# RESEARCH REPORT

CMHC EQuilibrium™
Sustainable Housing Demonstration Initiative
EchoHaven Project
One Year Monitoring Report

Canada

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CMHC EQuilibrium™ Sustainable Housing Demonstration Initiative EchoHaven Project One Year Monitoring Report

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EXECUTIVE SUMMARY

The EchoHaven project, in Calgary, Alberta, was a winning entry in Canada Mortgage and Housing Corporation's (CMHC's) EQuilibrium™ Sustainable Housing Demonstration Initiative. The objective of the builder-developer, Echo-Logic Land Corporation, was to design and build a grid-connected home that produced approximately as much energy as it consumed in a year (i.e.; a near net-zero energy home) which also featured a healthy indoor environment, low environmental impact, significant resource conservation, and affordability considerations. In addition, the project is part of a 25 building lot development, envisioned as a sustainable community, by Echo-Logic Land Corporation Ltd.

An important aspect of the EQuilibrium™ Housing Initiative was that each project undergo one year of performance monitoring once occupied. The goal was to assess the extent to which certain performance targets of each project were met – particularly with respect to their energy consumption and renewable energy generation, water consumption and indoor environmental quality. Such information is important as it provides valuable feedback to the project teams and other industry stakeholders seeking information and guidance on approaches to sustainable housing projects.

The performance indicators monitored (or measured) in each project included:
- Space heating, domestic hot water heating energy, and mechanical ventilation energy requirements;
- Photovoltaic electricity, solar thermal hot water and ground source heat pump hot water production;
- Air-tightness (pre-drywall and post construction);
- Thermal comfort – indoor temperature and relative humidity;
- Indoor Environmental Quality (IEQ) – carbon dioxide (CO_2), radon, total volatile organic compounds (TVOCs) and formaldehyde concentrations;
- Hot and cold water consumption.

CMHC contracted with the Saskatchewan Research Council (SRC) to gather and analyse the performance information from the projects. Monthly readings of total electricity consumption (EchoHaven does not consume fuel) as well as the key electricity end-uses in the EchoHaven project (space and domestic hot water heating and ventilation energy) were taken by a local subcontractor. The remaining electricity use in the house was attributed to appliance, lighting and other electrical equipment use and was represented by the difference between the total electricity consumption and the monitored electricity end-use point. The thermal comfort conditions were assessed through continuous measurements of indoor temperature and relative humidity. Indoor environmental quality of the house was assessed with continuous CO_2

concentration measurements taken over the monitoring year, as well as periodic measurements of formaldehyde, radon and TVOCs. The volume of the total water supply, outside water for irrigation, and domestic hot water were also recorded over the year.

Actual measured performance indicators from the monitoring period were compared to both the targets developed by the project team at the design stage and to those estimated by an "adjusted" performance model of the house prepared by SRC. Natural Resources Canada's (NRCan's) HOT2000 and RETScreen software were used for the predictions. The adjusted performance model took into account the as-built characteristics of the house, actual occupancy and actual measured weather conditions (temperature and solar insolation) during the monitoring period. The reported performance monitoring period was from October 6, 2011 to October 5, 2012.

Over the monitored year, the total measured annual energy consumption of EchoHaven was 9,369 kWh, or 41.6 kWh /m^2 of heated floor area, which was only 93% of the 10,062 kWh (44.7 kWh/m^2) predicted by the adjusted model. In contrast, based on Natural Resources Canada (NRCan) energy evaluations, the average predicted energy use of 1,945 houses constructed across Canada between 2007 and 2009 (i.e. the period in which the majority of EQuilibrium™ projects were under or completed construction), was 150.4 kWh/m^2, i.e. 3.6 times the measured annual energy consumption of EchoHaven. When the entire Canadian residential single detached housing stock is taken into consideration, the average annual energy consumption value is greater, i.e. in the range of 220 kWh/m^2. The relatively small energy requirements of EchoHaven are due to the design and construction of an air-tight, well insulated building envelope, which reduces space heating energy consumption, as well as more efficient water heating, mechanical systems, appliances and lighting.

With respect to various aspects of annual energy consumption, the measured space heating consumption was 3,837 kWh, 95% of that predicted (4,042 kWh), and the measured domestic hot water (DHW) heating requirement was 1,716 kWh, only 66% of that predicted (2,597 kWh).

The calculated consumption for appliances and lighting, and the measured consumption of the mechanical ventilation totalled 3,816 kWh, 11% more than predicted by the adjusted model (3,424 kWh).

The homeowner's absence during a winter vacation may be a factor contributing to the overall measured energy consumption being less than predicted.

The total measured annual renewable energy production was 9,028 kWh, slightly more (1.5%) than that predicted (8,890 kWh) by the adjusted model. The renewable energy produced by the

photovoltaic system over the year was 7,934 kWh, 10% more than predicted (7,234 kWh). The measured renewable energy production by the solar thermal system over the year was 1,094 kWh, only 66% of that predicted (1,656 kWh). One factor that may contribute to this discrepancy is that the modelling software used to predict the sole energy production (RETScreen) is not designed to model a combination space and water heating system, which was the case at EchoHaven.

The net annual energy consumption for a home can be calculated by combining the annual energy consumption and renewable energy generation values. A "net-zero energy home" would mean that the home generates as much energy as it consumes on an annual basis. EchoHaven had an original targeted net annual energy surplus of 322 kWh. The adjusted model predicted a net energy requirement of 1,172 kWh and the measured net annual energy consumption was 341 kWh over the year of monitoring. Thus while the actual net annual energy balance was one of consumption rather than the surplus targeted in the proposal, the net consumption was only 29% of that predicted by the adjusted model. Based on the NRCan sample referred to above an average Canadian home of similar size built in the same time period as the construction of the EQuilibrium™ projects would be expected to consume in the range of 33,840 kWh in a year, i.e. approximately 99 times the EchoHaven net annual consumption over the monitoring period.

The significance of, and reasons for the discrepancies between the original design energy performance targets, adjusted energy performance targets and measured performance values are discussed in the report. In summary, the primary reasons for the differences between the targeted and actual energy performance include modelling limitations and occupant-related energy use, the latter being a major factor impacting energy use in highly energy efficient homes.

A final blower door air leakage test was conducted at EchoHaven after the drywall was installed. It indicated an air change rate of 1.04 air changes per hour (ACH) at 50 Pascals. This is well within the allowable limit of the Canadian R-2000 standard for energy efficient house construction of 1.5 ACH.

The results of the indoor environmental quality testing indicated levels of formaldehyde and radon within the Health Canada guidelines and total volatile organic compound concentration within Health Canada's 'target' levels. The home was fitted with an active soil depressurization radon mitigation system.

Continuous measurements of temperature, relative humidity, and CO_2 concentration were taken for the 15 month period May 5, 2011 to August 5, 2012.   While recorded temperatures approached 30^0 C in the summer months (possibly due to a combination of the location of the recording device - the loft under the vaulted ceiling, and the solar gain through adjacent south

facing windows) temperatures where generally in the low to mid 20s.   Relative humidity and CO_2 levels were acceptable.

Total water use in the house and for outside use was 73.3 m^3 (66.3 m^3 potable water and 7.0 m^3 harvested rainwater, the latter used for toilet flushing and rainwater harvesting) during the year of monitoring. This equates to approximately 100 L/day/person, 30% of the average national per capita water use of 329 L/day/person. Considering only potable water (treated water delivered by the utility) the consumption would be 91 L/day/person, 28% the national average.

In summary, the one year of monitoring of the performance of EchoHaven showed that it met the objectives of the EQuilibrium™ Housing Initiative. While EchoHaven did not achieve the net energy production targeted in the proposal, it achieved a very low net energy consumption far outperforming conventional housing built in the same era.

RÉSUMÉ

La maison EchoHaven, construite à Calgary, en Alberta, fut un concept retenu dans le cadre de l'Initiative de démonstration de maisons durables EQuilibrium^MC de la Société canadienne d'hypothèques et de logement (SCHL). L'objectif du promoteur-constructeur, Echo-Logic Land Corporation, était de concevoir et de construire une maison raccordée au réseau produisant à peu près autant d'énergie qu'elle en consommerait en un an (c'est-à-dire une maison à consommation énergétique nette de près de zéro), qui se caractériserait également par son milieu de vie sain, son faible impact sur l'environnement, son importante capacité à conserver les ressources et son abordabilité. De plus, la maison fait partie d'un aménagement de 25 immeubles d'Echo-Logic Land Corporation Ltd. qui a comme vision d'en faire une collectivité durable.

Dans le cadre de l'Initiative des maisons EQuilibrium^MC, il fallait que la performance de chaque maison soit soumise, une fois habitée, à un suivi étalé sur un an. Le but de ce contrôle était d'évaluer dans quelle mesure certaines cibles de rendement étaient atteintes, en particulier au chapitre de la consommation d'énergie, de la production d'énergie renouvelable, de la consommation d'eau et de la qualité du milieu intérieur. De telles données sont essentielles pour fournir une rétroaction utile aux équipes de projet et autres intervenants de l'industrie qui ont besoin de renseignements et d'un encadrement sur l'approche à adopter pour des projets de logements durables.

Les indicateurs de performance contrôlés (ou mesurés) dans chaque maison comprenaient notamment :
- les besoins énergétiques pour le chauffage des locaux, le chauffage de l'eau chaude domestique et la ventilation mécanique;
- la production d'électricité photovoltaïque, d'eau chaude par énergie solaire thermique et d'eau par pompe géothermique;
- l'étanchéité à l'air (avant la pose des plaques de plâtre et après l'achèvement);
- le confort thermique : température intérieure et humidité relative;
- la qualité du milieu intérieur : concentrations de dioxyde de carbone (CO_2), de radon, de composés organiques volatils totaux (COVT) et de formaldéhyde;
- la consommation d'eau chaude et froide.

La SCHL a conclu une entente avec le Saskatchewan Research Council (SRC) pour recueillir et analyser les données sur le rendement des maisons. Des lectures mensuelles de consommation totale d'électricité (la maison EchoHaven ne consomme aucun combustible), ainsi que des principales utilisations électriques finales de la maison EchoHaven (consommation d'énergie pour la ventilation et pour le chauffage des locaux et de l'eau chaude domestique), ont été effectuées par un sous-traitant local. La consommation restante de la maison a été attribuée aux

électroménagers, à l'éclairage et à l'utilisation d'autres appareils électriques; elle est exprimée par la différence entre la consommation électrique totale et le relevé des utilisations électriques finales. Les conditions de confort thermique ont été évaluées au moyen de lectures continues de la température et de l'humidité relative intérieures. La qualité du milieu intérieur de la maison a été évaluée par des lectures continues de la concentration de CO_2 sur la période de suivi d'un an, ainsi que par des mesures périodiques des concentrations de formaldéhyde, de radon et de COV totaux. L'approvisionnement en eau, l'eau utilisée pour l'irrigation extérieure et la consommation d'eau chaude domestique ont également été totalisés au cours de l'année.

Les indicateurs de rendement effectivement mesurés au cours de la période de suivi ont été comparés à la fois aux cibles élaborées par l'équipe de projet lors de la conception et aux estimations fournies par le modèle de rendement « rajusté » tel que préparé par le SRC. Les logiciels HOT2000 et RETScreen de Ressources naturelles Canada (RNCan) ont servi à établir les prévisions. Le modèle de rendement rajusté tenait compte des caractéristiques de la maison telle que construite, de son occupation réelle et des conditions météorologiques effectivement mesurées (température, insolation) pendant la période de suivi. La période déclarée de suivi du rendement s'est étendue du 6 octobre 2011 au 5 octobre 2012.

Au cours de l'année de suivi, la consommation énergétique totale annuelle mesurée de la maison EchoHaven a atteint 9 369 kWh, ou 41,6 kWh/m^2 de surface de plancher chauffée, ce qui représentait seulement 93 % du résultat de 10 062 kWh (44,7 kWh/m^2) prévu par le modèle rajusté. Par comparaison, selon les évaluations énergétiques de Ressources naturelles Canada (RNCan), la consommation énergétique moyenne prévue pour les 1 945 maisons construites au Canada entre 2007 et 2009 (période pendant laquelle la majorité des maisons EQuilibriumMC étaient en chantier ou achevées) était de 150,4 kWh/m^2, soit environ 3,6 fois la consommation énergétique annuelle mesurée de la maison EchoHaven. Lorsqu'on se rapporte à l'ensemble du parc résidentiel canadien de maisons individuelles, la consommation énergétique annuelle moyenne est supérieure, soit de l'ordre de 220 kWh/m^2. Les besoins énergétiques relativement faibles de la maison EchoHaven sont attribuables à la conception et à la construction d'une enveloppe de bâtiment étanche à l'air et bien isolée qui permet de réduire la consommation d'énergie pour le chauffage des locaux, ainsi qu'à l'amélioration de l'efficacité du chauffage de l'eau, des installations mécaniques, des électroménagers et des appareils d'éclairage.

Pour ce qui est des divers aspects de la consommation énergétique annuelle, la consommation mesurée pour le chauffage des locaux s'élevait à 3 837 kWh, soit 95 % de la valeur prévue (4 042 kWh). Quant à la consommation mesurée pour le chauffage de l'eau, elle était de 1 716 kWh, soit seulement 66 % de la valeur prévue (2 597 kWh).

La consommation calculée pour les électroménagers et l'éclairage, ainsi que celle mesurée pour la ventilation mécanique, s'élevaient à 3 816 kWh, soit 11 % de plus que celle prévue par le modèle rajusté (3 424 kWh).

L'absence du propriétaire pendant les vacances d'hiver pourrait avoir contribué à ce que la consommation d'énergie totale mesurée soit inférieure à celle prévue.

La production annuelle d'énergie renouvelable totale mesurée a atteint 9 028 kWh, légèrement plus élevée (1,5 %) que celle prévue (8 890 kWh) par le modèle rajusté. L'énergie renouvelable produite par le système photovoltaïque au cours de l'année était de 7 934 kWh, soit 10 % de plus que la prévision (7 234 kWh). La production d'énergie renouvelable mesurée du système solaire thermique pendant l'année était de 1 094 kWh, seulement 66 % de celle prévue (1 656 kWh). L'un des facteurs qui a pu contribuer à`cet écart est que le logiciel de modélisation utilisé pour prévoir la production d'énergie uniquement (RETScreen) n'est pas conçu pour modéliser un système de chauffage des locaux et de l'eau combiné, ce qui était le cas pour EchoHaven.

La consommation énergétique annuelle nette d'une maison peut être calculée en combinant les valeurs annuelles correspondant à l'énergie consommée et à l'énergie renouvelable produite. Une maison « à consommation énergétique nette zéro » produit annuellement autant d'énergie qu'elle en consomme. À l'origine, les concepteurs de la maison EchoHaven visaient un surplus énergétique annuel net de 322 kWh. Le modèle rajusté prévoyait des besoins énergétiques nets de 1 172 kWh, alors que la consommation d'énergie nette a été mesurée à 341 kWh au cours de l'année de suivi. Ainsi, bien que bilan énergétique annuel net affichait un déficit au lieu du surplus ciblé par la proposition, la consommation nette n'était que de 29 % de celle prévue par le modèle rajusté. Même si les besoins énergétiques annuels nets se sont révélés supérieurs aux valeurs ciblées dans la proposition et estimées par le modèle rajusté, on s'attendrait à ce qu'une maison canadienne moyenne de taille similaire construite pendant la même période que celles bâties dans le cadre de l'initiative EQuilibriumMC consomme autour de 33 480 kWh par année, selon l'échantillon de RNCan susmentionné, soit environ 99 fois la consommation annuelle nette de la maison EchoHaven observée pendant la période de suivi.

Le rapport fait état de l'importance des écarts constatés entre les cibles de rendement énergétique du concept initial, les cibles rajustées et la performance mesurée et propose des raisons pour les expliquer. En bref, les principaux facteurs qui expliquent les divergences entre le rendement ciblé et le rendement réel ont trait notamment aux limites de la modélisation et aux habitudes de consommation d'énergie des occupants, ces dernières ayant une incidence majeure sur la consommation énergétique dans les maisons hautement éconergétiques.

Un test final d'infiltrométrie après l'installation des plaques de plâtre a été effectué et indiquait un taux de renouvellement d'air par heure (RA/h) de 1,04 à 50 pascals. Cette valeur est bien en deçà de la norme canadienne R-2000 de 1,5 RA/h pour la construction de maisons éconergétiques.

