RESEARCH HIGHLIGHT

Arviat E/2 Northern Sustainable House Energy Consumption Performance Assessment

April 2016 Technical Series

INTRODUCTION

The Arviat E/2 Northern Sustainable House (E/2 NSH) was designed and built by the Nunavut Housing Corporation (NHC), with the participation of Canada Mortgage and Housing Corporation (CMHC) under CMHC's Northern Sustainable House initiative (see figure 1). The initiative involved the design and construction of four NSHs built in the territories to demonstrate highly energy-efficient, culturally appropriate housing models for the North. One of the design goals of the initiative was to use 50 per cent of the energy compared with the house had it been designed to the 1997 Model National Energy Code for Houses (MNECH) and built to the building code of the time.

The E/2 NSH is a one-storey, three-bedroom house with a heated area of 128 m^2 (1,376 sq. ft.). The design of the E/2 NSH includes a large cold storage area, a large room for sewing skins and a large open kitchen/living area for family gatherings, with bedrooms located immediately adjacent to this open area. The house has a high level of insulation with nominal RSI-9.1 (R-51.5) in the floor, RSI-8.0 (R-46) in the walls and RSI-11.6 (R-66) in the roof. It also achieved relatively low levels of air leakage. The space heating and domestic hot water is provided by an oil-fired boiler. Fresh air is supplied to the house, and exhaust air is drawn out of the house by a heat recovery ventilator.

Figure 1 Arviat E/2 NSH (image credit: Arctic Energy Alliance)

To assess the extent to which the design energy performance targets were achieved and to compare the performance of the house to that of other similar houses in Arviat, CMHC supported a project to assess the energy bills of the E/2 NSH and to compare it to those of three other similar houses constructed at roughly the same time.

METHODOLOGY

Billing data (fuel oil and electricity) was accessed and utilized to determine the performance of the constructed E/2 NSH compared to the house had it been built to the requirements of the 1997 MNECH to see if it achieved its intended energy consumption objectives. The actual energy use of the E/2 NSH was also compared to its original design energy targets and the as-built targets as estimated by Natural Resources Canada's HOT2000 residential energy consumption simulation software. Fuel oil and electricity consumption and costs were characterized on a monthly and annual basis, and the energy end uses and heat loss points were also estimated.

A further investigation was conducted comparing the E/2 NSH energy consumption to three similar houses; one with an identical floor plan layout and mechanical system but with a building envelope made of structurally insulated

panels (SIP) (referred to as the "E/2 SIP" house), and other two SIP houses with different floor plan layouts and different SIP envelopes (known as the "NHC SIP A" or "NHC SIP B" houses). The main energy performance-related details of the four houses are provided in table 1.

FINDINGS

Energy consumption of E/2 NSH versus target

The results of the assessment of the E/2 NSH against its MNECH target are shown by the first and third columns in figure 2. E/2 NSH consumed 14 per cent less energy instead of the 50 per cent targeted. While the exact reasons for the discrepancy are difficult to determine given the limited information provided by the utility bill analysis, possible factors include:

- the difference in the number of occupants. The target energy model assumed 4 persons while the occupant survey found that 10 people were living in the house. This would increase hot water usage and electrical loads;
- the E/2 NSH house was constructed with an external sewage tank that has to be heated from the oil-fired hot water system to prevent freezing. The original target model did not include this feature; and
- differences in assumed weather conditions used in the target energy model versus actual weather conditions experienced during the period for which the utility bills were available.

