Spring 2024		Overall HP Group	
	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
No_HP	-1.88	0.36	-2.16	0.53	-2.02	0.39
HP_Start	-1.37	0.15	-1.03	0.23	-1.20	0.17
HP_During	-0.97	0.29	-0.64	0.42	-0.81	0.31
CC-MSHP	-1.50	0.45	-1.94	0.66	-1.72	0.48
Overall Time	-1.43	0.16	-1.44	0.24		

Table 28. ANOVA results for Time x HP Group analyses of winter overnight thermostat setbacks.

	<i>F</i>	<i>df</i>	<i>p</i>	Cohen's <i>d</i>
Time	0.00	1,212	0.957	0.00
No_HP vs HP_start	3.80	1,212	0.053	0.13
No_HP vs HP_during	5.97	1,212	0.015*	0.17
NO_HP vs CC-MSHP	0.24	1,212	0.628	0.03
Time x HP Group	0.95	3,212	0.416	na

4 Discussion

4.1 Comments on performance

The in-field performance of cold climate mini-split heat pumps has been the subject of studies that have revealed both potential and challenges. RDH (2020) reported on a study in British Columbia that involved year-round monitoring of ductless heat pump performance in residential homes. The findings indicated that these systems generally performed better than the manufacturer-rated efficiency, with an observed overall difference of approximately 30%. The National Renewable Energy Laboratory (NREL) in the US (Desai & Wu, 2022) summarized a series of studies in the U.S. on real world adaption of cold climate air-source heat pump, highlighting the importance of proper sizing and installation that considers room configuration and the backup heating system.

The results from this study confirm that the CC-MSHP system effectively reduced energy usage and winter morning demand during peak hours. As a more efficient heating system, it decreased energy usage by up to 12% in winter. Additionally, since the morning peak demand was primarily driven by heating load, the CC-MSHP also helped to flatten the demand profile, reducing peak hour demand by up to 16%.

Although the model assumed no interaction between the two interventions, it is interesting to see that this technology group responded exceptionally well to the TOD intervention. The TOD group not only achieved a reduction in energy use comparable to the no-TOD group, but also experienced a significantly greater reduction in morning demand, indicating that demand shifted away from peak hours. One possible explanation is that the introduction of the CC-MSHP system might have heightened awareness among participants about their energy consumption, encouraging more energy-conscious behaviours.

Because the CC-MSHP system used in the study was selected for its performance in extreme cold weather (with average outdoor temperatures below -25°C), it is naturally of interest to evaluate its performance under such conditions. However, extreme cold days were very uncommon throughout the course of the study, and only one observation from February 4, 2023, is available. Figure 6 depicts the average daily energy use for the entire CC-MSHP group for all days in the analysis range: The labelled data point is quite distant from the rest in the upper left corner. Despite this separation, this data point lies on the trajectory of the post-installation energy use by outdoor temperature, indicating stable performance during that extreme cold day. Nonetheless, due to the limited number of observations, no definitive conclusions can be drawn about the performance under extremely cold temperatures. This observation was also excluded from the analysis in this report as it fell on a non-working day.

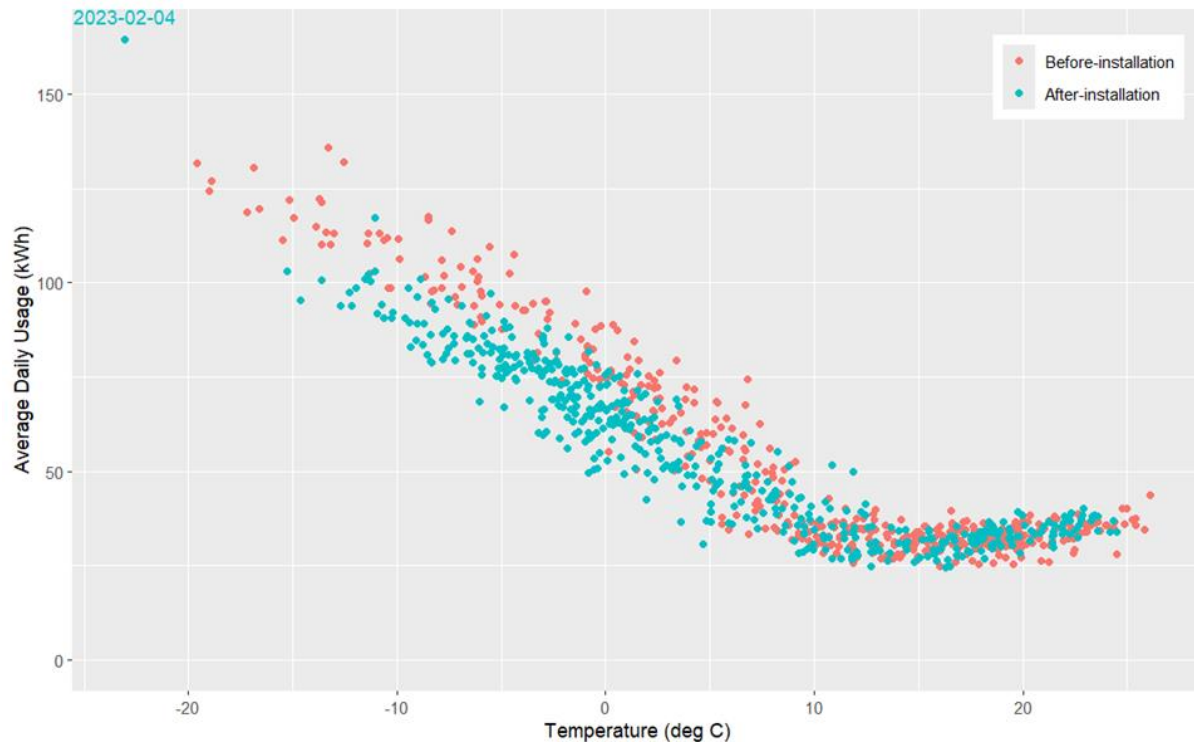


Figure 6. Average daily energy use before and after CC-MSHP installation for all days in the observation period, including weekends and holidays.

4.2 Comparison to existing MSHP

To evaluate the performance of the CC-MSHP against existing MSHP systems, we established a baseline group consisting of 22 homes, each with a single MSHP installed with electric baseboard as the supplementary heating source. Efforts were made to balance the building characteristics and heating capacity; however, due to a limited number of candidates, the baseline group ended up with a higher average floor area and heating capacity, and included one-third of MSHPs rated for extreme cold climates (below -25°C). See Appendix B for details.

An analysis of covariance (ANCOVA) was conducted to compare the means of both 24-hour energy usage and morning peak demand between the two groups, controlling for outdoor temperature, floor area, and heating capacity. The results indicated that on average the CC-MSHP group had significantly lower daily energy usage, by 6.9 kWh in Winter 2022 and by 4.2 kWh in Winter 2023, compared to the baseline MSHP group. Similarly, morning peak demand was lower by 0.3 kW in Winter 2022 and by 0.2 kW in Winter 2023.

Regarding performance in colder temperatures, regression model results confirmed that the CC-MSHP provided a slight advantage over the baseline MSHP in Winter 2022. However, there was a negligible difference in the milder winter in 2023.

4.3 Assumptions and limitations

The end of the COVID-19 stay-at-home order in Fall 2022 is an external event that overlapped with the technology intervention period. As more people returned to the office during the day, this could have decreased 24-hour energy usage on working days and increased morning demand during peak hours.

The effect of this external event may be captured by the "installation" term in the model. However, from Table 3, it is evident that the "installation" term is much weaker and smaller than the HDD-dependent term. This indicates that the risk of overestimating the savings from the technology intervention is small.

In these analyses, the following assumptions apply:

- There was no interaction between the TOD intervention and the Technology intervention.
- The effect size of the TOD intervention remained constant throughout the intervention period.
- The effect of the TOD intervention was not weather dependent.
- There were no spillover effects between TOD and no-TOD groups.
- There were no concurrent changes or external events that could influence the energy use or demand.

4.4 User experiences

The sample size is small, but it is clear from the survey data that participants who received the CC-MSHP units were generally satisfied with them. The small number of dissatisfied participants might have been expressing disappointment that they did not receive the solar PV and battery energy storage systems that were deployed to other dwellings in the larger Shediac study. The disruption of the change from the thermal storage heat pump (which had caused some water damage in a few homes) might also have influenced overall satisfaction.

The thermal comfort data showed that participants could use their units to achieve good thermal conditions. Survey data concerning temperature setpoints indicates that participants could achieve even better results with these units if they were to program them for a 'set it and forget it' operation, possibly with adjustments to their secondary heating systems (which we did not examine).

5 Conclusions

The study shows that CC-MSHPs are effective in reducing average energy usage and peak demand, with up to 12% energy savings in winter and a peak demand reduction of up to 16%. The technology was well-received by participants, who reported improved thermal comfort and were willing to recommend it to others. The findings suggest that CC-MSHPs could play a critical role in decarbonization efforts by enhancing energy efficiency and user satisfaction in addition to reducing peak loads.

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Appendix A - Shifted time windows for HDD and CDD

The impact of weather conditions on energy use in buildings is not always immediate. For instance, a drop in outdoor temperatures might not lead to an increased heating demand until later, as buildings have thermal inertia and retain heat. Similarly, a hot day might not cause an immediate spike in cooling load if a building is well-insulated or if occupants delay using air conditioning thermal discomfort sets in.

To account for this delayed impact, we shifted the 24-hour window used for HDD and CDD forward by 12 hours. This adjustment allowed us to better capture the lagged effect of temperature changes on energy consumption. Through several "what-if" scenarios, we determined that a 12-hour forward shift effectively encompassed the morning hours of interest and the preceding 19 hours. This technique is particularly valuable in predictive models, as understanding the temporal relationship between weather and energy use can lead to more precise forecasts and improved energy management strategies.

By plotting the average morning demand against the average outdoor temperature for the day (Figure A.1 left), and then against the outdoor temperature shifted 12 hours forward (Figure A.1 right), we observe a stronger linear relationship between the demand and the shifted outdoor temperature. This stronger correlation is the basis for using the shifted HDD and CDD in model (3) and (4).

The impact of weather conditions on energy use in buildings is not always immediate. For instance, a drop in outdoor temperatures might not lead to an increased heating demand until later, as buildings have thermal inertia and retain heat. Similarly, a hot day might not cause an immediate spike in cooling load if a building is well-insulated or if occupants delay using air conditioning thermal discomfort sets in.

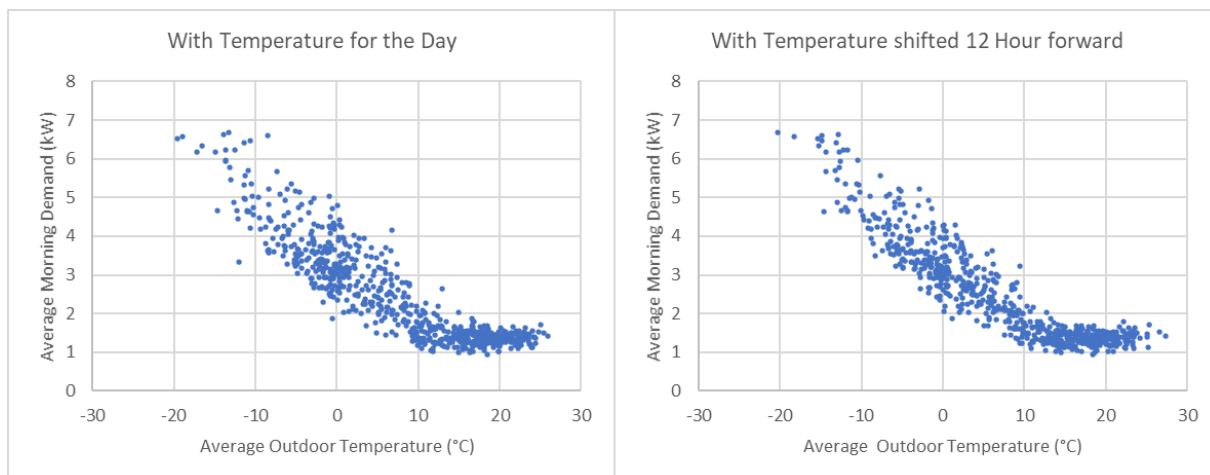


Figure A.1. Average morning demand (kW) in workings day during the study period against two ways of calculating average outdoor temperature.

Appendix B - Comparing winter performance: CC-MSHP and baseline MSHP groups

B.1 MSHP baseline group

To compare the performance of NBP-installed CC-MSHPs with existing MSHPs in participants' homes, 22 homes with one MSHP installed were selected to form the MSHP baseline group. The characteristics of the buildings and heating systems in both groups are summarized in Table B.1 below.

Table B.1. The characteristics of the building and the heating system of the CC-MSHP group and the baseline group.

	CC-MSHP (N)	CC-MSHP (%)	BASELINE MSHP (N)	BASELINE MSHP (%)
TOTAL SIZE	22		22	
DWELLING TYPE				
DETACHED	19	86.4%	19	86.4%
SEMIDETACH	1	4.5%	1	4.5%
TOWNHOUSE	2	9.1%	2	9.1%
HOME AREA (SF)				
0-1000	2	9.1%	2	9.1%
1000-2000	15	68.2%	18	81.8%
2000-3000	1	4.5%	2	9.1%
3000-4000	1	4.5%		
4000-5000	1	4.5%		
>5000	1	4.5%		
NOTKNOWN	1	4.5%		
CONSTRUCTION YEAR				
BEFORE 1961	4	18.2%	5	22.7%
1961-1974	5	22.7%		
1975-1984	2	9.1%	3	13.6%
1985-1994	1	4.5%	2	9.1%
1995-2004	6	27.3%	6	27.3%
2005-2009	4	18.2%	4	18.2%
AFTER 2010			2	9.1%
TOD ASSIGNMENT				
TOD	15	68.2%	11	50.0%
NO TOD	7	31.8%	11	50.0%
HEATING CAPACITY				
≤10,000 BTU	1	4.5%		
≤15,000 BTU	21	95.5%	5	22.7%
≤20,000 BTU			17	77.3%
% RATED FOR COLD CLIMATE (≤-25 DEG C)		100.0%		31.8%

Efforts were made to balance the two groups; however, because of the limited number of homes with a single MSHP, the groups are not exactly balanced. For the same reason, even though the baseline is supposed to represent less efficient systems with MSHPs not rated for extreme cold weather (below - 25°C), there are 7 homes with cold-climate models included.

The average area of the baseline group is 1,519 square feet, slightly higher than 1,395 square feet for the CC-MSHP group, although there are a few much larger houses in the CC-MSHP group. The average capacity of the baseline group is 16,000 BTU, while the CC-MSHP group averages 12,000 BTU. These two

factors have a direct and well-established impact on energy use and were therefore controlled for in the comparison analysis.

B.2 Performance in winter

An ANCOVA was conducted to assess the differences in daily energy use in winter between the two groups while controlling for the covariates: outdoor temperature, floor area, and heating capacity. The analysis confirmed that all three covariates—temperature, area, and capacity—are significant predictors of usage (Table B.2). Additionally, the difference in usage between the two groups was found to be statistically significant.

Table B.2. ANCOVA result for daily energy comparison.

Winter 2022						Winter 2023					
	Df	Sum Sq	Mean Sq	F Value	Pr(>F)		Df	Sum Sq	Mean Sq	F Value	Pr(>F)
Type	1	53,134	53,134	104.7	<2e-16	Type	1	42,110	42,110	96.3	<2e-16
Temperature	1	780,799	780,799	1,538.1	<2e-16	Temperature	1	508,315	508,315	1,162.4	<2e-16
Area	1	482,176	482,176	949.8	<2e-16	Area	1	466,857	466,857	1,067.6	<2e-16
Capacity	1	3,006	3,006	5.9	0.02	Capacity	1	2,436	2,436	5.6	0.02
Residuals	3,865	1,962,026	508			Residuals	3,354	1,466,701	437		

The estimated means were calculated using the ANCOVA models and are reported in Table B.3. Compared to the baseline MSHP group, the CC-MSHP group had lower daily usage by 6.9 kWh in Winter 2022 and by 4.2 kWh in Winter 2023.

Table B.3. Estimated mean of daily Energy use of baseline MSHP and CC-MSHP group.

Winter 2022					Winter 2023				
Group	emmean	SE	df	Cohen's d	Group	emmean	SE	df	Cohen's d
Baseline MSHP	85.50	0.67	3865		Baseline MSHP	83.70	0.63	3354	
CC-MSHP	78.60	0.65	3865	-0.26	CC-MSHP	79.50	0.67	3354	-0.26

The same analysis was repeated with morning (7-9 am) energy demand as the dependent variable (Table B.4). The temperature covariate was shifted 12 hours forward as seen in the model in Section 2.4.3.4. The ANCOVA results were similar to those for daily usage, except that heating capacity was no longer a significant predictor for winter 2023.

Table B.4 ANCOVA result for morning demand comparison.

Winter 2022						Winter 2023					
	Df	Sum Sq	Mean Sq	F value	Pr(>F)		Df	Sum Sq	Mean Sq	F value	Pr(>F)
Type	1	99	99	84.5	< 2e-16	Type	1	64	64	57.2	0.00
Temp.Shifted	1	2,700	2,700	2,300.3	< 2e-16	Temp.Shifted.	1	1,713	1,713	1,526.8	< 2e-16
Area	1	1,026	1,026	874.0	< 2e-16	Area	1	1,214	1,214	1,082.0	< 2e-16
Capacity	1	15	15	12.5	0.00	Capacity	1	0	0	0.1	0.74
Residuals	3,846	4,514	1			Residuals	3,337	3,744	1		

Compared to the baseline MSHP group, the CC-MSHP group had lower morning (7-9 am) demand by 0.3 kW in Winter 2022 and by 0.2 kW in Winter 2023 (Table B.5).

Table B.5. Estimated mean of morning demand of baseline MSHP and CC-MSHP group.

Winter 2022					Winter 2023				
Group	emmean	SE	df	Cohen's d	Group	emmean	SE	df	Cohen's d
Baseline MSHP	3.82	0.03	3846		Baseline MSHP	3.76	0.03	3337	
CC-MSHP	3.48	0.03	3846	-0.22	CC-MSHP	3.55	0.03	3337	-0.20

B.3 Comparison of performance as temperature gets colder

The NBP-installed heat pumps were selected for their performance in extreme weather conditions, therefore it is of particular interest to determine whether they outperform the baseline MSHP group as the weather becomes colder. The average daily usage for each group is plotted against outdoor temperature in Figure B.1 for both winters. A linear trendline was fitted to study how usage changes as the temperature decreases.

Observations from 2022 indicate that usage increases slightly more rapidly in the MSHP baseline group compared to the NBP-installed CC-MSHP. The divergence between the two trendlines at colder temperatures was less pronounced during the milder winter of 2023.

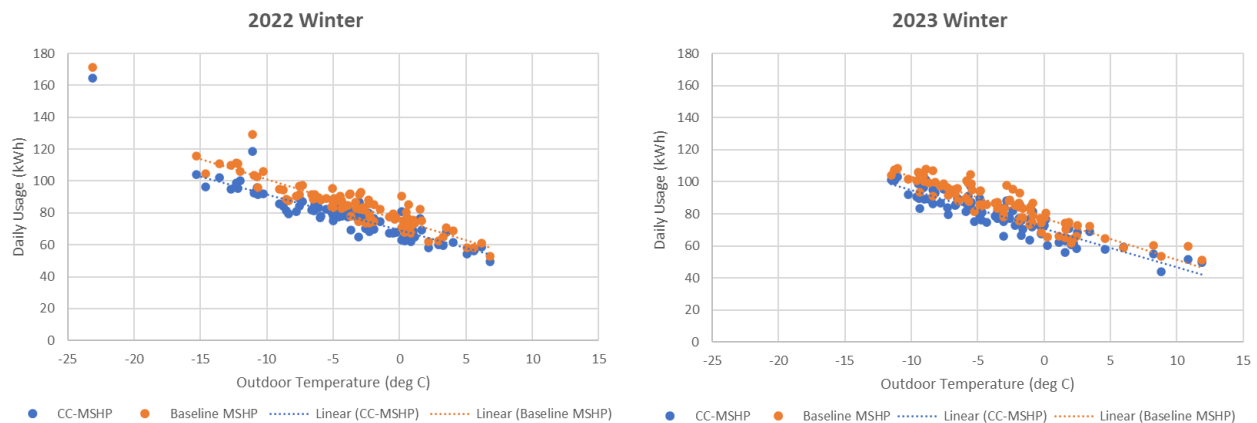


Figure B.1. Average group level daily energy use against outdoor temperature for winter 2022 and 2023.

To further investigate the relationship suggested by the observation, we created a linear regression model with an interaction term between the CC-MSHP group and HDD (Table B.6). The model identified the effect of CC-MSHP in lowering usage as the temperature gets colder for both winters, but it did not yield statistical significance (p -values > 0.05).

Table B.6. Regression model output with daily energy use as outcome.

winter 2022					winter 2023				
	Coefficient	Std. Error	t value	Pr(> t)		Coefficient	Std. Error	t value	Pr(> t)
(Intercept)	43.77	2.01	21.75	<2e-16	(Intercept)	45.02	2.01	22.44	<2e-16
GroupCC-MSHP	-2.46	2.85	-0.87	0.39	GroupCC-MSHP	-4.37	2.84	-1.54	0.13
HDD	2.54	0.12	21.30	<2e-16	HDD	2.58	0.12	20.96	<2e-16
GroupCC-MSHP:HDD	-0.31	0.17	-1.82	0.07	GroupCC-MSHP:HDD	-0.18	0.17	-1.01	0.31
DF:	174				DF:	166			
R-squared:	0.83				R-squared:	0.84			
P-value:	<2e-16				P-value:	<2e-16			

A similar analysis was conducted for morning (7-9 am) demand reduction. As shown in Figure B.2, the trend for morning demand mirrors that of 24 hour usage: the CC-MSHP group did not experience the

same increase in morning demand as the baseline group when temperatures dropped during the winter of 2022.

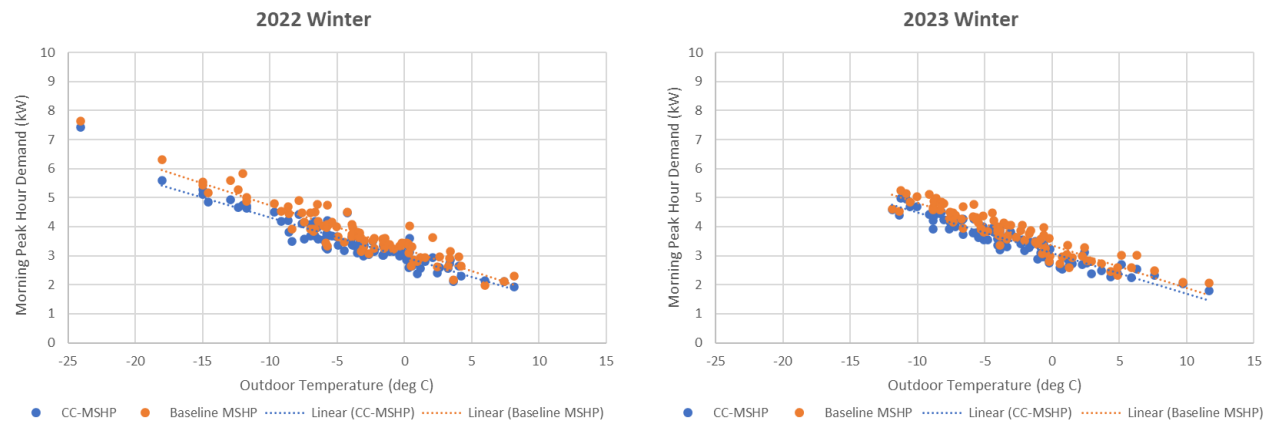


Figure B.2. Average group-level morning demand against outdoor temperature for winter 2022 and 2023

The regression model output again confirmed the observation but did not find the effect to be statistically significant (Table B.7).

Table B.7. Regression model output with morning demand as outcome.

winter 2022				
	Coefficient	Std. Error	t value	Pr(> t)
(Intercept)	1.33	0.10	13.14	<2e-16
GroupCC-MSHP	-0.09	0.14	-0.66	0.51
HDD (shifted)	0.15	0.01	25.22	<2e-16
GroupCC-MSHP:HDD(shifted)	-0.01	0.01	-1.65	0.10
DF:	174			
R-squared:	0.87			
P-value:	<2e-16			

winter 2023				
	Coefficient	Std. Error	t value	Pr(> t)
(Intercept)	1.54	0.09	17.15	<2e-16
GroupCC-MSHP	-0.20	0.13	-1.56	0.12
HDD (shifted)	0.15	0.01	26.30	<2e-16
GroupCC-MSHP:HDD(shifted)	-0.01	0.01	-0.70	0.49
DF:	166			
R-squared:	0.89			
P-value:	<2e-16			

It is important to note that the baseline group includes 7 MSHPs rated for temperatures below -25°C, which will reduce the estimated benefits of the CC-MSHP group.

Chapter 8: Understanding Smart Thermostat Use

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Executive Summary

Thermostats play a critical role in the energy performance of heating, cooling, and ventilation (HVAC) systems. They serve as the primary interface through which occupants interact with their HVAC systems, making their usability crucial for achieving energy efficiency. Smart thermostats offer the capability to program setpoint schedules both directly on the device and remotely via a web interface, facilitating the optimization of heating (and cooling) patterns based on occupancy and personal preferences. Smart thermostats also collect telemetry data, helping to improve our understanding of temperature preferences and to learn about occupancy schedules and behaviour.

The Shediak Residential Energy Study investigated smart thermostat use in residential settings, among other technologies. Conducted over five years, the study included the installation of smart thermostats in 340 homes to understand the impact of innovative energy technologies on energy use and participant attitudes. Three types of thermostats, totaling 973 units, were installed by NB Power, each suited for different heating systems:

- Type A thermostats were used for central heat pumps or furnaces with resistive heating (N=67)
- Type B thermostats were installed on mini-split heat pumps (MSHPs) (N=364).
- Type C thermostats controlled electric baseboards and radiant floor heating (N=542).

This report presents a comprehensive analysis that integrates both survey results and telemetry data to understand smart thermostat use. The survey analysis captures occupants' preferences concerning thermostat setpoints, thermal comfort, reasons for setpoint choices, thermostat usability, and the mental models influencing their decisions. The telemetry data analysis provides an objective examination of actual setpoint usage patterns, categorized by central or zonal controls of the primary heating system. The zonal control sample consists of dwellings with electric baseboard heaters and mini-split heat pumps (MSHPs) and used either type B or C or both types of thermostats, while the central control sample consists of central heat pumps or furnaces paired with type A thermostats.

Smart thermostat usability and satisfaction: The adoption of smart thermostats in the Shediak Residential Energy Study demonstrated high satisfaction among participants, with 90% of respondents indicating that they would recommend the devices to others. Despite this positive reception, evidence suggests that not all features of the thermostats were fully utilized, highlighting potential areas for improvement in user education and training. Participants also rated the installation by electricians with high ratings.

Thermostat settings: The majority of participants who received smart thermostats chose their thermostat setpoints based on comfort. Overall, the survey responses suggest that the desire for comfort is more dominant among participants, while saving money on energy bills, though important, is secondary. There is a noticeable trend towards balancing comfort with efficiency, indicating users are increasingly aware of both comfort and cost, yet they still place a higher priority on comfort.

Thermostat setpoint patterns: Analysis of telemetry data revealed consistent setpoint patterns across the different heating systems, with mid-peak hours generally having higher setpoints compared to peak and off-peak hours. This suggests occupants prioritize comfort during active hours at home. Comfort is

the dominant reason for choosing a setpoint. For example, the measured average daytime setpoints for dwellings with zonal heating were 20.9°C, with average nighttime setpoints at 20.3°C during winter 2021 (Dec 2021-Feb 2022) and winter 2022 (Dec 2022-Feb 2023).

Nighttime setback strategies: The measured nighttime setbacks varied by heating system type, with the Central systems having higher average setbacks ranging from 0.7°C (winter 2023) to 1°C (winter 2022), whereas the same setbacks for Zonal systems ranged from 0.4°C to 0.6°C.

Thermal comfort improvements: Participants reported improved thermal comfort over the course of the study, suggesting that smart thermostats contributed positively to perceived comfort levels.

Utility control and personal values: There was moderate acceptance of utility control for environmental benefits, particularly among participants with strong biospheric and altruistic values. This indicates a potential alignment of utility programs with environmentally conscious participants.

Thermostat mental models: Most participants adhered to the feedback model, which accurately describes thermostat operation. This suggests that users generally understand how to operate their thermostats efficiently, although higher income groups showed stronger adherence.

The insights gained from this report could inform design of future demand response and energy efficiency programs in the province. By understanding participants' preferences for comfort over energy bill savings and recognizing the significance of smart thermostat usability, NB Power can tailor programs that align with user priorities. The study's evidence of participants prioritising thermal comfort and moderate acceptance of utility control suggests that demand response initiatives could benefit from integrating time-of-day rates, incentives and educating users about the advantages of strategic temperature management. Furthermore, the identification of prevalent mental models can guide the design of user-friendly interfaces and training materials, ensuring that users are equipped to make informed choices that balance comfort, efficiency, and cost. These findings offer a valuable foundation for developing programs that not only reduce peak demand but also enhance customer satisfaction and promote sustainable energy practices.

1 Introduction

Space heating is the dominant energy use in most Canadian homes; in New Brunswick in 2021 nearly 60% of the total secondary energy in homes was used for space heating, and 18% for water heating. Nearly ~45% of the secondary energy was provided by electricity (Natural Resources Canada [NRCan], 2023) as shown in Appendix A. The proportion of space heating loads in the peak of winter increases significantly as the outdoor temperature drops. A study in New Brunswick of 50 occupied homes in Fredericton that used electricity as the primary source of heating observed that the majority of homes had space heating loads ranging from 60-90% of total usage from January to March 2016 (Pardasani, Veitch, & Newsham, 2016). Measures to reduce energy use associated with space heating clearly hold great potential to help utilities address the challenges of increased overall electricity demand and reduced carbon emissions.