Les résultats des tests de qualité du milieu intérieur ont indiqué des niveaux de formaldéhyde et de radon inférieurs aux limites de Santé Canada et des concentrations en composés organiques volatils totaux inférieures aux niveaux cibles de ce même organisme. La maison a été dotée d'un système actif d'atténuation du niveau de radon par dépressurisation du sol.

Les mesures constantes de la température, de l'humidité relative et de concentration de CO_2 ont été prises sur une période de 15 mois, soit du 5 mai 2011 au 5 août 2012. Bien que les températures approchaient les 30 ^{0}C durant les mois d'été (possiblement en raison d'une combinaison de l'emplacement des dispositifs d'enregistrement – le loft sous le plafond à voûtes et le gain solaire par les fenêtres orientées au sud), les températures se situaient généralement entre 20 et 25 ^{o}C. L'humidité relative et les niveaux de CO_2 étaient acceptables.

Durant l'année de suivi, la consommation totale d'eau dans la maison et à l'extérieur était de 73,3 m^3 (66,3 m^3 d'eau potable et 7,0 m^3 d'eau de pluie recueillie et utilisée pour la chasse de la toilette). Cela équivaut à environ 100 L/jour/personne, soit 30 % de la consommation d'eau moyenne nationale par habitant de 329 L/jour/personne. En ne tenant compte que de l'eau potable (eau traitée distribuée par le service public), la consommation serait de 91 L/jour/personne, soit 28 % de la moyenne nationale.

En résumé, l'année de suivi de la performance de la maison EchoHaven a montré que celle-ci atteignait les objectifs de l'Initiative des maisons EQuilibrium^{MC}. Bien que la maison EchoHaven n'ait pas atteint la production nette d'énergie prévue dans la proposition, elle a eu une consommation d'énergie très faible et a surpassé de beaucoup le rendement des habitations ordinaires construites à la même époque.

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1. INTRODUCTION

The EchoHaven house in Calgary, Alberta, is one of four houses in that province which were winning entries in Canada Mortgage and Housing Corporation's (CMHC) EQuilibrium™ Sustainable Housing Initiative. The house (Figure 1-1) and sub-division it resides in was developed by Echo-Logic Land Corporation, a Calgary-based development company. It is intended that the 25 lot sub-division will be a community of low environmental impact homes which will have a reduced ecological footprint and preserve 60% of the existing ecosystem. The 225 m^2 (2,425 ft^2) home was occupied by two persons, beginning at the end of May 2011.

This report is the one-year performance monitoring report for EchoHaven. It includes energy and water consumption records for a one-year period of occupation from October 6, 2011 to October 5, 2012 (365 days). The report compares the measured results with the values predicted by HOT2000 and RETScreen models of the house generated by the project designers as part of the CMHC proposal requirements, as well as with an adjusted performance model calculation to account for as-built and actual weather conditions for the monitoring time period. Differences between the actual energy consumption and production and those predicted by the models are discussed. The results of the indoor environmental quality measurements (relative humidity, temperature, carbon dioxide (CO2), formaldehyde, radon and total volatile organic compounds (TVOCs) are also discussed and compared to guidelines.

1.1. Monitoring Contractor

The year-long performance monitoring of EchoHaven was conducted by Saskatchewan Research Council (SRC) on behalf of CMHC, and consisted primarily of monthly manual readings of selected energy, water consumption and indoor environment parameters. SRC provided to CMHC an initial verification report based on the as-built home prior to commencement of the monitoring period, monthly reports documenting monitoring results, and this final report.

The initial verification was performed by Chris James of SRC on February 4, 2011. Shaun Aimoto, a resident of Calgary, was contracted to read the meters in the EchoHaven house for the duration of the occupancy period.

Figure 1.1. EchoHaven Southwest View February 2, 2011

1.2. House Overview

As with the other EQuilibrium™ Housing demonstration projects, the design team attempted first to significantly minimize the energy requirements of the home and then added renewable energy components predicted to be sufficient to meet the remaining energy requirements on an annual basis. Key features of the house include:

- site sensitive building location, orientation and design
- highly energy efficient building envelope, using advanced framing techniques
- airtight construction
- heat recovery ventilator (HRV) for fresh air ventilation
- energy and water efficient appliances
- electric radiant panels mounted in the ceiling behind the drywall, and electric wall radiators, for space heat
- tankless instantaneous electric water heater
- rain water collection system

- roof mounted solar photovoltaic (PV) technologies for electrical energy generation
- wall mounted flat plate solar thermal collectors for hot water and space heat
- low water landscaping

The house is very well insulated with R-108 (RSI 19.0) in the attic, R-54 to 59 (RSI 9.5 to 10.4) in the walls and R-32 (RSI 5.6) under the slab. The building envelope tested tight at 1.04 air changes per hour (ACH) at 50 Pa.

The house is heated by passive solar heat gains and approximately 10 kW of electric radiant panels (Figure 1.2) installed behind the ceiling drywall on all levels of the house. For rooms without the radiant panels installed (one bathroom, mechanical room and laundry room), wall-mounted radiant heaters (Figure 1.3) have been installed. A solar heat dump loop is also installed in the basement concrete floor.

Figure 1.2. Electric radiant panels that were installed behind ceiling drywall (right photo courtesy of Bow Crow Designs, Kornylo Walton, 2011)

Figure 1.3. Wall radiators

Two solar thermal panels are mounted on the south face of the home (Figure 1.4). They heat a 284 L solar storage tank located in the mechanical room. Domestic hot water is produced from the cold water line by first being preheated by a drain water heat recovery unit tied into the upper level shower drain line, then heated by the solar thermal system, and finally heated by a 24 kW electric instantaneous hot water heater. To maximize usable solar thermal energy production, any excess heat in the solar storage tank is distributed to a simple loop imbedded in the lower level (basement) concrete slab.

Figure 1.4. Solar thermal panels on south face of home

Onsite renewable electricity is supplied by the 5.46 kW$_{peak}$ PV array installed on the roof at 45° from horizontal (shown in Figure 1.1). The PV system consists of 26 Sanyo 210N HIT modules with individual Enphase micro-invertors for each panel.

Rain water is harvested from the metal roof and stored in a large cistern under the paving stone driveway. This harvested rain water is used for toilet flushing and irrigation.

A Lifebreath® 195 ECM (electronically commutated motor) heat recovery ventilator (HRV) with a dual heat exchanger core (Figure 1.5) has been installed to remove stale/humid air from the kitchen, bathrooms and laundry room and supply fresh air to all other spaces. The HRV normally operates on low speed, with manual timers and a humidity sensor so that it can operate at high speed when required. In-line booster fans have been installed to increase exhaust from the kitchen, bathrooms and laundry room (Figure 1.6). Natural ventilation is supplied by advantageous window placements to take advantage of buoyancy (the 'stack effect') and prevailing winds.

Figure 1.5. Lifebreath® HRV

Figure 1.6. Two of the booster fans installed to increase exhaust ventilation from specific rooms

Lighting is supplied by significant daylighting and the use of LED and fluorescent fixtures (Figure 1.7).

Figure 1.7. Lighting fixtures and daylighting on main level

Energy and water efficient fixtures and appliances are installed throughout the home (Figures 1.8 and 1.9).

Figure 1.8. Soaker tub that requires the same amount of water as a standard tub

Figure 1.9. Energy and water efficient stacked washing machine and clothes dryer (L) and dishwasher (R)

2.   MONITORING SCHEME

2.1. Monitored Parameters

While the performance monitoring scheme attempts to distinguish energy consumption and production by type of load and renewable energy source, the definitive measure of total purchased energy use is the utility electrical meter (EchoHaven is not connected to the natural gas distribution grid and does not utilize oil or wood fired space- or water- heating appliances). An effective monitoring scheme should help to determine how closely energy performance characteristics conform to the model predictions. In this project, monitoring has been designed to determine energy used for domestic hot water heat, space heat, and ventilation. Any energy not included in these measured parameters is considered appliance, lighting and other miscellaneous electrical equipment energy. Exterior energy use was not separately monitored. Manual meter readings were conducted monthly to document energy consumption.

Monitoring equipment installed by SRC for CMHC consisted of a pair of photovoltaic (PV) production meters, a connection to Enphase Enlighten (an on-line monitoring service) to monitor the PV system production, two water meters to measure domestic hot water (DHW) consumption and captured rain water use, and two thermal heat energy meters to measure the solar energy contribution to space and DHW heat. Electrical monitoring equipment measured the electrical consumption of the instantaneous hot water heater, radiant panels and ventilation booster fans. Kill A Watt™ plug load meters are used on the HRV and on some selected appliances and electronic equipment. Temperature, relative humidity, and carbon dioxide (CO_2) are monitored using an Onset HOBO logger and Vaisala CO_2 transducer. Meters provided by the local utilities include a water meter for whole-house water consumption installed by the City of Calgary and a bi-directional electrical energy meter installed by the electric utility.

Parameters monitored at EchoHaven are listed in Table 2.1.

Table 2.1. Installed Monitoring Equipment

Monitored Parameter	Meter Type	Unit of Measure
Water supply volume	Elster AMCO	m^3
Captured rain water	Sensus	m^3
Domestic hot water volume	Kamstrup Multical Flow meter	m^3
PV system electrical energy production Right meter Left meter	Focus Serial No. 92043707 Serial No. 92043713	kWh
Whole house electricity to grid	Elster Type R2S Serial No. 09579020 Register 02	kWh
Whole house electricity from grid	Elster Type R2S Serial No. 09579020 Register 01	kWh
Solar space heating energy	Kamstrup Multical 601 Serial No. 5503995	GJ
Solar DHW heating energy	Kamstrup Multical 601 Serial No. 5603998	GJ
DHW electrical energy	Brultech EML-2020	kWh
Temperature, relative humidity	Hobo T/RH Logger	°C/RH%
Carbon dioxide	Vaisala	ppm
Appliance energy [a]	Kill-a-Watt™ meters, Brultech EML-2020 logger	kWh

[a] Monthly energy consumption by selected appliances was measured using Kill A Watt™ meters. Meters were relocated occasionally to measure different appliances.

2.2. Space and Water Heating

In addition to the significant contributions of passive solar heating and heating by occupants and appliances in meeting the space heating requirements, active space heating is provided by electric radiant panels and some contribution from the solar thermal system. Energy consumption of the radiant panels was measured at the electrical panel with Brultech EML-2020 meters while the contribution from the solar thermal system was measured using a Kamstrup heat energy meter.

The DHW energy is supplied by a combination of the solar thermal heating system, an instantaneous electric water heater, and heat input via the drain water heat recovery (DWHR) device. The contribution of the solar thermal system is measured directly using a Kamstrup heat energy meter and the electrical consumption is measured using a Brultech EML 2020.

The plumbing schematic is shown in Figure 2.4, including the locations of the metering equipment.
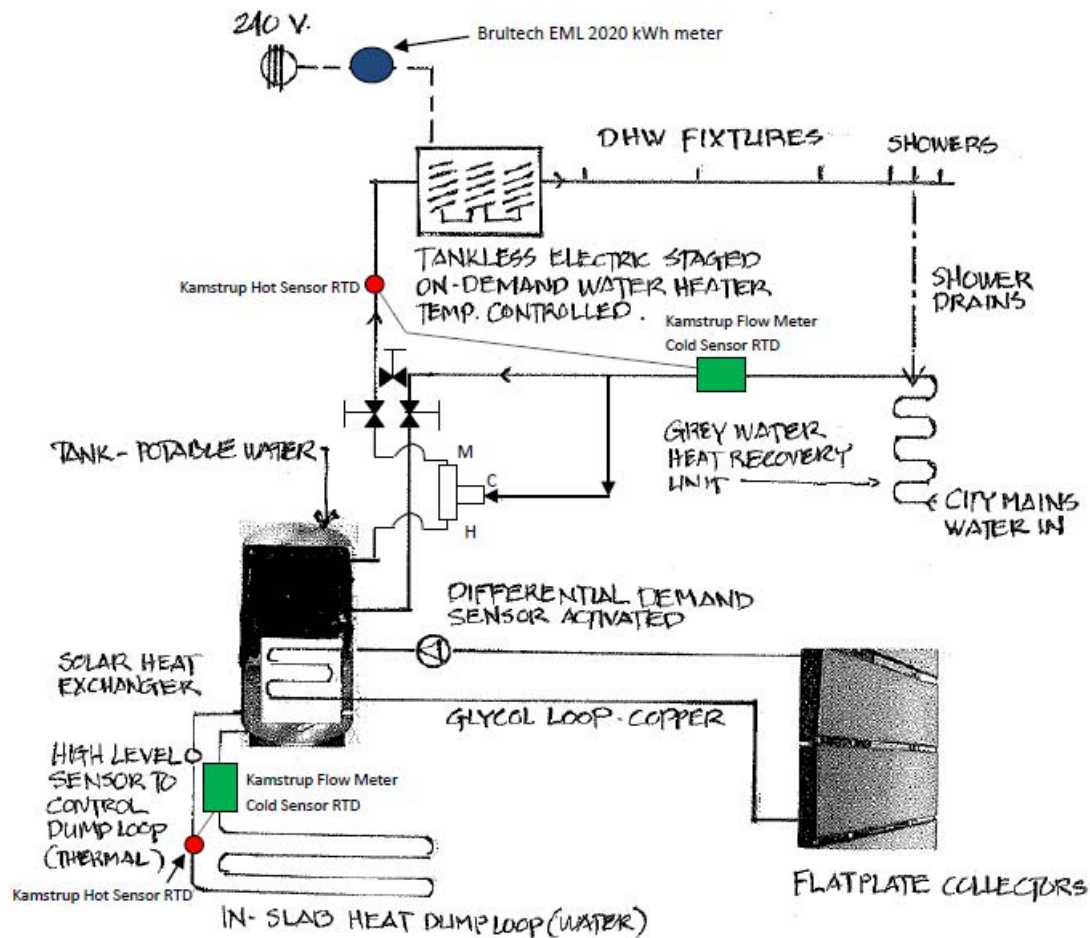
Figure 2.1. Mechanical Schematic for EchoHaven

2.3. **Photovoltaic Production**

The photovoltaic (PV) production was measured by two revenue-grade electrical energy meters in the utility room (Figure 2.2). The system utilizes individual inverters for each panel which are fed into the grid through the two electrical meters.

PV production was also monitored in real time through a connection to Enphase Enlighten, delivered as part of the PV system. Electrical production information from the invertors was fed

in real time to the Enphase server and updated on a web page to which the homeowner had access. SRC was granted access permission to the monitoring page where reports could be generated.

Figure 2.2. Electrical Energy Meters Measuring Photovoltaic System Production

2.4. **Ventilation Energy**

The electrical energy used by the HRV was recorded on a Kill A Watt™ meter at the plug, shown in Figure 2.3. The electrical consumption of the booster fans (which increase exhaust ventilation from specific rooms when required) was measured using a Brultech EML-2020 at the electrical panel.

Figure 2.3. Heat Recovery Ventilator Energy Measurement with Kill A Watt™ Meter

2.5. Indoor Environment Quality

Indoor environmental quality (IEQ) measurements were included in the monitoring scheme. One-time individual samples for total volatile organic compounds (TVOCs) and radon were taken during winter months. Passive sampler testing of formaldehyde concentrations was conducted twice, once shortly after construction was complete, and a second time during the monitored year to determine if there were changes in concentration during the first year of occupancy. A data logger that recorded ongoing temperature, relative humidity and CO_2 levels at a single location in the home was also installed. The real-time monitoring of indoor temperature, relative humidity (RH) and carbon dioxide (CO_2) began five months before the start of the year of energy monitoring. However, the sensors failed during the last two months of the year, hence there are a total of 15 (continuous) months of monitoring data.