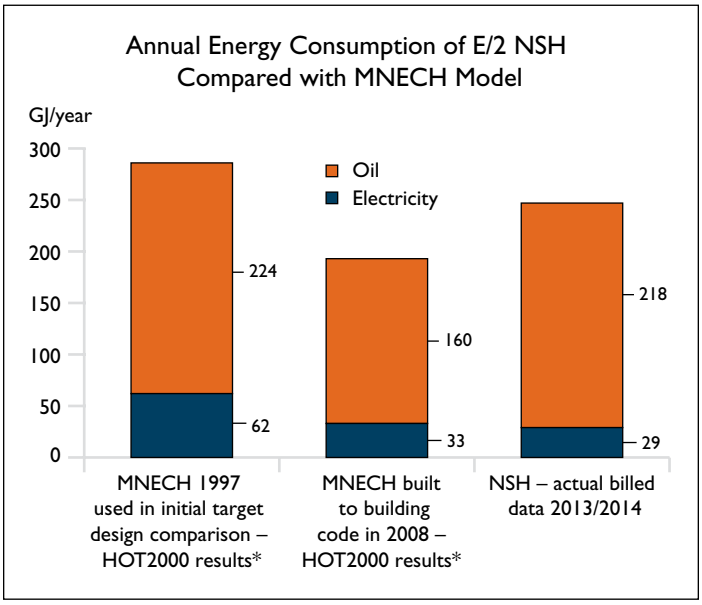

Figure 2 Actual energy consumption of E/2 NSH compared with MNECH

Table 1 Comparison of four houses included in the study

	Heated floor area	Floor insulation (effective)	Wall insulation (effective)	Ceiling/roof insulation (effective)	Mechanical systems	Occupants
E/2 NSH	127.8 m² (1,376 sq. ft.)	R-49 (RSI-8.6)	R-36 (RSI-6.3)	R-61 (RSI-10.7)	Oil-fired boiler (86.5% rated AFUE) Indirect hot water from boiler Heat recovery ventilator (HRV) External hydronic heating line for sewage tank	5 adults 5 children
E/2 SIP	127.8 m² (1,376 sq. ft.)	R-44 (RSI-7.8)	R-44 (RSI-7.8)	R-72 (RSI-12.7)	Oil-fired boiler (86.5% rated AFUE) Indirect hot water from boiler HRV External hydronic heating line for sewage tank	2-3 adults 4 children
NHC SIP A and B	118 m² (1,277 sq. ft.)	R-50 (RSI-8.8)	R-40 (RSI-7.0)	R-50 (RSI-8.8)	Oil-fired boiler (85.3% rated AFUE) Indirect hot water from boiler HRV Heated crawl space	2 adults 5-7 children (in each unit)

Energy consumption of E/2 NSH versus other benchmark houses

Figure 3 compares the energy performance of the E/2 NSH, and the three other houses. The E/2 SIP house had higher electrical loads than the E/2 NSH, and this may have been due to the use of an electric heater in the E/2 SIP house.

The higher fuel oil consumption of the E/2 NSH may have been due to lower insulations levels in the ceiling and floor and higher occupancy-related hot water loads relative to the E/2 SIP house. Although this may explain some of the differences in energy performance, the researchers noted potential problems with the fuel oil billing data for the E/2 SIP house that could have undermined the analysis.

On a per area basis, the E/2 NSH consumed 9 per cent and 16 per cent more energy overall compared with the NHC SIP A and B houses respectively, with most of that being from an increase in space and water heating energy consumption. The E/2 NSH has higher insulation values in the roof and walls but lower in the floor compared with the NHC SIPs and has a larger overall floor area. The E/2 NSH's external hydronic heating lines that warm the sewage tank to prevent freezing could have also added to the difference in fuel oil consumption (the NHC SIP houses sewage tanks are located in heated crawl spaces).

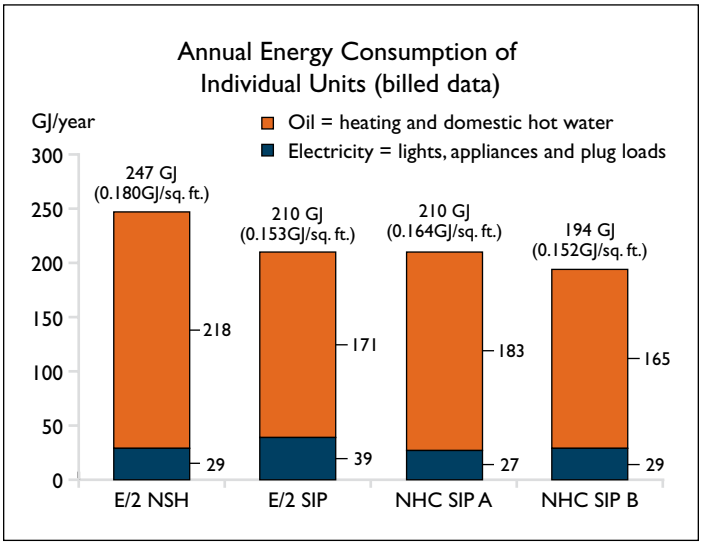

Figure 3 Comparison of annual energy consumption for the E/2 houses and the NHC SIP houses

Fuel oil and electricity consumption and costs

The cost of heating fuel in Arviat was $1.176/l during the period of time analyzed. The annual fuel oil consumption and costs for the four houses is shown in figure 4.