“Smart” or internet-connected thermostats are one tool that can contribute to achieving this goal due to their ease of use in programming setpoint schedules. They monitor run times, providing insights into how long the heating systems operate throughout the day, which can help optimize usage patterns. They are more precise than the analog thermostats they often replace, and they offer the ability to program temperature setpoints both on the device using a mobile phone app and alternatively using a web interface, even when one is outside the home. Because they are internet-connected they also offer the possibility for utility control of the heating system operation to regulate the electrical grid, for example by temporarily lowering the temperature setpoint in a cold period of high demand for electricity. Smart thermostats enable collection of telemetry data, providing a means to validate survey data and improve our understanding of temperature setpoint preferences and variations by types of heating systems.

This report is one of a family of reports from the Shediac Residential Energy Study. The Shediac Residential Energy Study was a 5-year field investigation of the effects of innovative energy technologies on residential energy use and participants’ attitudes and satisfaction. The project tested time-of-day electricity rates, cold-climate mini-split heat pumps, and rooftop solar photovoltaic panels with battery energy storage. Three hundred and forty of the 529 homes in the project received smart thermostats for their electric heating systems, and the data from these devices is the focus of this report. The report combines insights from both participant survey responses and device telemetry analyses to comprehensively understand thermostat use and preferences. The participant surveys encompass occupants’ reported thermostat setpoints, thermal comfort, reasons for setpoint choices, thermostat usability, and the mental models that underpin their decisions. The analysis of telemetry data collected directly from the thermostats examines actual setpoint usage patterns categorized by type of primary heating system. Together, these analyses offer a comprehensive and nuanced understanding of thermostat use and preferences. Details concerning the research design of the whole study are provided by Veitch et al. (2025).

1.1 Literature review

Residents’ behaviour plays a fundamental role in household energy use, with thermostat setpoint preferences being central to this. Panchabikesan et al. (2021) studied ecobee thermostat data from approximately 13,000 households from Alberta, Ontario, and Quebec during 2015-2019. The setpoints from Quebec might stand in for New Brunswick because both provinces primarily use electrical heating and have similar climates. The study found notable regional differences in thermostat setpoint preferences. In Quebec, the average setpoint for the 'home' schedule was 20.6°C, slightly lower than Ontario's average of 20.9°C. During the 'sleep' schedule, Quebec's setpoint was 18.8°C, compared to

Ontario's 19.1°C. For the 'away' schedule, Quebec averaged 17.5°C, while Ontario had 17.7°C, indicating similar trends in lower temperature preferences. Alberta's average setpoints were 20.4°C, 18.4°C, and 17.1°C for 'home', 'away', and 'sleep' modes, respectively, highlighting nuanced differences between provinces.

A previous NB power-NRC study of smart thermostat use in New Brunswick, with data from 567 residents in Saint John, Fredericton, and Moncton, found that slightly cooler setpoints prevailed than in the Quebec example (Pardasani et al., 2017). Participants whose homes used primarily electric baseboard heating reported temperature setpoints of 20.0°C (awake), 16.6°C (away), and 17.3°C (sleeping); those who heated their homes with mini-split heat pumps reported 20.5°C (awake), 17.0°C (away) and 18.1°C (sleeping). That project did not explore the reasons for these setpoint choices.

Perspectives for cognitive psychology propose that people's behaviors are often influenced by the mental models that they hold about how things work (Goodhew et al., 2017, Bremer, 2020). Mental models serve as internal representations of the physical world that help people understand, explain, and predict outcomes of their actions. People develop their understanding based on their experiences with the system, practical knowledge, and habits (Gram-Hanssen, 2010; Bremer, 2020). Other influences on their heating system choices include thermal comfort preferences, system complexity, and goals.

Mental models about thermostat operation fall into four categories (Kempton, 1986, Norman, 2013; Peffer et al., 2011, Revell and Stanton, 2014):

- Feedback model – There is a setpoint. When the temperature falls below it, the thermostat will cause the system to come on until the room warms back to the setpoint, at which time the thermostat will turn off the system.
- Valve model – The thermostat controls the rate at which the system generates heat, like pressing the gas pedal on a car causes the car to move faster. The user's task is to select the right setting to enable the system to maintain the desired level.
- Timer model – The thermostat acts like a kitchen timer, turning on the system for a period of time. The user chooses a high setpoint when they want the system to operate for a long time, and a lower setpoint if they want only a small change in temperature. This model demands user intervention.
- Switch model – The thermostat is like a wall switch: raise the setpoint above the current temperature to turn on the heat, or lower it to turn off the heat. This model requires user intervention.

Understanding residents' mental models is important because misconceptions about system operation affect energy use. For example, some people believe that turning the thermostat higher will heat the home faster (Revell and Stanton, 2014; Goodhew et al., 2017, Mallaband et al., 2017). Those who understand (correctly) that thermostats operate on the feedback model can use these technologies to achieve their energy and comfort goals.

That said, successful use of thermostats requires some understanding of the thermodynamics of dwellings, for example, to understand temperature patterns in different locations in the home relative to the thermostat (Revell & Stanton, 2018). The thermostat interfaces must be understandable; people are unlikely to engage with complex devices (Tamas et al., 2023). Revell and Stanton (2018) recommended putting users in control using training that deliberately builds a correct mental model. This may be challenging because people often do not recognize errors in their mental models and can retain inaccuracies or see no reason to change despite factual statements that contradict particular beliefs/models (Morgan et al, 2002).

The desire for comfort explains much of the variability in setpoint choices (Sintov et al., 2019), but financial motives are also influential. Huebner et al. (2013) investigated human factors related to energy consumption, specifically the meaning of comfort and comfort actions, barriers to and motivators for saving energy, and knowledge about the heating system. Those most willing to change their thermostat behaviours were those who wished to save money (Huebner et al., 2013).

Smart technologies permit the creation of demand-side management programs that give control to utilities to change thermostat setpoints to achieve utility goals such as reduced peak demand. The key drivers of such program enrollment and customer participation levels remain poorly understood (Langevin et al., 2024). Despite many benefits of these programs, customers' concern for losing control has been hindering its adoption. For example, Xu et al. (2018), investigated residents' willingness to accept a direct load control (DLC) program, either with or without financial incentives, or with or without an override option. Half of the participants were willing to accept DLC without any conditions, but the override option was more effective than the financial incentive option. Combining both an incentive option of \$30 and an override option boosted the overall acceptance rate.

1.2 Objectives

The report addresses the following questions related to participants' use of smart thermostats and their attitudes towards these technologies. The results provide pointers to possible future utility programs aimed at helping customers to achieve both comfort and efficiency goals.

- What were thermostat setpoint profiles for different heating system types?
- What were participants' priorities in choosing thermostat setpoints? Did their setpoints differ if they prioritized comfort over the size of their electricity bill?
- How satisfactory were the thermostats?
- What were participants' attitudes about the possibility of utility control over their thermostats?
- What were participants' mental models of thermostat operation? Did they understand their thermostats sufficiently to operate them in the most efficient manner?

2 Method

2.1 Participants

The data in this report come from the participants whose homes received smart thermostats as part of the project. Eligible participants were offered up to five smart thermostats from the project, the number and type depending on the heating system. Data from 340 homes who received smart thermostats forms part of this report. Table 1 characterizes these participants. The values for the full sample are shown to confirm that the subset of homes that received smart thermostats is similar in composition to the study as a whole.

The project also tested time-of-day (TOD) electricity rates (see Pardasani et al., 2025b). This report combines participants from the TOD and no-TOD groups to consider the overall use of smart thermostats.

Table 1. The characteristics of the participants whose data are reported here. Note that survey responding was not mandatory, so numbers may not add to N = 340.

	This Report, N = 340		Whole Sample, Dec. 2019, N = 529	
	N	Valid %		
Survey respondent sex (winter 2020)				
Male	200	58.8	297	59.5
Female	128	37.6	200	40.1
Prefer not to say	1	0.4	2	0.4
Respondent age (winter 2020)				
21-30	16	5.4	23	5.1
31-40	63	21.1	84	18.6
41-50	73	24.4	108	23.9
51-60	60	20.1	100	22.2
61-70	52	17.4	83	18.4
71-80	31	10.4	43	9.5
81+	2	0.7	6	1.3
Prefer not to say	2	0.7	4	0.8
Household Income (winter 2020)				
<\$20k	1	0.3	4	0.8
\$20k<\$40k	22	6.7	38	7.6
\$40k<\$60k	43	13.0	69	13.8
\$60k<\$80k	41	12.4	68	13.6
\$80k<\$100k	46	13.9	68	13.6
\$100k<\$150k	106	32.1	138	27.5
\$150+k	56	17.0	86	17.2
Don't Know	15	4.5	30	6.0
Home area (SF) (HA1)				
0-1000	20	5.9	36	7.0
1000-2000	247	72.6	360	70.5
2000-3000	58	17.1	93	18.2
3000-4000	10	2.9	15	2.9
4000-5000	4	1.2	6	1.2
>5000	1	0.3	1	0.2
Primary Heating System (winter 2020)				
Mini-split heat pump (MSHP)	196	57.6	256	50.4
Electric baseboards (EB)	80	23.5	114	22.4
Central heat pump	51	15.0	89	17.5
Central furnace	6	1.8	30	5.9
Radiant floor	7	2.1	8	1.6
Fireplace	0	0	11	2.2
Primary Heating System (March 2024)				
No heat pump ever	37	10.9	Not applicable	
Heat pump at start	247	72.6	Not applicable	
Heat pump purchased during project	35	10.3	Not applicable	
Heat pump given by project (CC-MSHP)	21	6.2	Not applicable	
Daily Occupancy Pattern (Spring 2022)				
Someone always home	136	56.7	Not applicable	
Someone home part of the day	69	28.8	Not applicable	
Out all day, back in evening	35	14.6	Not applicable	

2.2 Smart thermostats

As described in Veitch et al. (2025), participants' homes were assessed in winter 2020 by a contractor to obtain information about the building in order to determine its compatibility with the technologies to be tested in the project. The records included information about the heating system, which enabled a

determination of those homes whose heating systems would be compatible with smart thermostats that could be used to provide telemetry data about thermostat setpoints and system operation.

Three thermostat types were used, depending on the primary and secondary heating systems. Table 2 shows the connection of labels to the heating system types being controlled.

Table 2. Thermostat label and heating system it controlled.

Label	Heating System
A	Central heat pump or furnace
B	MSHP
C	Resistive heating, including electric baseboards (EB) and radiant floor heating

If the home had more than one room heated with either MSHP or EB, up to five thermostats could be installed, in order to provide information on the majority of the heating load for the home. The combinations of MSHP as primary heating system with EB as backup, or in other rooms of the home, meant that there were five variations of device types installed: A only, A+B, B only, B+C, and C only.

Thermostat installations commenced in November 2020 and concluded in the winter of 2021. Installers used installation checklists to document the thermostat serial number, its location within the house, the type of heating system, the capacity of the heating system (if applicable), and additional settings for auxiliary heat on central heat pumps. Table 3 summarizes the data from the thermostat installation checklists, including the number of smart thermostats installed and their corresponding heating system types.

There were 175 instances of B+C, and 3 instances of A+B.

At the start of winter 2021, data was being collected from 829 smart thermostats across 320 homes; attrition had occurred because of participants selling their homes and moving. By winter 2023, this number decreased to 615 smart thermostats in 250 homes, due to connection issues and participant opt-outs from the study.

Table 3. Number of smart thermostats installed by type and heating system based on installation checklists

Thermostat Type	Heating System Type	Installed	Uninstalled	Net
A	Furnace	12		12
	Central heat pump	49		49
	Boiler	6		6
	<i>Total</i>	<i>67</i>		<i>67</i>
B	Mini-split	289	6	283
	Multi-head heat pump	16	2	14
	Unknown (not recorded)	59		59
	<i>Total</i>	<i>364</i>		<i>356</i>
C	Resistive heating	542	2	540
Grand Total		973	10	963

2.3 Data sources and preparation

2.3.1 Thermostat telemetry

Thermostat telemetry data was shared by NB Power to the NRC through CSV files via their secure FTP server. The data model has been described in a separate report (Pardasani, 2025). The files were then ingested into the NRC's SQL data warehouse. The thermostat data was analyzed for completeness, and results until March 2024 are shown in Table 4. Note that not every thermostat returned data, either

because of connectivity issues or because the participant had not completed the utility authorization with the device vendor. The data was further analyzed for quality issues, including missing data points. The primary data quality issue was the missing room and setpoint temperature data, which affected 96 thermostats. Additional problems included incorrect readings and improperly mapped data fields. Despite these challenges, the thermostat setpoint and room temperature data were still reliable for computing seasonal averages. Thermostats with more than 50% missing or incorrect data for the season were excluded from the analysis.

Table 4. Thermostat data completeness by month.

Year	Month	Distinct ST Count	Number of Records	Expected Records	Percent Complete
2021	Dec	827	7,200,848	7,383,456	98
2022	Jan	828	7,187,448	7,392,384	97
2022	Feb	825	6,018,488	6,652,800	90
2022	Mar	831	7,258,104	7,419,168	98
2022	Apr	821	6,996,905	7,093,440	99
2022	May	835	7,239,261	7,454,880	97
2022	Jun	826	6,895,938	7,136,640	97
2022	Jul	811	6,955,121	7,240,608	96
2022	Aug	797	6,836,791	7,115,616	96
2022	Sep	796	6,076,345	6,877,440	88
2022	Oct	789	6,817,002	7,044,192	97
2022	Nov	779	6,515,564	6,730,560	97
2022	Dec	769	6,720,486	6,865,632	98
2023	Jan	767	6,645,598	6,847,776	97
2023	Feb	760	6,043,916	6,128,640	99
2023	Mar	752	6,568,820	6,713,856	98
2023	Apr	737	6,302,801	6,367,680	99
2023	May	737	6,425,329	6,579,936	98
2023	Jun	728	5,017,562	6,289,920	80
2023	Jul	714	5,773,267	6,374,592	91
2023	Aug	645	5,689,539	5,758,560	99
2023	Sep	645	5,397,552	5,572,800	97
2023	Oct	653	5,653,797	5,829,984	97
2023	Nov	658	4,901,639	5,685,120	86
2023	Dec	658	4,853,606	5,874,624	83
2024	Jan	661	5,415,692	5,901,408	92
2024	Feb	659	5,398,227	5,503,968	98
2024	Mar	645	5,076,684	5,758,560	88

Representative thermostat choices

Homes with zonal heating systems, such as those with electric baseboards or mini-split heat pumps (MSHP), had multiple thermostats that could be either type B or C or both. Occupants typically maintain a low setpoint for unused spaces and choose a comfortable setpoint for spaces in use to conserve energy and reduce bills. The presence of multiple thermostats raises the question of which thermostat should serve as the reference in zonal systems. Instead of averaging the setpoints of all smart thermostats in a home, we selected a representative thermostat based on the following criteria:

1. The average heating setpoint was meaningful, with a value between 15 to 25 degrees Celsius.
2. The thermostat controlled a primary heating system rather than a secondary system.
3. The thermostat was installed in a main area of a home such as kitchen or living room, rather than in a bedroom or basement.

In rare cases where multiple thermostats met the criteria, the thermostat with the higher heating setpoint in the morning was selected. If no thermostat met all the criteria, we chose one that met Criterion 1; otherwise, that home was excluded from the analysis.

2.3.2 Surveys

Participants completed online surveys on seven occasions between December 2019 and March 2024 (see Veitch et al., 2025). The surveys covered all parts of the project. The present report includes responses relevant to the smart thermostats provided by this project: priorities for choosing thermostat setpoints, thermal comfort, thermostat usability and satisfaction, mental models of thermostat operation, attitudes towards utility control, and personal values.

2.3.2.1 Thermostat usability and satisfaction

Satisfaction with the thermostats and with the installer were probed with 5-point Likert-scaled questions. Participants were also asked whether they would recommend the thermostats to others with a yes/no question.

Re-using the thermostat ratings used by Pardasani et al. (2018), participants assessed the usability of their thermostats using six questions adapted from Dugar, Donn, and Osterhaus (2011), shown in Table 5. These were rated between 0 and 10; scores on the appearance and attractiveness questions were reverse-coded. The questions were asked in winter 2021, winter 2023, and spring 2024; this report uses the responses in 2021 and 2024.

Table 5. Thermostat usability rating scales, adapted from Dugar et al. (2011).

Appearance [reverse-coded] <i>Looks like a temperature control</i>	0 ----- 10	<i>Does not look like a temperature control</i>
Attractiveness [reverse-coded] <i>Looks attractive</i>	0 ----- 10	<i>Does not look attractive</i>
Ease of use <i>Difficult to use</i>	0 ----- 10	<i>Easy to use</i>
Accuracy <i>Very inaccurate</i>	0 ----- 10	<i>Very accurate</i>
Responsiveness <i>Very Non-responsive-</i>	0 ----- 10	<i>Very responsive</i>
Learning speed <i>Very difficult to learn</i>	0 ----- 10	<i>Very easy to learn</i>

Seven questions with the same 0-10 rating format probed how participants program their smart thermostats. These are listed in Table 6 and were developed specifically for this study, asked in winter 2021 only.

Table 6. Thermostat programming habits.

I do not know how to change setting options manually on my thermostats	0 ----- 10	I can easily change setting options manually on my thermostats.
I cannot/don't know how to program my thermostats directly on the thermostat (e.g., rather than using the web interface).	0 ----- 10	I can easily program my thermostats directly on the thermostat (e.g., without using a computer for the web interface).
I don't use my thermostat's user guide.	0 ----- 10	I use my thermostat's user guide.
I am the only one who adjusts thermostat settings.	0 ----- 10	All the people in the household adjust thermostat settings.
I switch off my thermostat on a daily or weekly basis (turning off heating or cooling system)	0 ----- 10	I almost never switch off my thermostat (turning off heating or cooling system).
I can easily program my smart thermostats using a web interface	0 ----- 10	I cannot/don't know how to program my smart thermostats using a web interface
I fully understand the meaning of the icons, symbols and abbreviations shown on the thermostat displays and the web interface.	0 ----- 10	I don't know/don't understand the meaning of the icons, symbols and abbreviations shown on the thermostat displays and the web interface.

Participants rated their satisfaction with the thermostat installer in winter 2021 (0 very dissatisfied, to 4, very satisfied). They rated their disagreement (0) or agreement (4) with the statement “Our house has felt comfortable since the smart thermostats were installed” in winter 2021 and winter 2023 and in spring 2024, and indicated whether they would recommend these thermostats to others. In winter 2023 they had an opportunity to provide open-ended feedback about what they liked or disliked about the smart thermostats.

Questions about the acceptability of allowing the utility to control household electricity demand were asked on four occasions. These are reported in more detail in other project reports, but the results for winter 2023 are reported here as an indication of the openness of thermostat recipients to considering allowing their thermostats to be adjusted by a utility. The four questions were each answered on a scale from 0 = strongly disagree to 4 = strongly agree:

- Avoiding the need for new electrical generating stations is important to me.
- It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is reliable for everyone.
- Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.
- It is acceptable for utilities to adjust individual customer electrical demand to deliver the least costly electricity supply for everyone.

2.3.2.2 Thermostat priorities

Several questions probed participants' thermostat setpoint habits and reasons (see Table 7) with variations in the various surveys. Where possible we compared winter 2021 (just following the last installations of smart thermostats) and winter 2023 (after two years' experience with the thermostats).

Table 7. Survey questions about how and why participants chose their thermostat setpoints.

Question	When asked
How do you control your current thermostat? 1=I program my thermostat with different set points and schedules 2=I manually change the settings throughout the season depending on my schedule and the weather 3=I use a single set point throughout the season	winter 2019 summer 2022 winter 2022 winter 2023 spring 2024
Please select the most important objective in your use of a thermostat: 1=I care about how energy use affects the environment 2=I want to feel comfortable 3=I want to save money on my energy bills 4=Not sure	winter 2021 winter 2022 winter 2023
What is your priority for using your heating system? 0=Being comfortable is my top priority 1=Saving energy is my top priority 2=Keeping my electricity bills low is my top priority 3=I try to balance efficiency and comfort 4=I don't know	winter 2022
How do you decide what temperature to set your thermostat to? 1=Based on comfort 2=Based on utility bill	summer 2022 winter 2022 winter 2023
How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to? 0 = not important 9 = very important	spring 2024
Maximizing comfort:	
Minimizing utility bill:	
Minimizing environmental impact:	
Thermostat default settings:	
Social norms (society's shared understanding about the right thing to do)	

2.3.2.3 Thermal comfort

Thermal comfort was assessed with two questions. The ASHRAE thermal sensation scale (ASHRAE, 2023) is a 7-point rating in response to the prompt “Please rate your thermal sensation. At the moment I feel...” with possible answers cold, cool, slightly cool, neutral, slightly warm, warm, and hot. It is scored from -3 to +3. The McIntyre (1980) thermal preference rating is a three-point rating in response to the prompt “At the moment, I would like to be...” with possible answers cooler, no change, or warmer. It is scored from -1 to +1. These questions were asked in winter 2019 and winter 2023 and in summer 2022. To support these ratings we also asked about usual clothing worn in the home to calculate clothing insulation values. We asked these questions in winter 2019 and summer 2022 only.

2.3.2.4 Self-reported thermostat setpoints

Participants reported their usual thermostat setpoints for three times of day -- During the day when active; during the day while out of the house; and while sleeping – for winter and summer, on three occasions: winter 2019, summer 2022, and winter 2022. For this report we focused on winter settings reported in the winter. We report the settings for during the day when active, and setbacks for the periods when out of the house and while sleeping.

2.3.2.5 Thermostat mental models

Closed-ended questions using 5-point disagree-agree ratings assessed participants’ models of thermostat operation. Table 8 displays the statements. These questions were repeated in winter 2021,

winter 2022, winter 2023 and spring 2024. We used all of these responses to form two scale scores, one indicating the agreement with the feedback model (average of all scores on questions 1-3) and one indicating agreement with the valve model (average of all scores on questions 4-5).

Open-ended probes were included on two occasions. The open-ended question in winter 2021 was “Please describe how your household heating system works.” In winter 2023, the question was “In your own words, what do you think is the most efficient way to operate your heating system?”

Table 8. Disagree (0) /agree (4) questions were used to probe thermostat mental models and understanding.

Question	Model probed
1. When I feel too cold, I turn up the thermostat and the heat comes on until it reaches the new temperature; then it turns off.	Feedback
2. I turn down the thermostat before I have a big crowd over to visit, so it doesn't get too hot when they are here.	Feedback
3. When I set a lower temperature on the thermostat, the heat doesn't come on until the temperature drops to the new setting.	Feedback
4. I keep my thermostats at the same setting always because it uses more energy to reheat the house than it would to keep it at one temperature.	Valve
5. When I set a new temperature, the higher I set it, the faster the house heats up.	Valve

2.3.2.6 Individual differences

In winter 2019 and summer 2022, participants completed 16 questions concerning their fundamental values (Steg, Perlaviciute, van der Werff, & Lurvink, 2014). These responses combine to form ratings of four values: egoistic (concern for one's personal gains); hedonic (concern for feeling good and reducing effort); altruistic (concern for the welfare of others); biospheric (concern for the quality of nature and the environment) dimensions. These values have been shown to predict environmental concern and the likelihood of taking pro-environmental actions, including household energy use. In the present report we focused on the responses in summer 2022, after the smart thermostats had been installed.

We also examined the role of household income on thermostat priorities. We used income as reported in winter 2023 and compared it to the thermostat priorities at the same time.

3 Results

3.1 Surveys

3.1.1 Thermostat usability and satisfaction

3.1.1.1 Satisfaction

Satisfaction with the smart thermostats was high, with 90% of 205 respondents in 2021 and 88% of 163 respondents in spring 2024 responding that they would recommend the smart thermostats they had received to a friend. Figure 1 displays the distribution of spring 2024 responses to a 5-category rating of satisfaction with the smart thermostats. Fewer than 10% of respondents to this question felt dissatisfied; 84% were “satisfied” or “very satisfied”.

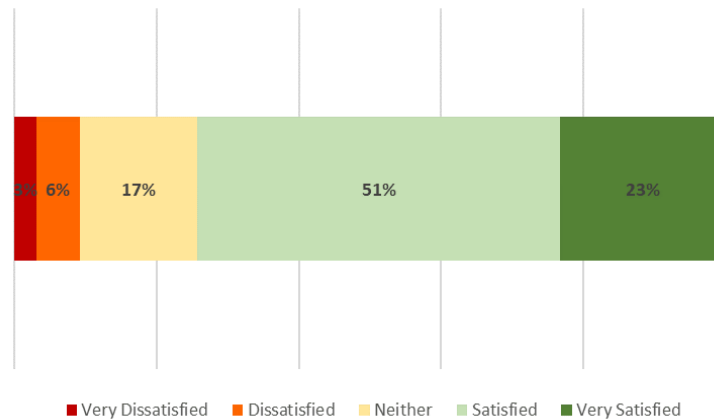


Figure 1. The distribution of satisfaction ratings with the smart thermostats as rated in Spring 2024 (N = 163).

In winter 2021, at the first opportunity after the thermostats had been installed, participants rated their satisfaction with the electrician who had performed the installation. Ratings were very high, with fewer than 25% giving a rating of less than 3 on a scale from 0-4 ($M = 3.18$, $SD = 0.92$).

Participants rated the comfort of their homes in winter 2021 and spring 2024 (Figure 2). This showed a very small increase in disagreement in 2024 after two years' experience of the smart thermostats. We tested this change using a paired samples t-test to compare the ratings for the 123 people who responded at both times. This showed that the change was not statistically significant⁵ ($t(122) = 1.87$, $p = 0.06$, Cohen's $d = 0.17$).

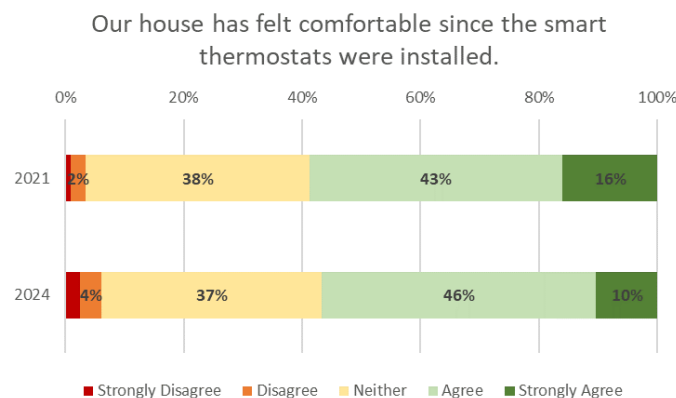


Figure 2. Ratings of home comfort since the smart thermostat installation (2021, N = 206; 2024, N = 164).

3.1.1.2 Thermostat usability

Participants' thermostat programming habits in 2021, when the smart thermostats were new, showed that they had a good understanding of how to manually change settings or to program their devices (first two questions) and that they could also program them using a web interface and understood the icons on the interfaces (last two questions) (Table 9). The survey in winter 2022 repeated the same

⁵ When a result is labelled "not statistically significant", it means that this outcome could have occurred by chance if the true value is that there no effect (i.e., no difference, no correlation, etc.).

questions, and we compared the two years using a multivariate analysis of variance to determine whether any of the average responses had changed between the two years.

Table 10 shows the MANOVA results. The multivariate test was statistically significant, and therefore we turn to the univariate tests to interpret this test. The average scores for the second question, concerning programming directly on the thermostat, and the fourth question, concerning household members who adjust thermostat settings, showed statistically significant changes between 2021 and 2022.

Interestingly, scores dropped for the question about programming directly on the thermostat, indicating a lower level of knowledge even after a year of experience with the smart thermostats. After the first year, however, more people in the household were using the thermostats. Both are small effect sizes (Cohen, 1988).

Table 9. Means and standard deviations for programming habits in winter 2021 and winter 2022 (N = 162).

	2021		2022		
Score = 0	M	SD	M	SD	Score = 10
I do not know how to change setting options manually on my thermostats	8.82	2.15	8.88	1.95	I can easily change setting options manually on my thermostats.
I cannot/don't know how to program my thermostats directly on the thermostat (e.g., rather than using the web interface).	7.74	2.97	6.98	3.36	I can easily program my thermostats directly on the thermostat (e.g., without using a computer for the web interface).
I don't use my thermostat's user guide.	4.93	3.67	4.34	3.85	I use my thermostat's user guide.
I am the only one who adjusts thermostat settings.	4.86	3.78	5.87	3.67	All the people in the household adjust thermostat settings.
I switch off my thermostat on a daily or weekly basis (turning off heating or cooling system)	7.04	3.41	6.56	3.43	I almost never switch off my thermostat (turning off heating or cooling system).
I can easily program my smart thermostats using a web interface	3.25	3.79	3.27	3.48	I cannot/don't know how to program my smart thermostats using a web interface
I fully understand the meaning of the icons, symbols and abbreviations shown on the thermostat displays and the web interface.	3.07	3.34	3.31	3.40	I don't know/don't understand the meaning of the icons, symbols and abbreviations shown on the thermostat displays and the web interface.

Table 10. MANOVA test results for the comparison of 2021 and 2022 ratings of smart thermostat programming habits.

	Wilks' Λ	F	df	p	Cohen's d
Multivariate	0.872	3.25	7,155	0.00	na
Manual settings		0.11	1,161	0.74	0.03
Program directly		6.57	1,161	0.01*	0.20
User guide		3.21	1,161	0.08	0.14
Only me		7.88	1,161	0.01*	0.22
Switch off		2.06	1,161	0.15	0.11
Web program		0.00	1,161	0.94	0.02
Icons		0.44	1,161	0.51	0.05

Thermostat usability ratings in winter 2021 and spring 2024 were available for 122 participants. We compared these using multivariate analysis of variance (MANOVA). The descriptive statistics are shown in Table 11 and the analysis results in Table 12. The 2021 ratings were provided at the start of the first winter with the smart thermostats and was very shortly after installation for some participants. The 2024 ratings came after three winters' experience with the smart thermostats. Although all of the average ratings are high (over 7 on a scale from 0-10), they are all lower in 2024 than in 2021. The inferential test results showed a statistically significant multivariate test and statistically significant effects for five of the six scales. Only the rating of appearance ("Looks like a temperature control") did

not have a statistically significant drop. The differences were small to medium in size, with the largest effect sizes for the ratings of ease of use (Cohen's $d = 0.36$) and responsiveness (Cohen's $d = 0.42$).

Table 11. Means and standard deviations for the six thermostat usability ratings in two years. Each is on a scale from 0-10, and N = 122.

	winter 2021		Spring 2024	
	M	SD	M	SD
Appearance	7.90	2.84	7.42	2.83
Attractiveness	8.52	2.06	7.90	2.45
Ease of use	8.31	2.70	7.17	3.17
Accuracy	8.21	2.30	7.34	2.90
Responsiveness	8.33	1.90	7.16	2.81
Learning speed	7.92	2.78	7.11	3.01

Table 12. MANOVA test results for the comparison of 2021 and 2024 ratings of smart thermostat usability.