2.6. Water Consumption

Whole-house water consumption was monitored with a utility-installed water meter, shown in Figure 2.4. A utility grade water meter was installed to measure the water use from the rainwater harvesting cistern, and a Kamstrup flow meter was used to measure DHW volume.
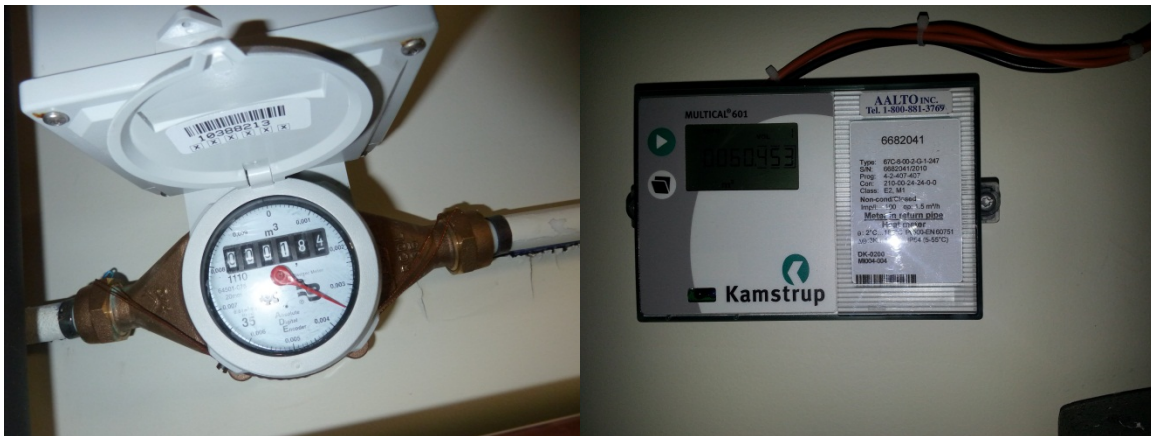
Figure 2.4. Water Meters Measuring Whole-House (L) and DHW Water (R) Use

2.7. **Whole-House Electrical Energy**

Whole-house electricity was monitored by the utility-installed, revenue-grade, bidirectional kilowatt-hour meter shown in Figure 2.5. The net energy measured by this meter is the definitive determination of the energy profile of the home over the course of the monitored year. Total electrical energy consumption was determined by adding the energy produced by the PV system to the difference between the energy recorded by the registers in the utility electrical meter.

Figure 2.5. Utility-Provided Whole-House Electrical Energy Meter

2.8. **Meter Specifications and Calibration**

Selected key parameters of the metering equipment supplied by SRC are listed in Table 2.2. No calibration of meters was performed by SCR.

Table 2.2. SRC-Supplied Equipment Specifications

Meter	Parameter	Range	Accuracy
Kill A Watt™ EZ	Active Power	0–1875 W	0.5% typical, 2% max
	Power Quantity	0.00–9999 kWh	0.5% typical, 2% max
	Time Quantity	00:00–9999	30ppm
Brultech EML-2020	Power	1–65,000 W	±1% plus Current Transformer accuracy
	Energy	0.001–16,277.216 kWh	±1% plus Current Transformer accuracy
Onset HOBO U12-013	Temperature	-20° to 70°C	±0.35°C
	Relative Humidity	10% to 90%	±2.5%
		0% to 100%	±3.5%
	External Inputs	0 to 2.5 V DC	±2 mV ±2.5% of absolute reading
	Time		±1 minute per month
Onset HOBO 4-20 mA Input Cable	Current	0 to 20.1 mA	±0.02 mA ±2.5% of reading
Vaisala GMW115	CO_2 Concentration	0 to 2000 ppm	±2.5% of range + 3% of reading ±5% of range/5 yrs

2.9. **Sources for Weather Data**

Weather data from nearby locations enabled adjustment of the initial model predictions to reflect actual conditions during the year of monitoring. These data (measured temperature conditions and incident solar radiation) were acquired from the University of Calgary Department of Geography's weather station, located approximately 15 km from the house and incorporated into the HOT2000 and RETScreen predictive programs to generate adjusted predictive performance models.

Table 2.3 shows the base 18°C annual heating degree days (HDD) and cooling degree days (CDD) predicted by HOT2000 and RETScreen, the 1971–2000 average for the Environment Canada

station at the Calgary International Airport, and the actual value for the monitoring period of October 6, 2011 to October 5, 2012 as measured at the University of Calgary station.

Table 2.3. Annual Degree Days Predicted and Measured for Calgary, AB.

Source	Annual Heating Degree Days (Base 18°C)	Annual Cooling Degree Days (Base 18°C)
HOT2000	5,200	n/a [a]
RETScreen	5,135	513
Environment Canada (Normals 1971–2000)	5,108	40
U of C Measurement (for monitoring period)	4,476	81

[a] HOT2000 does not list CDD.

The actual annual heating degree days (HDD) for Calgary during the monitoring period were lower than the historic (Environment Canada) average by about 12%. The HOT2000-standard HDD is approximately 14% higher than the measured data; the adjusted as-built model incorporates the measured data.

The monthly values of measured and normal HDD for the City of Calgary are contained in Table 2.4. On an annual basis the measured HDD were 12% less than normal; on a monthly basis the differences were more pronounced, with measured HDD ranged from 23% less (June 2012) to 2% more (September 2012) than the normal values.

Table 2.4. Measured and Normal Monthly HDD for Calgary

Month	Environment Canada HDD Norm Deg-Day (Base 18°C)	2011/12 HDD Measured Deg-Day (Base 18°C)	HDD Difference (%)
Jan	834.6	725.9	-13%
Feb	679.6	637.7	-6%
Mar	618.0	541.2	-12%
Apr	401.2	387.2	-3%
May	251.7	259.4	3%
Jun	130.9	133.0	2%
Jul	74.2	19.4	-74%
Aug	89.8	49.4	-45%
Sep	218.2	127.3	-42%
Oct	391.8	387.4	-1%
Nov	631.4	605.5	-4%
Dec	787.1	602.9	-23%
Total	5108.4	4476.3	-12%

The University of Calgary Geography Department solar radiation data were compared with the RETScreen solar radiation library data (Table 2.5) and incorporated into the RETScreen libraries for the adjusted as-built models.

Table 2.5. Measured and Predicted Horizontal Solar Radiation for Calgary, AB.

Month	RETScreen (Calgary) (kWh/m^2/day)	2011/12 Solar Radiation Measured (kWh/m^2/day)	Solar Radiation Difference (%)
Jan	1.34	1.10	-18%
Feb	2.31	1.98	-14%
Mar	3.59	3.01	-16%
Apr	4.96	4.10	-17%
May	5.68	5.25	-8%
Jun	6.38	4.91	-23%
Jul	6.34	5.92	-7%
Aug	5.36	5.40	1%
Sep	4.02	4.11	2%
Oct	2.70	2.11	-22%
Nov	1.54	1.27	-17%
Dec	1.06	0.84	-21%
Year	3.77	3.33	-13%

By incorporating the monthly average measured values for heating degree days and solar radiation (Tables 2.4 and 2.5 respectively) into the models, the monthly deviations from the normal year typically used in the models can be accounted for in the energy performance predictions. Two of the variables are thus removed when attempting to describe the difference between modelled, i.e. predicted energy consumption or production and that observed during the monitored year.

3. MODELLING METHODOLOGY

3.1. Energy Models

There are two software packages used in the EQuilibrium™ Sustainable Housing Initiative for energy modelling. HOT2000 is used for modelling the energy consumption of the house and RETScreen is used to estimate the production of the on-site renewable energy systems.

HOT2000 is residential building energy analysis software developed by NRCan's CanmetENERGY primarily for the support of the R-2000 new home and EcoENERGY housing retrofit programs. In the case of the EQuilibrium™ Housing Initiative, modifications to the HOT2000 program assumptions were allowed and formulas were developed by NRCan to enable predictions of very high energy performance (i.e. EnerGuide numbers in the 100 range[1]).

The Renewable Energy Technology Screen (RETScreen) software package, also developed in large part by and managed by NRCan, is built on Microsoft's Excel spreadsheet program. It performs clean energy project analysis to allow renewable energy project proponents /developers to quickly perform technical and financial analysis of potential projects. The energy production portion of RETScreen is used as the modelling tool in the EQuilibrium™ Housing initiative to predict solar thermal and photovoltaic energy production.

3.2. Modelling Methodology

The EQuilibrium™ Housing design teams were asked to submit HOT2000 and RETScreen models of their houses as part of the design competition. These predictive energy models incorporated:

1. The house design, including the energy-efficient building envelope, passive solar thermal design considerations, and an estimate of building air tightness.
2. Consideration for energy-efficient appliances, mechanical systems and lighting, as well as reductions in occupant use of hot water, etc.
3. Renewable energy production (PV, solar thermal for DHW and space heat, solar thermal air heat or preheat, etc.)

Incorporating these factors allowed the teams to predict the annual net energy profile.

As part of the CMHC performance monitoring evaluation process, SRC generated adjusted

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[1] Natural Resources Canada's EnerGuide For Houses (EGH) Rating is a standard measure of a home's energy performance, and can range from 0 to 100. The rating is based, in part, on the assumed energy consumption of appliances, assumed hot water draws, and other electricity usages in conventional homes. The modifications referred to above allow reductions in electricity and hot water loads in EQuilibrium™ homes, thereby more accurately reflecting the home's potential energy performance.

HOT2000 and RETScreen models of each of the projects based on the as-built house characteristics, actual occupancy and weather conditions (temperature and solar radiation) during the monitoring period in order to ensure a more realistic picture of the predicted performance. These as-built models are used when comparing the measured results to the modelled predictions. Using the same modeller (SRC) for all as-built EQuilibrium™ Housing projects creates more modelling consistency across the projects, as the same approach is used for each model.

3.3. HOT2000 Model

The following 'as-built' features were incorporated into the HOT2000 model to improve the accuracy of the model for the as-built EchoHaven house:
- Model uses as-built drawings;
- As-built window and door properties used;
- Basement changed to walkout with a pony wall;
- Post-construction air tightness results used; and
- Per person hot water consumption matched to other EQuilibrium™ house models.

The monthly average ambient temperature data recorded at the University of Calgary for the measured year were entered into the HOT2000 weather files to adjust the model for observed weather conditions. The key monthly energy allocation from the HOT2000 adjusted model is shown in Table 3.1. A HOT2000 report based on the as-built conditions and monthly average temperature data during monitoring is presented in Appendix A.

The modifications by SRC to the HOT2000 model result in predicted energy consumption of 10,062 kWh/y, 3,848 kWh (28%) less than the design team's original prediction of 13,910 kWh/y.

Table 3.1. HOT2000 Adjusted Model Monthly Predicted Energy Consumption (kWh) by Device

Month	Space Heating	DHW Heating	Lights & Appliances	HRV & Fans	Air Conditioner
Jan	970	231	257	49	0.0
Feb	606	210	232	37	0.0
Mar	353	231	257	34	0.0
Apr	234	219	249	30	0.0
May	136	221	257	28	0.0
Jun	81	208	249	26	0.0
Jul	38	210	257	26	0.0
Aug	50	209	257	26	0.0
Sep	67	203	249	25	0.0
Oct	153	215	257	30	0.0
Nov	600	214	249	39	0.0
Dec	754	227	257	44	0.0
Annual	**4,042**	**2,597**	**3,030**	**394**	**0.0**

3.4. **RETScreen Models**

As discussed above, the project team ran RETScreen models for the PV and solar thermal systems in an attempt to predict the renewable energy contributions at EchoHaven, and these predictions were subsequently refined by SRC to reflect the as-built project and weather conditions during monitoring (Table 3.2). Reports from the SRC RETScreen models are presented in Appendix B.

Table 3.2. RETScreen Adjusted Model Simulation Results Summary

Month	Rooftop PV Electricity Production (kWh)	Solar Thermal Energy Production (kWh)
January	422	98
February	532	131
March	629	141
April	658	147
May	752	165
June	637	142
July	788	186
August	811	192
September	743	179
October	512	118
November	417	93
December	333	64
Annual	**7,234**	**1,656**

3.4.1. RETScreen Solar Space and Domestic Hot Water Heat

The active solar thermal system delivers heat from the wall-mounted south facing panels to a storage tank in the mechanical room. The system is mainly for use with DHW heating. A controller ensures that the tank temperature does not exceed a specified threshold, set by the homeowner, and will direct excess heat to a single room in the walkout basement through an under floor heating loop. Since RETScreen does not simulate solar space and water heating directly, a service solar water heating system with the demand adjusted to match the sum of the HOT2000 space heating and DHW heating requirements (Table 3.1) on a monthly basis was used to estimate the useful active solar gain. A system with 2 collectors, a 284 L storage tank, and input temperatures more representative of the expected tank temperatures was used. The modelled contribution from the solar thermal system to DHW and space heat was 1,656 kWh/y, with adjustments included for temperature and solar radiation for the measured year.

3.4.2. RETScreen Solar Photovoltaics

EchoHaven utilizes an Enphase inverter system that provides a single inverter for each PV panel. The benefit of this type of system is that the energy output of each panel is independent of that of other panels and can be independently monitored. In contrast, the conventional approach has been to wire panels together in a series / parallel combination; if one or more panels are not operating as efficiently as possible under the current solar radiation conditions (e.g. due to component failure or shading) the output of the entire array will be negatively affected. It also

precludes straightforward monitoring of individual panel performance. Simulation was performed as though it were a single system, because all of the panels are installed on the roof of the house at a 45° slope and no significant differences in inverter and other related losses for each panel were expected. The adjusted model energy production prediction from the PV system was 7,234 kWh/y, with adjustments included for temperature and solar radiation for the measured year.

4. RESULTS

4.1. Annual Readings Summary

The readings shown in Table 4.1 are taken from site visits by the local contractor and are for the one-year period October 6, 2011 to October 5, 2012.

Table 4.1. Measured Consumption/Generation during Monitored Year

Monitored Parameter	Initial Reading 2011-Oct-6	Final Reading 2012-Oct-5[b]	Net	Unit of Measure
Water supply volume	29.523	88.893	59.37	m^3
Cistern water	5.2558	12.195	6.939	m^3
Domestic hot water volume	17.232	59.858	42.626	m^3
PV system electrical energy production Right inverter	2380	6360	3980	kWh
Left inverter	2371	6325	3954	
Whole house electricity to grid	5898	11907	6009	kWh
Whole house electricity from grid	6943	13293	6350	kWh
Active Solar DHW heating energy	1.673	5.502	3.829	GJ
Active Solar space heating energy	0.428	0.517	0.089	GJ
Space heating electrical energy	n/a	n/a	3813[a]	kWh
DHW electrical energy	n/a	n/a	645[a]	kWh
Ventilation electrical energy	n/a	n/a	366[a]	kWh

[a] Space heating, DHW and ventilation electrical energy consumption, measured using a Brultech EML-2020 meter and/or a Kill A Watt™ meter. Meters were reset monthly, i.e. no cumulative readings were taken.
[b] Actual reading was taken on October 10, 2012. The consumption as at October 5, 2012 is based on an interpolation of the data.

4.2. Energy Balance Summary

The adjusted model predictions generated by HOT2000 and RETScreen for the as-built home and actual weather during the monitoring period, and the actual measured data are shown in Table 4.2 and Figure 4.1. The HOT2000 weather updates include only temperature from the monitored period, whereas RETScreen models include both temperature and solar radiation updates.

Readings were not performed on the same day of each month; therefore, adjustments were made to compensate for the fact that each monthly reading does not represent the same period of time. Straight line interpolation is used between the actual reading date and the proper reading date to adjust the readings for the month. The last reading was on October 10, 2012, so an interpolation was required for this reading to remove the extra days subsequent to the end of the one-year monitoring period (October 5, 2012) of energy consumption/production.