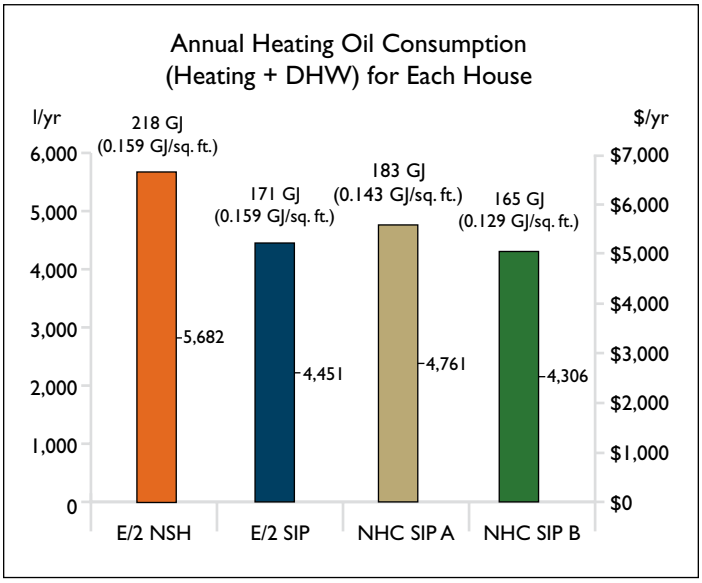

Figure 4 Annual heating oil consumption of the E/2 NSH, the E/2 SIP and the NHC SIP houses

Airtightness of E/2 NSH

The air leakage characteristics of the E/2 NSH were measured with a blower door test pre-drywall on February 7, 2013, and post-drywall on March 15, 2013. The results are shown in table 2. As a point of comparison, to meet the R2000 standard, the air change rate at 50 pascals (Pa) must be less than 1.5 ACH (air change per hour), a performance level achieved by E/2 NSH.

Table 2 Blower door test results for E/2 NSH

E/2 NSH unit pre-drywall	E/2 NSH unit post-drywall
ACH: 1.44 at 50 Pa	ACH: 1.42 at 50 Pa
ELA: 162.58 cm^2 at 10 Pa	ELA: 147.10 cm^2 at 10 Pa

Electricity consumption

The electricity used in the houses was metered by a dedicated meter and billed to the housing corporation with a portion being billed to the tenants. The price was $0.79/kWh with an $18 base charge (May 2014). The occupants paid a subsidized rate of $0.06/kWh. Electricity consumption data for lights, appliances, equipment and plug loads from the billing data was available for October 2013 to October 2014 and is presented in figure 5.

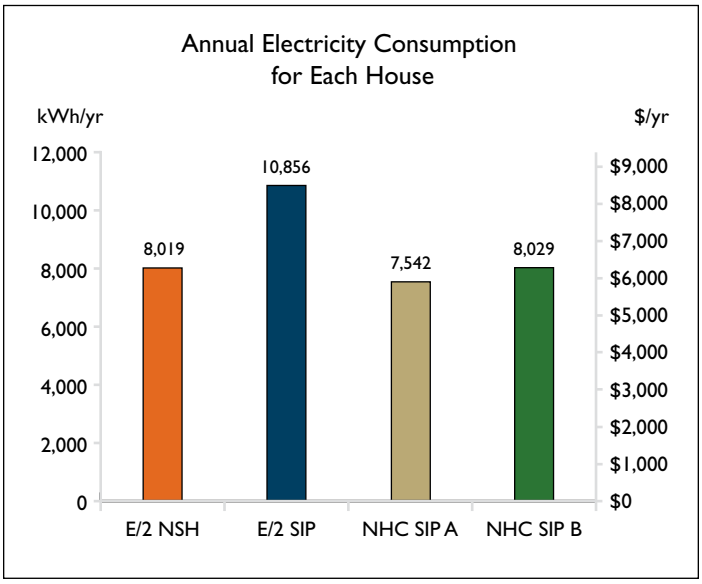

Figure 5 Annual electricity consumption of the E/2 NSH, the E/2 SIP and the NHC SIP houses

The E/2 NSH used 35 per cent less electricity than the E/2 SIP house and 6 per cent more and 1 per cent less than the NHC SIP A and B houses respectively. The higher consumption in the E/2 SIP house may have been due to the use of an electric heater in the cold porch.

Indoor air quality

During the interviews with the occupants, spot measurements of temperature, relative humidity and carbon dioxide were taken as well as thermostat readings (see table 3).