	Wilks' Λ	F	df	p	Cohen's d
Multivariate	0.808	4.60	6,116	0.00	
Appearance		2.76	1,121	0.10	0.15
Attractiveness		6.75	1,121	0.01*	0.24
Ease of use		15.47	1,121	0.00*	0.36
Accuracy		10.38	1,121	0.00*	0.29
Responsiveness		22.01	1,121	0.00*	0.42
Learning speed		7.12	1,121	0.01*	0.24

3.1.1.3 Acceptability of utility control

Participants with smart thermostats showed modest support for utility control, with scores on related questions having averages above the scale midpoint (2) in both 2021 and 2022 (Table 13). Comparison of the ratings for the two years (Table 14) showed that support for adjusting individual customer demand to benefit the environment dropped in 2022, but this was a statistically small effect (Cohen, 1988) and the mean remained above the scale midpoint.

Table 13. Means and standard deviations for the acceptability of utility control over one's electricity use in two years. Each is on a scale from 0-4, and N = 206.

	winter 2021		winter 2022	
	M	SD	M	SD
Avoiding the need for new electrical generating stations is important to me.	2.43	0.93	2.57	0.92
It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is reliable for everyone	2.54	0.91	2.42	0.96
Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	2.75	0.88	2.53	0.94
It is acceptable for utilities to adjust individual customer electrical demand to deliver the least costly electricity supply for everyone. [2022 only]			2.48	0.98

Table 14. MANOVA test results for the comparison of 2021 and 2022 ratings of the acceptability of utility control.

	Wilks' Λ	F	df	p	Cohen's d
Multivariate	0.925	5.45	3,203	0.00	
Acceptable to avoid new generation		3.31	1,205	0.07	0.13
Acceptable for reliable supply		2.77	1,205	0.10	0.12
Acceptable for environmental benefits		11.91	1,205	0.00	0.24

3.1.2 Thermostat priorities

Our probes for the reasons for choosing thermostat setpoints changed throughout the project and in a few surveys we asked this question more than once with different response options. Table 15 shows the descriptive statistics for these questions for the whole sample, with the times of asking indicated.

A few facts stand out. First, the proportion of participants reporting that they manually change thermostat settings dropped between winter 2019 (when they did not have the smart thermostats from the project) and winter 2023 (after two years with the project-provided smart thermostats). This might be expected. However, 44% reported making manual adjustments to the smart thermostats, suggesting that they did not take full advantage of the devices' capabilities.

Second, the question format influences the outcomes. When asked a forced-choice question about their priority for choosing a thermostat setting, the large majority of respondents in 2019, 2022 and 2023 reported prioritizing comfort, with fewer than 10% reporting they try to minimize their utility bills. A new question "Please select the most important objective in your use of a thermostat" added in winter 2021 provided a different picture. In winter 2021 the dominant objective (just over half of the sample) was to save money on electricity bills, but in 2023 being comfortable was the choice of 60% of the sample on that question. However, also in 2023 64.8% of respondents said that they try to balance efficiency and comfort, when offered that option in response to "What is your priority for using your heating system?"

Third, at the end of the study in spring 2024, participants were asked to indicate the importance of each priority on a scale of 0-9. Being comfortable had the highest score, with a mean of 7 and the smallest of the standard deviations. This was closely followed by minimizing one's utility bill, mean score of 6. Although it was rarely the highest priority in the forced-choice questions, environmental considerations were not unimportant, having a mean score of 5.3, well above the scale midpoint of 4.

Table 15. Descriptive statistics describing how and why participants who received smart thermostats chose their thermostat setpoints. Empty cells reveal survey times when the question was not asked.

Question	winter 2019		winter 2021		winter 2022		winter 2023	
	N	%	N	%	N	%	N	%
How do you control your current thermostat?								
I program my thermostat with different set points and schedules	38	11.8			61	25.7	41	20.4
I manually change the settings throughout the season depending on my schedule and the weather	215	66.6			134	56.5	93	46.3
I use a single set point throughout the season	70	21.7			42	17.7	67	33.3
Please select the most important objective in your use of a thermostat:								
I care about how energy use affects the environment			53	20.0	24	10.1	17	8.5
I want to feel comfortable			68	25.7	143	60.1	132	65.7
I want to save money on my energy bills			139	52.5	62	26.1	50	24.9
Not sure			5	1.9	9	3.8	2	1.0
What is your priority for using your heating system?								
Being comfortable is my top priority					58	24.6		
Saving energy is my top priority					9	3.8		
Keeping my electricity bills low is my top priority					15	6.4		
I try to balance efficiency and comfort					153	64.8		
I don't know					1	0.4		
How do you decide what temperature to set your thermostat to?								
Based on comfort	272	87.2			216	90.8	169	84.1
Based on utility bill	40	12.8			22	9.2	20	10.0
Based on environmental considerations [offered 2023 only]							12	6.0
How important are each of these factors when you are deciding which temperature(s) to set your heating/cooling system to?							Spring 2024	
0 = not important 9 = very important							<i>M</i>	<i>SD</i>
Maximizing comfort							7.0	1.8
Minimizing utility bill							6.0	2.2
Minimizing environmental impact							5.3	2.2
Thermostat default settings							3.9	2.7
Social norms (society's shared understanding about the right thing to do)							3.9	2.6

3.1.3 Thermal comfort

winter thermal comfort data are available for winter 2019 and winter 2023. Winter 2019 was the project start, before these homes had smart thermostats. Winter 2023 came after two years' experience with the smart thermostats; some dwellings also had changed their primary heating systems, having acquired one or another heat pump independently or from the project. These analyses use data from 187 participants who provided responses on all the relevant variables.

3.1.3.1 Change over time

We compared thermal sensation scores in the two years using a repeated-measures analysis of variance (ANOVA). Recall that thermal sensation is a 7-point rating from -3 to +3. There was a statistically significant change in average thermal sensation from +0.27 (SD = 1.09) (just above the neutral point, 0) to +0.52 (SD = 1.09) (nearer to the label 'slightly warm') [$F(1,173) = 53.93, p < 0.000$, Cohen's $d = 0.56$]. This is a medium sized effect (Cohen, 1988).

We compared thermal preference scores for 2019 and 2023 using crosstabulation and the nonparametric Sign test of differences (see Siegel & Castellan, 1988). Thermal preference ratings answer

the question “Right now, I would like to feel...”. The pattern across the two years shows a shift with an increase in the proportion of people reporting ‘no change’ in 2023 and a decrease in proportion wanting to feel warmer. This difference is statistically significant, meaning that we can reject the idea that the two distributions are in fact the same ($Z = -2.49$, $p=0.013$).

Combining the results from the thermal sensation scores and the thermal preference scores we can conclude that the participants reported improved thermal comfort in winter 2023 than in winter 2019 (Table 16). There are many possible explanations, which will be discussed below.

Table 16. Thermal preference scores from 2019 and 2023 show improved thermal comfort over time.

		winter 2023			Total
		Cooler	No Change	Warmer	
	Cooler	2	5	1	8
winter 2019	No Change	5	87	16	108
	Warmer	1	37	33	71
Total		8	129	50	187

3.1.3.2 Thermal comfort and heating system priorities

Noting that there had been a change in heating priorities during the project (see above), we examined the effects of heating priorities on thermal comfort by using the priorities that were measured in the same survey as the thermal comfort ratings. For thermal sensation in winter 2019 we grouped the data according to the priorities rated in winter 2019 when only two response options were provided. For winter 2023 we grouped based on the priorities as rated in the same survey. In both cases we excluded “Don’t know” as a response because the sample size was too small. We made two planned comparisons: (1) Comparing comfort to saving money as priorities; (2) comparing the environmental priority to comfort. Note that the very large differences between the group sizes push the bounds of test validity, but serve to provide indications of possible substantive differences.

Table 17 shows the descriptive statistics and Table 18 shows the inferential statistics. For both years, the group sizes (N) show that feeling comfortable was the priority for the largest proportion of participants. In both years, the people who indicated that their priority was to feel comfortable reported feeling warmer than people who prioritized saving money. In 2023, when the additional option was provided, those who prioritized the environment felt slightly cooler than neutral; those who wanted to save money felt just slightly warmer than neutral. These statistically significant effects are small according to common guidance for the Cohen’s d statistic (Cohen, 1988).

Table 17. Descriptive statistics for thermal sensation scores in 2019 and 2023, by heating system priorities ($N = 187$).

Heating System Priority	winter 2019			winter 2023		
	N	M	SD	N	M	SD
I care about how energy use affects the environment.				16	-0.25	1.18
I want to feel comfortable.	166	0.36	1.06	125	0.75	1.05
I want to save money on my energy bills.	21	-0.33	1.07	46	0.11	0.99

Table 18. Inferential test results for planned comparisons between heating priority groups, in 2019 and 2023.

		F	df	p	Cohen’s d
2019	Comfort vs Saving	7.92	1,185	0.04	0.21
2023	Comfort vs Saving	12.75	1,184	0.00	0.26
	Environment vs Comfort	13.05	1,184	0.00	0.26

3.1.4 Thermostat mental models

The scale scores for overall mental models of how heating systems work are summarized in Table 19. Each is scored on a scale from 0 (low adherence to this mental model) to 4 (high adherence to this mental model). Cronbach's alpha is an indicator of the internal consistency of the scale; values above 0.7 are conventionally considered "good", meaning that the scale assesses a coherent concept. Adherence to the feedback model has a high mean, above the scale midpoint; the valve model has low adherence. This difference is statistically significant and is large ($F(1,238) = 133.327$, $p < 0.000$, Cohen's $d = 0.74$).

Table 19. Descriptive statistics for two mental models of thermostat operation (N = 240 participants with smart thermostats).

	M	SD	Median	Min	Max	Cronbach's alpha
Feedback model	2.50	0.54	2.56	0.67	4.00	0.71
Valve model	1.83	0.67	1.88	0.00	3.25	0.71

Qualitative data from open-ended questions in surveys in winter 2021 and winter 2022 bear this out. Particularly in 2021, most participants did not choose to answer the questions, and of those that did many answers were too brief to determine their mental models. However, the pattern (seen in Table 20) was clear in both years that the dominant mental model is the feedback model, which is the correct model to describe the operation of a thermostat.

Table 20. Frequency of open-ended responses indicating use of each mental model for thermostat function.

	2021		2022	
	N	%	N	%
Feedback model	55	82%	175	84%
Valve model	3	4%	10	5%
Timer model	4	6%	13	6%
Switch model	5	7%	14	7%

3.1.5 Individual differences

Our analyses for the role of individual differences in understanding thermostat use behaviours are exploratory, and are primarily correlations intended to highlight topics that might influence future communications with energy users. The focus here is on four value orientations (egoistic, hedonic, altruistic, and biospheric) and household income. We used the value scores from summer 2022 (the later of two times these had been asked) and the household income from winter 2023 (the last time this question was asked).

3.1.5.1 Personal values and income

Relationships between the individual differences can reveal potential confounding variables that would complicate interpretation of other results. For a sample of 224 individuals in homes with smart thermostats for whom there was complete data, we examined the differences between the values and the relationship between income and the values. Table 21 shows the means and standard deviations.

Table 21. Means and standard deviations for personal values by household income categories of participants with smart thermostats (N = 224). The personal values fall on a scale from -1 to +7.

	Egoistic		Hedonic		Altruistic		Biospheric	
	M	SD	M	SD	M	SD	M	SD
\$20k<\$40k	2.98	1.15	5.11	1.26	5.50	1.20	5.75	1.09
\$40k<\$60k	2.57	1.33	4.83	1.55	5.37	0.90	5.43	1.01
\$60k<\$80k	2.72	1.27	4.84	1.26	5.57	0.96	5.39	1.31
\$80k<\$100k	2.94	1.33	4.94	1.29	5.25	1.40	5.38	1.26
\$100k<\$150k	2.54	1.40	4.78	1.11	5.24	1.18	5.30	1.12
\$150+k	2.72	1.04	4.95	1.22	5.11	1.01	5.15	1.27
OVERALL	2.68	1.26	4.88	1.24	5.28	1.11	5.32	1.18

Multivariate analysis of variance (MANOVA) was used to assess the relationship between income (the predictor) and personal values (the outcome variable). Income was not related to personal values (Table 22). In testing for differences between the strength with which participants held to each of the personal values, we used planned comparisons with MANOVA. We tested for the difference between Egoistic and Hedonic, between the inward-facing values (Egoistic and Hedonic) and outward-facing values (Altruistic and Biospheric), and between Altruistic and Biospheric. Table 22 also shows those results. The first MANOVA established that there is an overall difference between the values. The second determined that the strength of Egoistic values is lower than Hedonic (and at the lower end of the scale, which runs from -1 to +7). Egoistic and Hedonic together are lower than Altruistic and Biospheric together. The small difference between the means of Altruistic and Biospheric values is not statistically significant. The means for these outward-facing values are at the high end of the scale.

Table 22. Inferential test results for effects within the individual differences.

		<i>F</i>	<i>df</i>	<i>p</i>	Cohen's <i>d</i>
Values x Income	Values	345.42	3,654	0.00	na
	Income	0.60	5,218	0.70	na
	Values * Income	0.51	3,654	0.94	na
Values Comparisons	Egoistic vs Hedonic	570.15	1,223	0.00	1.60
	(Egoistic & Hedonic) vs (Altruistic & Biospheric),	317.45	1,223	0.00	1.19
	Altruistic vs Biospheric	0.45	1,223	0.50	0.04

3.1.5.2 Utility control

We examined correlations between the ratings of the acceptability of utility control (winter 2022) and the four values, and with household income also as measured in winter 2022. These are exploratory analyses. The strongest correlations (but still modest, with values over 0.20) occurred for the relationship between Biospheric values and the need to avoid new electrical generating stations and between the acceptability of utility control to deliver environmental benefits. Altruistic values also predicted this variable. In all cases, the stronger the values, the stronger the agreement with that reason for utility control. Egotistical and Altruistic values both showed small relationships with the acceptability of utility control to ensure a reliable supply, and for the acceptability of utility control to deliver the least costly supply for everyone (Table 23).

Table 23. Correlations between household income, values, and opinions about utility control, all measured in 2022 (N = 192).

		Income	Egoistic	Hedonic	Altruistic	Biospheric
Avoiding the need for new electrical generating stations is important to me.	<i>r</i>	-0.02	-0.05	0.07	0.12	0.23*
	<i>p</i>	0.82	0.52	0.31	0.10	0.00
It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is reliable for everyone	<i>r</i>	-0.08	0.15*	0.11	0.15*	0.13
	<i>p</i>	0.30	0.04	0.12	0.04	0.09
Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	<i>r</i>	-0.02	0.09	0.07	0.21*	0.21*
	<i>p</i>	0.81	0.21	0.37	0.00	0.00
It is acceptable for utilities to adjust individual customer electrical demand to deliver the least costly electricity supply for everyone.	<i>r</i>	0.03	0.16*	0.14	0.16*	0.12
	<i>p</i>	0.68	0.03	0.06	0.02	0.10

3.1.5.3 Heating system priorities

We asked the question, do personal values differ in relation to heating system priorities? This test uses the same statistical model as was used in sections 3.2.3 and 3.2.4 above. These analyses used the values from summer 2022 and the heating priorities from winter 2022 (the nearest time for which the priorities were available). Neither of the multivariate planned comparisons showed statistical significance; we can conclude that groups formed by the heating system priorities do not differ in terms of personal values (Tables 24 and 25).

Table 24. Means and standard deviations for personal values heating priority categories (N = 207). The personal values fall on a scale from -1 to +7.

		Egoistic		Hedonic		Altruistic		Biospheric	
	N	M	SD	M	SD	M	SD	M	SD
I care about how energy use affects the environment.	19	2.64	1.19	5.04	1.04	5.62	0.76	5.84	1.06
I want to feel comfortable.	130	2.66	1.21	4.87	1.29	5.20	1.17	5.24	1.25
I want to save money on my energy bills.	38	2.74	1.24	4.88	1.43	5.13	1.18	5.15	1.22

Table 25. MANOVA test results for the relationship between heating priority groups and personal values.

		Wilks' Λ	F	df	p	Cohen's d
Comfort vs Saving	Multivariate	0.997	0.13	4,201	0.97	na
	Egoistic		0.20	1,204	0.65	0.03
	Hedonic		0.00	1,204	0.96	0.00
	Altruistic		0.18	1,204	0.67	0.03
	Biospheric		0.20	1,204	0.66	0.03
Environment vs Comfort	Multivariate	0.980	1.04	4,201	0.39	na
	Egoistic		0.00	1,204	0.96	0.00
	Hedonic		0.27	1,204	0.61	0.04
	Altruistic		2.21	1,204	0.14	0.10
	Biospheric		4.03	1,204	0.05	0.14

Similarly, we tested for differences in income category by heating system priorities. This test result also did not pass our criterion for statistical significance ($F(1, 179) = 0.91, p = 0.34$).

In the final survey in spring 2024, participants rated the importance of five considerations in choosing a thermostat setting. Correlations of these ratings with the personal values reported in summer 2022 and income from winter 2023 are shown in Table 26. The correlations that reached statistical significance (i.e., for which we reject the null hypothesis of no relationship) make logical sense. Higher Egotistical values predict stronger importance for minimizing one's utility bill and for meeting social norms. Higher Altruistic values predict higher importance for minimizing environmental impact and for meeting social

norms. Higher Biospheric values predict greater importance for minimizing environmental impact, use of thermostat default settings, and meeting social norms. The strongest relationship ($r=0.33$) is between Biospheric values and the importance of minimizing environmental impact.

Table 26. Correlations between household income, values, and importance ratings of considerations about thermostat choices (N = 183).

		Income	Egoistic	Hedonic	Altruistic	Biospheric
Maximizing comfort	<i>r</i>	0.00	-0.10	0.12	0.10	-0.02
	<i>p</i>	0.98	0.17	0.10	0.16	0.78
Minimizing utility bill	<i>r</i>	-0.05	0.16*	0.07	0.11	0.12
	<i>p</i>	0.51	0.03	0.32	0.12	0.12
Minimizing environmental impact	<i>r</i>	-0.11	-0.08	0.04	0.24*	0.33*
	<i>p</i>	0.14	0.29	0.59	0.00	0.00
Thermostat default settings	<i>r</i>	-0.18	0.01	0.08	0.13	0.23*
	<i>p</i>	0.01	0.92	0.28	0.07	0.00
Social norms (society's shared understanding about the right thing to do)	<i>r</i>	-0.09	0.16*	0.08	0.16*	0.14*
	<i>p</i>	0.22	0.03	0.30	0.03	0.05

3.1.5.4 Mental models

The only variables to which income was correlated were the strength of adherence to the two mental models of thermostat operation. Higher income was associated with stronger adherence to the feedback model and lower adherence to the valve model (Table 27).

Table 27. Correlations between household income, values, and mental model strength (N = 183).

		Income	Egoistic	Hedonic	Altruistic	Biospheric
Feedback model	<i>r</i>	0.18*	-0.06	-0.03	0.10	0.01
	<i>p</i>	0.02	0.46	0.66	0.18	0.93
Valve model	<i>r</i>	-0.21*	0.11	0.10	0.10	0.12
	<i>p</i>	0.00	0.12	0.16	0.17	0.10

3.2 Thermostat heating temperature setpoints

Thermostat setpoints are one of the critical factors that influences energy usage at home. To the authors' knowledge, the published literature has not reported on occupant thermostat setpoint preferences by types of heating systems. This section presents analyses based on the thermostat telemetry data and self reported setpoints from survey responses. While the setpoints from telemetry data are categorised by type of heating system, the survey responses do not offer that breakdown.

The telemetry data analysis focuses on the no-Tech sample, which includes only the 255 participants who used electricity as the primary means for heating and received smart thermostats, but did not receive either the solar and battery storage system or cold climate mini-split heat pumps (Veitch et.al. 2025). The no-Tech group consists of dwellings with various configurations of primary and secondary heating systems (Pardasani et al., 2025a). As previously explained in Section 2.2, there are five possible variations of thermostat types installed: A only, A+B, B only, B+C, and C only, depending on the combination of primary and secondary heating systems.

To understand the influence of primary heating system on thermostat setpoints, we divided the no-Tech group into the following two mutually exclusive subsets to gain deeper insights into the influence of heating systems on the setpoints:

- Central heating systems connected to the type A thermostat;

- Zonal heating systems connected to types B or C or B+C. Note that the data here are based on the one representative thermostat selected for each home (see section 0).

3.2.1 Telemetry data

3.2.1.1 no-Tech Group

Table 28 displays the descriptive statistics for the no-Tech households with smart thermostats regardless of heating system type (and TOD intervention group assignment). Recall that thermostats with more than 50% missing or incorrect data for the season were excluded from analysis.

Table 28. Descriptive statistics for setpoints and night setbacks in winter 2021, 2022 and 2023 for the no-Tech sample.

	winter Season (°C)	no-Tech sample					
		<i>N</i>	<i>M</i>	<i>SD</i>	<i>Median</i>	<i>Min</i>	<i>Max</i>
2021	7 a.m. - 9 a.m.	168	20.83	2.06	21.00	12.00	27.19
	9 a.m. - 10 p.m.	168	20.90	2.01	21.02	12.00	27.16
	10 p.m. - 7 a.m.	168	20.36	2.44	20.70	7.17	27.19
	Night setback	168	-0.64	1.60	0.04	-1.20	15.45
2022	7 a.m. - 9 a.m.	164	20.77	2.29	21.00	13.81	30.00
	9 a.m. - 10 p.m.	164	20.92	2.16	21.06	14.08	30.00
	10 p.m. - 7 a.m.	164	20.35	2.71	20.82	6.49	30.00
	Night setback	164	-0.65	1.62	0.02	-0.22	15.16
2023	7 a.m. - 9 a.m.	115	20.35	2.63	20.70	5.00	30.00
	9 a.m. - 10 p.m.	115	20.42	2.58	20.90	5.00	30.00
	10 p.m. - 7 a.m.	115	19.95	2.84	20.25	5.00	30.00
	Night setback	115	-0.46	1.26	0.00	-0.52	10.14

Figure 3 shows the average setpoint pattern for the peak, mid-peak and off-peak hours for the no-Tech sample for winters of 2021, 2022, and 2023 corresponding to Table 28.

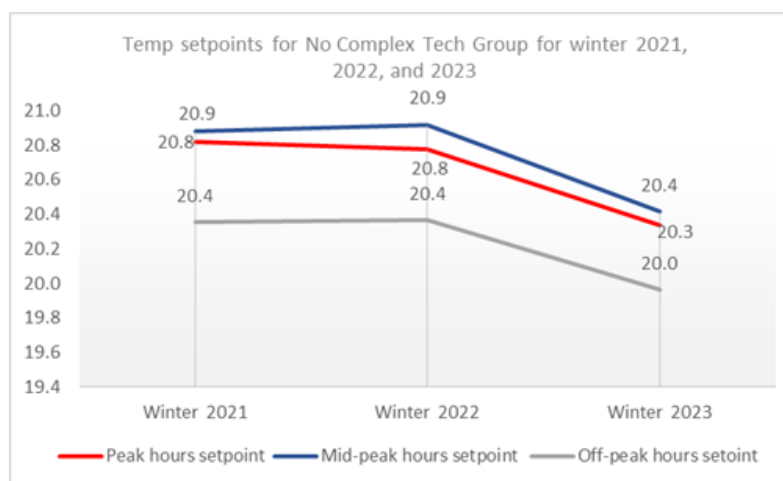


Figure 3. Average temperature setpoints for the No Tech group for winter 2021, 2022, and 2023.

The analysis of the sample across the winters demonstrated a stable pattern for peak and mid-peak hours from winter 2021 to winter 2022, with both maintaining setpoints at 20.8°C and 20.9°C, respectively. The off-peak setpoint also remained unchanged at 20.4°C during this period. However, in winter 2023, there is a noticeable decrease in all setpoints: peak hours dropped to 20.3°C, mid-peak hours to 20.4°C, and off-peak hours to 20.0°C. This change likely reflects a shift in occupant behaviour towards energy conservation rather than being influenced by winter conditions, as the Heating Degree Days (HDD) for winter 2022 and winter 2023 were similar, unlike the colder winter 2021. Additionally,

there is a possibility that this shift was a response to the 6.7% electricity rate hike on April 1, 2023. This trend is further illustrated by the average outdoor temperatures displayed in Figure 4 for each of the three winters.

The 24-hour heating setpoint profile for the No-Tech sample, as shown in Figure 4 illustrates the setpoint, room temperature, and outdoor temperature. The hours between 7–9 a.m. correspond to the on-peak rates and this period is highlighted on the charts. Notice that the night setback began around 9 p.m., and the heating system started to recover from the setback between 5 a.m. and 6 a.m. The No-Tech sample primarily consists of MSHPs and EBs, resulting in multiple heating sources, not all of which were connected to smart thermostats. The room temperature tended to be higher than the setpoint because of the presence of other heating sources in the dwelling.

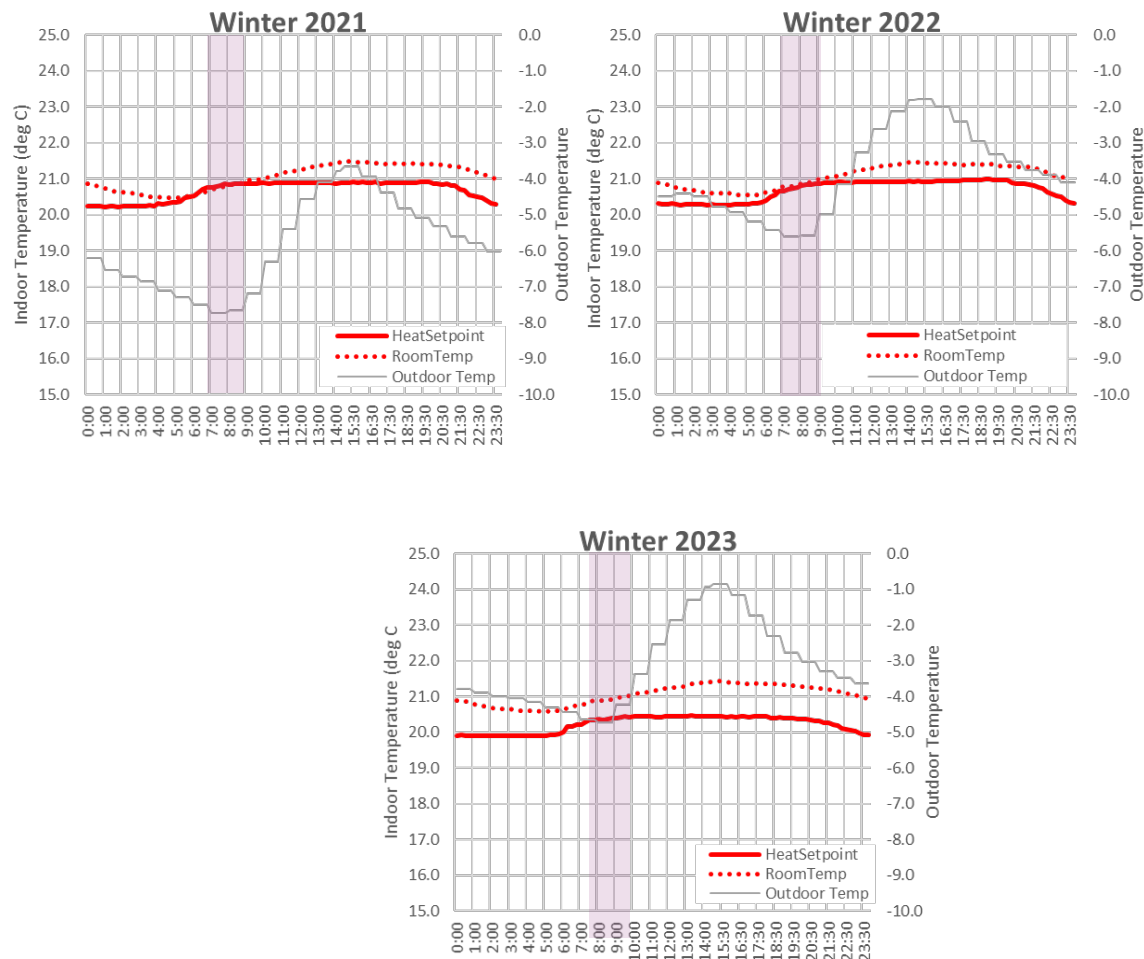


Figure 4. Average thermostat temperature setpoint daily profile for the no-Tech group for winters 2021, 2022, and 2023.

3.2.1.2 Zonal heating systems

The zonal heating sample consists of all dwellings under no-Tech that used electric baseboards or MSHP. The heating equipment in the zonal system could be connected to either type B or C or B+C thermostats. Table 29 displays the descriptive statistics for the no-Tech households with smart thermostats on zonal heating systems.

Table 29. Descriptive statistics for setpoints and night setbacks in winter 2021, 2022 and 2023 for the Zonal heating sample.

	winter Season	Zonal sample					
	(°C)	<i>N</i>	<i>M</i>	<i>SD</i>	<i>Median</i>	<i>Min</i>	<i>Max</i>
2021	7 a.m. -9 a.m.	136	20.80	2.15	21.00	12.00	27.19
	9 a.m. – 10 p.m.	136	20.86	2.09	21.03	12.00	27.16
	10 p.m. – 7 a.m.	136	20.36	2.56	20.84	7.17	27.19
	Night setback	136	-0.59	1.71	0.03	-1.20	15.45
2022	7 a.m. -9 a.m.	132	20.76	2.43	21.00	13.81	30.00
	9 a.m. – 10 p.m.	132	20.89	2.33	21.02	14.08	30.00
	10 p.m. – 7 a.m.	132	20.39	2.83	20.90	6.49	30.00
	Night setback	132	-0.57	1.64	0.01	-0.22	15.16
2023	7 a.m. -9 a.m.	89	20.14	2.82	20.34	5.00	30.00
	9 a.m. – 10 p.m.	89	20.20	2.79	20.42	5.00	30.00
	10 p.m. – 7 a.m.	89	19.77	3.06	20.07	5.00	30.00
	Night setback	89	-0.38	1.30	0.00	-0.24	10.14

Figure 5 shows the average setpoint pattern for the peak, mid-peak and off-peak hours for the zonal sample for winters of 2021, 2022, and 2023 corresponding to Table 29. Setpoints for the zonal heating sample across the three winters demonstrated a pattern similar to the no-Tech group as a whole, remaining stable for the winters of 2021 and 2022 and lowering slightly for the winter of 2023. This is not surprising, as zonal heating is a subset of the No-Tech group. Setpoints for mid-peak hours were slightly higher than those for morning peak hours (7 am-9 am), and, as expected, the setpoints for off-peak hours were lower.