Table 4.2. EchoHaven Energy Balance Summary (Modelled and Measured)

Oct 2011 to Sep 2012		Energy Consumption					Produced Energy			Energy Balance
		Space Heating (kWh)	Domestic Water Heating (kWh)	Appliances Lighting (kWh)	Mech Ventilation (kWh)	Total Energy Use (kWh)	Solar Electricity (kWh)	Solar Heating (kWh)	Total Production (kWh)	('-' import) (kWh)
Jan '12	Modelled	-970	-231	-257	-49	-1507	422	98	520	-987
	Measured	-710	-185	-182	-28	-1105	480	66	546	-559
Feb '12	Modelled	-606	-210	-232	-37	-1086	532	131	663	-422
	Measured	-614	-215	-245	-53	-1127	531	102	633	-494
Mar '12	Modelled	-353	-231	-257	-34	-875	629	141	770	-105
	Measured	-400	-134	-344	-40	-918	704	103	807	-111
Apr '12	Modelled	-234	-219	-249	-30	-732	658	147	805	73
	Measured	-254	-158	-322	-30	-764	752	101	853	89
May '12	Modelled	-136	-221	-257	-28	-642	752	165	917	275
	Measured	-186	-108	-364	-42	-700	784	102	886	186
Jun '12	Modelled	-81	-208	-249	-26	-564	637	142	779	215
	Measured	-36	-104	-343	-18	-501	755	81	838	337
Jul '12	Modelled	-38	-210	-257	-26	-531	788	186	974	442
	Measured	-24	-120	-301	-13	-459	830	99	931	472
Aug '12	Modelled	-50	-209	-257	-26	-542	811	192	1003	462
	Measured	-47	-155	-273	-23	-498	928	115	1044	546
Sep '12	Modelled	-67	-203	-249	-25	-545	743	179	922	377
	Measured	-25	-138	-308	-19	-489	803	118	922	433
Oct '11	Modelled	-153	-215	-257	-30	-654	512	118	630	-24
	Measured	-35	-135	-363	-26	-559	646	107	755	196
Nov '11	Modelled	-600	-214	-249	-39	-1101	417	93	510	-592
	Measured	-776	-159	-308	-57	-1301	339	82	423	-878
Dec '11	Modelled	-754	-227	-257	-44	-1283	333	64	397	-886
	Measured	-730	-103	-98	-17	-948	383	18	404	-544
Year	Modelled	-4042	-2597	-3030	-394	-10062	7234	1656	8890	-1172
	Measured	-3837	-1716	-3450	-366	-9369	7934	1094	9028	-341

The original proposal submitted by the EchoHaven team predicted an annual energy export of 3,056 kWh (Spencer et Al., 2006). The adjusted as-built models (Table 4.2), corrected for weather and solar radiation during the monitoring period, predicted an annual energy requirement of 1,172 kWh. The measured results show the net annual energy requirement was 341 kWh for the monitoring period, only 29% of the as-built model predictions.

The supplemental space heating energy, in addition to passive and internal gains, used during the monitored year was 3,837 kWh, which is 205 kWh (5%) less than the 4,042 kWh predicted. Only 24 kWh of space heat was provided by the solar thermal system, through the in-floor loop in the single basement room, which represents 0.6% of the total space heating energy. Energy used for DHW was 1,716 kWh, only 66% of the 2,597 kWh predicted. The solar thermal system contributed 1,070 kWh to the DHW heating, 62% of the total DHW heating energy. The amount

of energy attributed to appliances and lighting was 3,450 kWh, 14% more than the 3,030 kWh predicted. This represents an additional 1.2 kWh/day of energy use or a 48 W constant load. The energy used in this category is determined by taking the difference between the overall energy use measured by the electrical utility meter and the sum of the electrical energy consumption measured for space, DHW, and mechanical ventilation. The homeowners were vacationing in the winter which may be a factor contributing to the lower than predicted overall consumption.

Solar thermal energy production (1094 kWh) was only 66% of the 1,656 kWh predicted by RETScreen. The method used to model the solar thermal energy production is a contributor to this deviation since RETScreen is not designed to model a combination space and water heating system, which was the case at EchoHaven. The very low amount of active solar space heating used in the house (24 kWh) indicates that the solar thermal system is almost utilized for DHW production. Because of the difficulty in generating an accurate model, it is difficult to make any meaningful comparisons between the modelled and measured solar thermal energy production.
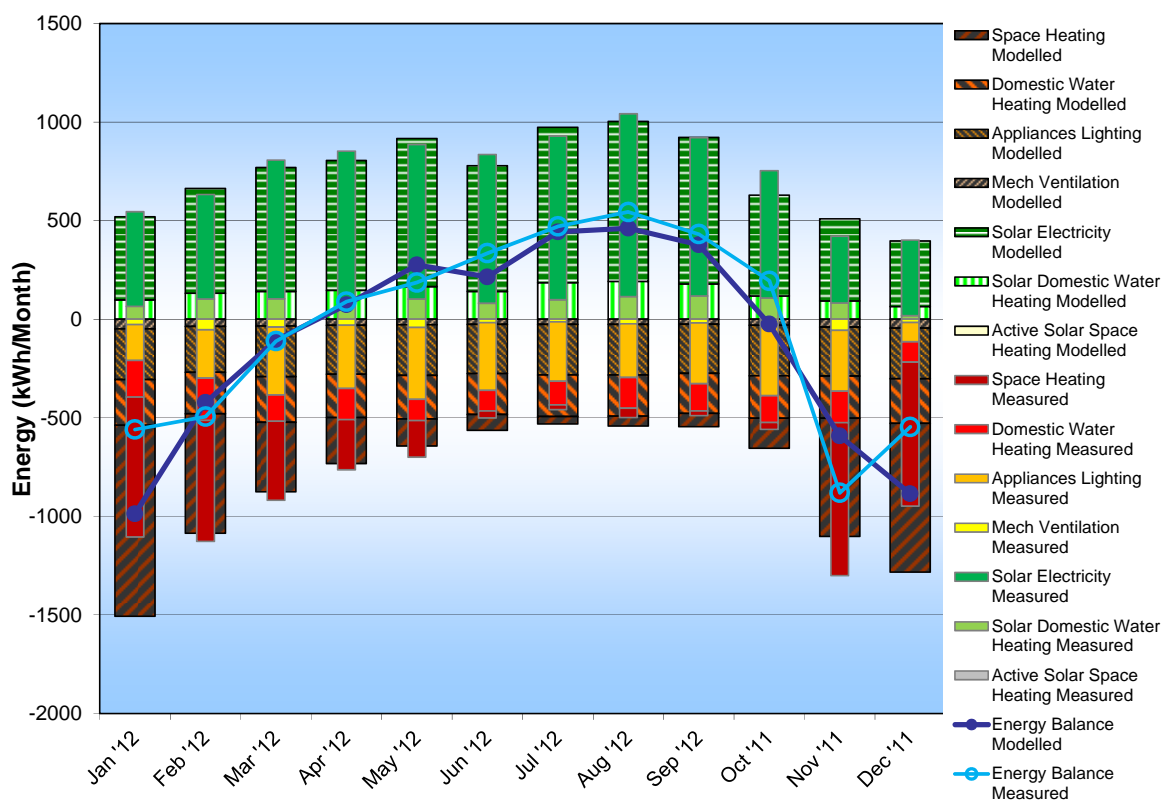
Figure 4.1. EchoHaven Energy Balance Graph – Modelled/Measured

Figure 4.1 shows the consumption (negative portion of the vertical axis) and production (positive portion of the vertical axis) for each month and each measure of energy use or production. The hatched bar graphs in the background show the as-built modelled amounts adjusted for weather

and solar radiation, while the solid color bars represent the measured values. The lines show the predicted and measured energy balance. The total monthly energy balance data, measured and modelled, show generally good agreement over the year, mainly due to balanced decreases in consumption matching with decreased energy production from the active systems. The homeowners were away during a portion of December and January, which was likely why less energy used than predicted.

4.3. Photovoltaic Production

The measured photovoltaic production at the EchoHaven house was 7,934 kWh, 9.7% or 700 kWh higher than the RETScreen adjusted model predicted production for the weather and solar radiation conditions experienced (7,234 kWh). The measured incident solar radiation, from the University of Calgary, was 13% lower than the standard RETScreen values, without accounting for site-specific shading issues such as snow cover. The photovoltaic production, measured and modelled, is shown in Figure 4.2.
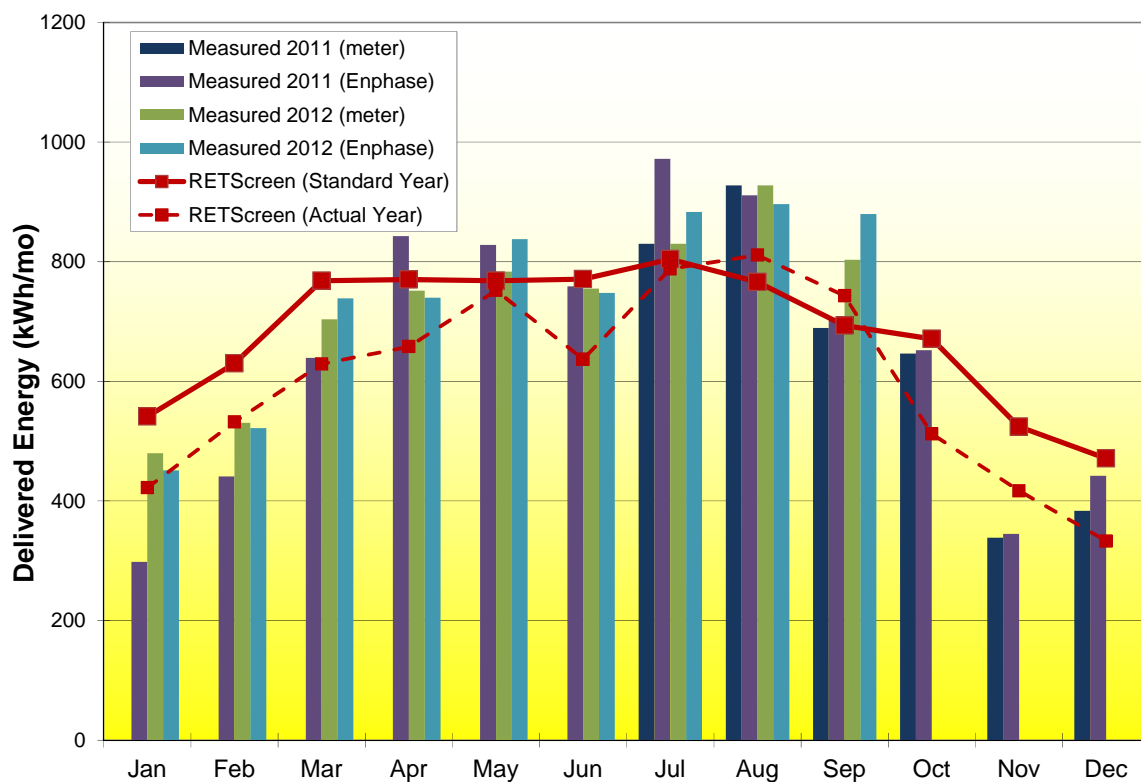
Figure 4.2. EchoHaven Photovoltaic Production – Modelled/Measured

The manual recording of PV production as indicated by the installed meters (as opposed to the Enphase results, discussed below) began July 2011 and ended January 2012. Two modelled

results are shown; the adjusted RETScreen model has been corrected for measured solar radiation and temperature in Calgary for the monitored year (October 2011 through September 2012) so that it can be compared more directly with the measured values for the monitored year, while the RETScreen model for the standard year uses the default solar radiation and temperature values in RETScreen.

Production during the winter months (November through March) was near to the predicted values, but the summer (June through September) months' production was about 11% higher than predicted. It is possible that there were fewer losses in the system than modelled (4% for system and 5% inverter miscellaneous losses) because of the lack of obstructions to the south of the house. Another potential explanation is that the PV panels supplied by the manufacturer exceed their rated output, typical in colder months. The capacity factor for the PV system was 16.6%, indicating the system provided full capacity output for about 1,454 hr during the year.

4.4. **Enphase Monitoring**

The homeowner graciously granted SRC access to the Enphase Enlighten monitoring system for the PV array.   The in-home Enphase dashboard is easy to use, records the performance of each panel and the entire system, and can generate a variety of reports.

Included on Figure 4.2 are the measured monthly results from the Enphase monitoring system. The measured results from the Enphase system begin in January 2011 and are provided up to September 2012. Comparing the results from the Enphase system can show the variability in production from year to year. In the nine common months of monitoring (January to September) the difference is about 300 kWh higher in the 2012 calendar year. It should also be noted that the output recorded from the Enphase system did not agree completely with the manual meter readings on the installed meters. The annual Enphase number for the EchoHaven house for the measured year was 8,135 kWh, while the electrical energy meters recorded 7,934 kWh over a similar timeframe. The difference between the readings is 201 kWh, with the Enphase system recording 2.5% more than the meters. Enphase Envoy aggregates measurements from the micro-inverters but does not qualify as revenue grade metering. The differences are likely attributed to different algorithms to calculate electrical energy and accuracy of equipment. For the performance reporting of the house, readings from the installed utility grade meters were used because of their accuracy requirements and standard in industry.

4.5. **Solar Thermal Production**

The EchoHaven solar thermal system contributed to meeting the DHW loads; total solar DHW production accounted for 1,070 kWh and 24 kWh was utilized for space heating of the total 1,716

kWh utilized. Figure 4.3 shows the total predicted solar thermal production for both space and DHW heating using a solid red line for the standard year and a dashed red line for the monitored period. The green bars show the measured DHW heating energy used and the blue bars show the DHW energy provided by the solar thermal system. The solar fraction (portion of solar heating requirements provided by the solar thermal system) ranged from 12% to 93% on a monthly basis and is indicated by the purple diamonds. Because the DHW consumption in the house was lower than expected, the solar thermal energy delivered can be lower as it is demand based energy use.
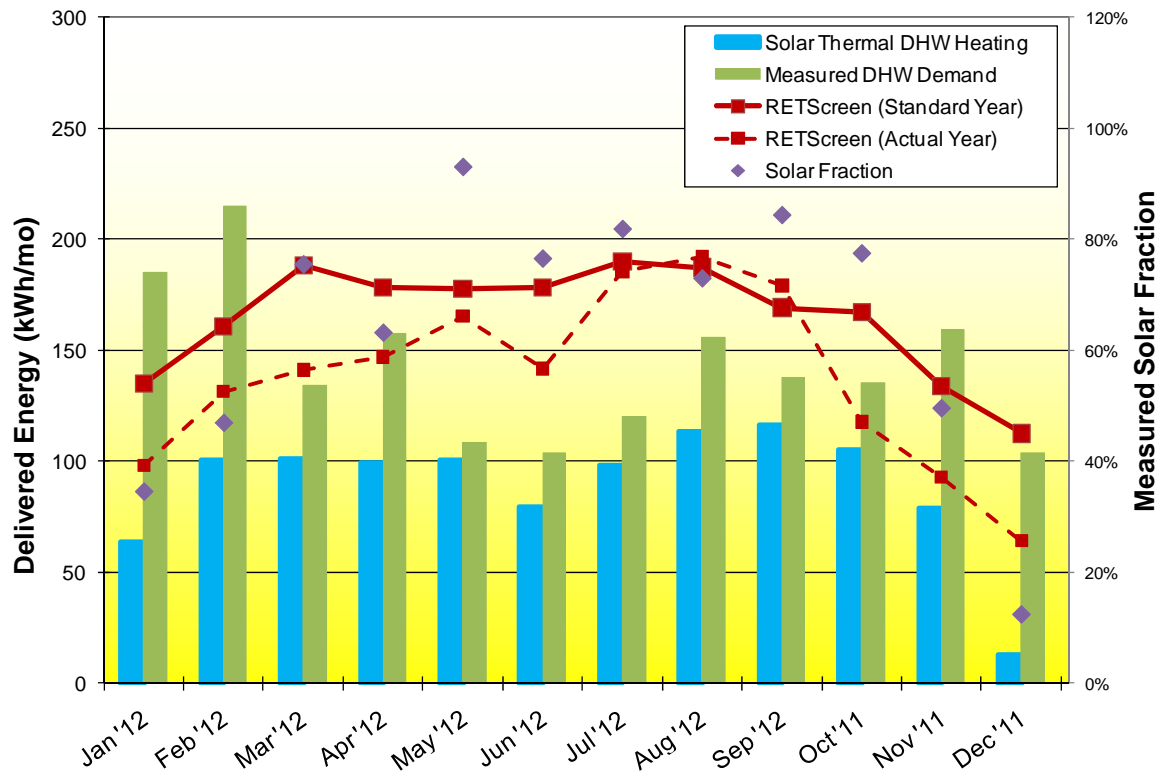
Figure 4.3. Solar Thermal Production for DHW Use

The solar thermal system was installed as a combination space and DHW heating system, with DHW priority. If the temperature of the tank was high enough that additional energy could not be captured, the system would "dump" heat to a distribution line below one of the rooms on the ground level. Only 24 kWh of heat was dumped to space heating throughout the year of monitoring, indicating that the tank temperature was rarely high enough to require the heat dump. Total space heat requirements were 3,837 kWh, for which the active solar thermal system contributed 0.6%.