While the indoor temperatures and relative humidity levels were within acceptable limits, the $C0_2$ levels in the E/2 SIP unit were over double recommended levels. The reasons for this level were not diagnosed as part of this study.

CONCLUSIONS

Although the E/2 NSH project did not meet its original design target, its as-built EnerGuide rating system of 85 would put this house in the same category as some of the most energy-efficient new houses currently on the Canadian market. Though the scope of the project made it difficult to determine the reason for the discrepancy between targeted and actual performance, the differences in actual versus modelled assumptions pertaining to occupancy, installed energy consuming equipment (sewage system antifreezing system), energy loads and usage could have contributed to much of the difference. The occupants appeared to be generally satisfied with the layout and performance of the house though cold spots and dry air were noted.

Implications for the Northern housing industry

This project demonstrated that energy-efficient and culturally appropriate houses can be delivered in Canada's North. It also showed that achieving targeted design performance not only involves good design and best construction practices, it also involves understanding and planning for post-occupancy operation of the house. Active monitoring of energy and water consumption, along with key indoor air quality indicators, for the first year post-occupancy, can provide valuable feedback to housing providers and occupants on how to identify and fix problems, optimize performance and better manage operating costs.

Table 3 Spot measurements taken during occupant interviews

Spot measurements	Kitchen			Bedroom			All zones	Outdoor*	
Unit	Air Temp	RH	CO_2	Air Temp	RH	CO_2	Thermostat Settings	Air Temp	RH
E/2 NSH	21°C	25%	935 ppm	21°C	24%	880 ppm	23°C	-22°C	72%
E/2 SIP	23°C	33%	2776 ppm	21°C	34%	2723 ppm	22-23°C	-22°C	72%
NHC SIP A	24°C	25%	1279 ppm	23°C	24%	1164 ppm	23-24°C	-22°C	72%
NHC SIP B	21°C	25%	695 ppm	21°C	24%	562 ppm	21°C	-22°C	72%

*Outdoor temperatures and relative humidity taken from Environment Canada (2015)

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Alternative text and data for figures

Figure 2 Annual energy consumption of E/2 NSH compared with MNECH model

	MNECH 1997 used in initial target design comparison – HOT2000 results*	MNECH built to building code in 2008 – HOT2000 results*	Targeted design of NSH in 2008 – HOT2000 results	NSH as-built design – HOT2000 results	NSH – actual billed data 2013/2014
Heating oil energy use (GJ)	224.5	159.7	70.3	75.7	218
Electrical energy use (GJ)	62.4	33.3	37.7	33	29
Total (GJ)	286.9	193	108	108.7	247
% energy used compared with MNECH 1997		67%	38%	38%	86%

* The MNECH built to building code in 2008—HOT2000 results were used for comparison in the *Arviat Design and Construction* report (Canada Mortgage and Housing Corporation, 2014). However the initial design of the NSH was targeted compared with a house built to MNECH 1997 using 1997 standards.

Figure 3 Annual energy consumption of individual units (billed data)

Unit	Gigajoules of electrical energy used (GJ/yr)*	Gigajoules of heating oil energy used (GJ/yr)**	Total gigajoules of energy used (GJ/yr)	Gigajoules per square foot of heated floor space (GJ/sq. ft.)
E/2 NSH	29	218	247	0.180
E/2 SIP	39	171	210	0.153
NHC SIP A	27	183	210	0.164
NHC SIP B	29	165	194	0.152

* Electricity = lights, appliances and plug loads

** Oil = heating and domestic hot water

Figure 4 Annual heating oil consumption (Heating + DHW) for each house

Unit	Heating oil use in litres (l/yr)	Cost of heating oil used ($)	Square footage of the unit (sq. ft.)	Gigajoules of heating oil energy used (GJ)	Gigajoules of energy used per square foot (GJ/sq. ft.)
E/2 NSH	5,682.4	6,755.18	1,376	218	0.159
E/2 SIP	4,451.1	5,191.94	1,376	171	0.124
NHC SIP A	4,761.9	5,640.79	1,277	183	0.143
NHC SIP B	4,305.8	5,079.97	1,277	165	0.129

Figure 5 Annual electricity consumption for each house

Unit	Electricity use in kWh/yr	Cost of electricity used ($)	Square footage of the unit (sq. ft.)
E/2 NHS	8,019	6,176.99	1,376
E/2 SIP	10,856	8,113.08	1,376
NHC SIP A	7,542	5,836.59	1,277
NHC SIP B	8,029	6,161.13	1,277