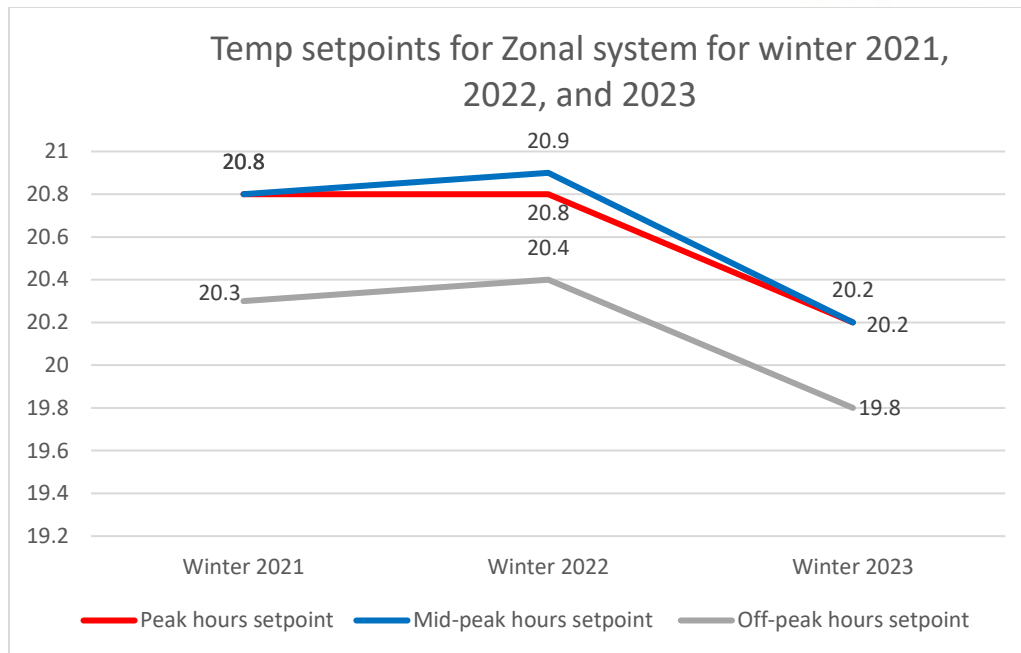


Figure 5. Average temperature setpoints for the zonal heating system group for winter 2021, 2022, and 2023.

For the zonal heating systems, the setpoints were observed to be lower by 0.5°C in winter 2023 compared to winter 2022 as shown in Figure 5. This change is possibly in response to the 6.7% electricity rate hike on April 1, 2023.

Figure 6 illustrates the 24-hour heating setpoint profile for the zonal sample. This sample contains the majority of the No-Tech data, so it exhibits a similar profile.

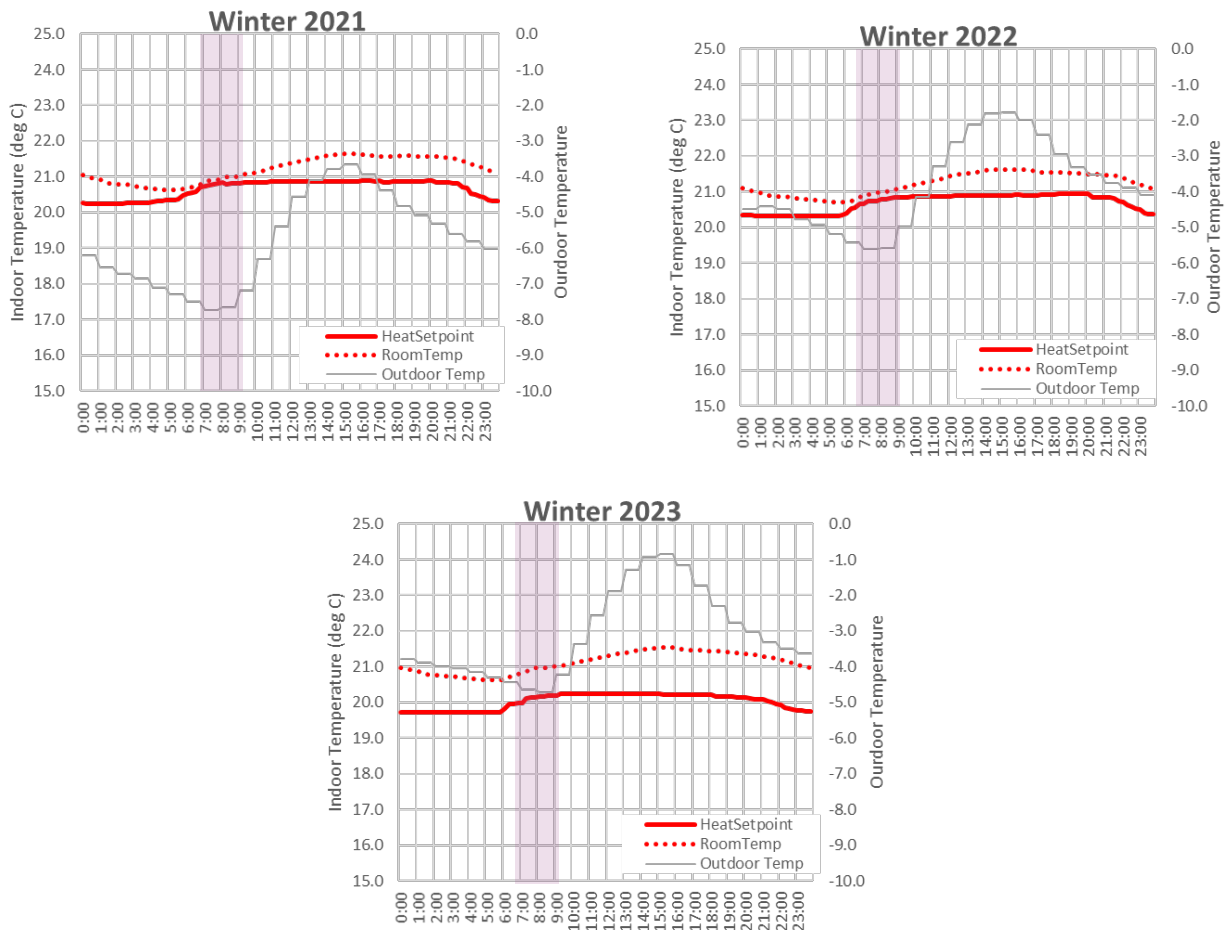


Figure 6. Average daily thermostat temperature setpoint profile for the zonal sample for winter 2021, 2022, and 2023.

3.2.1.3 Central heating systems

The central heating sample includes all dwellings under No-Tech that used forced air systems, such as central heat pumps and electric furnaces. The major difference between the central systems and the zonal systems is that, unlike the zonal systems, the central systems typically had one type A thermostat.

Table 30 displays the descriptive statistics for the central system households with smart thermostats.

Table 30. Descriptive statistics for setpoints and night setbacks in winter 2021, 2022 and 2022 for the no-Tech sample.

	winter Season	Central system sample					
	(°C)	<i>N</i>	<i>M</i>	<i>SD</i>	<i>Median</i>	<i>Min</i>	<i>Max</i>
2021	7 a.m. -9 a.m.	33	20.87	1.75	20.88	15.31	24.00
	9 a.m. – 10 p.m.	33	20.96	1.79	20.98	14.41	23.96
	10 p.m. – 7 a.m.	33	20.29	1.93	20.53	13.48	23.11
	Night setback	33	-0.82	0.94	0.49	-0.20	3.39
2022	7 a.m. -9 a.m.	33	20.70	1.73	21.25	16.47	23.97
	9 a.m. – 10 p.m.	33	20.94	1.40	21.22	17.07	23.97
	10 p.m. – 7 a.m.	33	20.10	2.19	20.76	11.86	23.96
	Night setback	33	-0.99	1.50	0.27	-0.04	7.60
2023	7 a.m. -9 a.m.	25	20.96	1.73	21.35	16.41	23.78
	9 a.m. – 10 p.m.	25	21.06	1.61	21.31	16.42	23.76
	10 p.m. – 7 a.m.	25	20.47	1.84	20.99	16.04	23.76
	Night setback	25	-0.72	1.11	0.04	-0.52	4.19

The analysis of setpoint trends for the central systems over the three winters showed distinct patterns for each time period as shown in Figure 7. During peak hours, the setpoint started at 20.9°C in winter 2021, decreased slightly to 20.7°C in winter 2022, and then increased to 21.0°C in winter 2023. For mid-peak hours, the setpoints followed a similar trajectory: starting at 21.0°C in winter 2021, dipping to 20.9°C in winter 2022, and rising again to 21.1°C in winter 2023. Off-peak hours maintained a consistent pattern, beginning at 20.3°C in winter 2021, decreasing to 20.1°C in winter 2022, and increasing to 20.5°C in winter 2023. Overall, the data suggest an initial trend to lower temperatures in winter 2022, followed by a rebound to higher setpoints in winter 2023.

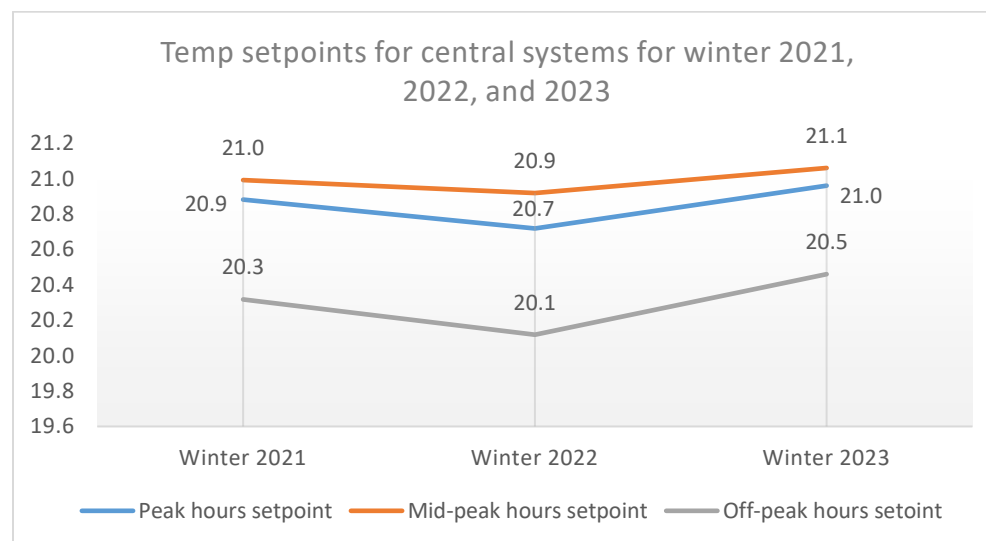


Figure 7. Average temperature setpoints for central heating systems for winter 2021, 2022, and 2023.

Figure 8 illustrates the average 24-hour heating setpoint profiles for the central heating system sample. Unlike the zonal heating systems, where the room temperature tracked higher than the setpoint, the room temperature in the central heating system sample tracked lower than the setpoint, likely because of the absence of active secondary heating sources. The setpoint remained consistent across three winters.

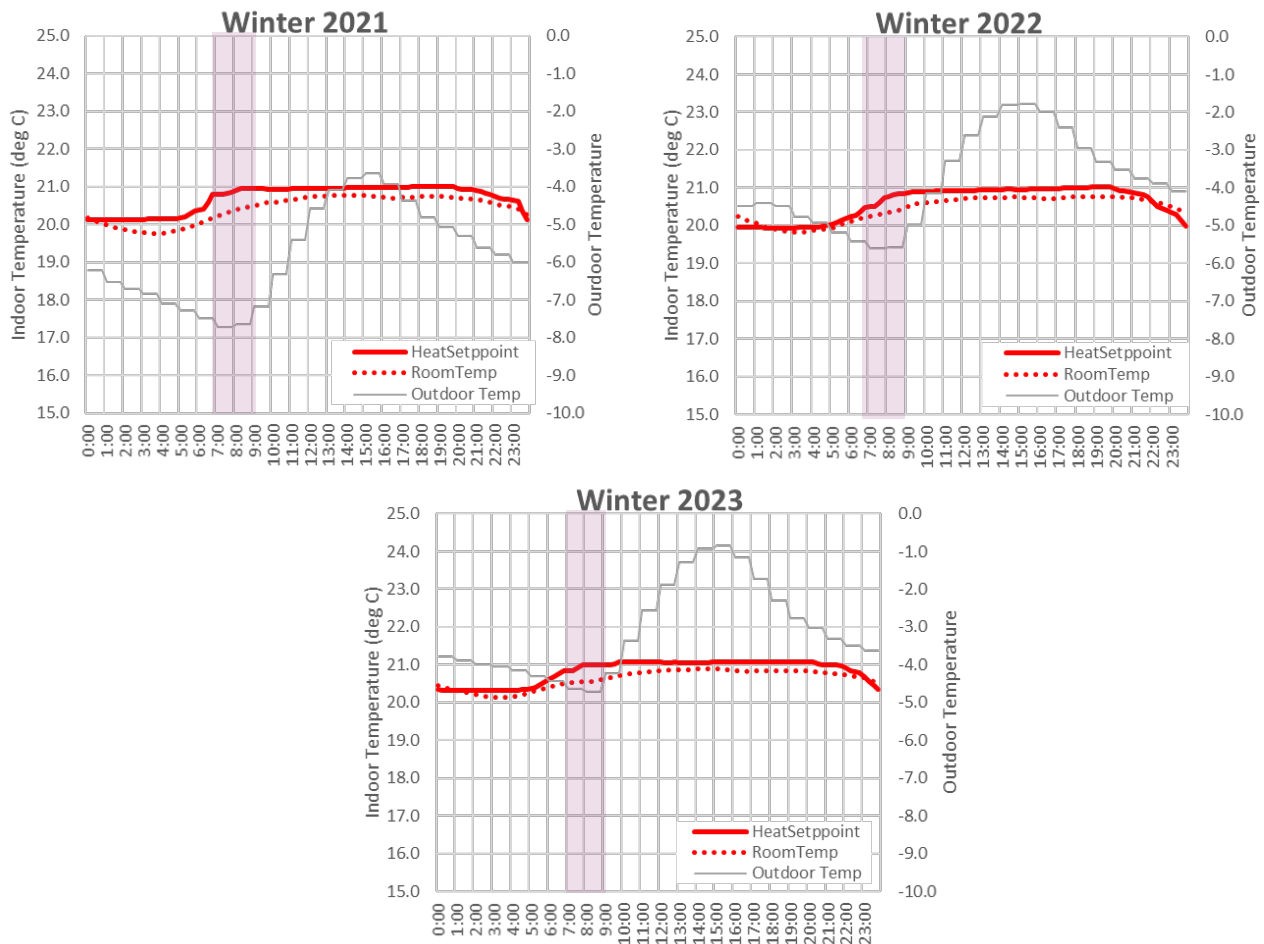


Figure 8. Average daily temperature setpoints for central heating systems for winter 2021, 2022, and 2023.

The analysis of the setpoint data from all sample types indicates that mid-peak setpoints tended to be slightly higher than both peak and off-peak setpoints across all heating system types and winters. During these hours, occupants might prioritize comfort over energy savings, leading to higher setpoints compared to other times of the day.

The comparison of setpoints derived from the telemetry data for the central heating system in the Shediac study with those reported for Quebec by Panchabikesan et al. (2021) shows that while the daytime setpoints for Shediac participants in winter 2021 (20.87°C) are close to the Quebec's average (20.6°C), the nighttime setbacks are significantly higher in Quebec, at 3°, compared only 0.82°C for Shediac using the same type of thermostat.

3.2.1.4 Nighttime setback

The effectiveness of a nighttime setback strategy in saving energy is primarily determined by the concept of degree-hours, which combines two key components: the magnitude of setback (measured in degrees Celsius) and the duration of the setback period. A higher magnitude means a greater reduction in temperature, while a longer duration extends the period of reduced heating. Together, these factors determine the total degree-hours, which quantify the overall reduction in heating energy consumption during the setback period.

In analyzing thermostat nighttime temperature setbacks, a setback is defined in the context of this section as the difference between the average base setpoint during the evening hours (18:00, 19:00, 20:00, 21:00) and the average nighttime setpoint during the early hours (0:00, 1:00, 2:00, 3:00). This difference must exceed 0.25°C to be classified as a setback.

The analysis of nighttime setbacks for the three system categories—no-Tech (overall), zonal heating system, and central heating system—reveals distinct patterns over the winters from 2021 to 2023 as shown in Figure 9.

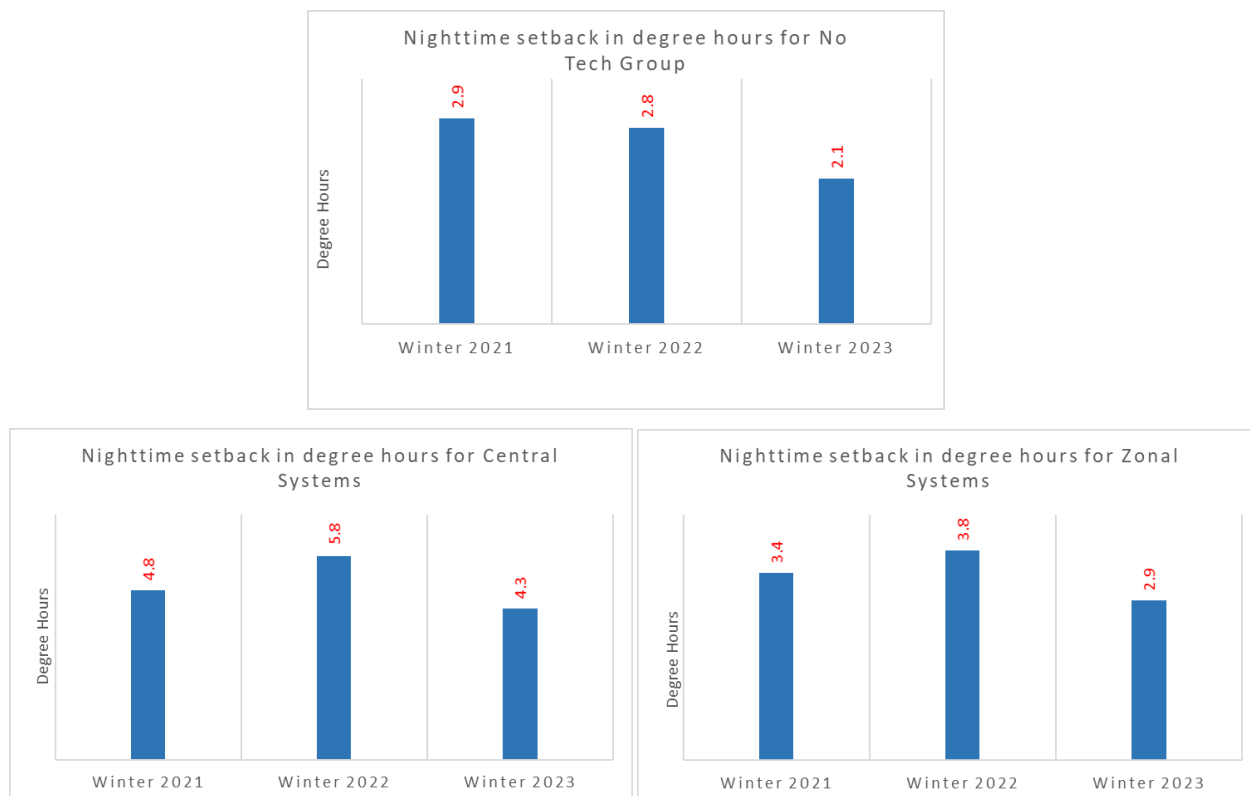


Figure 9. Average nighttime setbacks for No-Tech (all) group, and the subgroups with zonal and central heating systems.

For the no-Tech system, there was a decrease in setback degree-hours from 2.9 in winter 2021 to 2.8 in winter 2022, and further to 2.1 in winter 2023, indicating a gradual reduction in setbacks. The zonal system connected to either thermostat type B or C or both showed an increase to 3.8 in winter 2022, before dropping down to 2.9 in winter 2023. The central heating system connected to the type A thermostat demonstrated a similar pattern to the zonal system; an increase in 2022 winter and reduction in winter 2023. Note that half of the sample were in the time-of-day (TOD) electricity rates trial, which received instructions in autumn 2023 not to program a nighttime setback. This is discussed in more detail in Pardasani et al. (2025b).

The telemetry data from smart thermostats was analyzed over three winters to understand the distribution of nighttime setbacks and how they change over time. The dataset of setbacks per home was divided into the following interval groups for visualisation:

- Setpoint increase at night <-0.25°C
- No setback is assumed to be applied if the setback is between -0.25°C to 0.25°C
- Setback is considered low/slight when it is between 0.25°C to 2°C

- Setback is considered large when it is between 2°C to 5°C
- Setback is considered extreme when it is greater than 5°C

Figure 10 and Figure 11 illustrate the distributions of temperature setbacks for the zonal and central heating systems respectively, each over three winters.

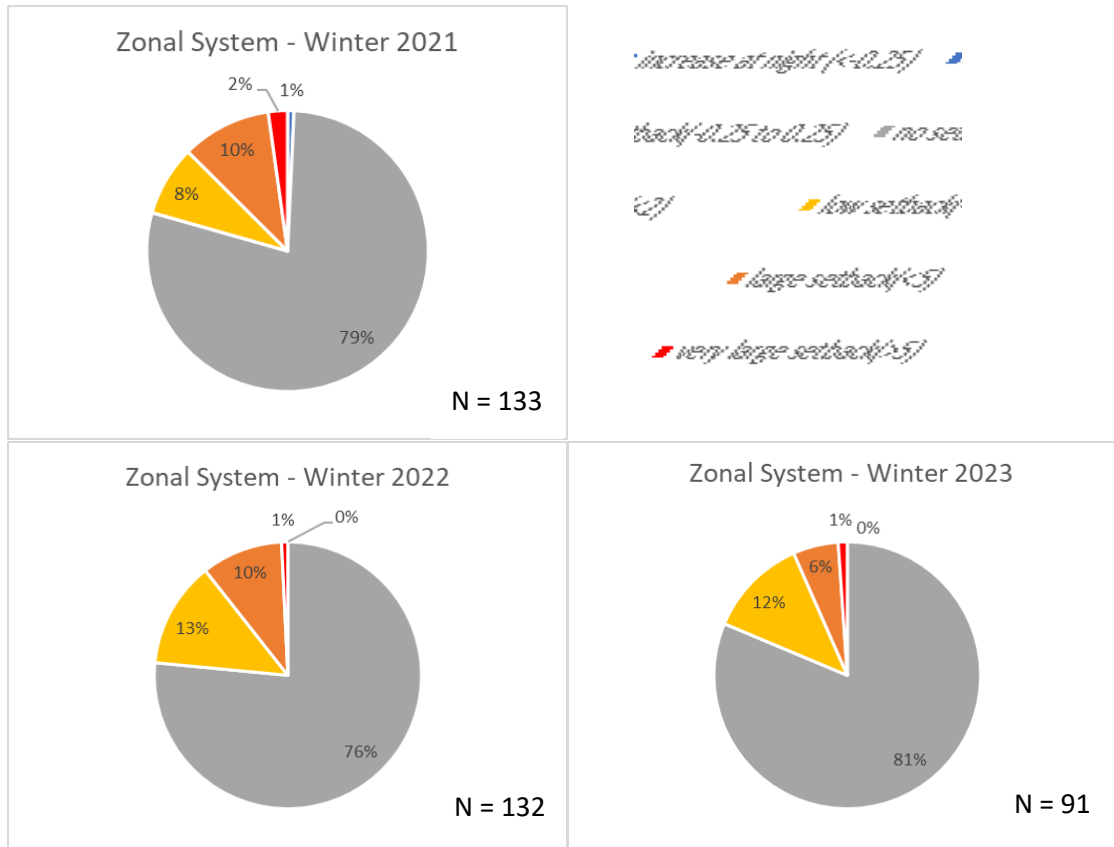


Figure 10. Distribution of nighttime setbacks for zonal heating systems over three winters.

The telemetry data from the type B and C representative thermostats in the zonal heating systems revealed that most participants in the zonal group did not adjust their thermostats for nighttime setbacks. Approximately 8-12% applied a small setback of less than 2°C, while a very small number applied setbacks exceeding 5°C. The distribution of these behaviors remained consistent over the three winter seasons. Note that the selection rule for the representative thermostat indirectly favoured thermostats that did not have deeper setbacks (see section 0).

In contrast to the zonal heating systems, a higher proportion of participants with central heating systems used low and large setbacks as shown in Figure 32. Although the distribution changed slightly over the three winters, no consistent trend is evident. The proportion of large setbacks increased from 16% in 2021 winter to 22% in 2022 winter and then dropped back to 13%. See also Pardasani et al. (2025b) for a discussion of nighttime setbacks in the context of the TOD electricity rates trial.

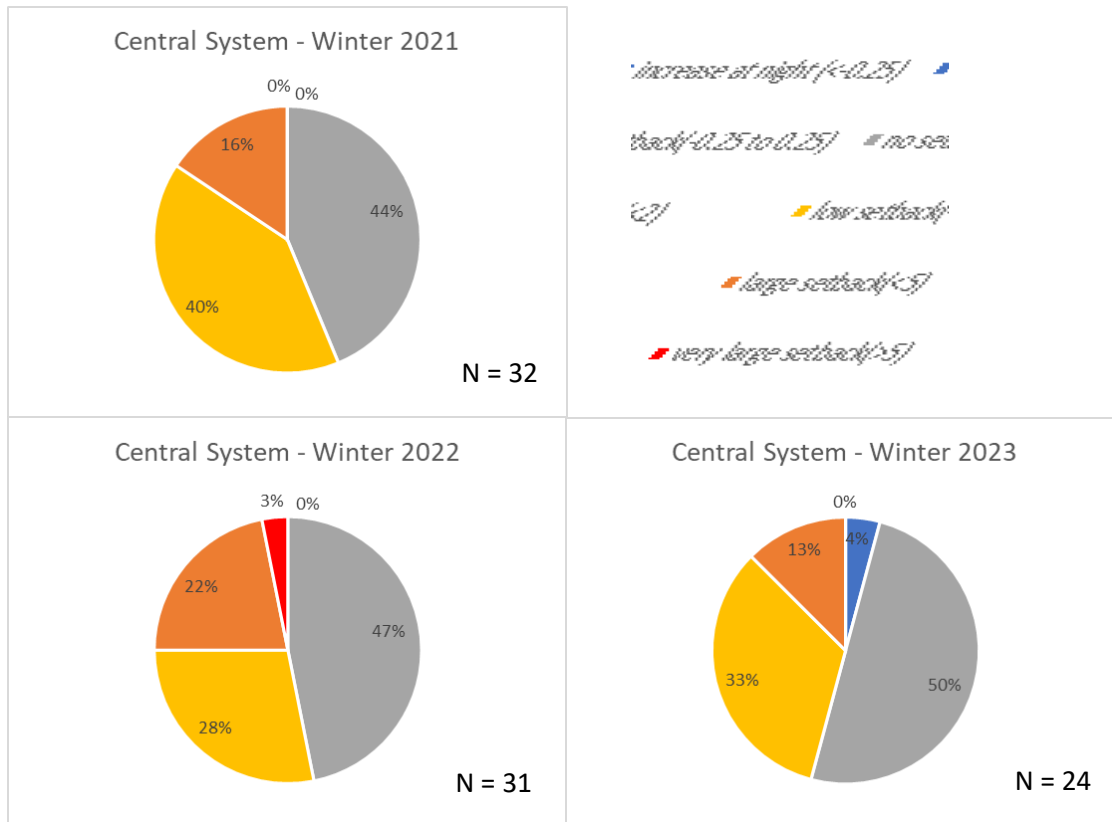


Figure 11. Distribution of nighttime setbacks for central heating systems over three winters.

3.2.2 Survey reports of thermostat setpoints and priorities

We report the setpoint when the household is awake in the daytime, the setback from that value while sleeping, and when out during the day.

For inferential statistics reported in this section we selected cases that had complete data for self-reported setpoints in winter 2019 and 2022, thermostat priorities in 2019, 2021, and 2022, and average telemetry-recorded setpoints in winter 2021 and 2022. This provided a data set of 139 cases. We conducted inferential tests on temperature when awake, and setbacks from that value.

3.2.2.1 Self-reported winter setpoints

Table 31 displays the descriptive statistics for the entire sample of households with smart thermostats and the subset selected for the inferential tests. The subset values are close to the values for the whole sample, but it appears that participants with the more extreme values are those that either did not continue, or did not participate in all the relevant surveys. This is evident from the different minimum and maximum values.

We used analysis of variance (ANOVA) to compare the two years for the analysis subset. The average values for self-reported household temperatures and setbacks did not change between 2019 and 2022 (see Table 32 for test results).

Table 31. Descriptive statistics for self-reported setbacks in winter 2019 and 2022 for the whole sample and the subset with complete data for inferential analyses in this section.

	winter Season	<i>Whole Sample (Variable N)</i>						<i>Analysis Subset (N = 139)</i>				
	(°C)	<i>N</i>	<i>M</i>	<i>SD</i>	<i>Median</i>	<i>Min</i>	<i>Max</i>	<i>M</i>	<i>SD</i>	<i>Median</i>	<i>Min</i>	<i>Max</i>
2019	Daytime setpoint	326	20.46	1.70	21.00	14	24	20.58	1.48	21.00	16	24
	Night setback	323	-1.29	1.71	0.00	-11	0	-1.33	1.84	0.00	-11	0
	Out setback	310	-1.81	2.23	-2.00	-13	5	-1.89	2.05	-2.00	-11	0
2022	Daytime setpoint	237	20.65	1.82	21.00	10	24	20.66	1.65	21.00	15	24
	Night setback	236	-1.40	1.77	-1.00	-10	1	-1.29	1.72	0.00	-8	1
	Out setback	234	-1.83	2.25	-1.00	-12	0	-1.68	2.06	-1.00	-10	0

Table 32. ANOVA test results for comparisons between 2019 and 2022 self-reported thermostat settings show that these did not change.