4.6. **Water Use**

During the monitored year, the EchoHaven occupants consumed a total of 73.3 m^3 of water; 66.3 m^3 of potable water (for drinking, cooking and bathing) and 7.0 m^3 of harvested rainwater (for toilet flushing and exterior uses). Figure 4.4 presents the monthly consumption; the very low consumption in December, and to a lesser degree in January, was likely due to the occupants being absent.

In 2004, the typical water consumption in Canada was 329 L/day/person according to Environment Canada's report on municipal water use (Environment Canada, 2007). The EchoHaven consumption is equal to approximately 100 L / person / day, i.e. only 30% the national average.
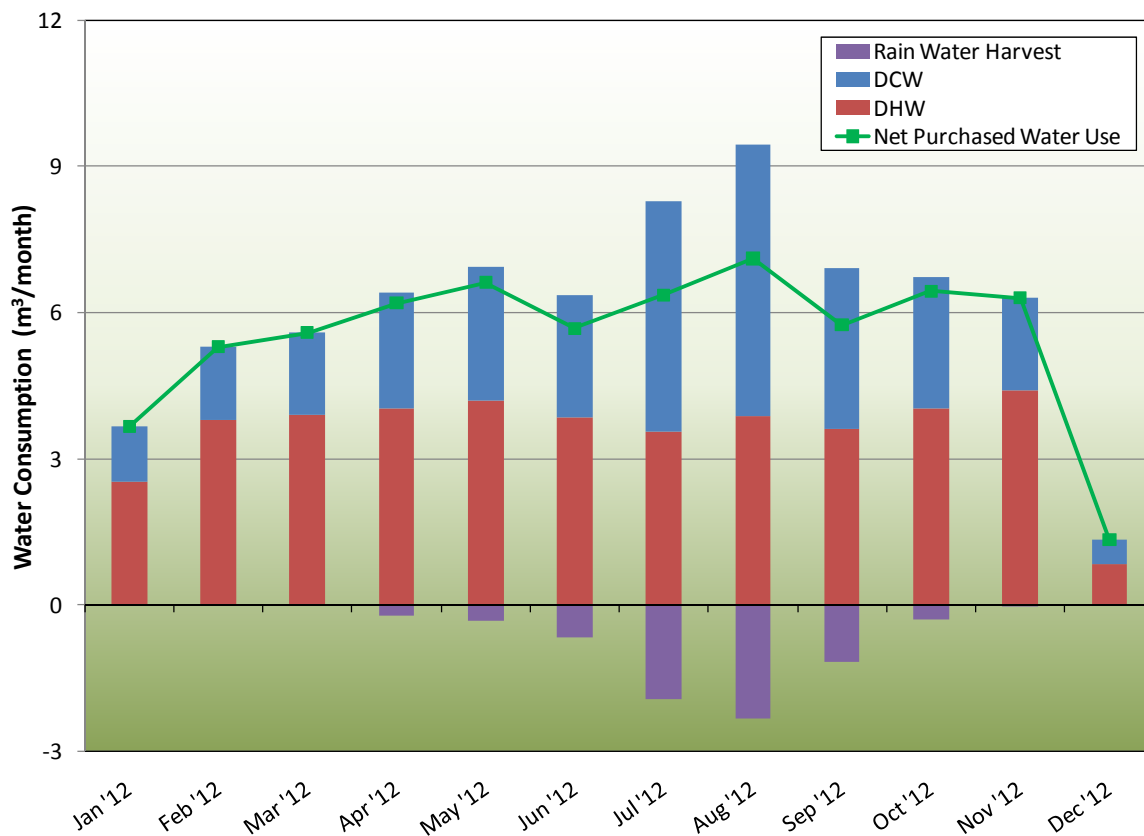
Figure 4.4. Measured Monthly Water Use

4.7. **Indoor Environmental Quality**

Indoor environmental quality measurements include real-time measurement of temperature, relative humidity, and CO_2 concentration. An initial formaldehyde measurement was taken before the house started the monitoring period, and formaldehyde, radon, and total volatile organic compound (TVOC) measurements were taken during different periods of the monitored year. A test was also performed using passive samplers and specific source emitters to evaluate the ventilation effectiveness of the house.

4.7.1. One-Time Environmental Quality Sampling

The initial formaldehyde test, conducted April 9 to 16, 2011 prior to occupancy, indicated a concentration of 20 ppb. The final test for formaldehyde, performed in October 2012, indicated a concentration of 15 ppb, about three quarters the concentration found in the initial test. The findings are in Appendix C.

Health Canada has developed a target guideline of 40 ppb for long term exposure to formaldehyde (Health Canada, 2010). The levels observed in both tests are below the Health Canada target. It was anticipated that the concentration of formaldehyde would be lower after one year of occupancy due to the reduced off-gassing of new materials and furniture; this reduction was observed at EchoHaven.

Radon is an odourless, tasteless and colourless radioactive gas which is a recognized health risk associated with the development of lung cancer. It typically enters homes through cracks in the building foundation that are in direct contact with the soil. The radon concentration in the EchoHaven basement was measured January 21 to February 28, 2012 using a passive sampler. Analysis of the sample by SRC Analytical Labs in Saskatoon, SK showed a radon concentration in the basement of 70 Bq/m^3 (becquerels per cubic meter), which is well under the Health Canada guideline of 200 Bq/m^3 (Health Canada 2009). EchoHaven has an active radon mitigation system that depressurizes the under slab area of the house and vents the gasses to the outside. This system was in operation during the testing.

A measurement of the total volatile organic compounds (TVOCs), using a passive sampler, was taken from January 20, 2012 to February 28, 2012, i.e. the same period as the radon testing. The sample was analyzed by SRC Analytical Labs in Saskatoon, SK. Usually testing will supply only the TVOC concentration, but SRC chose to have a more detailed breakdown of the actual VOCs measured. Table 4.3 presents the findings.

Table 4.3. EchoHaven TVOC Concentrations and 'Comfort Guidelines'

VOC	Concentration (as measured at EchoHaven) (mg/m^3)	Concentration ('Comfort Guidelines') (mg/m^3)
Ethyl Benzene	0.005	86.8
Methyl Benzene	0.075	75.4
Dimethyl Benzene	0.022	434.2
Trimethyl Benzene	0.002	122.9
Styrene	0.004	85.2
Alpha Pinene	0.020	n/a
Beta Pinene	0.002	n/a
Camphene	0.008	n/a
Delta 2 Carene	0.014	n/a
dl-Limonene	0.016	n/a
1,1-Biphenyl	0.003	1.26
Benzene oxybis	0.007	n/a
Hexanal	0.003	n/a
Acetic Acid Butyl Ester	0.001	n/a
Siloxane	0.006	n/a
Hydrocarbons (C7-C15)	0.005	200
Total	**0.193**	

There are currently no set standards or guidelines for TVOCs in Canada. The Health Canada document, "Indoor Air Quality in Office Buildings: A Technical Guide," discusses TVOC levels. It references ASHRAE Standard 62-1989, which recommends limits of one-tenth of the levels described as comfort guidelines in the ACGIH (American Conference of Government Industrial Hygienists) Threshold Limit Values Handbook (ACGIH, 2010). These levels are presented in Table 4.3 for comparison.

Based on the results in Table 4.3, the TVOC concentration for EchoHaven was 0.193 mg/m^3, with small contributions from all found compounds.

The Health Canada document further states, "Although there are at present no Canadian or U.S. standards for TVOC, target and action units of 1 and 5 mg/m^3 respectively, are being discussed. Target level refers to the maximum permissible level and action level refers to the level where counter measures should be employed." The VOCs identified in the testing had levels orders of magnitude less than the ASHRAE Standard 62-1989 and the TVOC was only 20% of the Health Canada target level.

Ventilation effectiveness testing was performed in March 2011. The testing, as recommended by Brookhaven National Laboratory, involves the placement of unique compound-emitting canisters in various rooms in the house along with passive samplers that will collect the compound through exposure. For houses with more than one zone, additional types of compounds are used to identify cross contamination between zones. EchoHaven was tested as two zones, because it has a radiant heat delivery system, without the intentional mixing of air between various rooms that happens with a forced air heating system. The results of the testing indicate an overall air change rate of 0.089 ± 0.009 ACH (air changes per hour) or 57.8 m^3/hr (16.1 L/s).

The HOT2000 model includes a F236 calculator to determine the air change requirements of a house; in the case of EchoHaven the recommended rate is 0.27 ach. Measurements on January 20, 2011 indicated that the HRV was providing 62 L/s (approximately 0.34 ACH) on high speed, meeting the F236 requirements. The measured supply at low speed was 20 L/s (approximately 0.11 ACH) and the supply and exhaust flows were balanced within 10%. The HRV ran mainly at low speed during the year with on-demand increases to the higher speed based on humidity measurement or requests by occupants.

A blower door air leakage test was conducted on the EchoHaven house after construction was complete. The result indicated an air change rate of 1.04 ACH at 50 Pa. At a pressure difference of 5 Pa, the equivalent airflow rate due to natural ventilation would be 41 L/s. The R-2000 standard in Canada, a standard for energy efficient house construction, stipulates a maximum air change rate of 1.5 ACH at 50 Pa (NRCan, 2005), i.e. EchoHaven is well within the R-2000 standard for air tightness.

The sum of the mechanical ventilation at 20-62 L/s and the natural ventilation due to air leakage, estimated at 41 L/s, far exceeds the value of 16.1 L/s measured with the tracer gas test. The cause of the discrepancy cannot be determined from the information available, but potential contributions could be short circuiting of the ventilation supply and exhaust in the house, or improper administration of the tracer gas test.

4.7.2. Real-Time Indoor Environmental Quality Measurements

The real-time monitoring of indoor temperature, relative humidity (RH) and carbon dioxide (CO_2) began five months before the start of the year of energy monitoring. However, the sensors failed during the last two months of the year, hence there are a total of 15 (continuous) months of monitoring data.   Figure 4.5 shows temperature, relative humidity and CO_2 from May 3, 2011, until August 5, 2012.
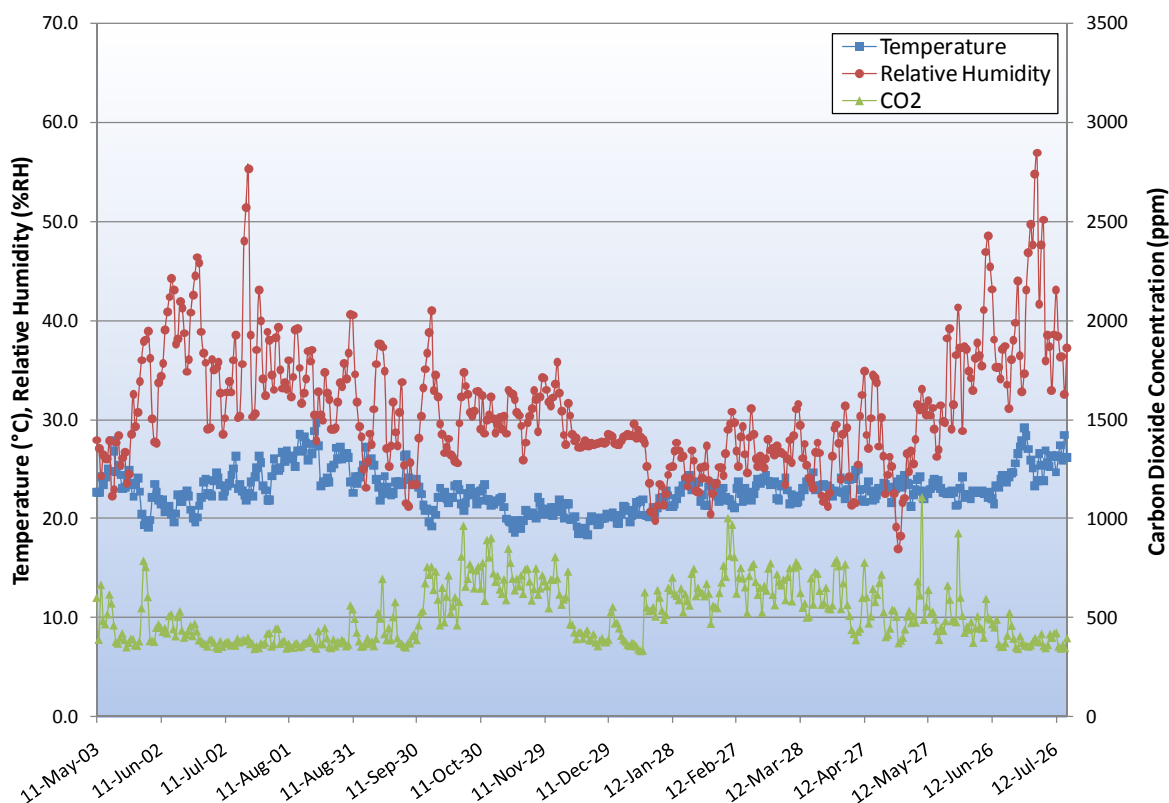
Figure 4.5. Measured EchoHaven Daily Average Temperature, Relative Humidity and CO_2

The temperature and RH were measured in the loft area, above the kitchen in the main living area. The average daily temperature in some of the summer months show that the house did heat up close to 30°C as an average daily temperature. The temperature in this area would likely be a little higher than on the "main" level but it is in the same space. The highest recorded hourly temperature was 34°C in August 2011 and the lowest was 18°C in December 2011. The loft area was equipped with a large operable window to allow passive cooling, using a chimney effect, in the house. The daily averaged relative humidity was rarely above 50%, especially in winter months; typically occupants desire a relative humidity in the order of 30 to 50% at normal ambient temperatures of around 21°C in heating periods. The CO_2 concentrations were typically in the 750 ppm range and rarely above 800 ppm during the winter months. Good ventilation strategies should ensure the CO_2 concentrations never exceed 1,000 ppm for an extended period of time.

One reason for the higher temperatures in the summer months is the lack of overhangs over the south facing windows to block direct sunlight (Figure 4.6).

Figure 4.6. South view of EchoHaven house showing small overhangs over majority of south facing windows

4.8. **Appliance Energy Use**

Table 4.4 presents the electrical energy use of selected appliances (measured using Kill A Watt™ meters) at EchoHaven. The monitoring of the select appliances accounts for 279 kWh.

The project team predicted 2,628 kWh/yr of electrical use from lights, appliances and other electrical equipment. SRC adjusted as-built modelling of the house increased this estimate to 3,030 kWh. The electricity actually used for appliances, etc., was determined, from measurements and calculations, to be 3,450 kWh (see Table 4.2), 14% more than the adjusted HOT2000 prediction.

Table 4.4. Monthly Energy (kWh) Used by Selected EchoHaven Electrical Equipment

Electrical Device	Oct 2011	Nov 2011	Dec 2011	Jan 2012	Feb 2012	Mar 2012	Apr 2012	May 2012	Jun 2012	Jul 2012	Aug 2012	Sep 2012
Cistern Pump	3.0	2.2	1.2	1.7	1.9	2.3	2.6	2.9	0.4	5.2	6.6	4.9
Central Vacuum	4.4	3.2	4.4	5.6	10.5	9.2	12.5	10.5	n/a	n/a	n/a	n/a
Radon Pump/ Security System	n/a	0.2	45.4	26.1	6.6	7.4	21.6	29.7	1.7	1.2	1.6	6.7
Electric Indoor Composter	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	10.5	8.3	8.7	8.3

The EchoHaven appliances, listed in Table 4.6, were chosen for their energy efficiency but also to reflect the level of finishes in the home. Most of the energy use estimates are taken from the EnerGuide Appliance Directory published by Natural Resources Canada (NRCan, 2010)

Table 4.6. List of Appliances in the EchoHaven house

Appliance	Model	EnerGuide Rating (kWh/y) (NRCan, 2010)
Induction Range	Bosch NIT5065UC	230
Wall Oven	Bosch HBN3450UC	389
Dishwasher	Bosch SHE68E15UC	180
Microwave	Bosch HMV3051C	137[a]
Refrigerator	Bosch B22CS50SNS	539
Freezer	Sundanzer SDR 165	99[b]
Clothes Dryer	Bosch WTE86300US	449
Clothes Washer	Bosch WAS20160UC	125
Total		**2,148**

[a] Microwave energy use estimated based on 15 minutes/day of use at 1500W for one year

[b] Freezer energy based on 272 Whr/day for one year as per manufacturers website (Sundanzer, 2012)

The predicted appliance energy use accounts for 2,148 kWh of the total 3,450 kWh calculated electrical used for appliances and lighting energy. After also considering the monitored plug load (Table 4.5) the remaining 1,023 kWh was used for meet lighting and other electrical needs (e.g.

computers, televisions, stereo equipment, and small kitchen appliances). It should also be noted that HOT2000 models the dryer energy use as external energy. The reason for this approach is that the heat energy created by the dryer is exhausted outside and is therefore not an internal heat gain as with the other appliances. Although HOT2000 models the dryer energy this way, it reports the dryer energy use (as well as the exterior energy use) under the Appliance and Lighting category.   However, the EchoHaven condensing dryer does not vent directly to the exterior directly. The dryer has a condenser system that removes the majority of the water from the air stream, and places it in a trap, before the air is expelled to the interior space.

5. DISCUSSION

5.1. Photovoltaic Production

Photovoltaic electrical production was generally higher than predicted by the RETScreen models, after the solar radiation and temperature were updated for observed conditions. Winter production was comparatively less, however. This trend has been observed in most of the EQuilibrium™ houses monitored to date. Site issues such as shading (trees, snow coverage, etc.) can reduce solar radiation in the winter months when the sun is low on the horizon. The higher than anticipated electrical production over the monitored year may be due to an over-estimation of the losses in the system and of the losses associated with the inverter. The EchoHaven system also uses micro inverters on each panel where individual panel failure or reduced production does not affect adjacent panel production. Another potential explanation for higher than predicted production is that PV module manufacturers rate their modules production based on the anticipated production at the end of their warranty period (often 25 years), so it is not unusual for a PV module to generate somewhat more than its rated production capacity early in its lifetime.

The monitoring shows production from the PV system of 7,934 kWh compared to the adjusted model output of 7,234 kWh, after the model was adjusted for actual solar radiation and weather. Using the average year weather and sunshine data in RETScreen would predict 8,177 kWh, which is close to the actual.

There are also monthly differences between the Enphase monitoring and the utility style meters installed for this project. The Enphase electrical production, from reports generated by the online dashboard, was 8,135 kWh (2.5% higher) over the same period as the measured data from the installed meters. Enphase monitoring systems do not meet the same accuracy requirements of utility meters which may explain this difference.

5.2. Solar Thermal Energy

The EchoHaven solar thermal system is a combination space and domestic hot water (DHW) heating system, with a DHW priority. The system controller activates a pump to supply space heating to one room on the ground floor when the tank meets a specified temperature. Below this temperature the solar thermal system provides (pre) heated DHW. The system contributed 1,094 kWh to the consumed energy in the building, 1,070 kWh for DHW and the remainder, 24 kWh, for space heating. The solar fraction for DHW was quite high (~80%) for many months (Figure 4.3) indicating the system was well sized for this particular load. There was higher solar fraction in summer months than winter months, even with the vertically oriented panels. The

addition of the space heating loop to dissipate heat from the tank when required was likely an expensive addition compared to the benefit.

The RETScreen model over-predicted the energy production from this system by 51%. The lower than expected performance can be attributed to lower than expected loads in the model, compared to actual. The model assumed a demand on the solar thermal system to match the requirements for DHW heating and a portion of the space heating. In reality, the house used less energy than expected for DHW and very little energy for space heating therefore the delivered heat from the solar thermal system will be less. The over prediction in available solar thermal energy can lead to contingency efforts to reduce stored heat, such as the installation of the space heating loop.

5.3. Appliance, Lighting and Plug Load Energy Use

The electrical energy used in the EchoHaven house for lighting, appliances and other miscellaneous electrical loads was 3,450 kWh, which was 420 kWh (14%) more than predicted. Some specific plug loads (cistern pump, radon pump, security system, electric composter, and central vacuum) were monitored that accounted for 279 kWh of electrical use. The estimated electrical energy use by the appliances was 2,148 kWh.

At the homeowners' request, SRC has estimated the electrical use of the monitoring equipment used during the monitoring period. The monitoring equipment plug load is estimated to have been approximately 100 kWh for the year (based on a 12 W draw). Note that, during the heating season, heat loss from this equipment contributed to reducing the active space heating requirements.

With the limited monitoring equipment used for measuring plug loads, it is difficult to determine where all the electrical energy was used. Detailed electrical monitoring could determine the areas for improvement and / or better characterize the lighting, appliance and plug load electrical use.

6. CONCLUSIONS AND RECOMMENDATIONS

EchoHaven, located in Calgary, Alberta, one of the winning projects in the CMHC EQuilibrium™ Sustainable Housing Demonstration Initiative, was monitored for one year. Modelling of the anticipated energy consumption and production – using a HOT2000 model for the house that was adjusted for as-built construction, occupancy, and observed temperature in Calgary and RETScreen models for the renewable energy adjusted for temperature and solar radiation observed during the monitored year – showed a predicted net energy requirement for the house of 1,172 kWh. The actual energy use balance measured for the year of monitoring indicated a net consumption of 341 kWh, approximately a third of that predicted. The energy used for domestic hot water heat was less than predicted, and the energy produced by the solar photovoltaic system was more than predicted, contributing to the better-than-expected performance of the house. The solar thermal system provided less energy than expected during the monitored year. Most other metrics compared well between the measured and modelled results over the year of monitoring. As mentioned earlier, the homeowners were on holidays for a period of the winter, hence there was less energy consumed than expected, especially in December and January. This would not be considered uncommon for many Canadians.

The ventilation effectiveness testing showed an air exchange in the house of about 0.09 ach, which is lower than the air change rate anticipated from the HRV and the measured building envelope air leakage rate. The ventilation effectiveness testing results are suspect when comparing them to natural infiltration and the HRV runtime and flow rate. The real-time indoor temperature, relative humidity and CO_2 measurements are largely within desirable ranges, with the exception of short periods of both elevated temperatures in summer and elevated CO_2 levels. The former is likely due, in part, to the small and less than optimal overhangs to shade direct sunlight entering the south facing windows. The other IEQ testing showed acceptable levels of formaldehyde, radon, selected VOC and TVOC concentrations.

The EchoHaven water use (66.3 potable and 7.0m^3 rainwater capture) was significantly lower than the average Canadian consumption, which would be approximately 240 m^3 for two people for a year. Both the water saving features, such as fixtures and appliances, and the use of harvested rainwater reduced the use of potable water. The low DHW demand contributed to lower energy requirements and likely had an effect on the solar thermal contributions based on the system configuration. If the amount of heat used by the solar thermal system is reduced, the amount of solar heat captured will also be reduced.

The fact that the house required less heating energy than predicted by the models is an indication that the passive design features (high insulation levels, south-facing windows, thermal mass, etc.) performed well. The overall energy use was very close to net zero, on an annual basis. Small

reductions in energy use and / or additional sunshine (which would contribute to additional annual PV and solar thermal production and passive solar gain) could lead to net zero consumption on an annual basis.

7. REFERENCES

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APPENDIX A

HOT2000 Simulation Reports

HOT2000

Natural Resources CANADA
Version 10.51

File: SRC-EchoHaven.v8 mathc to weather data
Application Type: General

Weather Library: G:\Building Performance\1011_Projects\12323_CMHC EQuilibrium Monitoring\Projects\Echo Haven Calgary\Models\Wth100 Calgary 1112 adjustmentv3.WEA

Weather Data for CALGARY, ALBERTA

Builder Code:

Data Entry by:
Date of entry: 2/15/2011
Company:

Client name: Spencer/Wiltshire, Dave/Deb
Street address: 42 Rocky Ridge Crescent

City: Calgary   **Region:** Alberta
Postal code: **Telephone:**

GENERAL HOUSE CHARACTERISTICS

House type:	Single Detached		
Number of storeys:	One and a half		
Plan shape:	Rectangular		
Front orientation:	South		
Year House Built:	2000-		
Wall colour:	Light green	**Absorptivity:**	0.47
Roof colour:	Medium brown	**Absorptivity:**	0.84
Soil Condition:	Normal conductivity (dry sand, loam, clay)		
Water Table Level:	Normal (7-10m/23-33ft)		

House Thermal Mass Level: (C) Heavy, masonry

Effective mass fraction 0.500

Occupants :   2 Adults for 50.0% of the time
2 Children for 50.0% of the time
0 Infants for 0.0% of the time

Sensible Internal Heat Gain From Occupants: 2.40 kWh/day

HOUSE TEMPERATURES

Heating Temperatures

Main Floor:	21.0 °C
Basement:	21.0 °C
TEMP. Rise from 21.0 °C:	5.5 °C

Basement is- Heated: YES **Cooled:** NO **Separate T/S:** YES
Fraction of internal gains released in basement : 0.150

Indoor design temperatures for equipment sizing

Heating:	22.0 °C
Cooling:	26.7 °C

WINDOW CHARACTERISTICS

Label	Location	#	Overhang Width (m)	Header Height (m)	Tilt deg	Curtain Factor	Shutter (RSI)
South							
Window - 1	S. Kitchen 2	1	0.15	0.61	90.0	1.00	0.00
Window - 10	South master BR	1	0.15	1.83	90.0	1.00	0.00
Window - 21	South master BR	1	0.15	1.37	90.0	1.00	0.00
Window - 22	Walkout	1	0.15	4.80	90.0	1.00	0.00
Window - 23	S. Living Room 2	1	0.15	2.06	90.0	1.00	0.00
Window - 24	Walkout	1	1.83	0.46	90.0	1.00	0.00
Window - 6	Walkout	1	1.83	0.46	90.0	1.00	0.00
Window - 8	Walkout	1	0.15	3.20	90.0	1.00	0.00
Window - 9	S. Living Room 2	1	0.15	0.53	90.0	1.00	0.00
Southeast							
Window - 17	SE Facing 2	1	0.91	1.83	90.0	1.00	0.00
Window - 18	SE Facing 2	1	1.52	3.89	90.0	1.00	0.00
Window - 19	SE Facing 2	1	1.52	2.29	90.0	1.00	0.00
Window - 20	SE Facing 2	1	0.91	0.76	90.0	1.00	0.00
Window - 5	SE Facing 2	1	1.52	0.76	90.0	1.00	0.00
Window - 7	Walkout	1	0.91	4.80	90.0	1.00	0.00
East							
Window - 12	Door - 4	1	0.61	4.27	90.0	1.00	0.00
Window - 16	E. Mast BR 2	1	0.61	0.53	90.0	1.00	0.00
Window - 27	Door - 5	1	0.00	0.00	90.0	1.00	0.00
Window - 29	E. Living Room 2	1	0.61	1.52	90.0	1.00	0.00
North							
Window - 14	North	2	0.61	0.76	90.0	1.00	0.00
West							
Window - 2	West 2	1	0.61	1.52	90.0	1.00	0.00
Window - 3	West 2	1	0.61	2.59	90.0	1.00	0.00
Window - 4	West 3 (loft)	1	0.61	1.30	90.0	1.00	0.00
Southwest							
Window - 26	Door - 3	1	0.00	0.00	90.0	1.00	0.00

| Window - 28 | Door - 2 | 1 | 1.22 | 1.22 | 90.0 | 1.00 | 0.00 |

Label	Type	#	Window Width (m)	Window Height (m)	Total Area (m²)	Window RSI	SHGC
South							
Window - 1	0PLIron	1	1.52	1.02	1.55	0.830	0.6128
Window - 10	0HLIron	1	0.81	1.22	0.99	0.826	0.5354
Window - 21	0PLIron	1	1.32	1.22	1.61	0.830	0.6169
Window - 22	0HLIron	1	1.19	0.41	0.49	0.820	0.4289
Window - 23	0HLIron	1	1.19	0.41	0.49	0.820	0.4289
Window - 24	0PLIron	1	0.76	1.02	0.77	0.827	0.5724
Window - 6	0HLIron	1	0.76	1.02	0.77	0.825	0.5154
Window - 8	0PLIron	1	1.19	1.60	1.91	0.831	0.6240
Window - 9	0PLIron	1	1.19	1.60	1.91	0.831	0.6240
Southeast							
Window - 17	0PLIron	1	1.19	2.01	2.40	0.831	0.6319
Window - 18	0HLIron	1	1.19	0.41	0.49	0.820	0.4289
Window - 19	0PLIron	1	1.19	1.60	1.91	0.831	0.6240
Window - 20	0PLIron	1	1.19	0.44	0.53	0.824	0.5225
Window - 5	0PLIron	1	1.19	1.02	1.21	0.829	0.6016
Window - 7	0PLIron	1	1.19	0.51	0.61	0.825	0.5401
East							
Window - 12	0PCLR	1	0.76	1.90	1.45	1.113	0.4006
Window - 16	0HLIron	1	0.61	1.22	0.74	0.824	0.5003
Window - 27	0PCLR	1	0.76	1.90	1.45	1.113	0.4006
Window - 29	0PCLR	1	1.83	1.14	2.09	1.159	0.4183
North							
Window - 14	0HLIron	2	0.61	1.22	1.49	0.824	0.5003
West							
Window - 2	0HCLR	1	0.79	1.19	0.94	1.039	0.3552
Window - 3	0HCLR	1	1.02	0.41	0.41	0.924	0.2820
Window - 4	0HCLR	1	1.22	0.61	0.74	1.003	0.3353
Southwest							
Window - 26	0PLIron	1	0.76	1.90	1.45	0.829	0.5997
Window - 28	0PLIron	1	0.76	1.90	1.45	0.829	0.5997

USER-DEFINED WINDOW CODES SCHEDULE

Code	Description	Window Type
00PLIron	0PLIron	Picture
00HLIron	0HLIron	Hinged
00PCLR	0PCLR	Picture
00HCLR	0HCLR	Picture

USER-DEFINED WINDOW CODES: DATA

Code	RSI - Centre of Glass	RSI - Edge of Glass	RSI - Frame	Frame Ht mm	Centre of Glass SHGC
00PLIron	0.838	0.810	0.820	48.3	0.720
00HLIron	0.838	0.807	0.819	68.6	0.720
00PCLR	1.356	0.863	0.854	48.3	0.480
00HCLR	1.350	0.850	0.820	68.6	0.480

BUILDING PARAMETER DETAILS

CEILING COMPONENTS

	Construction Type	Code Type	Roof Slope	Heel Ht.(m)	Section Area (m^2)	R. Value (RSI)
Above Entry Door	Scissor	T@R100	6.000/12	0.91	7.11	17.39
Mast Bath & Bed	Scissor	T@R100	6.000/12	0.91	33.55	17.41
Spare Bed & Bath	Attic/gable	T@R100	3.000/12	0.91	26.60	17.40
Vaulted Living R	Scissor	T@R100	12.000/12	0.99	58.85	17.41

MAIN WALL COMPONENTS

Label	Lintel Type	Fac. Dir	Number of Corn.	Number of Inter.	Height (m)	Perim. (m)	Area (m^2)	R. Value (RSI)
E. Living Room 2 Type: w1 truss	LL2	East	2	1	2.50	4.61	11.51	8.15
E. Mast BR 2 Type: w1 truss	LL2	East	2	1	2.50	2.44	6.09	9.97
North Type: w1 truss	LL2	North	2	3	2.46	14.53	35.73	10.45
S. Kitchen 2 Type: w1 truss	LL2	South	2	1	2.50	3.83	9.58	9.67
S. Living Room 2 Type: w1 truss	LL2	South	2	1	2.50	2.08	5.21	7.91
SE Facing 1 Type: w1 truss	LL2	Southeast	1	1	2.45	3.44	8.43	10.56
SE Facing 2 Type: w1 truss	LL2	Southeast	1	1	3.96	3.44	13.65	7.92
SW Facing 1 Type: w1 truss	LL2	Southwest	1	1	2.45	1.89	4.63	10.49
SW Facing 2 Type: w1 truss	LL2	Southwest	1	1	3.05	1.60	4.88	9.36

South master BR Type: w1 truss	LL2	South	1	1	2.50	2.88	7.19	8.92
West 2 Type: w1 truss	LL2	West	1	1	2.50	8.13	20.31	10.23
West 3 (loft) Type: w1 truss	LL2	West	2	2	1.85	3.96	7.32	9.89

EXPOSED FLOORS

Label	Floor Code Type	Area (m^2)	R. Value (RSI)
MBed Ensuite	Floor Below MBed	24.07	8.64