Variable	<i>F</i>	<i>df</i>	<i>p</i>	Cohen's <i>d</i>
Daytime setpoint	0.42	1,136	0.53	.05
Night setback	0.05	1,136	0.82	.02
Out setback	1.86	1,136	0.17	0.12

We grouped these variables according to scores on the forced-choice question about the reason for choosing a thermostat setting because we had the same question in the data for 2019 and 2022. The descriptive statistics for these groupings are in Table 33. We used ANOVA to test for differences between the groups. The very large differences between the group sizes push the bounds of test validity, but serve to provide indications of possible substantive differences. See Table 34 for the results. In both years, the multivariate test (which combines the variability on all three variables) was statistically significant. This was interpretable only for 2019, however, when the univariate test for the daytime setpoint showed a statistically significant, but small, effect. Participants who prioritized comfort over savings chose a higher daytime setpoint (20.67°C vs 19.45 °C). In 2022 the difference between these groups on that variable cannot be distinguished from random variation.

Table 33. Descriptive statistics for self-reported setbacks in winter 2019 and 2022 for the whole sample and the subset with complete data for inferential analyses in this section.

winter Season		<i>2019</i>			<i>2022</i>		
(°C)		<i>N</i>	<i>M</i>	<i>SD</i>	<i>N</i>	<i>M</i>	<i>SD</i>
Daytime setpoint	I want to feel comfortable.	128	20.67	1.44	127	20.72	1.65
	I want to save money on my energy bills.	11	19.45	1.57	12	20.00	1.54
Night setback	I want to feel comfortable.	128	-1.25	1.81	127	-1.25	1.72
	I want to save money on my energy bills.	11	-2.27	2.10	12	-1.75	1.66
Out setback	I want to feel comfortable.	128	-1.88	2.09	127	-1.58	1.95
	I want to save money on my energy bills.	11	-2.00	1.67	12	-2.75	2.86

Table 34. MANOVA test results for comparisons between 2019 and 2022 self-reported thermostat settings show that these did not change.

		<i>Wilks' Λ</i>	<i>F</i>	<i>df</i>	<i>p</i>	<i>Cohen's d</i>
2019 Comfort vs Saving	Multivariate	0.912	4.32	3,135	0.01*	na
	Daytime setpoint		7.12	1,137	0.01*	0.23
	Night setback		3.17	1,137	0.08	0.15
	Out setback		0.03	1,137	0.86	0.01
2023 Comfort vs Saving	Multivariate	0.952	2.59	3,135	0.05*	na
	Daytime setpoint		2.13	1,137	0.15	0.12
	Night setback		0.92	1,137	0.34	0.08
	Out setback		3.60	1,137	0.06	0.16

3.2.2.2 Winter average measured setpoints by thermostat priorities

We matched the telemetry data to survey data using seasonal averages for each home by time of day. We compare here the average winter values for 2021 and 2022 for the mid-peak (daytime) setpoint and the night-time setback. It is not possible to differentiate within the mid-peak period the times when someone was at home and times when the household was out. Thus, the meaning of this variable is not precisely the same as the daytime setpoint that was reported by participants.

Table 35 presents descriptive statistics for the data set corresponding to the 139 cases (as in section 3.2.2.1) that had complete data for self-reported setpoints in the winters of 2019 and 2022, thermostat priorities in 2019, 2021, and 2022, and average telemetry-recorded setpoints in the winters of 2021 and 2022. This data set ($n=139$) partially overlaps with the data sets for setpoints for the no-Tech sample discussed in section 3.2.1, but it is not the same. Therefore, while the measured setpoints from two data sets are close, they are not identical.

Univariate ANOVA tests comparing the 2021 and 2022 values showed that the average mid-peak setpoint changed between winter 2021 and 2022 ($F(1,138) = 25.89$, $p < 0.000$, *Cohen's d* = 0.43), dropping from 19.41 to 18.68. This is a small-to-medium sized effect in statistical terms (Cohen, 1988). The night-time setback did not change between the years ($F(1,138) = 1.29$, $p = 0.26$, *Cohen's d* = 0.10).

Table 35. Descriptive statistics for measured setpoints and setbacks in winter 2021 and 2022 for the analytic sample and for the subgroups formed by reported heating system priorities in the same season.

	Winter 2021			Winter 2022		
	<i>N</i>	<i>M</i>	<i>SD</i>	<i>N</i>	<i>M</i>	<i>SD</i>
Mid-peak average thermostat setpoint						
Full analytic sample	139	19.41	2.48	139	18.68	3.18
Thermostat priority groups:						
<i>I care about how energy use affects the environment.</i>	31	19.31	2.48	16	18.03	3.38
<i>I want to feel comfortable.</i>	37	19.79	2.00	87	18.84	3.32
<i>I want to save money on my energy bills.</i>	71	19.26	2.71	36	18.57	2.76
Measured night-time average setback						
Full Analytic sample	139	-0.39	1.02	139	-0.33	1.07
Thermostat priority groups:						
<i>I care about how energy use affects the environment.</i>	31	-0.55	1.63	16	-0.93	2.31
<i>I want to feel comfortable.</i>	37	-0.25	0.72	87	-0.23	0.78
<i>I want to save money on my energy bills.</i>	71	-0.40	0.78	36	-0.32	0.74

The multivariate analysis of variance (MANOVA) results for the tests within years, comparing groups formed by heating system priority, showed that in 2021 neither comparison reached statistical significance. In 2022, there was a statistically significant difference for the comparison between people prioritizing the environment and those who prioritized comfort, both in the multivariate test and in the

univariate comparison for the night-time setback (Table 36). The people who prioritized the environment showed a deeper average night-time setback than those who prioritized comfort. This is a statistically small effect according to the Cohen's *d* statistic (Cohen, 1988).

Table 36. Inferential test results for planned comparisons of measured thermostat setpoints and setbacks between heating priority groups, in 2021 and 2022.

			<i>Wilks' Λ</i>	<i>F</i>	<i>df</i>	<i>p</i>	Cohen's <i>d</i>
2021	Comfort vs Saving	Multivariate	0.986	0.983	2,135	0.38	
		Mid-peak setpoint		1.12	1,136	0.29	0.09
		Measured night-time setback		0.54	1,136	0.46	0.06
	Environment vs Comfort	Multivariate	0.982	1.25	2,135	0.29	
		Mid-peak setpoint		0.61	1,136	0.44	0.07
		Measured night-time setback		1.51	1,136	0.22	0.10
2022	Comfort vs Saving	Multivariate	0.997	0.23	2,135	0.80	
		Mid-peak setpoint		0.19	1,136	0.66	0.04
		Measured night-time setback		0.19	1,136	0.66	0.04
	Environment vs Comfort	Multivariate	0.946	3.86	2,135	0.02*	
		Mid-peak setpoint		0.88	1,136	0.35	0.08
		Measured night-time setback		5.96	1,136	0.02*	0.21

3.2.2.3 Comparing self-reported and measured setpoints

The 2022 data are available for both self-reported and measured average seasonal setpoints. We calculated the correlations between the relevant variables for daytime temperatures and night-time setbacks (Table 37). The agreement between measured and self-reported values was very good for the night-time setbacks ($r = 0.42$, $p = 0.00$), and modest for the daytime temperature and mid-peak setpoint ($r = 0.17$, $p = 0.04$). The lower level of agreement is unsurprising given the difference in meaning for the two variables.

There was also a negative correlation between the self-reported daytime temperature and the self-reported night setback. People who reported lower daytime temperatures also reported larger night-time setbacks.

Table 37. Correlations between self-reported and measured thermostat daytime setpoints and night-time setbacks in 2022 (N = 139). The Pearson correlations are above the diagonal and the corresponding probabilities are below the diagonal.

	Self-reported temp when up	Self-reported night setback	Mid-peak setpoint	Measured night-time setback
Self-reported temp when up		$r = -0.20^*$	$r = 0.17^*$	$r = 0.13$
Self-reported night setback	$p = 0.02$		$r = 0.12$	$r = 0.42^*$
Mid-peak setpoint	$p = 0.04$	$p = 0.18$		$r = -0.14$
Measured night-time setback	$p = 0.13$	$p = 0.00$	$p = 0.10$	

4 Conclusions

The smart thermostats were well rated, although it appears that not all features were fully utilized by participants over the course of the study. Providing targeted training for the specific devices may enhance the use of all available features, thereby increasing their effectiveness. While the concept of utility control is moderately acceptable among participants, its acceptance for achieving environmental goals saw a slight decline over time. The project did not focus on gathering input for specific demand-side management (DSM) program designs related to utility control of thermostats, as this was outside the scope of the study.

Over time, participants experienced a slight increase in thermal comfort attributed to the use of smart thermostats. They demonstrated a solid understanding of thermostat operations, specifically the feedback model, which reflects a positive aspect of energy literacy suggesting that further focused training in this area may not be necessary. Interestingly, individuals with higher incomes exhibited a stronger adherence to this model. Comfort remains the primary reason for choosing thermostat setpoints, with those prioritizing comfort tending to select higher temperature settings.

The emphasis on comfort among these participants might explain why their reported and measured setpoints are higher than had been previously observed in a New Brunswick sample (Pardasani et al., 2017). The measured night-time setback in this study was $\sim 0.8^{\circ}\text{C}$ in 2021 (before any TOD intervention, which included setback instructions for some participants) and by self-report $\sim 1.3^{\circ}\text{C}$ in 2019, whereas in 2017 the night-time setbacks reported by participants were $\sim 2.5^{\circ}\text{C}$.

Environmental values play a significant role in predicting efficient behaviours. Participants who prioritize environmental consequences in their thermostat choices tend to adopt deeper nighttime setbacks and show greater acceptance of utility control aimed at achieving environmental benefits. Conversely, while egoistic values correlate with the desire to reduce utility bills, this is not the primary reason most participants choose their thermostat settings. Overall, the study reveals a complex interplay between comfort, environmental priorities, and economic considerations in thermostat usage. This could be further complicated by the growing recognition that heat pump technologies work best when their setpoints are not changed frequently.

The insights gained from smart thermostat use and setpoint preferences can significantly inform the design of future energy efficiency and demand response programs. Understanding that participants prioritize comfort over cost savings and the usability issues associated with smart thermostats can help NB Power tailor programs that align with their customer preferences. The insights that participants did not use all features of the thermostats suggests the importance of education in using smart thermostat features to maximize their use and effectiveness. The study also highlights the moderate acceptance of utility control, particularly for achieving environmental benefits, indicating potential for designing demand response programs. Additionally, the self-reported and telemetry data on setpoint patterns during peak and off-peak hours offers valuable insights into setpoints preferences during different time periods of the day, which can guide the development of strategies for more efficient energy use and management of heating loads. By recognizing the importance of thermal comfort, occupant attitudes and perceptions, NB Power can create programs encouraging participation and achieving both comfort and efficiency goals.

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Appendix A - Energy use by end-use

The total secondary energy used in 2019, 2020, and 2021 was 1474 PJ, 1429 PJ, and 1397 PJ, respectively. The breakdown of total secondary use by end-use is shown in the following table (NRCan, 2023). For the year 2021, the end-use is broken down by percentage.

<i>Energy Use by End-Use</i>	<i>2019 (PJ)</i>	<i>2020 (PJ)</i>	<i>2021 (PJ)</i>	<i>2021 %</i>
Space Heating	953.6	873.8	840.4	60%
Water Heating	246.7	255.5	253.2	18%
Appliances	197.4	208.1	209.3	15%
Lighting	49.8	52.3	52.9	4%
Space Cooling	26.6	39.2	41.5	3%

Chapter 9: Understanding Energy Behaviours, Attitudes, and Perceptions

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Executive Summary

This report is one of a series concerning the Shediac Residential Energy Study, a 5-year project to evaluate smart grid technologies in homes in Shediac, New Brunswick. There was one behavioural intervention, time-of-day (TOD) electricity rates, and two technology interventions: cold-climate mini-split heat pumps and a 5 kW rooftop solar photovoltaic panel array with a solar inverter and a 13.5 kWh (maximum 5 kW charge or discharge rate) battery energy storage device. Participants were assigned to TOD groups using stratified random sampling to control for demographic and dwelling characteristics, and offered interventions based on detailed home assessments of home compatibility and stratified random selection from the pool of compatible homes. Participants also completed seven surveys about various energy behaviours, values, attitudes, and beliefs throughout the project.

Energy conservation behaviours have been the target of psychological research for nearly 50 years, resulting in a strong consensus that personal value orientations, beliefs, and social norms are among the strong influences on both energy behaviour intentions and actual behaviours. Financial considerations and other structural barriers also influence how people use energy. Successful policy development and program design must take into account these local contextual factors as well as technical considerations about the specific energy outcome that is intended.

To support program development following the Shediac Residential Energy Study, this report concerns the energy behaviours, attitudes and beliefs as reported at the end of the project in March 2024. Their value orientations as reported early in the study (June 2022) form the foundation for understanding these subsequent attitudes and behaviours.

Participants in this sample show a high concern for the environment, reflected in strong Biospheric value orientations (reflecting concern for nature and the environment); for 44% of the sample this orientation is stronger than Altruistic (reflecting concern for the welfare of other people), Hedonic (focus on pleasure and comfort), or Egoistic (focusing on the costs and benefits of choices that influence wealth, power, and achievement) values. Biospheric and Altruistic values are the orientations most strongly related to proenvironmental behaviours, suggesting that this sample is predisposed to contributing to energy conservation efforts.

Participants reported moderate to strong beliefs in the benefits of energy efficiency, such as a financial benefit to using less electricity. However, they also reported the belief that using less energy could result in reduced comfort or convenience, pointing to the possibility that some energy efficiency or conservation behaviours might receive little support.

Participants reported in large numbers that utility control over individual electricity demand would be acceptable, with the support largely unchanged whether the reason for the utility control were keeping costs low, keeping the supply reliable, or providing environmental benefits. They also strongly believed that they had a personal moral obligation to engage in energy behaviours that are beneficial to the environment, although they were less sure that all Canadians share that norm.

Turning to the relationship between these values, beliefs, and norms and energy behaviours, there were two analyses. In the first instance, multiple regression models predicting energy use intensity (EUI) in winter 2023 (December 2023 through February 2024) showed that the presence of the solar+battery system (explaining 6.5% of the variance) and smaller household sizes reduced EUI (explaining 3.6% of the variance), but beliefs in the benefits of energy efficiency also predicted lower EUI (explaining 2.6% of the variance) with nearly the same strength of influence as household size. People who perceived stronger benefits showed lower household EUI. The overall model was statistically significant and the effect sizes were small to medium.

Future energy behaviour intentions showed a clearer pattern of support for the values-beliefs-norms model. This model showed medium to large effects, in which Biospheric values, beliefs about the benefits of energy efficiency, and social norms all predicted a stronger willingness to engage in future energy efficiency behaviours, including joining a time-of-day electricity rates program and upgrading household insulation. Values collectively explained ~8.5% of the variance in future energy behaviour intentions, beliefs about energy efficiency explained ~10% of the variance, and social norm acceptance explained a further ~3% of the variance. These analyses controlled for household income, which is an important structural barrier.

Taken together these results point the way for successful program design and technology integration into the NB Power portfolio. To the extent that these Shediak participants are typical of the province as a whole, there is openness to participating in new programs, provided that they are communicated clearly. Activating existing values to protect the environment and society, making clear the costs and benefits to participants and society, and engaging our collective responsibility for one another, should all contribute to program uptake. These psychological considerations will need to be integrated into comprehensive program design that also addresses technical, financial, and social equity considerations.

1 Introduction

1.1 Background

This report is one of a series stemming from the Shediac Residential Energy Study, a 5-year project funded by Natural Resources Canada and Industry, Science and Economic Development Canada with grants to New Brunswick Power (NBP). NBP engaged the National Research Council of Canada as its primary research partner and engaged Siemens Canada to develop an energy systems platform to enable utility control of smart energy devices. The Town of Shediac provided support and residents of Shediac participated.

Responding to a decision by The Town of Shediac made a commitment to become “Atlantic Canada’s first Smart Energy Community”, NBP developed this study in 2018 to help it to respond to the significant challenge facing it in the coming decades, with rising demand for electricity associated with the adoption of electric vehicles and other technologies coming at the same time as the need to replace aging generation facilities while reducing carbon emissions to meet national climate change targets (New Brunswick Power, 2023). Taking steps to manage demand and to integrate renewable technologies into the electricity grid are among the tactics to address this conundrum, and this project was designed to provide the utility with experience and guidance on its future programs and services in this regard.

The project included technology interventions: a time-of-day (TOD) electricity rates program, rooftop solar photovoltaic panels with battery energy storage (SOL), and cold-climate mini-split heat pumps. These technologies and the research design in which they were tested are described in Veitch et al. (2025). Other reports have addressed the results of these interventions (Cooper et al., 2025; Hu et al., 2025; Pardasani et al., 2025a). In addition, most participants also received smart thermostats installed at no charge on compatible heating systems. Pardasani et al. (2025b) have reported on the use and usability of these devices. This report examines the relationship between psychological, technical, and demographic factors that might explain current and future energy behaviours.

1.2 Literature review

Two categories describe behaviours that can lead to reduced energy use (Stern & Gardner, 1981a): technology adoption, which are one-time behaviours that have lasting consequences; and habit change (often called curtailment), which are repeated behaviours that involve ongoing decisions to choose the lower-energy option. Arguably, technology adoption is the more promising path in that a single decision can have substantial and lasting consequences (Stern & Gardner, 1981b). However, technology adoption has barriers, among them affordability, feasibility, and availability. Habit change can be practiced by almost anyone, for instance by turning off lights or changing a thermostat setpoint. These behaviours may be easy to perform, and may reward the utility customer with a lower bill, but as the name “curtailment” suggests they can also come with a loss of convenience or comfort. The complicated process of understanding how to motivate the public to engage in energy conservation through either technology or curtailment has engrossed psychologists since the energy crisis of the 1970s (Geller, 1987; Stern & Oskamp, 1987; Steg, 2023).

Smart technologies might help to bridge the gap between technology adoption and habit change, particularly those that can help to reduce peak electrical demand. Smart thermostats, for example, can support utility programs in which the utility sends a signal to the device to change its operation temporarily at a time of high demand (for example, by raising the setpoint temperature by 1 degree to reduce air conditioner operation). The technology removes the need for user effort in the time when the

action is required. The devices themselves are relatively inexpensive as retrofits, and may be the default option for a new heating or cooling system purchase. A U.S. survey found that half of potential participants were willing to join such a utility control program with no conditions, but adding the option for user override of the signal made the program more attractive and was more effective than a financial incentive (Xu, Chen, Zhu, & Hu, 2018).

Building on the Theory of Planned Behaviour (Ajzen, 1991), Stern et al. (1999) proposed the Values-Beliefs-Norms (VBN) theory to explain engagement in environmental action. In this theory, one's values – particularly altruistic values – lead one to become aware of the consequences of one's actions and to take responsibility for them. This, in turn, prompts the development of proenvironmental norms, and these in turn lead to environmental action. The theory has widespread support in the psychological literature (Kaiser et al., 2005; Steg, 2023).

Steg, Perlaviciute, van der Werff, and Lurvink (2014) developed a set of questions about personal values that differentiates between egoistic, hedonic, altruistic and biospheric values. Biospheric values – emphasizing responsibility towards preserving the planet and its ecosystems – are most strongly related to proenvironmental behaviour (Steg, 2023). However, as Steg has noted, merely holding strong biospheric beliefs does not guarantee that they will be acted upon. Structural barriers can prevent desired behaviours, as can competing values such as personal comfort (i.e., hedonic values). The countervailing desire for comfort is reflected in Xu et al.'s (2018) finding concerning the desire for user override. Furthermore, progress towards energy conservation can be impeded by Jevon's paradox, or the rebound effect (Jevons, 1865), in which the energy savings from one action are then 'spent' on a new action, resulting in no overall reduction.

As many authors have noted, making headway towards societal environmental goals will require integrated policy approaches that take into account the local context, individual values, attitudes and understanding, social norms, and public support in addition to technical solutions (Dietz, Stern, & Weber, 2013; Rau, Moran, Manton, & Goggins, 2020; Steg, 2023; Trotta, 2018). Building public support for policies and programs requires a nuanced understanding of the population, its characteristics, and its priorities in order to develop effective communications about the problem and useful programs to address it.

1.3 Objectives

This paper reports analyses of the data provided by participants in the Shediak Residential Energy Study to address the following questions:

- What are participants' beliefs about energy efficiency? Do they believe they could benefit from it, or might they have to compromise on their lifestyle?
- Are participants willing to consider allowing the utility to control their electricity demand? Does this willingness depend on the reason for control actions?
- How willing are participants to engage in new programs, particularly time-of-day electricity pricing, or to adopt new technologies?
- What predicts participants' energy behaviours both today and in future? Can this information contribute to developing comprehensive policies or programs?

2 Method

2.1 Participants

The data in this report come primarily from the participants who had complete data on all of the variables for the regression analyses that follow. (Descriptive data from all available cases is also reported; this will be noted where it occurs). Table 1 characterizes these participants, contrasting their characteristics to the sample as it existed at the start of the project in winter 2019. Overall, the sample reported here, from the end of the project in March 2024, reflects the distribution of participants at the start of the project with no evidence of bias through attrition over the years; most of the departures from the study took place when participants sold their homes and moved. The increased age is to be expected over the 4 years between measurement times. The change in primary heating system type is partly attributable to the project itself, which gave cold-climate mini-split heat pumps to some participants. The dramatic change in the proportion of people at home all day is attributable to the occurrence of the COVID-19 pandemic and its changes in the way of working, and to the increased age of the participants and the possibility that some had retired during the project.

Table 1. The characteristics of the participants whose data are reported here. Note that survey responding was not mandatory, so numbers may not add to the same total.

	Reported Sample, Mar. 2024 (N=165)		Whole Sample, Dec. 2019 (N=529)	
	N	Valid %	N	Valid %
Respondent sex				
Male	100	60.6	297	59.5
Female	65	39.4	200	40.1
Prefer not to say			2	0.4
Respondent age				
21-30	3	1.8	23	5.1
31-40	20	12.1	84	18.6
41-50	36	21.8	108	23.9
51-60	36	21.8	100	22.2
61-70	42	25.5	83	18.4
71-80	23	13.9	43	9.5
81+	4	2.4	6	1.3
Prefer not to say	1	0.6	4	0.8
Household Income	Dec 2023			
<\$20k	3	1.8	4	0.8
\$20k<\$40k	15	9.1	38	7.6
\$40k<\$60k	20	12.1	69	13.8
\$60k<\$80k	20	12.1	68	13.6
\$80k<\$100k	23	13.9	68	13.6
\$100k<\$150k	39	23.6	138	27.5
\$150+k	45	27.3	86	17.2
Don't Know			30	6.0
Home area (SF) (HA1)				
0-1000	10	6.1	36	7.0
1000-2000	118	71.5	360	70.5
2000-3000	32	19.4	93	18.2
3000-4000	4	2.4	15	2.9
4000-5000	1	0.6	6	1.2
>5000			1	0.2

	Reported Sample, Mar. 2024 (N=165)		Whole Sample, Dec. 2019 (N=529)	
	N	Valid %	N	Valid %
Primary Heating System (Winter 2020)				
Mini-split heat pump (MSHP)	86	52.1	256	50.4
Electric baseboards (EB)	43	26.1	114	22.4
Central heat pump	20	12.1	89	17.5
Central furnace	9	5.5	30	5.9
Radiant floor	3	1.8	8	1.6
Fireplace	4	2.4	11	2.2
Primary Heating System (March 2024)				
No heat pump ever	19	11.5	Not applicable	
Heat pump at start	106	64.2	Not applicable	
Heat pump purchased during project	26	15.8	Not applicable	
Heat pump given by project (CC-MSHP)	14	8.5	Not applicable	
Daily Occupancy Pattern				
Someone always home	111	67.3	195	38.8
Someone home part of the day	31	18.8	144	28.7
Out all day, back in evening	23	13.9	163	32.5

2.2 Interventions

Veitch et al. (2025) described the study design and interventions in detail. The project began in December 2019 and continued until March 2024. Work was disrupted by pandemic-related delays, but in spring 2022 the interventions began.

There was one behavioural intervention, a time-of-day (TOD) electricity rates program. Participants were assigned to a TOD and no-TOD group using stratified random sampling. For details about the TOD intervention and its results, see Pardasani et al. (2025a).

There were two technology interventions:

(1) Following extensive home assessments, participants in 75 compatible homes received 5 kW rooftop solar photovoltaic panels and a 5kW battery energy storage system. This group is called the SOL group henceforth. Installation and commissioning of these systems was complete in December 2022. See Cooper et al. (2025) for details about the SOL intervention and its results. The battery energy storage systems were operated differently for the TOD and no-TOD participants in the SOL group.

(2) Twenty-three homes received high-efficiency cold-climate mini-split heat pumps (CC-MSHP) in autumn 2022. Hu et al. (2025) have reported the details about this intervention and its results. In the analyses reported here, participants in this group were combined with others whose homes used heat pumps.

2.3 Current energy use

This report focuses on energy behaviours at the end of the study period (winter 2023) to maximize any behavioural effects of the interventions. Participants' homes were equipped with smart electricity meters in winter 2020 (see Veitch et al. 2025). Household electricity demand in 15-minute intervals was recorded and the data provided to the NRC (see Pardasani, 2025, for details about the data scheme). This report uses the total energy used in kWh in winter 2023 (December 1, 2023 through February 29, 2024) divided by the above-ground occupied area of the home to calculate the energy use intensity in kWh/m²) for that season.

2.4 Survey data

Online surveys took place on seven occasions between December 2019 and March 2024. The surveys addressed all parts of the project and are described in detail in Veitch et al. (2025). Only those variables reported here are described below. Additional survey results of interest to NB Power (e.g., general project satisfaction, water heater issues) are reported in Appendix A. A summary of open-ended responses to about how participants' actions and conversations at home had changed during the project is in Appendix B.

2.4.1 Personal values

In winter 2019 and summer 2022, participants completed 16 questions concerning their fundamental values (Steg, Perlaviciute, van der Werff, & Lurvink, 2014). These responses combine to form ratings of four values: Egoistic (5 items focusing on the costs and benefits of choices that influence wealth, power, and achievement); Hedonic (3 items about concern for feeling good and reducing effort); Altruistic (4 items about concern for the welfare of others); Biospheric (4 items about concern for the quality of nature and the environment) dimensions. Each is scaled with a possible range of -1 to +7. These values have been shown to predict environmental concern and the likelihood of taking pro-environmental actions, including household energy use. In the present report we focused on the responses in summer 2022, when the interventions were being launched. Internal consistency ranged from good to very good (on the full sample, N=323: Egoistic, Cronbach's alpha = 0.71; Hedonic, Cronbach's alpha = 0.78; Altruistic, Cronbach's alpha = 0.78; Biospheric, Cronbach's alpha = 0.89).

2.4.2 Costs and benefits of energy efficiency

Following the example of Dello Russo, Lytle, Hoffenson, and Mahoney (2023), we assessed participants' beliefs about the costs and benefits of energy efficiency; see Table 2. The questions were asked in June 2023 and March 2024; this report uses the March 2024 data as being most closely related to the outcome measures and reflecting any experiences of wintertime energy demands. The statements were coded on a 5-point scale from 0 = strongly disagree to 4 = strongly agree. Two items (CBEE5 and CBEE7) were reverse-coded. In subsequent analyses items CBEE5 and CBEE6 were excluded from calculating an overall scale score because they represent beliefs in costs of energy efficiency and correlated poorly with the other items. The overall scale score was the average of the responses to the remaining eight questions. Higher values indicate a stronger belief in benefits of energy efficiency. The internal consistency of this scale was acceptable (Cronbach's alpha = 0.66 with eight items and N=240 from the full sample).

Table 2. The costs and benefits of energy efficiency questions.

Q #	Prompt	Coding	CBEE scale
CBEE1	If I reduce my at-home energy consumption, I will personally receive financial benefits.	Benefit	
CBEE2	If I do not reduce my at-home energy consumption, I will incur financial costs.	Benefit	
CBEE3	If I invest in renewable energy sources (e.g., by installing solar panels), I will personally receive financial benefits.	Benefit	
CBEE4	If I do not invest in renewable energy sources (e.g., by installing solar panels), I will personally incur financial costs.	Benefit	
CBEE5	If I reduce my at-home energy consumption, I will have to give up some comfort and convenience.	Cost	Excluded
CBEE6	If I personally invest in renewable energy sources, it will cost me money.	Cost	Excluded
CBEE7	One down side to installing renewable energy sources like solar panels is that they can make the home look unattractive. / Reverse coded to mean "One up side ...is that they can make the home look attractive."	Cost	Included, reverse-coded
CBEE8	Having a source of backup power to keep important electrical devices running during a power outage is important to me.	Benefit	
CBEE9	If incentives were available, I would be willing to invest in energy storage that would provide back up power for my home if there was a grid outage.	Benefit	
CBEE10	Having renewable energy sources like solar panels would make me more likely to invest in battery energy storage.	Benefit	

2.4.3 Social norms

Eighteen items related to social norms about energy use, modelled after Dello Russo et al (Dello Russo et al., 2023), were developed and presented in March 2024 (see Table 3). These were coded on a 5-point scale from 0 = strongly disagree to 4 = strongly agree. In subsequent analyses MRE9 and MRE10 were excluded from calculating an overall score. These two items correlated poorly with the rest, and on closer reflection it became clear that their meaning did not reflect a strong adherence to a social norm favouring energy efficiency and proenvironmentalism. The resulting scale score was the average of the responses to the remaining 16 questions. Higher values indicate a stronger adherence to energy efficiency as a social norm. The internal consistency reliability of this scale was very good (Cronbach's alpha = 0.84 with N=241 from the full sample).

Table 3. The questions relating to social norms concerning energy use.

Q #	Prompt	MRE scale
MRE1	I feel a moral obligation to engage in energy behaviours that are beneficial for the environment.	
MRE2	Most Canadians engage in energy behaviours that are beneficial for the environment.	
MRE3	Most Canadians believe it is morally right to engage in energy behaviours that are beneficial for the environment.	
MRE4	Most of my neighbours engage in energy behaviours that are beneficial for the environment.	
MRE5	Most of my neighbours believe it is morally right to engage in energy behaviours that are beneficial for the environment.	
MRE6	Avoiding the need to build new fossil-fuel-burning electrical generating stations is important to me.	
MRE7	Increasing the use of renewable energy sources to generate electricity is important to me.	
MRE8	Decreasing the use of nuclear generating stations is important to me.	
MRE9	How we generate electricity is less important to me than making sure it's there when we need it.	Excluded
MRE10	Keeping customer electricity bills as low as possible, no matter how it's generated, is important to me.	Excluded
MRE11	Giving the utility the ability to adjust individual customer electrical demand is acceptable if it keeps costs low for everyone.	
MRE12	It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is stable for everyone.	
MRE13	Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	
MRE14	Avoiding the need for new electrical generating stations is important to me.	

Q #	Prompt	MRE scale
MRE15	It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is reliable for everyone.	
MRE16	Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	
MRE17	It is acceptable for utilities to adjust individual customer electrical demand to deliver the least costly electricity supply for everyone.	
MRE18	Increasing the amount of non-emitting electricity generation is important to me.	

2.4.4 Energy behaviour intentions

In March 2024, participants were asked about their likelihood of engaging in any of 11 energy use behaviours (see Table 4). The responses sat on a scale from 0 = very unwilling, through 1 = somewhat unwilling, 2 = neither willing nor unwilling, 3 = somewhat willing, 4 = very willing, and 5 = I have already done this. Two questions were presented in a reversed format (which is a common practice to prevent automatic answering). After these were reverse-coded an energy behaviour intention (EBI) scale was calculated as the sum of scores on the 11 questions, scaled to be out of 100. This scale had poor internal consistency reliability (Cronbach's alpha = 0.55 with N=240) but was retained because it was unclear that there were any statistical means to create a more reliable overall scale.

Table 4. The energy behaviour intentions questions.

Q #	Prompt	Coding
EBI1	Replace my light bulbs with energy efficient light bulbs.	
EBI2	Replace my appliances with more energy efficient appliances (e.g., a refrigerator with an Energy Star certification).	
EBI3	Install solar panels on my home (or increase the number of panels, if you have them already).	
EBI4	Participate in a time-of-day electricity rate program.	
EBI5	Install a mini-split heat pump.	
EBI6	Upgrade the insulation or windows.	
EBI7	Reduce my hot water consumption.	
EBI8	Wash and rinse my clothes with hot water. Reversed to "Wash and rinse my clothes with cold water."	Reversed
EBI9	Leave lights on when I am not using them. reversed to "Turn lights off when I am not using them:"	Reversed
EBI10	Lower my thermostat setting in winter to save energy.	
EBI11	Schedule appliances to operate at off-peak times.	

3 Results

3.1 Descriptive statistics – full sample

This section uses the full sample to report the summary statistics for personal values, beliefs, norms, and energy behaviour intentions, as these may provide guidance for future program development. The later analyses of the relationship between these variables will necessarily include only those cases for which full data are available.

3.1.1 Personal values

The nature of these personal variables is that every person's values are a blend of the four value orientations. That said, one or another of the orientations may dominate. Table 5 shows the results for the overall mean, standard deviation, and quartile scores for these variables, and the number of respondents with that value as their dominant value (the orientation for which their score is highest).

Note that the negative values for the minima for Egoistic and Hedonic values indicate that there are some participants for whom these values are the opposite of their personal beliefs. Biospheric values are the most strongly held for this sample, both in terms of the average score and the proportion of participants for whom it is the value orientation with the highest score.

Table 5. Personal value orientations of this sample, June 2022 (N=323).

	Egoistic	Hedonic	Altruistic	Biospheric
Mean	2.76	4.88	5.27	5.28
SD	1.29	1.32	1.14	1.22
Minimum	-1	-1	1	1
25 th	2.00	4.00	4.50	4.75
50 th	2.60	5.00	5.50	5.50
75 th	3.60	6.00	6.25	6.00
Maximum	7.00	7.00	7.00	7.00
Dominant for %	1	24	31	44

3.1.2 Costs and benefits of energy efficiency

Examination of the individual questions making up the CBEE scale shows that overall, the participants held strong beliefs about several of the questions. The scale was from 0 to 4, and seven of the 10 questions had median values of 3, meaning that half of the sample had given a rating of either 3 or 4. Table 6 shows the descriptive statistics for each question.

Table 6. Descriptive statistics for individual questions about costs and benefits of energy efficiency (March 2024). Questions 5 and 6 are not included in the overall scale.

Q #	Prompt	M	SD	Median	N
CBEE1	If I reduce my at-home energy consumption, I will personally receive financial benefits.	2.91	0.83	3.00	239
CBEE2	If I do not reduce my at-home energy consumption, I will incur financial costs.	2.64	0.96	3.00	239
CBEE3	If I invest in renewable energy sources (e.g., by installing solar panels), I will personally receive financial benefits.	2.74	0.87	3.00	239
CBEE4	If I do not invest in renewable energy sources (e.g., by installing solar panels), I will personally incur financial costs.	2.20	1.04	2.00	239
CBEE5*	If I reduce my at-home energy consumption, I will have to give up some comfort and convenience.	2.27	0.93	2.00	239
CBEE6*	If I personally invest in renewable energy sources, it will cost me money.	3.01	0.85	3.00	240
CBEE7	One down side to installing renewable energy sources like solar panels is that they can make the home look unattractive.	1.46	1.10	1.00	240
CBEE8	Having a source of backup power to keep important electrical devices running during a power outage is important to me.	3.27	0.75	3.00	240
CBEE9	If incentives were available, I would be willing to invest in energy storage that would provide back up power for my home if there was a grid outage.	3.24	0.83	3.00	240
CBEE10	Having renewable energy sources like solar panels would make me more likely to invest in battery energy storage.	2.93	0.84	3.00	175
CBEE scale		2.80	0.49	2.75	240

Figure 1 shows the pattern of responses for two selected questions that illustrate the hopes (CBEE1) and fears (CBEE5) about energy efficiency. On the one hand, people believe that reducing their energy consumption will save them money. On the other hand, they also believe that it will cost them comfort and convenience. The colour coding is reversed in the two bars to illustrate this dichotomy.

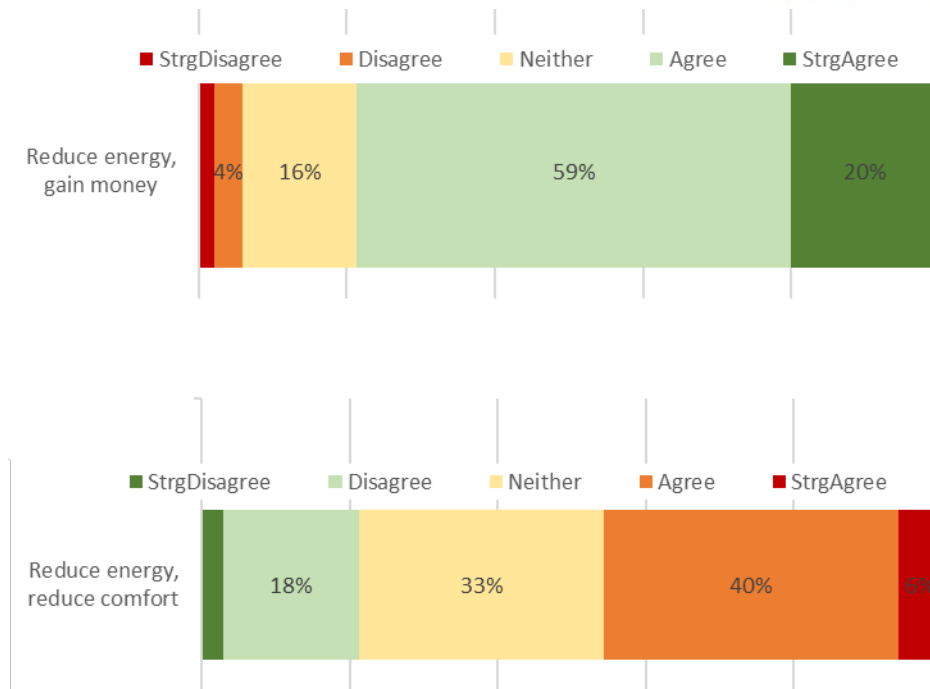


Figure 1. The distribution of responses to questions CBEE1 and CBEE5 show the contrasting hopes and fears about energy efficiency.

3.1.3 Social norms for energy behaviours

The descriptive statistics for the 18 questions related to social norms are shown in Table 7. Individuals reported a strong obligation to engage in energy behaviours that are beneficial to the environment: 50% of them responded 3 or 4 on the scale from 0-4 (question MRE1). They were less certain about their fellow Canadians (MRE2) and neighbours (MRE4), for both of which the median score was 2.

Table 7. Descriptive statistics for agreement with individual statements about social norms related to energy use (March 2024), on a scale from 0 (strongly disagree) to 4 (strongly agree). Questions 9 and 10 were not used in calculating the overall scale.

Q #	Prompt	M	SD	Median	N
MRE1	I feel a moral obligation to engage in energy behaviours that are beneficial for the environment.	2.92	0.74	3.00	242
MRE2	Most Canadians engage in energy behaviours that are beneficial for the environment.	1.95	0.82	2.00	242
MRE3	Most Canadians believe it is morally right to engage in energy behaviours that are beneficial for the environment.	2.26	0.76	2.00	242
MRE4	Most of my neighbours engage in energy behaviours that are beneficial for the environment.	2.13	0.70	2.00	242
MRE5	Most of my neighbours believe it is morally right to engage in energy behaviours that are beneficial for the environment.	2.25	0.67	2.00	242
MRE6	Avoiding the need to build new fossil-fuel-burning electrical generating stations is important to me.	2.83	0.89	3.00	242
MRE7	Increasing the use of renewable energy sources to generate electricity is important to me.	3.15	0.75	3.00	242
MRE8	Decreasing the use of nuclear generating stations is important to me.	2.24	1.10	2.00	242

Q #	Prompt	M	SD	Median	N
MRE9	How we generate electricity is less important to me than making sure it's there when we need it.	1.78	0.98	2.00	242
MRE10	Keeping customer electricity bills as low as possible, no matter how it's generated, is important to me.	2.51	1.11	3.00	242
MRE11	Giving the utility the ability to adjust individual customer electrical demand is acceptable if it keeps costs low for everyone.	2.45	1.01	3.00	242
MRE12	It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is stable for everyone.	2.33	0.97	2.00	242
MRE13	Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	2.38	0.96	3.00	242
MRE14	Avoiding the need for new electrical generating stations is important to me.	2.16	0.91	2.00	242
MRE15	It is acceptable for utilities to adjust individual customer electrical demand to ensure that the supply is reliable for everyone.	2.34	0.90	2.50	242
MRE16	Giving the utility the ability to adjust electrical demand is acceptable if it results in environmental benefits.	2.34	0.92	2.00	242
MRE17	It is acceptable for utilities to adjust individual customer electrical demand to deliver the least costly electricity supply for everyone.	2.43	0.89	3.00	242
MRE18	Increasing the amount of non-emitting electricity generation is important to me.	2.79	0.76	3.00	242
MRE scale		2.43	0.47	2.50	241

Several questions addressed the acceptability of permitting utility control over individual customer energy demand. These were included to address one of the project objectives. Figure 2 shows the distribution of responses to these questions. Questions were repeated to increase the reliability of measurement. The pattern shows fair agreement with the idea of utility control over individual electrical demand for any of the reasons given, with nearly half of the sample agreeing that it would be acceptable and only 20% disagreeing.

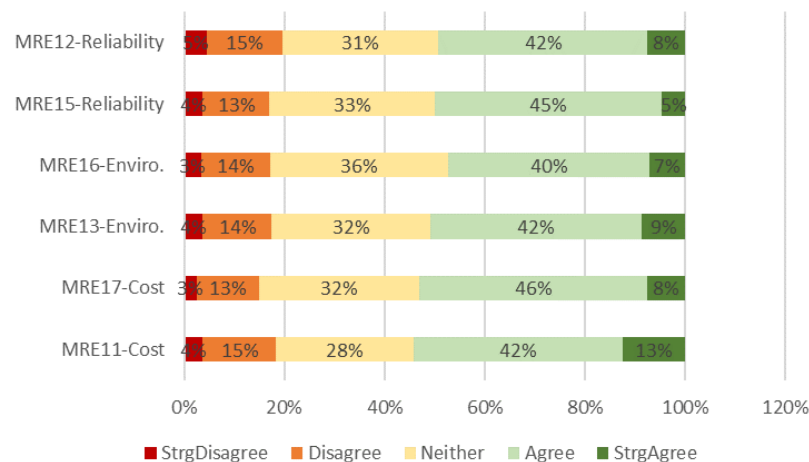


Figure 2. The distribution of responses to questions about the acceptability of utility control over individual electrical demand.

3.1.4 Energy behaviour intentions

The individual questions for energy behaviour intentions are shown in Table 8 together with the overall scale score. The results show a sample that is already engaged in energy efficiency behaviours, with the median (50% response) being “I have already done this” to replacing light bulbs with energy efficient bulbs, turning lights off when not using them, and installing a mini-split heat pump. The median score of 4 (very willing) for several other questions shows high willingness to engage further. Note that the total scale score is out of 100.

Table 8. Descriptive statistics for the likelihood of engaging in individual energy behaviours, on a scale from 0 (very unlikely) to 5 (I have already done this).

Q #	Prompt	M	SD	Median	N
EBI1	Replace my light bulbs with energy efficient light bulbs.	4.52	0.82	5.00	240
EBI2	Replace my appliances with more energy efficient appliances (e.g., a refrigerator with an Energy Star certification).	4.05	1.13	4.00	240
EBI3	Install solar panels on my home (or increase the number of panels, if you have them already).	3.34	1.20	4.00	240
EBI4	Participate in a time-of-day electricity rate program.	3.35	1.16	4.00	239
EBI5	Install a mini-split heat pump.	4.18	1.38	5.00	240
EBI6	Upgrade the insulation or windows.	3.77	1.23	4.00	240
EBI7	Reduce my hot water consumption.	3.15	1.30	3.00	239
EBI8	“Wash and rinse my clothes with cold water.” (after reverse coding)	3.76	1.48	4.00	240
EBI9	“Turn lights off when I am not using them” (after reverse coding)	3.90	1.62	5.00	240
EBI10	Lower my thermostat setting in winter to save energy.	2.73	1.58	3.00	240
EBI11	Schedule appliances to operate at off-peak times.	3.48	1.17	4.00	240
EBI scale	Sum of scores on all items, scaled out of 100	73.10	11.15	72.73	240

Figure 3 shows the response pattern for the two questions related to TOD electricity rates programs. The 12% who reported already having joined a TOD program apparently interpreted the question as referring to the TOD trial in the study, although it was scheduled to end within days of the survey being completed. Assuming those individuals would remain interested in a TOD program, it is clear that over 70% of respondents would be willing to join a TOD rates program if one were offered. Only 6% were opposed to the idea.

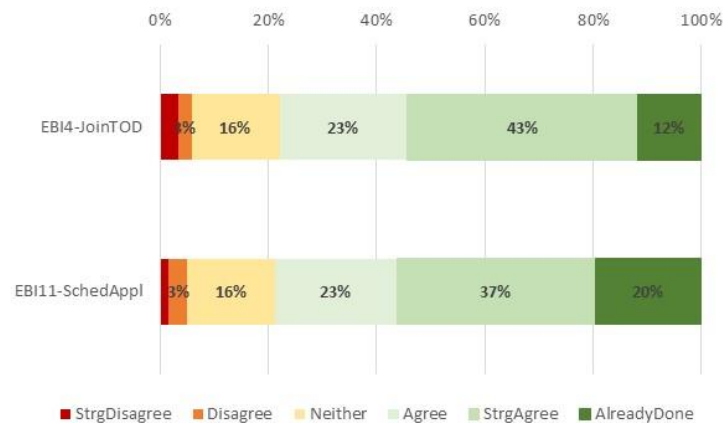


Figure 3. The distribution of responses to questions about a possible TOD electricity rates program.

3.2 Explaining current and future energy behaviours

These analyses used hierarchical multiple regression, in which we entered predictors into a regression equation in a predetermined order. In step 1, we entered the values that participants brought into the study. In step 2, we added the research groups to which they had been assigned: TOD, SOL, and the interaction of TOD and SOL. Given the large number of homes with existing mini-split heat pumps, it would not have been logical to include the experimental group CC-MSHP; instead, we added a variable to indicate whether the home used electric baseboard heating or a heat pump of any kind or quality. On step 3 we added a demographic term that was known to affect the outcome variable, using the report that occurred closest in time to the outcome measure. For EUI this was the number of occupants in the home. For EBI on step 4 it was household income. On step 4 we added participants' average score on the scale of costs and benefits of energy efficiency (CBEE). On step 5, we added their average score on the MRE scale of adherence to social norms about energy use.

In order to have data from the same set of participants, only cases with data on all of the variables in the two models were included in these analyses. This resulted in a total N=165.

3.2.1 Current behaviours: Energy use intensity, winter 2023

The indicator of participants' current energy behaviours was energy use intensity in kWh/m² in winter 2023 (December 2023-February 2024). This quantity controls for one of the important influences on household energy use: home size. The results are summarized in Table 9. Note that outdoor temperature, a known influence on household energy use, was constant for all homes because it was available only as a single measurement from a weather station many kilometers away, in Moncton. There was no point to include it in these models.

As Table 9 shows, the model did not pass the criterion for statistical significance ($p \leq 0.05$) until step 3, when occupancy was added to the model. The presence of the SOL intervention was itself statistically significant at step 2, but this was insufficient to differentiate the model results from the null hypothesis (that the predictor variables did not explain EUI-Win 2023). Occupancy itself explained 3.6% of the variance in EUI-Win 2023 (ΔR^2 for step 3). At step 3, the full model passed the criterion for statistical significance, with occupancy and SOL being the explanatory variables. The SOL intervention reduced EUI Win 2023 and was a stronger influence than occupancy, as seen in the larger absolute value of its

standardized coefficient (-0.31 vs 0.19). Larger occupancy increased EUI Win 2023, as might be expected.

Table 9. This table summarizes the hierarchical regression of EUI-Winter2023 on behavioural and study variables. * $p \leq 0.05$. ** $p \leq .01$.

	M	SD	Standardized Coefficients (β)				
			Step 1	Step 2	Step 3	Step 4	Step 5
EUI Win 2023	3.66	1.42					
Egoistic (-1 to +7)	2.72	1.24	-0.06	-0.07	-0.07	-0.05	-0.05
Hedonic (-1 to +7)	4.88	1.35	-0.04	0.00	-0.02	-0.03	-0.03
Altruistic (-1 to +7)	5.31	1.12	0.02	0.00	0.03	0.05	0.06
Biospheric (-1 to +7)	5.33	1.25	0.13	0.15	0.15	0.14	0.15
TOD (0/1)	0.53	0.50		-0.07	-0.05	-0.04	-0.04
SOL (0/1)	0.27	0.45		-0.31**	-0.31**	-0.30**	-0.30**
SOL x TOD	0.15	0.36		0.20	0.17	0.18	0.18
Electric baseboards (0/1)	0.12	0.32		0.13	0.14	0.12	0.12
# occupants	2.53	0.99			0.19**	0.19**	0.19*
CBEE (0-4)	2.84	0.46				-0.17*	-0.15
MRE (0-4)	2.45	0.48					-0.05
ΔR^2				0.065	0.036	0.026	0.002
R^2			0.021	0.087	0.123	0.148	0.150
$R^2_{adjusted}$			-0.003	0.040	0.072	0.093	0.089
df			4,160	8,156	9,155	10,154	11,153
p			0.480	0.071	0.014*	0.005**	0.007**

Adding the beliefs about costs and benefits of energy efficiency in step 4 added 2.6% to the explained variance. As might be expected, higher CBEE scores reduced EUI Win 2023. This effect was only slightly smaller than the effect of increased occupancy. After step 4, 14.8% of the variance in EUI Win 2023 was explained.

The addition of the social norms scale (MRE) added only a very small amount to the explained variance, although the model as a whole remained statistically significant. At this step only occupancy and the SOL system predicted EUI Win 2023. The fact that CBEE and MRE were correlated ($r=0.33$) probably explains this change; the variance was split across the two variables and neither achieved the status of significant predictor.

3.2.2 Future behaviours: Energy behaviour intentions

The regression model for EBI was fundamentally the same, except for one variable. On step 3 we added a categorical variable representing household income (as reported in winter 2023), in recognition of the reality that income will influence the affordability of some of the more costly energy behaviours, such as insulating the home or adding solar panels.

The results, shown in Table 10, show that participants' value orientations – particularly the biospheric orientation – predicted the willingness to engage in future energy behaviours. The stronger the biospheric orientation, the more willing participants became. The values alone explained 8.5% of the variance in energy behaviour intentions. Adding the experimental conditions added another 3.1% to the explained variance but no single variable was statistically significant. Adding income to the model at step 4 did not add to the explained variance.

Adding the beliefs about costs and benefits of energy efficiency at step 4 made a large addition to explained variance, with 10.3% added. Biospheric values and CBE scores were the significant predictors in this equation, and both increased the willingness to engage in future energy behaviours. At step 5,

adding social norms explained a further 3% to the explained variance, for a total of ~25% explained variance (19.7% when adjusted for the number of predictors).

Table 10. This table summarizes the hierarchical regression of EBI-Winter2023 on behavioural and study variables. * $p < 0.05$. ** $p < 0.01$. * $p < 0.001$.**

	M	SD	Standardized Coefficients (β)				
			Step 1	Step 2	Step 3	Step 4	Step 5
EBI	72.61	10.91					
Egoistic	2.72	1.24	-0.01	-0.01	-0.01	-0.06	-0.05
Hedonic	4.88	1.35	-0.09	-0.12	-0.11	-0.10	-0.09
Altruistic	5.31	1.12	-0.07	-0.05	-0.05	-0.10	-0.13
Biospheric	5.33	1.25	0.36**	0.34**	0.34**	0.35***	0.33**
TOD (0/1)	0.53	0.50		0.04	0.03	0.00	-0.01
SOL (0/1)	0.27	0.45		0.11	0.12	0.10	0.11
SOL x TOD	0.15	0.36		0.07	0.08	0.06	0.04
Electric baseboards (0/1)	0.12	0.32		0.01	0.01	0.04	0.03
Household income (1-7)	5.07	1.75			-0.03	-0.05	-0.03
CBEE	2.84	0.46				0.33***	0.27***
MRE	2.45	0.48					0.20**
ΔR^2				0.031	0.001	0.103	0.031
R^2			0.085	0.116	0.117	0.220	0.251
$R^2_{adjusted}$			0.063	0.071	0.066	0.169	0.197
df			4,160	8,156	9,155	10,154	11,153
p			0.006**	0.012**	0.020*	0.000***	0.000***

4 Conclusions

Understanding the local context is a necessary element of effective behaviour change programs and their associated communications (Dietz et al., 2013; Steg, 2023). This snapshot of Shediak participants' values, beliefs, and norms related to energy efficiency and the effects of these concepts on both their current and possible future energy behaviours can inform future policy and program design and communications.

Participants in this project held strong Biospheric values, with these having the highest average scores of the four value orientations and Biospheric being the highest scoring value orientation for 44% of the sample. It is possible that this reflects a selection bias in that the participants were volunteers in a smart energy project. It is, however, also notable that Egoistic values were very low in this sample despite the recruitment communications having included the possibility of receiving a free rooftop solar + battery energy storage system. If a financial incentive had been the principal motivation for participating one might have expected more participants with an Egoistic-dominated value orientation.

In general, participants believed that there are benefits to energy efficiency (CBEE average score = 2.84/4). Nonetheless, their individual responses showed that people hold competing beliefs about the consequences of energy-efficiency. On the one hand, reducing energy use could save them money, but on the other hand it could also result in discomfort and lost convenience.

This internal debate manifests itself in reports of participants' willingness to engage in future behaviours, seen in both the quantitative ratings and the open-ended responses (Appendix B). Space heating is the major energy use in New Brunswick homes, making lowering a thermostat setpoint an easy way to lower household energy use. Nonetheless, the median rating for this behaviour intention was 3 ("somewhat willing"), and its average was the lowest of the 11 behaviours that were rated. Similarly, Pardasani et al. (2025b) reported on the importance of comfort to participants' choice of

thermostat settings. This pattern is consistent with the literature, such as Xu et al.'s (2018) finding that participants in a hypothetical utility control program would be more likely to participate if a user override were available to them to ensure their comfort in the event of a utility action.

This sample also showed high willingness to participate in utility programs, with over half of the participants being willing to join a TOD electricity rates program (see also Pardasani et al. 2025a). Nearly half endorsed the acceptability of utility control programs as part of the social norms ratings, which is similar to the proportion of participants willing to join the hypothetical program described by Xu et al. (2018).

We set out to test the applicability of the values-beliefs-norms model (Stern et al. 1999) to explain current and possible future energy behaviours. We found mixed evidence, with good prediction for future energy behaviour intentions and less clear results for current energy behaviours.

EBI was well predicted in the full model, explaining an adjusted 19.7% of the variance (25.1% unadjusted for the number of predictors). Holding Biospheric values, beliefs in the benefits of energy efficiency, and agreeing with social norms for energy efficiency all predicted a higher likelihood of engaging in these behaviours.

The measure of current energy behaviours, EUI, is a gross metric that combines many influences, only some of which could be included in these analyses⁶. To our knowledge, few studies of the relationship between values and beliefs and energy behaviour have included this outcome. The final model was statistically significant and explained 8.9% of the adjusted variance, and 15% unadjusted. As might be expected, the presence of rooftop solar PV panels and battery energy storage was the strongest predictor, followed by the number of people in the home. Interestingly, however, a less constrained model without social norms in the equation explained nearly the same amount of variance but included beliefs about the costs and benefits of energy efficiency as an explanatory variable. These beliefs explained 2.6% of the variance and were nearly as important to the outcome as the household size. In this model, households with participants who held stronger beliefs about the benefits of energy efficiency showed a lower EUI. Social norms did not influence EUI in this analysis, although this might be a statistical artifact of the high correlation with beliefs about costs and benefits of energy efficiency.

Overall, the results suggest that future program design in New Brunswick could leverage the existing high level of Biospheric values and further develop beliefs in the costs of inaction and the benefits of energy conservation action as messages to motivate participation in utility programs. Note that messages about financial considerations can themselves influence social norms (Dello Russo et al., 2023), normalizing the idea of adopting renewable energy or joining a TOD program.

As others have noted, motivating behaviour change is difficult. People do not always act in accordance with their values and beliefs, and they can hold opposing beliefs at the same time. People use shortcuts to process complex information and they fear loss more than they value gain (cf. Frederikson et al. 2015; Kahneman, 2011). Households differ in their ability to finance technology adoption, meaning that what might be a sufficient financial incentive for one might be insufficient for another despite equally strongly held values, beliefs, and norms.

⁶ Household energy use is also influenced by the building envelope; the heating and cooling system type, efficiency, and control choices; weather; household size; dwelling type and area; energy-using equipment in the home and its usage patterns; and, daily activity patterns of each person in the home. The analyses reported here controlled for dwelling area and household size and only in the most simple way for heating system type (electric baseboards or heat pumps). Weather was not a factor in this analysis because all of the homes were in the same community and the data were for the same season.

Policies succeed in part to the extent that there is social licence, which in addition to these other considerations requires attention to equity issues in policy and program development (Rotmann et al. 2025; Steg, 2023). Participants in this study were very happy to have participated (Appendix A.1), and rated the interactions with the project team highly. The median of their overall satisfaction with NB Power in March 2024 was 7 out of 10, which many researchers would consider excellent, but which was one point lower than it had been nine months previously. This underlines the importance of careful, comprehensive program planning and design for new approaches to succeed. We speculate that the drop in satisfaction related at least in part to the upcoming rate increase that followed the March 2024 survey. New programs will need to address these concerns, and clear communications about the benefits of energy-efficiency will be an important part of successful implementation.

Useful short introductions to effective program design and evaluation include Dietz et al. (2013), Steg and Abrahamse (2013), and Frederikson et al. (2016). Careful consideration of the broad range of psychological, demographic, technical and financial factors in policy and program design should facilitate success in New Brunswick Power's efforts to continue successfully providing reliable electric power to New Brunswickers while also meeting its financial and our collective environmental goals.

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Appendix A - General survey results

A.1 General satisfaction

Surveys 2, 4, 5 and 7 included questions about satisfaction with the project and the communications from it. On a scale from 0 to 4, satisfaction with both was stable and high throughout the project.

Table A.1.1 Overall how satisfied are you with your participation in this project? (0 to 4 scale)

	Nov-21	Nov-22	Jun-23	Mar-24
Sample Size (N)	337	301	290	234
Very Dissatisfied (%)	1	4	2	2
Dissatisfied (%)	2	7	9	6
Neither (%)	18	23	19	17
Satisfied (%)	45	37	42	52
Very Satisfied (%)	34	29	28	23
Mean	3.1	2.8	2.9	2.9
SD	0.8	1.1	1.0	0.9
Median	3	3	3	3

Sample open-ended comments about the project overall:

- “Thank you for allowing me to be part of this important project. It has given me an elevated awareness on power usage. It has also pronounced the fact that we can all do a little more to manage the usage of power. A little action by many can make a big difference. I encourage NB Power to continue working with governments and residences in finding more effective ways to manage our power consumption.”
- “Thanks for giving me the opportunity and hope we can bring it to the next level !”
- “Overall, it was a great experience. The staff is very friendly and helpful. The opportunity to keep the equipment is very appreciated. I have learned a lot about new technologies, time of day consumption and other things to help our family to be more energy efficient. I am very happy to have participated. Thank you!!”
- “If there are any return of solar panels at the end of the project, we might be interested in buying them at a reduced price, even getting a second battery if possible to add to current installation. Time of the day different rate are a must to be set up for all NB power customers to get clients to make changes in their day to day consumption habits. I would love my time the day rate kept on our account. “

Table A.1.2. Overall how satisfied are you with your communications/contact with the project team? (0 to 4 scale)

	Nov-21	Nov-22	Jun-23	Mar-24
Sample Size (N)	336	299	291	235
Very Dissatisfied (%)	1	4	2	2
Dissatisfied (%)	1	3	5	3
Neither (%)	13	20	21	20
Satisfied (%)	51	46	46	52
Very Satisfied (%)	35	27	26	23
Mean	3.2	2.9	2.9	2.9
SD	0.8	1.0	0.9	0.8
Median	3	3	3	3

Satisfaction with NB Power was probed using a question that is commonly used in NB Power customer experience surveys. It showed a small decline between June 2023 and March 2024. Note that a sizeable

rate increase was scheduled to take place on April 1, 2024, shortly after this survey (and the project) was completed.