DOORS

Label	Type	Height (m)	Width (m)	Gross Area (m^2)	R. Value (RSI)
Door - 2 Loc: SW Facing 2	Fibreglass polyurethane core	2.07	0.81	1.68	0.98
Door - 3 Loc: Walkout	Fibreglass polyurethane core	2.08	0.91	1.90	0.98
Door - 4 Loc: E. Living Room 2	Fibreglass polyurethane core	2.08	0.91	1.90	0.98
Door - 5 Loc: E. Living Room 2	Fibreglass polyurethane core	2.08	0.91	1.90	0.98
to garage Loc: Walkout	Steel polyurethane core	2.03	0.91	1.86	1.14

USER-DEFINED STRUCTURE CODES SCHEDULE

Name	Description
11w1 truss	Copy of T@R57
11H@R60	Hdr w XPS, Blw Cell, Icy
21T@R100	
31Floor Below MBed	

FOUNDATIONS

Foundation Name:	Walkout		
Foundation Type:	Walkout	**Volume:**	212.0 m^3
Data Type:	Library	**Opening to Main Floor:**	8.64 m^2
		Thermal Break R-Value:	0.00 RSI

Walkout with Slab, with Pony wall

Total wall height :	2.44 m	**Length 1:**	10.01 m
Height of corner 1:	2.13 m	**Length 2:**	8.69 m
Length 3:	4.27 m	**Length 4:**	5.49 m
Height of concrete wall above grade:	0.15 m		

Interior wall type:	User specified	**R-value:**	0.00 RSI
Exterior wall type:	User specified	**R-Value:**	8.81 RSI
Number of corners :	6		
Lintel type:	N/A		
Added to slab type :		**R-Value:**	7.04 RSI

Floors Above Found.: User specified   **R-Value:**   0.53 RSI

Exposed areas for: Walkout
Exposed Perimeter: 19.66 m

Exposed Area Above Grade: 2.70 m^2
Exposed Area Below Grade: 37.28 m^2

Exposed Pony Wall Area: 3.24 m^2

Configuration: BWEB_2
- wood walls and wood floor
- exterior surface of wall insulated over full-height
- sub-surface of floor slab fully insulated but no insulation under footings
- first storey brick veneer placed directly on basement's concrete walls

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FOUNDATION CODE SCHEDULE

PONY WALL COMPONENTS

Label	Lintel Type	Fac. Dir	Number of Corn.	Number of Inter.	Height (m)	Perim. (m)	Area (m^2)	R. Value (RSI)
Walkout Type: User specified	N/A	East	6	2	1.37	37.39	51.18	7.92

BASEMENT FLOOR HEADER COMPONENTS

Label	Lintel Type	Fac. Dir	Number of Corn.	Number of Inter.	Height (m)	Perim. (m)	Area (m^2)	R. Value (RSI)
Floor Header - 1 Type: H@R60	N/A	East	4	4	0.41	11.81	4.79	10.22

Basement Floor Header Code Schedule

Name	Internal Code	Description (Structure, typ/size, Spacing, Insul1, 2, Int., Sheathing, Exterior, Studs)
H@R60	11H@R60	N/A, N/A, N/A, N/A, N/A, Wood, None

USER-DEFINED LINTEL CODES SCHEDULE

Name	Code	Description
LL2	LL2	

ROOF CAVITY INPUTS

Gable Ends		Total Area:	2.22 m^2
Sheathing Material	Plywood/Part. bd 9.5 mm (3/8 in)		0.08 RSI
Exterior Material:	Hollow metal/vinyl cladding		0.11 RSI

Sloped Roof		Total Area:	145.96 m^2
Sheathing Material	Plywood/Part. bd 12.7 mm (1/2 in)		0.11 RSI
Exterior Material:	Asphalt shingles		0.08 RSI

Total Cavity Volume: 56.4 m^3 **Ventilation Rate:** 0.50 ACH/hr

BUILDING ASSEMBLY DETAILS

Label	Construction Code	Nominal (RSI)	System (RSI)	Effective (RSI)
CEILING COMPONENTS				
Above Entry Door	T@R100	17.46	17.39	17.39
Mast Bath & Bed	T@R100	17.46	17.41	17.41
Spare Bed & Bath	T@R100	17.46	17.40	17.40
Vaulted Living R	T@R100	17.46	17.41	17.41
MAIN WALL COMPONENTS				
E. Living Room 2	w1 truss	10.53	9.66	8.15
E. Mast BR 2	w1 truss	10.53	10.28	9.97
North	w1 truss	10.53	10.56	10.45
S. Kitchen 2	w1 truss	10.53	10.33	9.67
S. Living Room 2	w1 truss	10.53	9.53	7.91
SE Facing 1	w1 truss	10.53	10.56	10.56
SE Facing 2	w1 truss	10.53	9.52	7.92
SW Facing 1	w1 truss	10.53	10.49	10.49
SW Facing 2	w1 truss	10.53	9.97	9.36
South master BR	w1 truss	10.53	9.99	8.92
West 2	w1 truss	10.53	10.51	10.23
West 3 (loft)	w1 truss	10.53	10.39	9.89
EXPOSED FLOORS				
MBed Ensuite	Floor Below MBed	9.01	8.64	8.64

BUILDING PARAMETERS SUMMARY

ZONE 1 : Above Grade

Component	Area m² Gross	Area m² Net	Effective (RSI)	Heat Loss MJ	% Annual Heat Loss
Ceiling	126.11	126.11	17.41	2525.57	4.52
Main Walls	134.53	109.55	9.78	5233.85	9.37
Doors	5.49	1.13	0.98	589.48	1.06
Exposed floors	24.07	24.07	8.64	1346.24	2.41
South Windows	6.55	6.55	0.83	4036.84	7.23
Southeast Windows	6.53	6.53	0.83	4028.65	7.21
East Windows	5.74	5.74	1.08	2716.53	4.86
North Windows	1.49	1.49	0.82	922.04	1.65
West Windows	2.10	2.10	1.00	1069.80	1.92
Southwest Windows	1.45	1.45	0.83	895.32	1.60
			ZONE 1 Totals:	**23364.32**	**41.83**

INTER-ZONE Heat Transfer : Floors Above Basement

Area m² Gross	Area m² Net	Effective (RSI)	Heat Loss MJ
86.93	86.93	0.528	10355.75

ZONE 2 : Basement

Component	Area m² Gross	Area m² Net	Effective (RSI)	Heat Loss MJ	% Annual Heat Loss
Walls above grade	2.70	2.70	-	258.51	0.46
Doors	3.76	2.31	1.10	1066.11	1.91
South windows	3.94	3.94	0.83	2427.20	4.35
Southeast windows	0.61	0.61	0.83	374.41	0.67
Southwest windows	1.45	1.45	0.83	891.99	1.60
Basement floor header	4.79	4.79	10.22	394.82	0.71
Pony walls	51.18	42.87	7.92	4557.56	8.16
Below grade foundation	124.21	124.21	-	6834.97	12.24
			ZONE 2 Totals:	16805.56	30.09

Ventilation

House Volume	Air Change	Heat Loss MJ	% Annual Heat Loss
656.30 m³	0.362 ACH	15683.434	28.08

AIR LEAKAGE AND VENTILATION

Building Envelope Surface Area: 467.59 m^2

Air Leakage Test Results at 50 Pa.(0.2 in H$_2$O) = 1.04 ACH

Equivalent Leakage Area @ 10 Pa = 254.84 cm2

Terrain Description	Height	m
@ Weather Station : Suburban, forest	Anemometer	10.0
@ Building site : Suburban, forest	Bldg. Eaves	8.5

Local Shielding:	Walls:	Light
	Flue :	None

Leakage Fractions- **Ceiling:** 0.200 **Walls:** 0.600 **Floors:** 0.200

Normalized Leakage Area @ 10 Pa: 0.5450 cm^2/m^2

Estimated Airflow to cause a 5 Pa Pressure Difference: 41 L/s

Estimated Airflow to cause a 10 Pa Pressure Difference: 64 L/s

F326 VENTILATION REQUIREMENTS

Kitchen, Living Room, Dining Room	3 rooms @ 5.0 L/s: 15.0 L/s
Utility Room	1 rooms @ 5.0 L/s: 5.0 L/s
Bedroom	1 rooms @ 10.0 L/s: 10.0 L/s
Bedroom	1 rooms @ 5.0 L/s: 5.0 L/s
Bathroom	1 rooms @ 5.0 L/s: 5.0 L/s
Basement Rooms	: 10.0 L/s

CENTRAL VENTILATION SYSTEM

System Type:	HRV
Manufacturer:	Lifebreath
Model Number:	195ECM

Fan and Preheater Power at 0.0 °C:	34 Watts
Fan and Preheater Power at -25.0 °C:	34 Watts
Preheater Capacity:	0 Watts
Sensible Heat Recovery Efficiency at 0.0 °C	85%
Sensible Heat Recovery Efficiency at -25.0 °C	69%
Total Heat Recovery Efficency in Cooling Mode	25%

Low Temperature Ventilation Reduction:	0%
Low Temperature Ventilation Reduction: Airflow Adjustment	0 L/s (0.0%)

Vented combustion appliance depressurization limit: 5.00 Pa.

Ventilation Supply Duct

Location:	Basement	**Type:**	Flexible
Length:	1.5 m	**Diameter:**	152.4 mm

Insulation:	0.7 RSI	**Sealing Characteristics:**	Sealed

Ventilation Exhaust Duct

Location:	Basement	**Type:**	Flexible
Length:	1.5 m	**Diameter:**	152.4 mm
Insulation:	0.7 RSI	**Sealing Characteristics:**	Sealed

SECONDARY FANS & OTHER EXHAUST APPLIANCES

	Control	**Supply (L/s)**	**Exhaust (L/s)**
Dryer	Continuous	-	0.00

Dryer is NOT vented outdoors

AIR LEAKAGE AND VENTILATION SUMMARY

F326 Required continous ventilation:	50.000 L/s (0.27 ACH)
Central Ventilation Supply Rate ():	49.979 L/s (0.27 ACH)
Total house ventilation is Balanced	
Gross Air Leakage and Ventilation Energy Load:	34247.586 MJ
Seasonal Heat Recovery Ventilator Efficiency:	83.005 %
Estimated Ventilation Electrical Load: Heating Hours:	913.269 MJ
Estimated Ventilation Electrical Load: Non-Heating Hours:	158.956 MJ
Net Air Leakage and Ventilation Load:	16140.068 MJ

SPACE HEATING SYSTEM

Primary Heating Fuel:	Electricity
Equipment:	Baseboard/Hydronic/Plenum(duct) htrs.
Manufacturer:	
Model:	
Calculated* Output Capacity:	8.50 kW
* Design Heat loss X 1.00 + 0.5 kW	
Steady State Efficiency:	100.00 %
Fan Mode:	Auto
ECM Motor:	No
Low Speed Fan Power:	0 watts
High Speed Fan Power:	165 watts

Radiant / Hydronic Heating

Location	Effective Temp. (Deg °C)	% of Total Area
Floor above Basement	33.00	90.00
Basement	33.00	90.00

DOMESTIC WATER HEATING SYSTEM

Primary Water Heating Fuel:	Electricity
Water Heating Equipment:	Instantaneous
Energy Factor:	1.000
Manufactuer:	
Model:	

ANNUAL DOMESTIC WATER HEATING SUMMARY

Daily Hot Water Consumption:	124.00 Litres
Hot Water Temperature:	55.00 °C
Estimated Domestic Water Heating Load:	9349 MJ
Primary Domestic Water Heating Energy Consumption:	9349.03 MJ
Primary System Seasonal Efficiency:	100.00%

ANNUAL SPACE HEATING SUMMARY

Design Heat Loss at -33.00 °C (12.20 Watts / m3):	8007.93 Watts
Gross Space Heat Loss:	55853.32 MJ
Gross Space Heating Load:	63399.56 MJ
Usable Internal Gains:	12800.53 MJ
Usable Internal Gains Fraction:	22.92 %
Usable Solar Gains:	35763.82 MJ
Usable Solar Gains Fraction:	64.03 %

Auxilary Energy Required: 14835.21 MJ

Space Heating System Load: 14835.21 MJ
Furnace/Boiler Seasonal efficiency: 100.00 %
Furnace/Boiler Annual Energy Consumption: 14552.88 MJ

BASE LOADS SUMMARY

	kwh/day	Annual kWh
Interior Lighting	1.00	365.00
Appliances	3.80	1387.00
Other	3.00	1095.00
Exterior Use	0.50	182.50
HVAC Fans		
HRV/Exhaust	0.82	297.84
Space Heating	0.21	78.42
Space Cooling	0.00	0.00
Total Average Electrical Load	9.33	3405.76

FAN OPERATION SUMMARY (kWh)

Hours	HRV/Exhaust Fans	Space Heating	Space Cooling
Heating	253.7	78.4	0.0
Neither	44.2	0.0	0.0
Cooling	0.0	0.0	0.0
Total	297.8	78.4	0.0

ENERGY CONSUMPTION SUMMARY REPORT

Estimated Annual Space Heating Energy Consumption	= 14835.21 MJ	= 4120.89 kWh
Ventilator Electrical Consumption: Heating Hours	= 913.27 MJ	= 253.69 kWh
Estimated Annual DHW Heating Energy Consumption	= 9349.03 MJ	= 2596.95 kWh
ESTIMATED ANNUAL SPACE + DHW ENERGY CONSUMPTION	= 25097.51 MJ	= 6971.53 kWh
Estimated Greenhouse Gas Emissions	5.446 tonnes/year	

ESTIMATED ANNUAL FUEL CONSUMPTION SUMMARY

Fuel	Space Heating	Space Cooling	DHW Heating	Appliance	Total
Electricity (kWh)	4374.58	0.00	2596.95	3073.65	10045.18

ESTIMATED ANNUAL FUEL CONSUMPTION COSTS

Fuel Costs Library = Embedded

RATE	Electricity (Calgary)	Natural Gas (Ottawa08)	Oil (Ottawa08)	Propane (Ottawa08)	Wood (Sth Ont)	Total
$	823.76	0.00	0.00	0.00	0.00	823.76

Fuel Costs Library Listing

Filename = Embedded

Record # 1	Fuel: Electricity		
Rate ID = Ottawa08	Hydro Rate Block		
Rate Block		Dollars	Charge
	kWhr	Per kWhr	($)
Minimum	0.0		9.540
1	600.0	0.0926	
2	99999.0	0.1016	

Record # 2	Fuel: Natural Gas		
Rate ID = Ottawa08	Gas Rate Block		
Rate Block		Dollars	Charge
	m3	Per m3	($)
Minimum	0.0		14.000
1	30.0	0.5338	

		Litre	Per Litre	($)
	2	85.0	0.5277	
	3	170.0	0.5229	
	4	99999.0	0.5194	

Record # 3 Fuel: Oil

Rate ID = Ottawa08   Oil Rate Block

Rate Block			Dollars	Charge
		Litre	Per Litre	($)
Minimum		0.0		0.000
	1	99999.0	1.1750	

Record # 4 Fuel: Propane

Rate ID = Ottawa08   Propane Rate Block

Rate Block			Dollars	Charge
		Litre	Per Litre	($)
Minimum		0.0		0.000
	1	99999.0	0.7200	

Record # 5 Fuel: Wood

Rate ID = Sth Ont   Cord Rate

Rate Block			Dollars	Charge
		Cord	Per Cord	($)
Minimum		0.0		0.000
	1	99999.0	210.0000	

Record # 6 Fuel: Electricity

Rate ID = Calgary

Rate Block			Dollars	Charge
		kWhr	Per kWhr	($)
Minimum		0.0		7.120
	1	99999.0	0.0735	

MONTHLY ENERGY PROFILE

Month	Energy Load (MJ)	Internal Gains (MJ)	Solar Gains (MJ)	Aux. Energy (MJ)	HRV Eff. %
Jan	8651.1	1074.6	4016.6	3560.0	82.2
Feb	7417.5	967.6	4225.8	2224.1	82.2
Mar	6762.7	1074.6	4393.5	1294.6	83.1
Apr	5246.4	1048.6	3339.6	858.2	83.6
May	4261.7	1095.9	2665.0	500.9	83.5
Jun	3007.3	1072.4	1636.6	298.2	83.7
Jul	2256.0	1030.5	1085.4	140.1	83.3
Aug	2737.9	1102.8	1451.4	183.7	82.7
Sep	3410.6	1081.2	2082.3	247.0	83.0
Oct	5155.7	1108.2	3487.8	559.7	83.4
Nov	7114.4	1060.5	3853.6	2200.3	82.9
Dec	7378.2	1083.6	3526.2	2768.5	82.8
Ann	63399.6	12800.5	35763.8	14835.2	83.0