Sample quotations following up on the ratings given to NB Power:

- “Great communications with staff !”
- “I know NB Power has a difficult job trying to manage the power grid and keeping its cost manageable. “
- “I signed up for this program hoping to see a savings in my bills but NB Power keeps increasing the price such as the increase coming April-1-2024!”
- “The rates are good, we were fortunate to take part in this study.”

Table A.1.3. Overall how satisfied are you with NB Power?

			Jun-23	Mar-24
Sample Size (N)			289	240
0 = Not at all satisfied (%)			0	3
			1	2
			2	4
			2	5
			3	6
			9	9
			7	12
			16	21
			25	22
			18	18
10 = Most satisfied (%)			16	0
Mean			7.5	6.5
SD			2.1	2.3
Median			8	7

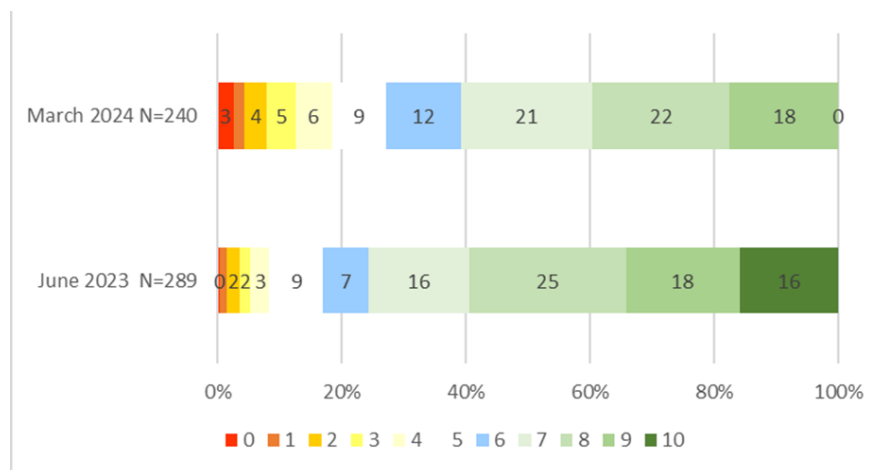


Figure A.1.1 This chart shows the responses to the two occasions of questioning about satisfaction with NB Power.

A.2 Water heater controllers

A subset of participants with NBP rental electric hot water tanks received wireless control devices as part of the smart technologies being considered for distributed energy resources interventions, in which the water heater operation would be briefly interrupted to reduce peak demand. The interruptions

were designed to be short enough that the water would remain hot enough for domestic use during the intervention. Some interventions were implemented by Siemens. We could not ask directly about whether these interventions had been noticed because the surveys were not timed to coincide with periods in which interventions had been conducted, so we asked indirectly about water heater performance (Table A.2.1, Table A.2 2, and A.2.3). It does not appear that any signals sent to the water heaters were noticed, nor that there were substantial problems with the availability or temperature of the hot water.

Table A.2.4 reveals that a strong majority of all participants (78%) would take part in a utility control program involving water heater signals if one were offered.

Table A.2.1. I have experienced issues with my water heater while I have been in the project. (Participants with water heater devices only.)

	Nov 2023	Mar-2024
Sample Size (N)	193	184
No (%)	92	84
Yes (%)	8	16

In follow-up questions, most of the reported issues were necessary repairs, unrelated to the water heater devices.

Table A.2 2. Hot water is always available when I need it. (0 to 4 scale) (Participants with water heater devices only.)

	Nov 2023	Mar-2024
Sample Size (N)	191	183
Strongly disagree(%)	2	1
Disagree (%)	4	7
Neither (%)	2	3
Agree(%)	45	52
Strongly agree((%)	48	37
Mean	3.3	3.2
SD	0.8	0.9
Median	3	3

Table A.2.3. Hot water is always available when I need it. (0 to 4 scale) (Participants with water heater devices only.)

	Nov 2023	Mar-2024
Sample Size (N)	192	182
Strongly disagree(%)	2	1
Disagree (%)	5	2
Neither (%)	5	9
Agree(%)	50	62
Strongly agree((%)	38	26
Mean	3.2	3.1
SD	0.9	0.7
Median	3	3

Table A.2.4. If NB Power were to offer you a program in which they could send signals to your water heater, would you sign up for it? (All participants)

	Mar-2024
Sample Size (N)	241
No (%)	22
Yes (%)	78

Appendix B - Open-ended responses about energy conversations

B.1 Energy habits

What kinds of conversations about energy habits have been happening in your household since the project began?

In terms of energy habits, participants were asked what conversations had been happening in their house since the project began. The majority of the No-TOD participants who responded to this question (N=105) reported that there were no major changes in their conversations (36 %). Managing the lights (reducing or turning off) was the next most mentioned conversation (34%), together with discussions about temperature setting and heating (14%), hot water use (8%), and renewable energy options (8%). Participants also discussed an increased awareness about energy consumption overall, considering adjusting their habits and trying to be more energy efficient.

Participants' responses in the TOD group (N=109) highlighted that energy usage awareness and habits related to energy savings were the most discussed topics in their households (40%), while around 28% mentioned no or minimal conversations. Time of day usage was also frequently discussed (17%) with main topics relating to changing energy usage and the use of household appliances to align with better rates. Practical energy-saving actions, such as shutting off unnecessary appliances and washing clothes in cold water, were also mentioned (20%). There was a clear interest in renewable energy options where participants (9%) discussed the pros and cons of the technology, and the possibility of installing solar panels in the future.

Participants in the Solar group (N=71) reported discussing how to use appliances based on the time of day to save energy and reduce costs (28%). They also mentioned increased awareness of energy usage and monitoring of their energy consumption using tools available to them (Tesla app). Discussions about energy-saving practices (21%) and renewable energy and technologies (14%) were also mentioned. Overall, the responses indicate a mixed level of engagement with energy-saving practices, with some individuals actively making changes and others maintaining their previous habits.

B.2 Changes in energy use

What changes have you noticed in how you use energy at home since joining this project?

Increased awareness about energy usage and consumption and being more conscientious about savings and costs were mentioned by some participants (No-TOD = 19%, TOD = 14%, Solar group only = 25%). In the No-TOD group, most reported noticing minimal changes in their energy use (28%), while others noted increased energy-saving behaviours, such as using less hot water, reducing electricity usage (17%), reducing the usage of appliances to save energy (12%), and the use of smart devices including smarter energy management (10%).

Similarly in the TOD group, most participants reported no changes in their energy habits (27%), but others reported possible changes related to the time-of-day rates and energy behaviours that could be adopted (21%) to save energy and cost, such as setting lower temperatures, using less hot water, and using appliances at different times in the day (17%).

In the Solar group, the most reported changes included the strategic use of appliances based on the time of day to reduce cost (29%), such as using appliances at different times, turning off lights, and not wasting water. Other behavioural changes included using devices to monitor energy consumption and lower energy costs (25%). Around 17% of participants in the Solar group report minimal or no changes to their energy behaviours.

B.3 Most important lesson

What is the most important thing you have learned about smart energy technology at home?

The analysis of responses related to gaining knowledge about smart energy technologies showed that participants most valued the convenience and ease of use of these technologies, highlighting the ability to control home energy settings remotely (No-TOD = 19%, TOD = 18%, Solar only = 21%). The No-TOD group valued the increased awareness and knowledge about these technologies and how they relate to reduced energy consumption (17%) and the potential savings of these technologies for reducing bills (14%). They also reported an increased interest in renewable technologies (11%).

Participants in the TOD group valued the ease of use, specifically the simplicity and user-friendliness of these technologies (smart thermostats) and potential cost savings (11%), and they indicated that smart energy technologies have helped them become more conscious of their energy use (16%).

Understanding the importance of time-of-day usage was also highlighted, recognizing the benefits of using energy during off-peak times (11%).

Similar to other groups, the Solar group participants mentioned energy awareness (21%), potential cost, and energy savings (25%) as the main lessons learned about smart home technologies, and some expressed enthusiasm for solar power and energy storage solutions for doubling their savings (14%). However, participants in all groups highlighted that there are challenges and limitations with smart technologies, specifically, the high cost of upgrades and the perceived lack of significant energy savings. Overall, the responses indicate that while smart energy technologies are generally seen as beneficial for increasing energy awareness and saving costs, some limitations need to be addressed for the successful adoption and usage of these technologies by homeowners.

B.4 Looking to the future

Looking to the future, how might you change your energy habits even more as a result of this project?

Considering the end of the project, participants were asked to indicate how they might change their energy habits after the project was completed. Most participants remained optimistic that they would change some of their behaviours.

In the No-TOD group, most responses indicate an interest in adopting energy-efficient technologies and behaviours. The most frequently mentioned actions include installing solar panels and battery storage (9%), or other energy-efficient technologies such as heat pumps, thermostats, and other smart technologies (11%). Participants also expressed that they will be more aware of energy usage, and checking energy consumption when buying new appliances (12%). Some mentioned that they are already practicing a lot of energy-efficient behaviours and do not plan to change their habit, other expressed a desire to keep up their education on how they can further reduce their energy consumption and increase savings.

In the TOD group, some participants expressed a tendency towards adopting energy conservation behaviours and technologies, such as solar panels, battery storage, or heat pumps (15%), as well as adopting energy efficient practices such as keeping thermostats low in winter, turning off unused items, and doing laundry at night. Some expressed the need to improve their home isolation, fixing windows and doors (7%), and purchasing energy-efficient appliances (6%) to reduce their energy consumption and cost. Some noted that they are now more aware of their energy consumption and more disciplined in their habits (6%).

The Solar group participants declared a desire to invest in other smart and energy-efficient technologies (32%) technologies such as adding solar panels and battery storage options (15%), investing in energy-efficient products and appliances (9%), and purchasing electric vehicles (4%). They also expressed a great interest in better energy management behaviours, specifically monitoring their energy usage effectively to minimize costs (26%). These behaviours might include reducing heating, through lower settings, optimizing the usage of their current technologies (battery), and switching to cold water use and clothesline.

Overall, participants conveyed a proactive approach towards energy conservation, with a mix of immediate behavioural changes and long-term investments in energy-efficient technologies. The key findings suggest that while there is a willingness to adopt new technologies and behaviours to save energy, financial constraints and the need for more information and incentives play a are important influences on decision-making.

Chapter 10: A Summary of Results and Implications

Ajit Pardasani, Jennifer A. Veitch, Natalia Cooper, and Hadia Awad

Project overview: At a glance

- Project Proponent: NB Power
- Project Funding: Natural Resources Canada, Industry Science and Economic Development Canada
- Project partners: Town of Shediac, Siemens Canada, and the National Research Council of Canada (NRC)
- Participant recruitment: June 2019 – December 2019
 - 529 participants were recruited initially.
 - From March 2020 through winter 2021 there were repeated pandemic pauses.
- All participants received smart electricity meters in 2020; most participants received one or more smart thermostats in 2021.
- The baseline measurement period was May 2021 to April 2022.
- The intervention period ran from June 2022 to March 2024.
 - 334 active participants remained at the study conclusion.
- Interventions followed detailed home assessments for compatibility and NRC-led research group assignments. Participants not in an intervention group formed the comparison group:
 - A time-of day electricity rate program (TOD) was offered to 211 participants from May 2022 to March 2024. The following table shows the rates tested in the trial:

TOD rates tested in the trial				
Time of Day (hours)	Weekdays		Weekends and holidays	
	May 2022 – Mar. 2023	Apr. 2023 – Mar. 2024	May 2022 – Mar. 2023	Apr. 2023 – Mar. 2024
On-peak, 7:00 – 9:00	\$ 0.2564	\$ 0.2752	\$ 0.1138	\$ 0.1215
Mid-peak, 9:00 – 22:00	\$ 0.1138	\$ 0.1215		
Off-peak, 22:00 – 7:00	\$ 0.0738	\$ 0.0784		

- Cold-climate mini-split heat pumps (CC_MSHP), installed in 23 homes;
- 5 kW rooftop solar photovoltaic panels with a 13.5 kWh battery energy storage unit (SOL), installed in 75 homes;
 - There were two modes of battery operation (time-based control mode for participants on TOD rates and resilience mode for the comparison group).

Key Findings:

Solar PV and Battery Storage Research Group (SOL):

- The dwellings in the Time-of-Day (TOD) group, whose batteries were operated in time-based control mode, demonstrated a greater reduction in demand during peak hours than the no-TOD (resilience mode of battery operation) group, whose batteries stayed in a state of readiness to provide backup power. The average demand reduction for dwellings in the TOD group was 3.1 kW (74% of load) during weekday on-peak hours in Winter 2022, and 3.0 kW (75%) in Winter 2023.
- Participants in the TOD group saved \$840 per year on average, while those on the no-TOD rate structure saved \$460 per year on average. These savings include avoided electricity use from the

grid because of generation by the rooftop PV panels, and solar energy credits for electricity sent to the grid from the panels averaging \$71 for TOD and \$123 for no-TOD participants. The sum includes ~\$337 on average in TOD credits annually paid to the TOD participants because the time-based control mode charged their batteries overnight at lower rates.

- Total TOD credits paid by NB Power to the SOL group: \$13,540, total solar energy credits: \$2,640. Total NB Power cost for bill credits including both TOD and solar energy credits: \$16,180
- Solar PV generated at these homes and used on-site saved NB Power an estimated \$20,520 per year in avoided generating costs.
- Overall, the estimated annual GHG emissions reduction per household associated with this technology is 1,384 kg CO₂e/year for the no-TOD group and 1,444 kg CO₂e/year for the TOD group. For these 75 homes, the total annual estimated GHG emissions reduction was 109.9 tCO₂e/year.
- Participants were overall very satisfied with the project and their technology (which they had received for free).
- When asked about necessary incentives to purchase this technology, the median response was an incentive of 50% of the purchase price, and the majority of respondents expected a payback time of 10 years.

Cold-climate Mini-split Heat Pump Research Group (CC-MSHP):

- These units delivered demand reductions of 16.3% and 15.5% for the daily morning peak in winter 2022 and winter 2023, respectively, as a result of the technology intervention. Additionally, the TOD intervention led to peak demand reductions of 7.5% and 7.3% for the same periods.
- The technology intervention delivered annual energy savings of 9.5% for the working days during the experiment period and nearly 12% in winters irrespective of the TOD rates compared to the same homes pre-installation. The TOD group showed an additional year-round energy savings of 4%.
- Total TOD credits paid to CC-MSHP participants: \$365.
- Users were generally satisfied with the units and would recommend them to others.

No-Tech Research Group:

- This research group consisted of all participants neither in SOL or CC-MSHP. The TOD intervention delivered a 3.3% reduction in morning peak demand over the whole sample in winter 2022, though this effect was not statistically significant in 2023. Homes that already had MSHP showed a larger effect on morning peak demand, with statistically significant reductions of 5.4% in winter 2022 and 3% in winter 2023.
- A weaker conservation effect was also observed for the whole no-Tech group for 2022, with a 2.4% reduction in total energy use observed for the TOD group compared to the no-TOD group. Homes with existing MSHP achieved a 3.4% reduction in daily energy use during winter 2022 with TOD compared to no-TOD, and 2.0% in 2023.
- Total TOD credits paid to all no-Tech TOD participants: \$4,645.
- Surveys showed gaps in energy literacy: Participants reported only moderate understanding of their electricity bills and over 50% could not report their approximate monthly electricity consumption.
- Participants in both TOD and no-TOD groups ended the project with a high degree of willingness to take part in a future TOD program if it did not take too much effort and was not too complex.

Energy behaviours:

- Shediak participants showed high concern for the environment as a value orientation, suggesting a predisposition to contribute to energy conservation efforts.
- Participants believed in the benefits of energy conservation, but also expressed the belief that using less energy could compromise their comfort or convenience.
- Analysis of smart thermostat setpoints through telemetry and surveys showed that this sample values comfort in making setpoint choices, and secondarily seeks a balance between comfort and the size of their electricity bills.
- Beliefs in the value of energy efficiency predicted lower household energy use intensity in winter 2023.
- Valuing the environment, beliefs in the value of energy efficiency and upholding societal norms for energy efficiency all predicted future intentions to engage in future energy-efficiency behaviours, providing guidance that can contribute to successful program design and technology integration.

1 Project Description

1.1 Background

This report provides a comprehensive overview of the Shediac Residential Energy Study, a five-year project, addressing both the technical and customer dimensions of smart energy technologies. This project is part of Smart Grid Atlantic, a four-year federally-funded initiative supporting energy technology projects in Nova Scotia and New Brunswick. Responding to a commitment by The Town of Shediac to become “Atlantic Canada’s first Smart Energy Community”, New Brunswick Power (NBP) developed this research project in 2018. As the project proponent NBP entered into a partnership with the Town of Shediac, Siemens Canada, and the National Research Council of Canada (NRC) in 2019. The study was supported by \$35 million in grants from Natural Resources Canada and Industry Science and Economic Development Canada. The study aimed to gain the experience and knowledge necessary to modernize the electrical grid, while addressing increasing customer energy needs and the necessary pace of decarbonization (New Brunswick Power, 2023a). This was accomplished by piloting smart energy technologies in over 500 homes in Shediac to gather data and insights into how these technologies perform in everyday residential settings.

The study was conducted as a quasi-experiment in a real-world setting, featuring a baseline period from May 2021 to May 2022, followed by an experimental phase from June 2022 to March 2024. At its peak, the study engaged 529 households, with 333 households remaining active in the project at its conclusion in March 2024. The study assessed both advanced energy technologies and human behavioural interventions, including time-of-day electricity rates (TOD), rooftop solar photovoltaic arrays with battery energy storage (abbreviated SQL later), and high-efficiency cold-climate mini-split heat pumps (abbreviated CC-MSHP later). Additionally, the project included trials targeting distributed energy resources for demand curtailment through test signals to battery storage systems, and to thermal storage provided by dispatchable domestic hot water tanks.

The successful adoption of TOD and advanced energy technologies within the province depends on the utility's ability to gain experience with these technologies on a smaller scale through pilot studies to resolve technical challenges, as well as a comprehensive understanding of customer attitudes towards these technologies to ensure smooth acceptance and facilitate large-scale deployments. This project effectively addressed both the technical and human dimensions of these challenges.

The NRC was the primary research partner for this project, and its research team was responsible for designing the experiment, ensuring compliance with research ethics policies, collaboratively developing participant-facing communications, developing and conducting surveys, analyzing data, and interpreting the data. This summary report synthesizes ten technical reports, listed in Appendix A, produced by the NRC to evaluate the performance, customer experience, and acceptance of the interventions.

1.2 Participants

1.2.1 Recruitment and consent

A sample of 529 participants was initially recruited in autumn 2019. The requirements for taking part in the study included that the participant legally owned a home located in the Town of Shediac, where they lived year-round. This residence was either a single-detached, semi-detached, or row housing unit with a single electricity meter, and the owner’s NB Power account was maintained in good standing. Additionally, participants needed to be equipped to handle electronic communications, enabling them to receive emails and respond to surveys. To begin participating in the study, homeowners were required to sign the Phase 1 participation agreement. When the study duration was extended,

participants had the opportunity to renew their participation by signing additional agreements, which were also necessary for receiving smart thermostats and water heater devices, as well as for complex energy technologies such as solar PV and battery storage or thermal storage as detailed in Table 1.

Table 1. Various participation agreements and number of participants signing agreements

Phase	Purpose	Period when signed	Sample size (N)
Phase 1	Surveys, energy monitoring, and home assessments through June 30, 2022	Oct. 2019 to Jan. 2020	529
Phase 1a	Participation extended to June 30, 2023 and smart thermostats and water heater devices offered for all compatible homes	Oct. 2020 and Apr. 2021	427
Phase 2	Complex technology agreement (selected participants only; others remained on agreement 1a)	May and Sept. 2022	99
Phase 2, extension	Participation extended to March 31, 2024	Mar. and May 2023	334

All parts of this project that engaged individual participants were reviewed and approved by the NRC Research Ethics Board under Protocol 2019-34.

Most of the attrition during the project occurred during the pandemic, as rising property prices in the province led some participants to sell their homes and relocate.

1.2.2 Demographics

Figure 1 illustrates the demographics of survey respondents both at the outset of the study, conducted from December 2019 to January 2020, and at its conclusion in March 2024. These demographics encompass participant age, occupants per home, household income, and home occupancy patterns. Notably, the occupancy pattern reveals that pre-pandemic, 39% of participants reported being at home all day on a regular weekday, whereas by March 2024, this figure had increased to 67%. This shift may be attributed to a combination of aging demographics and the adoption of work-from-home protocols. Although attrition reduced the final sample size to N=334, yielding approximately 65% retention over 4.5 years, it does not appear to have introduced any bias into the sample. Changes to age and income are expected because of the passage of time and probable inflation-related increases in income.

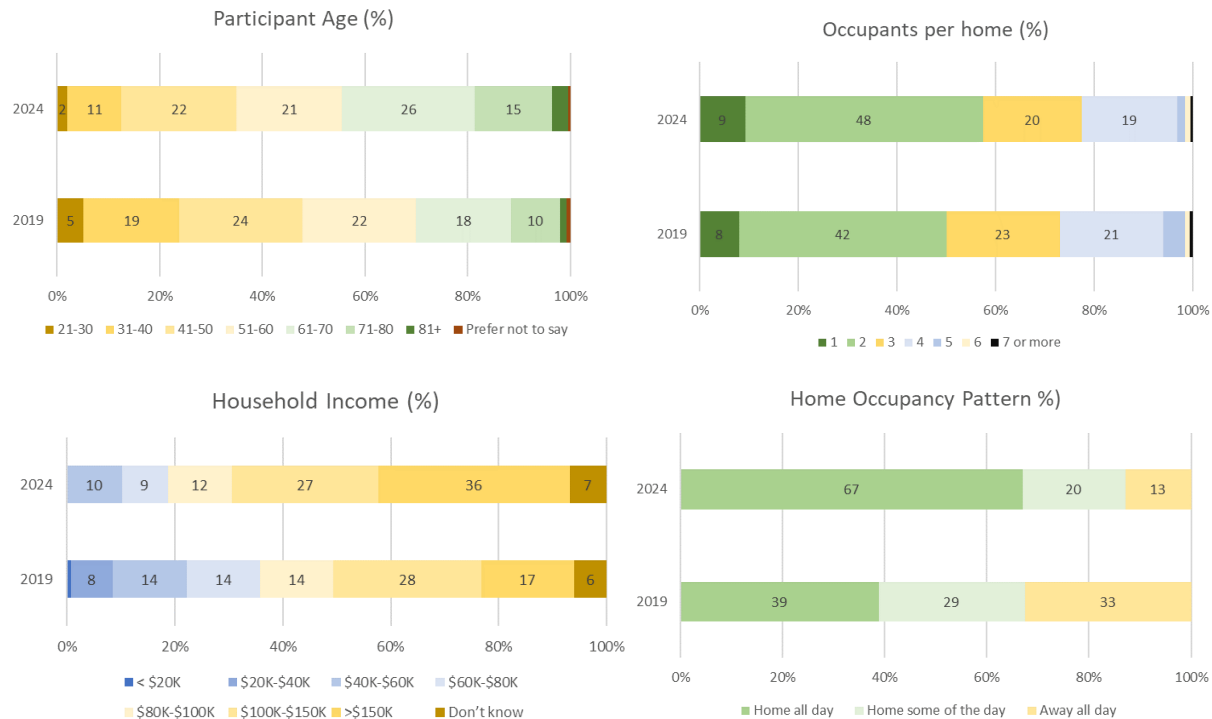


Figure 1. Demographics of the participants from survey responses.

1.2.3 Dwellings

Energy use in dwellings is influenced by several factors, including the occupants' schedules and behaviours, the physical characteristics of the dwellings, the efficiency and type of heating and cooling systems, and prevailing weather conditions. The histograms in Figure 2 show that most dwellings in the sample were built after 1995 and most houses had floor areas between 1001 to 2,000 sq. ft.

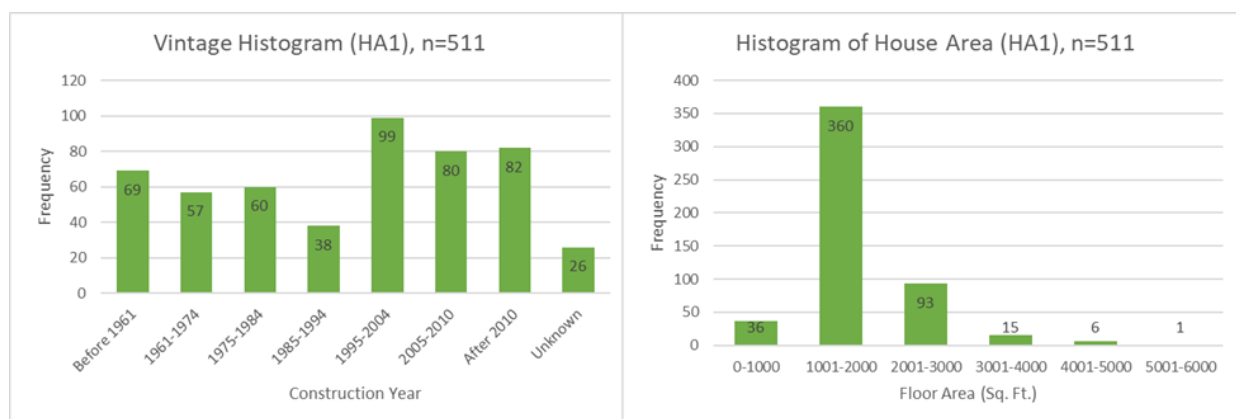


Figure 2. Distribution of vintage and house area from the first home assessment (HA1) in December 2019.

Table 2 shows the distribution of primary heating systems at the beginning of the project and at the end of the project. The initial data on heating systems collected at the time of recruitment was updated based on survey responses. The percentage of homes with mini-split heat pumps increased during the

course of the project, and the percentage of homes with electric baseboard heating as their primary heat source decreased. A tabulation at the end of the project determined that by December 2022, 84% of the homes had either mini-split or central heat pumps. Nine per cent had independently acquired a heat pump during the project, and 4.3% (23 homes) had been given a CC-MSHP as part of the project. All central furnaces were electric.

Table 2. distribution of primary heating system at the beginning of the project and at the end of the project.

Primary Heating System	Dec-19		Mar-24	
	N	Percent%	N	Percent %
MSHP	256	50.4	218	65.7
Baseboards	114	22.4	31	9.3
Central Heat Pump	89	17.5	62	18.7
Central Furnace	30	5.9	14	4.2
Radiant Floor	8	1.6	5	1.5
Fireplace	11	2.2	2	0.6
Total	508		332	

1.3 Procedure and timeline

The project was planned to be executed in phases, but the schedule changed considerably due to the COVID-19 pandemic. Figure 3 shows the timeline and main events. Phase 1 began in January 2020, following the initial recruitment of participants in a pool, a home assessment and an online survey to collect demographic and other baseline information. The home assessments were completed just as the pandemic began around mid-March 2020, at which time all participant contact stopped for several months. Phase 1 continued until June 30, 2022.

Smart electricity meters were installed in all participating homes in November 2019 through January 2020, and upgraded to new bi-directional meters in late autumn 2020. In May 2021, all participants received access to the online “Participant Energy Portal” through which they could view their electricity usage at an hourly level.

The design of the study was modified to accommodate the pandemic delays, and Phase 1a began in June 2020. All participants with a compatible heating system were offered free installation of up to 5 smart thermostats for their homes. Those with NBP rental electric water heaters were also offered a dispatchable water heater control device to enable distributed energy resource (DER) interventions. A second home assessment (HA2) was conducted in fall 2021 and early 2022 for those homes where HA1 had suggested compatibility with the complex technologies to be evaluated.

The intervention phase included the TOD rates trial and the technology trials for SOL and CC-MSHP. These interventions are described below. Phase 2 (the name for the intervention phase for the participants who received technologies) began in May 2022 with offers of a rooftop solar photovoltaic panel array + battery energy storage systems (SOL) to 75 participants and offers of thermal storage heat pumps (HP) to 24 participants. Installations of the SOL systems began in June 2022 and continued until December 2022. Thermal storage systems that had been installed were removed and replaced with high-efficiency cold climate heat pumps (CC-MSHP) in October 2022 because of technical problems with the thermal storage units. Phase 2 was extended by nine months from its original end date of June 30, 2023 to March 31, 2024 to ensure data collection would continue over two winters for all participants in the various technology groups.

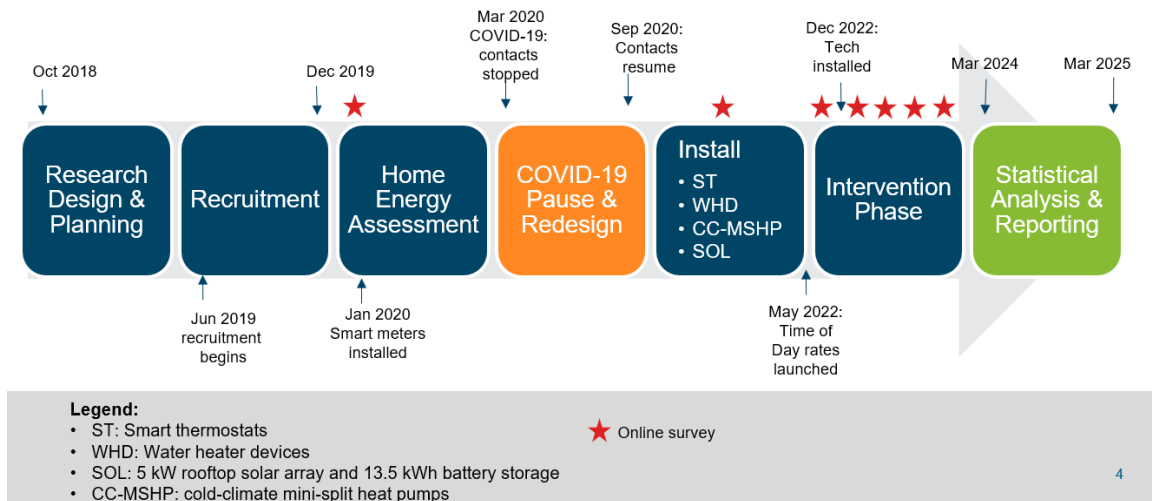


Figure 3. Timeline for the project.

The assignment of participants to the intervention phase research groups was an NRC responsibility. The team used stratified random assignment to balance these group assignments, using data from the first home assessment (HA1), survey 1, and household energy monitoring. This approach ensured equality between the groups in terms of several key attributes, including energy usage, peak demand, dwelling size, occupancy schedule, and household income. For technology assignments, HA2 results ensured that technologies were offered to participants with compatible homes.

Figure 4 shows the breakdown of participants and research groups. For greater detail, see Veitch et al. (2025a).

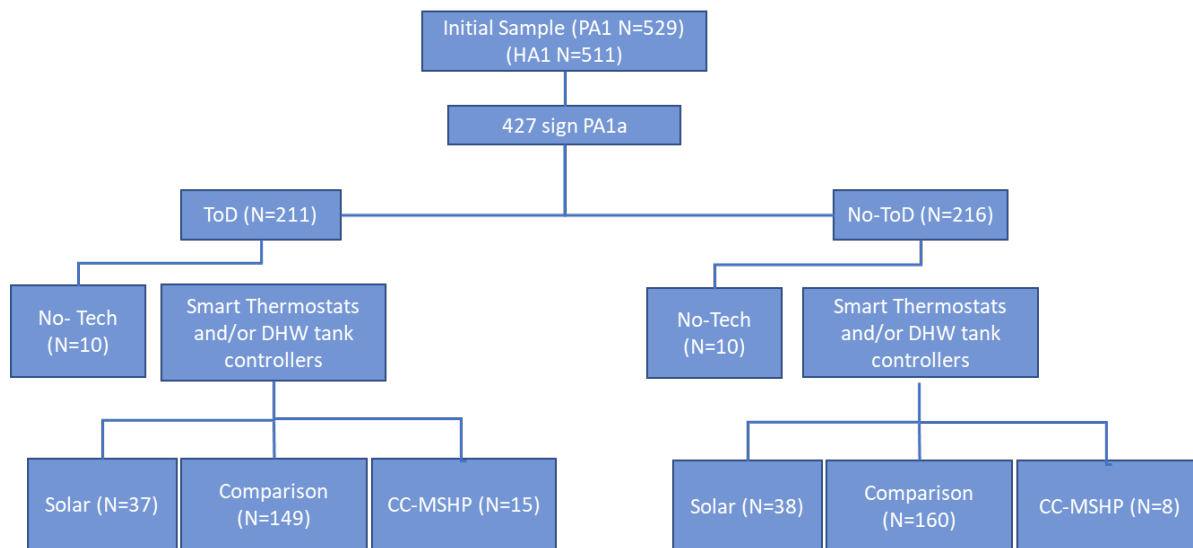


Figure 4. Research design showing the sample size for each research group

1.4 Interventions

1.4.1 TOD electricity rates intervention

Pardasani et al. (2025a) described this intervention in detail. The TOD rates tested in this project are shown in Table 3. The mid-peak rate was the flat rate charged to all New Brunswickers. The rate structure with the peak rate $\sim 2.25\times$ the mid-peak rate was chosen following extensive evaluation of various rate structure options by both NBP and NRC (Newsham, 2019) with the goal of achieving revenue neutrality for the utility under expected performance scenarios. The scenarios were modelled from data collected in an earlier project (Pardasani et al., 2018) and from smart meter data collected in the Shediach study. The rates increased in the second year of the trial together with the general increase in the approved flat rate for electricity on April 1, 2023. The TOD rate structure did not change as a result of this increase.

Table 3. The TOD electricity rates tested in this trial.

	Weekdays		Weekends and holidays	
	May 2022 – Mar. 2023	Apr. 2023 – Mar. 2024	May 2022 – Mar. 2023	Apr. 2023 – Mar. 2024
On-peak 7:00 – 9:00	\$ 0.2564	\$ 0.2752	\$ 0.1138	\$ 0.1215
Mid-peak 9:00 – 22:00	\$ 0.1138	\$ 0.1215		
Off-peak 22:00 – 7:00	\$ 0.0738	\$ 0.0784		

Each month, Time-of-Day (TOD) participants received shadow reports corresponding to their billing periods. Participants were billed for their electricity usage at the regular flat rate approved by the New Brunswick Energy & Utilities Board. However, if their shadow report indicated that a lower amount would have been charged based on their time-of-day usage, they received a corresponding credit on their monthly bill. Importantly, participants were not penalized if the bill would have been higher under the TOD rates.

TOD participants received information about how best to take advantage of the TOD rates (see Pardasani et al., 2025a). In fall 2022 this information was tailored to their primary heating system. Participants with electric baseboard heating or central electric furnaces were instructed to set back their thermostats at night, to preheat their homes by 1°C in the two hours before waking, and to set back their thermostats by 1°C from their preferred daytime setpoint during peak hours. In fall 2023, based on preliminary analysis of the preceding winter’s results, all participants were instructed to set their thermostats to a comfortable setpoint and not to change it (“set and forget”).

1.4.2 Cold-climate mini-split heat pump intervention

The originally planned test of a pre-market thermal storage heat pump gave way to a test of a high-efficiency cold-climate mini-split heat pump when it became clear that the original technology was not ready for widespread adoption. Participants received instead one CC-MSHP installed in one of the principal rooms of their homes. The selected CC-MSHP was rated with a COP of 2.13 at -25°C for the model with a capacity of 9,640 BTUh. Most homes received the 12,000 BTU capacity unit. Figure 5 shows how an exterior CC-MSHP unit might look.



Figure 5. This image shows an exterior view of an example CC-MSHP. Credit: NRC.

1.4.3 Solar PV and battery storage intervention

This intervention involved the installation of a 5kW rooftop solar photovoltaic panel array and a solar inverter with 13.5 kWh battery energy storage with maximum 5 kW charge or discharge rate (SOL) in the homes of compatible, and willing, participants. Figure 6 shows how the PV panels might look on a rooftop. Participants were compatible to the SOL group based on nine criteria, such as electrical service, space for equipment, WiFi, suitable roof conditions, and no whole-home generators. Other dwelling and household characteristics were balanced as best as possible with the other groups.

The SOL battery energy management system (BEMS) was programmed differently for the TOD and no-TOD groups. For the TOD group, BEMS were set up to use a time-based control strategy to take advantage of TOD rates by optimizing energy consumption and storage. For the no-TOD group the BEMS were programmed in resilience mode to provide power in case of an outage. Regardless of the battery mode, electricity production during the day served the home's demand first, and excess production (if any) was sent to the electricity grid. The SOL intervention included a solar energy credit (SEC) program through which participants were paid \$0.0487 per kWh for electricity exported to the electrical grid.



Figure 6. This AI-generated rendering shows conceptually how the rooftop PV panels would be installed.

1.5 Data sources

The data in CSV files were shared by NBP through their secure file transfer protocol (SFTP) server with the NRC. Figure 7 illustrates the data sources and data flows used to support various analyses. The data fall into the following categories:

- Device telemetry data from smart meters, smart thermostats, dispatchable water heater devices, and SOL data. The number of devices and time intervals is shown in Figure 7. A majority of homes had more than one smart thermostat installed by NBP; five was the maximum.
- Home assessments: Home assessment 1 (HA1) collected data on the type of building structure, vintage, the primary energy source for heating, type of heating system, and other attributes that affect energy performance and compatibility with the technologies. A subset of homes received a second home assessment (HA2) to verify compatibility with the solar PV and battery storage and/or the thermal storage technologies.
- Surveys: Participants completed seven surveys during the project. All surveys were conducted online by the NRC using a secure server located in Ottawa, Canada.
- Electricity bill settlement and project-related credits: The data reported for the bill settlement file were: meter reading date; number of days since last reading; monthly usage (kWh); dollar amount billed; on-peak usage (kWh); mid-peak usage (kWh); off-peak usage (kWh); on-peak cost (\$), mid-peak cost (\$); off-peak cost (\$); solar energy export (kWh); solar energy credit (\$); TOD credit (\$).
- DER dispatch: Homes in the SOL research group were dispatched through DERs interventions by Siemens Canada through their Energy System Platform (ESP) to evaluate their contribution to load shifting.

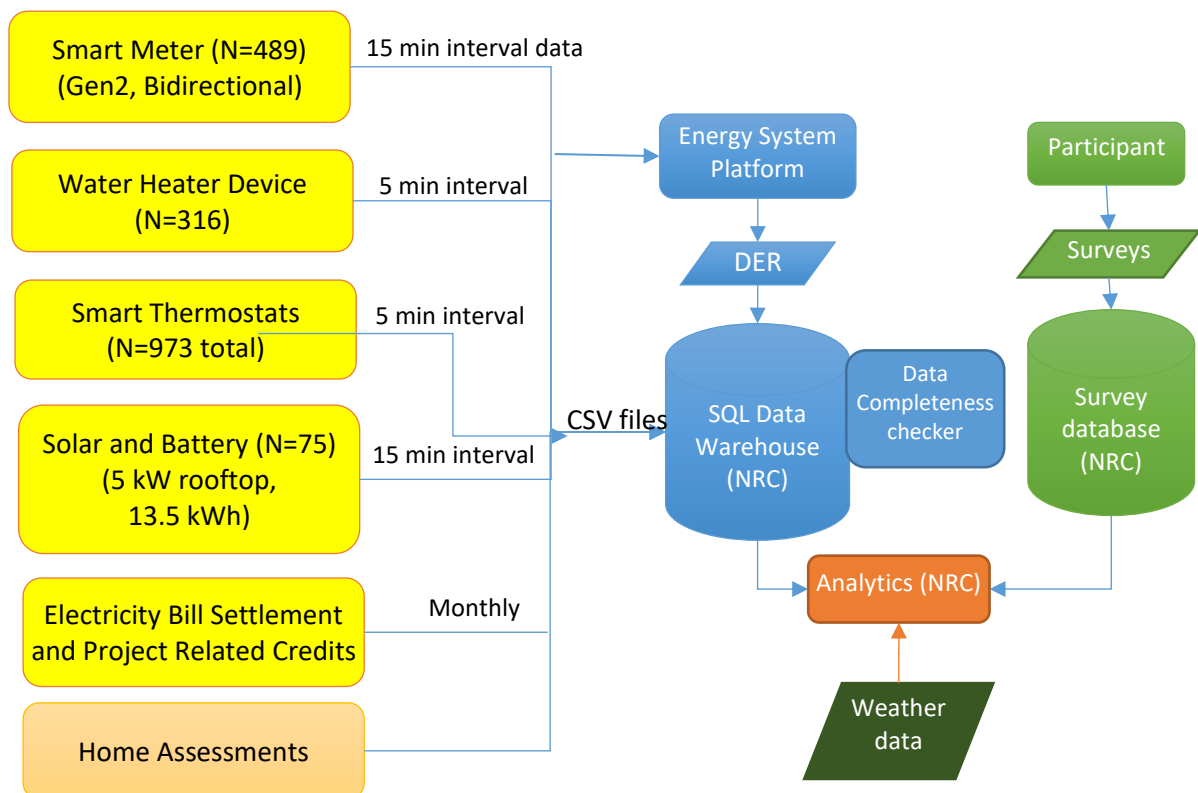


Figure 7. Data Sources and data flows

2 Key Findings

2.1 Solar PV and battery energy storage

Detailed results of the SOL test are found in Cooper et al. (2025).

2.1.1 Attitudes and perceptions

The majority of SOL participants reported high satisfaction with the overall project processes, including satisfaction with the installation process, technology performance, and the information about the technologies that were provided for them. They were satisfied with the project overall, and would recommend this technology to others, although there was evidence of opinions moderating after the initial post-installation enthusiasm. Many noted that they appreciated NB Power's support for renewable energy projects and valued the opportunity to participate in the study. Figure 8 summarizes the solar and battery storage program experiences.

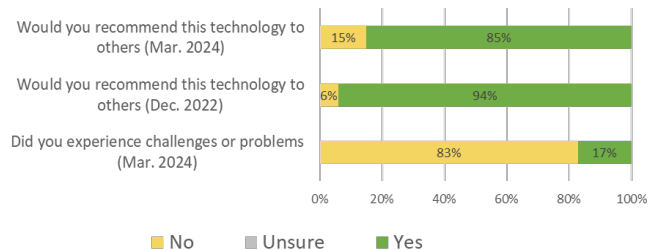


Figure 8. Survey responses about the solar and battery storage program experiences

Over 70% of survey respondents in December 2023 (at least one year after commissioning their systems) reported having viewed their Solar Energy Credit report, and of these 67% agreed or strongly agreed that the information on the report was clear and easily understood.

The lower environmental impact, higher energy efficiency, and increased resiliency that SOL technologies afforded were often cited as the main benefits of these technologies. In open-ended questions, participants shared that the availability of backup power was important to them, many of them citing its reliability during outages, protection of essential appliances, and peace of mind as the main advantages. In quantitative ratings, asked of the whole sample of participants, having backup power was rated as very important, with the median rating being 7 or higher on a scale of 0-9 (very unimportant to very important).

The actual cost to install a system like the one tested here was ~\$45,000, of which ~\$25,000 was for the battery energy storage, \$15,000 for the solar panels, and the remainder for installation costs. This contrasts sharply with the participants' willingness to pay for a solar PV or battery energy storage system, with a median value of \$1,500 to pay for a battery energy storage unit (without the solar PV). Of the participants without the solar PV + battery energy storage systems, nearly none reported the willingness (or ability) to purchase such a system without a financial incentive, with most reporting that the incentive would need to be at least 50% of the cost.

Despite many positive outcomes, the study also highlighted challenges, such as the perceived high initial costs and complexity of the systems, which deter broader adoption. Although most participants reported positive attitudes toward renewable technologies and valued their benefits, the calculated savings might not provide enough motivation to enable other customers to acquire such systems. Addressing these concerns through improved incentives and education could enhance user satisfaction and increase adoption rates.

2.1.2 System performance

On average, the solar PV installations for the Shediac study participants generated 5,958 kWh of energy annually per household with a median 5,990 kWh, a minimum 4,467 kWh, a maximum 7,352 kWh, and a standard deviation 718 kWh. The average annual usage was 20,829 kWh, with a median of 20,404 kWh, a minimum of 4,419 kWh, a maximum of 40,852 kWh, and a standard deviation of 8,108 kWh. On average, the solar generation accounted for 29% of the household load.

The dwellings in the Time-of-Day (TOD) group demonstrated a greater reduction in demand during peak hours, as their battery energy management systems were programmed to supply the maximum stored energy during this period. Additionally, the TOD group batteries were programmed for energy arbitrage, charging during off-peak hours at night for use during peak-rate periods.

In contrast to TOD group, the batteries for the no-TOD group were programmed for resilience, retaining their charge unless there was a power outage or a signal from NB Power (DER interventions from Siemens were not analyzed by the NRC). In the no-TOD group, solar generation was prioritized for household use, with any surplus energy being exported to the grid.

Data from the bi-directional meter and the SOL was analyzed to estimate the amount of energy shifted from peak hours (7 a.m. – 9 a.m.) to off-peak (10 p.m. – 7 a.m.), revealing a reduction of 6–7 kWh during peak hours and an increase of 12 kWh during off-peak hours. The increase during off-peak hours resulted from the battery charging from the grid to capitalize on energy arbitrage. Grid draw during mid-peak hours was reduced due to the on-site use of solar-generated energy and energy flows from the battery.

The average demand reduction for dwellings under the TOD group was 3.1 kW (74% of load) during weekday on-peak hours in Winter 2022, and 3.0 kW (75%) in Winter 2023. Converting these load shifts to dollar savings translate to savings of \$1.86 per day for Winter 2022 and \$1.93 per day for Winter 2023.

In Winter 2023, 7 kWh/day (37%) of solar energy and 11.7 kWh/day (63%) of grid energy were required to charge the battery energy storage unit to a usable state of charge for optimal peak reduction. Annually, the battery was charged 30% from solar energy and 70% from the grid for the TOD group. Energy arbitrage resulted in average savings of \$1.90 per day.

The annual grid energy draw for all participants without solar export under the TOD group was reduced by 16% (~3.5 MWh), while the no-TOD group saw a reduction of 9% (~2.0 MWh). When accounting for the solar energy export, the energy savings for both TOD and no-TOD groups were found to be nearly equal at 22% (~4.8 MWh). Figure 9 shows that although the reduction in grid draw across various seasons was nearly the same for TOD and no-TOD, participants under the TOD group reaped greater bill savings because of the control strategy.

Participants in the TOD group saved \$840 per year on average (combining lowered bills, TOD credits of \$337, and SEC credits of \$71), while those on the no-TOD rate structure saved \$460 per year on average (combining lowered bills and \$123 in SEC credits).

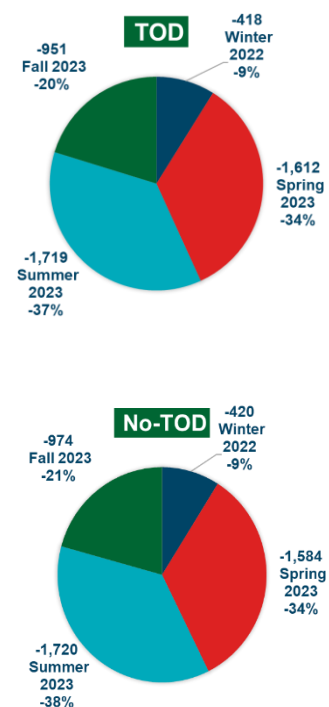


Figure 9. Seasonal grid draw for participants under TOD and no-TOD

GHG emissions were reduced for solar group participants through on-site use of renewable energy and export to the grid. Overall, the total annual estimated GHG emissions reduction for all 75 solar participants was 109.9 tCO₂e/year.

In total, the annual utility cost savings through avoided electricity generation for these 75 homes amounted to \$20,520. The analysis of battery operation modes indicates that the implementation of a time-based control strategy has significantly enhanced solar on-site usage, resulting in a 1.44-fold increase in utility cost savings (\$224.62/year for the no-TOD (backup reserve) group and \$323.91/year for the TOD (time-based control) group).

Concerning the TOD rate structure specifically, it appears that for the SOL participants, it was not revenue-neutral for NB Power, as it had been designed for a general load profile in the province. Considering the substantial costs associated with the TOD program and the dispatch signaling of battery energy storage units, it may be beneficial to develop a new rate structure specifically for devices such as electric vehicles and household battery energy storage units that charge during off-peak hours.

2.2 Cold climate mini-split heat pumps

CC-MSHP systems were awarded to 23 qualified dwellings with electric baseboard heaters and without heat pumps. Figure 10 presents a scatterplot comparing energy consumption relative to the outdoor temperature before and after the installation of the CC-MSHP, represented by red and blue dots respectively, for both the cooling and heating seasons. The x-axis represents average (mean) outdoor temperature, and the y-axis illustrates the average (mean) daily energy usage for the CC-MSHP group. Data points prior to the installation of the heat pump are generally higher on the plot. In contrast, post-installation data points tend to lower as temperatures drop, indicating increased energy savings at colder temperatures. Additionally, a small increase in energy use at warmer temperatures during summer suggests the use of air conditioning for comfort.

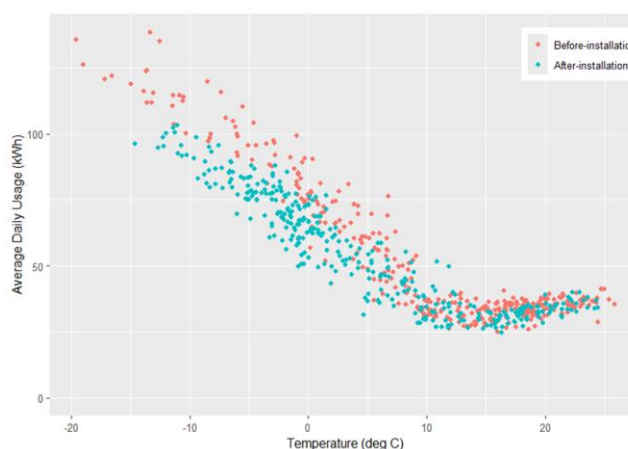


Figure 10. Average daily energy use before and after CC-MSHP installation (working days only)

Similar to the SOL, this technology group received two interventions concurrently, one in the form of a highly efficient heating system, and second from the TOD. To isolate the effect of each intervention we used a Difference-in-Differences (DiD) statistical model. In this model significant savings are realized in winter, with minimal savings in summer. This analysis demonstrated the conservation effect due to the technology intervention in form of annual energy savings of 9.5% for the working days during the experiment period and nearly 12% in winters irrespective of the TOD rates. TOD had an additional year-round energy savings of 4% (Hu et al., 2025).

Similarly, the morning peak demand was affected by both the technology intervention and Time-of-Day (TOD) rates. The DiD statistical model indicates demand reductions of 16.3% and 15.5% for the daily morning peak in winter 2022 and winter 2023, respectively, as a result of the technology intervention. Additionally, the TOD intervention led to reductions of 7.5% and 7.3% in the same periods. Notably, the reductions from both interventions are 4-5% higher during the morning (7-9 a.m.) compared to the 24-hour period, highlighting that both interventions effectively shift demand from on-peak hours to mid-

peak or off-peak hours.

With an average daily energy savings of 9.5% (5.2 kWh/household/day) through the year, the installation of the CC-MSHP is estimated to save an average household \$231.49 annually on electricity bills. Survey responses indicated a positive satisfaction level with the CC-MSHP, with a mean score of 2.8 out of 4 and a median score of 3, based on assessments conducted in March 2024.

The utility cost savings from the CC-MSHP system are attributed to reduced electricity usage for heating, which leads to avoided costs in electricity generation. For the one-year period from March 2023 to February 2024, these savings were estimated at \$153.29 per household. Across all 23 CC-MSHP installations, the total utility cost savings amounted to \$3,525.65.

Heat pumps operate most efficiently with the thermostat set at a constant temperature (Natural Resources Canada, 2022). If there is a temperature setback, depending on the model, there may be a period of increased demand to catch-up together with a lower-than-desired temperature that occupants may find uncomfortable. Consequently, both the manufacturer and project guidelines advised participants to 'set it and forget it.' Analysis of overnight setbacks from survey responses revealed that many participants with heat pumps continue to reduce their thermostat settings at night, although they set back less than participants without heat pumps. Interestingly, participants with CC-MSHP adjusted their thermostats similarly to those without heat pumps. A possible explanation is that prior to acquiring CC-MSHP, this group relied on electric baseboard heating, suggesting their previous habits might not have changed yet.

2.3 Time-of-Day rates

This section presents the results for the no-Tech research group, which includes all dwellings that did not receive SOL or CC-MSHP systems. Comprehensive details regarding the methodology and results are provided in Pardasani et al. (2025a).

The introduction of TOD rates led to a reduction in wintertime average morning peak demand across dwellings, though the savings depended on the type of heating system. For example, the no-Tech group as a whole saw a 3.3% reduction in morning peak demand in winter 2022, though this effect was not statistically significant in 2023 for the full sample. The people whose homes already had MSHP (a subset of no-Tech) saw a greater effect of TOD, with average morning peak demand reduced by 5.4% in winter 2022 and 3% in winter 2023.

Although TOD rates primarily target load shifting, they also encouraged energy conservation. The existing MSHP group with TOD achieved a 3.4% reduction in daily energy use during winter 2022 compared to the no-TOD group and 2.0% in 2023. A weaker conservation effect was also observed for the whole no-Tech (2.4%) group for 2022.

Survey responses indicated improved knowledge and awareness of TOD rates among participants. Most reported efforts to adapt to TOD pricing, despite minimal financial rewards.

At the end of the study, 80% of responding participants reported that if a TOD program were offered by NB Power, they would sign up for it. Of those who would not, 45% gave the reason “My daily schedule is complicated enough without changing it.” This was also the dominant reason given for not having tried to change their behaviours.

Participation in TOD programs is influenced by bill consequences. The analysis of bill settlement data for TOD participants not in the SOL research group shows few savings for most TOD participants. Average monthly TOD credits only appeared in the winters (Figure 11). When credits were paid, the dollar values were small, averaging at most \$1 per month per participant.

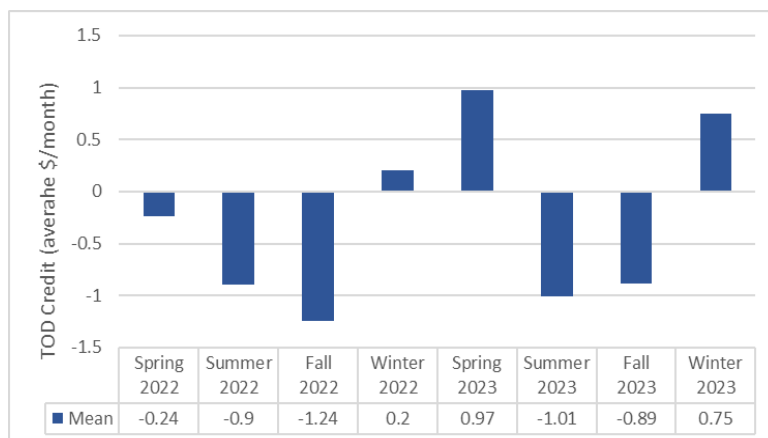


Figure 11. Average TOD credits, averaged over seasons, from the start to end of the intervention

The variability in TOD credits was very large, and the shadow reports showed some significant penalties, especially in Winter 2023 (-\$58) and Winter 2023 (-\$53). Some participants would have seen very large penalties had these been applied, as they used a large amount of electricity at on-peak rates. As mentioned earlier, when the TOD calculation resulted in a negative value there was no penalty for participants. Without protection against penalties, their total billing (over all no-Tech TOD participants) would have increased by \$5,538. During the TOD experiment from June 2022 to March 2024, no-Tech TOD participants received an aggregated sum of \$4,645 in bill credits. Had there been penalties applied, NB Power would have gained \$893 because of the TOD-related bill penalties.

ACEEE’s 2025 report by, Malinowski et al. emphasized the significance of utilities offering heat pump-specific electricity rate plans, such as winter-specific Time-of-Use (TOU) rate structures, to encourage the adoption of heat pumps. Heat pumps generally consume more electricity during nighttime off-peak periods, which coincide with the coldest temperatures and lower grid strain. TOU and demand-based rates can reduce energy bills for consumers by offering lower charges during these off-peak times when heat pumps are most active. Additionally, integrating heat pump installations with energy efficiency envelope upgrades can further reduce electricity bills. These types of rate plans tailored to heat pumps could simplify decision-making for customers, making them more appealing and accessible.

2.4 Summarizing customer credits

Although TOD and Solar Energy Credit programs help electric utilities to manage energy demand, promote renewable energy, and enhance customer satisfaction, there are costs to develop, design and roll out these programs. These program costs were outside the scope of this project, but would factor into developing new programs.

We analysed the credits paid by NB Power to participants using data in bill settlement files.

Table 4 shows the totals paid by NB Power in credits to participants for the TOD and SEC programs.

Table 4. The total amounts paid to participants as credits as a result of the TOD and SEC programs in this project, from June 1, 2022 to March 31, 2024.

	TOD credits	SEC
SOL	\$13,540	\$2,640
CC-MSHP	\$365	
no-Tech	\$4,645	

Conversely, programs that perform as intended should also achieve intended goals for the utility, including reducing the costs of generation or avoiding the need for new generating capacity. Analyzing these benefits is outside the scope of this project.

2.5 Energy behaviours and future intentions

Surveys throughout the project also probed participants' attitudes and beliefs about energy use and their motivations for their choices.

2.5.1 Thermostat use and occupant comfort

Telemetry data from smart thermostats installed by NB Power in 340 dwellings was analyzed by the NRC (Pardasani et al., 2025c). Participants expressed high satisfaction with the smart thermostats, with 90% of respondents indicating that they would recommend the devices to others.

The majority of participants who received smart thermostats reported that they chose their thermostat setpoints based on comfort. The desire for comfort was dominant among participants, while saving money on energy bills, though important, was secondary. Participants reported improved thermal comfort over the course of the study, suggesting that smart thermostats contributed positively to perceived comfort levels.

2.5.2 Utility control

There was moderate acceptance of utility control for environmental benefits, particularly among participants with strong biospheric and altruistic values. This indicates a potential alignment of utility programs with environmentally conscious participants.

2.5.3 Customer value

Overall satisfaction with NB Power among Shediak project participants was high, with a median value of 8 out of 10 in November 2023 and 7 out of 10 in March 2024. At the conclusion of the study in March 2024, the median overall satisfaction of participants with the project was 3 out of 4. Throughout the project, similar high ratings were given for satisfaction with project communications, service personnel, and responsiveness to technology problems.

Open-ended questions about how the project affected household energy use revealed that although there is willingness to adopt new technologies and behaviours to save energy, financial constraints and the need for more information and incentives play key roles in decision-making.

2.5.4 Future intentions

The Values-Beliefs-Norms model (Stern et al., 1999) is a popular tool for predicting how people intend to behave regarding the environment. When we applied this model to data from Shediak, it was well-supported by the results (Veitch et al., 2025b). Out of the four types of value orientations, participants most strongly embraced biospheric values, which focus on protecting the environment. On the other hand, they were less concerned with egoistic values, which means they did not prioritize personal gain to a large degree. Having a stronger focus on biospheric values, a belief that the benefits of energy

efficiency outweigh the costs, and a perception that most Canadians value environmental responsibility all predicted a higher likelihood of participants engaging in various energy-reducing behaviours in the future.

3 Conclusions

The Shediak Residential Energy Study has illuminated the transformative potential of smart energy technologies in residential settings. The project has revealed significant benefits in energy efficiency and consumer acceptance of interventions such as solar photovoltaic systems, battery energy storage, cold-climate mini-split heat pumps, and Time-of-Day (TOD) electricity rates. The study demonstrated that these technologies not only reduce peak demand and household energy consumption but also contribute to grid modernization and decarbonization efforts.

Participants expressed high levels of satisfaction with the project, especially with the environmental benefits and reliability provided by these technologies. However, challenges remain, particularly regarding the initial and operating costs, complexity, and customer education that may hinder wider adoption. To address these barriers, the study has underscored the need for both enhanced financial incentives and consumer education to demonstrate the real benefits to the consumer, society, and the planet. Messaging that connects with consumers' existing values and their sense of social responsibility could encourage more people to adopt these technologies, especially if financial incentives are available to make them more affordable.

The insights gained from this project serve as a valuable guide for future large-scale deployments of residential energy technologies and programs. They provide guidance for a balanced approach to technical innovation and consumer engagement.

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Appendix A - List of project reports and authors

A.1 Project reports

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