FOUNDATION ENERGY PROFILE

			Heat Loss (MJ)		
Month	Crawl Space	Slab	Basement	Walkout	Total
Jan	0.0	0.0	0.0	174.0	174.0
Feb	0.0	0.0	0.0	254.2	254.2
Mar	0.0	0.0	0.0	468.0	468.0
Apr	0.0	0.0	0.0	581.9	581.9
May	0.0	0.0	0.0	500.9	500.9
Jun	0.0	0.0	0.0	298.2	298.2
Jul	0.0	0.0	0.0	140.1	140.1
Aug	0.0	0.0	0.0	183.7	183.7
Sep	0.0	0.0	0.0	247.0	247.0
Oct	0.0	0.0	0.0	399.7	399.7
Nov	0.0	0.0	0.0	180.8	180.8
Dec	0.0	0.0	0.0	204.7	204.7
Ann	0.0	0.0	0.0	3633.1	3633.1

FOUNDATION TEMPERATURES & VENTILATION PROFILE

	Temperature (Deg °C)			Air Change Rate		Heat Loss
Month	Crawl Space	Basement	Walkout	Natural	Total	(MJ)
Jan	0.0	0.0	21.5	0.106	0.380	2403.8
Feb	0.0	0.0	21.2	0.103	0.377	2052.3
Mar	0.0	0.0	21.1	0.096	0.371	1749.3
Apr	0.0	0.0	21.3	0.096	0.370	1291.6
May	0.0	0.0	21.9	0.090	0.364	984.3
Jun	0.0	0.0	22.3	0.079	0.353	589.2
Jul	0.0	0.0	24.2	0.066	0.340	329.0

Aug	0.0	0.0	24.7	0.065	0.339	472.0
Sep	0.0	0.0	23.7	0.074	0.348	712.3
Oct	0.0	0.0	21.4	0.087	0.361	1262.0
Nov	0.0	0.0	21.2	0.096	0.370	1884.6
Dec	0.0	0.0	21.4	0.099	0.373	1953.1
Ann	0.0	0.0	22.2	0.088	0.362	15683.4

SPACE HEATING SYSTEM PERFORMANCE

Month	Space Heating Load (MJ)	Furnace Input (MJ)	Pilot Light (MJ)	Indoor Fans (MJ)	Heat Pump Input (MJ)	Total Input (MJ)	System Cop
Jan	3560.0	3492.3	0.0	67.8	0.0	3560.0	1.0
Feb	2224.1	2181.8	0.0	42.3	0.0	2224.1	1.0
Mar	1294.6	1270.0	0.0	24.6	0.0	1294.6	1.0
Apr	858.2	841.8	0.0	16.3	0.0	858.2	1.0
May	500.9	491.3	0.0	9.5	0.0	500.9	1.0
Jun	298.2	292.5	0.0	5.7	0.0	298.2	1.0
Jul	140.1	137.4	0.0	2.7	0.0	140.1	1.0
Aug	183.7	180.2	0.0	3.5	0.0	183.7	1.0
Sep	247.0	242.3	0.0	4.7	0.0	247.0	1.0
Oct	559.7	549.0	0.0	10.7	0.0	559.7	1.0
Nov	2200.3	2158.4	0.0	41.9	0.0	2200.3	1.0
Dec	2768.5	2715.8	0.0	52.7	0.0	2768.5	1.0
Ann	14835.2	14552.9	0.0	282.3	0.0	14835.2	1.0

MONTHLY ESTIMATED ENERGY CONSUMPTION BY DEVICE (MJ)

	Space Heating		DHW Heating		Lights &	HRV &	Air
Month	Primary	Secondary	Primary	Secondary	Appliances	FANS	Conditioner
Jan	3492.3	0.0	831.7	0.0	926.3	158.8	0.0
Feb	2181.8	0.0	756.5	0.0	836.6	124.6	0.0
Mar	1270.0	0.0	831.7	0.0	926.3	115.7	0.0
Apr	841.8	0.0	789.6	0.0	896.4	104.5	0.0
May	491.3	0.0	794.3	0.0	926.3	100.6	0.0
Jun	292.5	0.0	747.7	0.0	896.4	93.8	0.0
Jul	137.4	0.0	756.8	0.0	926.3	93.7	0.0
Aug	180.2	0.0	751.0	0.0	926.3	94.6	0.0
Sep	242.3	0.0	732.4	0.0	896.4	92.8	0.0
Oct	549.0	0.0	772.7	0.0	926.3	101.7	0.0
Nov	2158.4	0.0	768.7	0.0	896.4	130.0	0.0
Dec	2715.8	0.0	815.9	0.0	926.3	143.8	0.0
Ann	14552.9	0.0	9349.0	0.0	10906.2	1354.6	0.0

ESTIMATED FUEL COSTS (Dollars)

Month	Electricity	Natural Gas	Oil	Propane	Wood	Total
Jan	117.56	0.00	0.00	0.00	0.00	117.56
Feb	86.73	0.00	0.00	0.00	0.00	86.73
Mar	71.30	0.00	0.00	0.00	0.00	71.30
Apr	60.86	0.00	0.00	0.00	0.00	60.86
May	54.33	0.00	0.00	0.00	0.00	54.33
Jun	48.58	0.00	0.00	0.00	0.00	48.58
Jul	46.20	0.00	0.00	0.00	0.00	46.20
Aug	46.98	0.00	0.00	0.00	0.00	46.98
Sep	47.22	0.00	0.00	0.00	0.00	47.22
Oct	55.09	0.00	0.00	0.00	0.00	55.09
Nov	87.84	0.00	0.00	0.00	0.00	87.84
Dec	101.07	0.00	0.00	0.00	0.00	101.07
Ann	823.76	0.00	0.00	0.00	0.00	823.76

The calculated heat losses and energy consumptions are only estimates, based upon the data entered and assumptions within the program. Actual energy consumption and heat losses will be influenced by construction practices, localized weather, equipment characteristics and the lifestyle of the occupants.

APPENDIX B

RETScreen Simulation Reports

RETScreen® Energy Model - Solar Water Heating Project

Site Conditions		Estimate	Notes/Range
Project name		**Echo Haven**	*See Online Manual*
Project location		**Calgary, AB**	
Nearest location for weather data		Calgary Int'l. A, AB	➡ *Complete SR&HL sheet*
Annual solar radiation (tilted surface)	MWh/m²	1.13	
Annual average temperature	°C	6.0	-20.0 to 30.0
Annual average wind speed	m/s	4.4	
Desired load temperature	°C	45	
Hot water use	L/d	596	
Number of months analysed	month	12.00	
Energy demand for months analysed	MWh	9.90	

System Characteristics		Estimate	Notes/Range
Application type		Service hot water (with storage)	
Base Case Water Heating System			
Heating fuel type	-	**Electricity**	
Water heating system seasonal efficiency	%	100%	50% to 190%
Solar Collector			
Collector type	-	Glazed	*See Technical Note 1*
Solar water heating collector manufacturer		Thermo Dynamics	*See Product Database*
Solar water heating collector model		G32	
Gross area of one collector	m²	2.96	1.00 to 5.00
Aperture area of one collector	m²	2.78	1.00 to 5.00
Fr (tau alpha) coefficient	-	0.74	0.50 to 0.90
Fr UL coefficient	(W/m²)/°C	5.25	1.50 to 8.00
Temperature coefficient for Fr UL	(W/(m·°C)²)	0.00	0.000 to 0.010
Suggested number of collectors		5	
Number of collectors		2	
Total gross collector area	m²	5.9	
Storage			
Ratio of storage capacity to coll. area	L/m²	51.0	37.5 to 100.0
Storage capacity	L	284	
Balance of System			
Heat exchanger/antifreeze protection	yes/no	Yes	
Heat exchanger effectiveness	%	70%	50% to 85%
Suggested pipe diameter	mm	10	8 to 25 or PVC 35 to 50
Pipe diameter	mm	17	8 to 25 or PVC 35 to 50
Pumping power per collector area	W/m²	14	3 to 22, or 0
Piping and solar tank losses	%	15%	1% to 10%
Losses due to snow and/or dirt	%	5%	2% to 10%
Horz. dist. from mech. room to collector	m	10	5 to 20
# of floors from mech. room to collector	-	0	0 to 20

Annual Energy Production (12.00 months analysed)		Estimate	Notes/Range
SWH system capacity	kW$_{th}$	4	
	million Btu/h	0.013	
Pumping energy (electricity)	MWh	**0.17**	
Specific yield	kWh/m²	383	
System efficiency	%	34%	
Solar fraction	%	23%	
Renewable energy delivered	MWh	**2.27**	
	MJ	8,169	

Version 3.1   © Minister of Natural Resources Canada 1997-2005.   NRCan/CETC - Varennes

RETScreen® International

Clean Energy Project Analysis Software

Project information

See project database

Project name	EchoHaven PV
Project location	Calgary, AB
Prepared for	
Prepared by	
Project type	Power
Technology	Photovoltaic
Grid type	Central-grid
Analysis type	Method 1
Heating value reference	Higher heating value (HHV)
Show settings	☐

Site reference conditions

Select climate data location

Climate data location	Calgary Int'l. Airport
Show data	☑

	Unit	Climate data location	Project location
Latitude	˚N	51.1	51.1
Longitude	˚E	-114.0	-114.0
Elevation	m	1,084	1,084
Heating design temperature	°C	-26.2	
Cooling design temperature	°C	26.3	
Earth temperature amplitude	°C	23.9	

Month	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	-5.4	63.0%	1.10	88.8	4.4	-12.1	856	0
February	-4.0	62.5%	1.98	88.8	4.2	-10.3	680	0
March	0.5	64.0%	3.01	88.7	4.4	-4.8	636	0
April	5.1	57.5%	4.10	88.9	4.7	3.8	417	0
May	9.6	56.5%	5.25	88.9	5.0	9.9	257	0
June	13.6	58.0%	4.91	89.0	4.7	13.9	120	120
July	18.8	60.0%	5.92	89.2	4.2	16.4	50	198
August	17.6	60.5%	5.40	89.2	3.9	15.4	71	177
September	13.8	61.0%	4.11	89.1	4.2	9.2	222	18
October	5.5	56.0%	2.11	89.0	4.2	2.3	381	0
November	-2.2	63.5%	1.27	88.8	4.2	-6.1	630	0
December	-1.4	64.0%	0.84	88.8	4.4	-11.4	815	0
Annual	6.0	60.5%	3.34	88.9	4.4	2.3	5,135	513
Measured at	m				10.0	0.0		

Complete Energy Model sheet

RETScreen Energy Model - Power project

☐ Show alternative units

Proposed case power system		Incremental initial costs

Technology   Photovoltaic

Analysis type
- ☐ Method 1
- ☑ Method 2

Resource assessment

Solar tracking mode		Fixed
Slope	°	45.0
Azimuth	°	0.0

☑ Show data

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity export rate $/MWh	Electricity exported to grid MWh
January	1.10	2.67		0.422
February	1.98	3.77		0.532
March	3.01	4.10		0.629
April	4.10	4.50		0.658
May	5.25	5.07		0.752
June	4.91	4.48		0.637
July	5.92	5.55		0.788
August	5.40	5.71		0.811
September	4.11	5.34		0.743
October	2.11	3.39		0.512
November	1.27	2.76		0.417
December	0.84	2.13		0.333
Annual	**3.34**	**4.12**	**0.00**	**7.234**

Annual solar radiation - horizontal	MWh/m²	1.22
Annual solar radiation - tilted	MWh/m²	1.50

Photovoltaic

Type		mono-Si
Power capacity	kW	5.46
Manufacturer		Sanyo
Model		mono-Si - HIP-210NKHA5
Efficiency	%	16.7%
Nominal operating cell temperature	°C	45
Temperature coefficient	% / °C	0.40%
Solar collector area	m²	33
Miscellaneous losses	%	4.0%

26 unit(s)

See product database

Inverter

Efficiency	%	95.5%
Capacity	kW	5.0
Miscellaneous losses	%	3.0%

Summary

Capacity factor	%	15.1%
Electricity exported to grid	MWh	7.234

EchoHaven PV
Calgary, AB

10/4/2013
RETScreen4-2

Emission Analysis

Base case electricity system (Baseline) Country - region	Fuel type	GHG emission factor (excl. T&D) tCO2/MWh	T&D losses %	GHG emission factor tCO2/MWh
Canada	All types			0.000
Electricity exported to grid	MWh	7	T&D losses	

GHG emission

Base case	tCO2	0.0
Proposed case	tCO2	0.0
Gross annual GHG emission reduction	tCO2	0.0
GHG credits transaction fee	%	
Net annual GHG emission reduction	tCO2	0.0

is equivalent to 0.0 | Cars & light trucks not used

GHG reduction income

GHG reduction credit rate	$/tCO2	

Financial Analysis

Financial parameters

Inflation rate	%	
Project life	yr	
Debt ratio	%	

Initial costs

Power system	$	0
Other	$	
Total initial costs	$	0

Incentives and grants	$		0.0%

Cumulative cash flows graph

Annual costs and debt payments

O&M (savings) costs	$	
Fuel cost - proposed case	$	0
	$	
Total annual costs	$	0

Annual savings and income

Fuel cost - base case	$	0
	$	
Total annual savings and income	$	0

Financial viability

Pre-tax IRR - assets	%
Simple payback	yr
Equity payback	yr

Cumulative cash flows ($) — Year
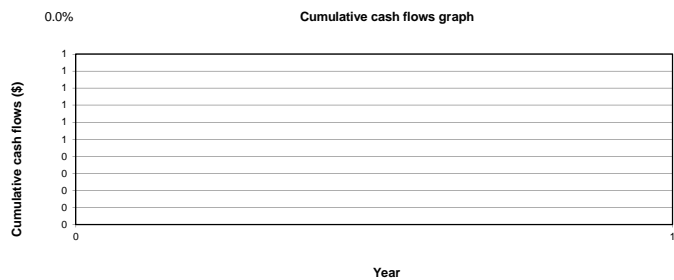
Settings

☐ As fired fuel	☐ Ground heat exchanger	☐ User-defined fuel - gas
☐ Biogas	☐ Heat rate	☐ User-defined fuel - solid
☐ Building envelope properties	☐ Heating value & fuel rate	☐ Water & steam
☐ Appliances & equipment	☐ Hydro formula costing method	☐ Water pumping
☐ Electricity rate - monthly	☐ Landfill gas	☐ Window properties
☐ Electricity rate - time of use	☐ Unit conversion	☐ Custom 1
☐ GHG equivalence	☐ User-defined fuel	☐ Custom 2

APPENDIX C
SRC Analytical Labs Analysis Reports

APPENDIX C

SRC Analytical Labs Analysis Reports

SRC ANALYTICAL

Building Performance, SRC

Sample #	**10012**	Client PO #:
Date Sampled:	**Apr 09, 2011 15:31 to Apr 16, 2011 15:31**	Date Received: **Apr 20, 2011**
Sample Matrix:	**PASSIVE CHARCOAL SAMPLER**	
Description:	**BP-F12**	

Analyte	Units	Result	DL
Organic Chemistry			
Formaldehyde	mg/m3	0.024	0

SRC ANALYTICAL

422 Downey Road
Saskatoon, Saskatchewan, Canada
S7N 4N1
(306) 933-6932 or 1-800-240-8808

Building Performance, SRC
15 Innovation Blvd
Saskatoon, SK   S7N 2X8
 Attn: Brad Boyle, 12323

Date Samples Received: Oct-24-2012   Client P.O.:

This is a final report.

Organics results have been authorized by Pat Moser, Supervisor

ICP results have been authorized by Keith Gipman, Supervisor

Inorganics and Radiochemistry results have been authorized by Jeff Zimmer, Supervisor

SLOWPOKE-2 results have been authorized by Dave Chorney

---

* Test methods and data are validated by the laboratory's Quality Assurance Program.

* Routine methods follow recognized procedures from sources such as

> * Standard Methods for the Examination of Water and Wastewater APHA AWWA WEF
> * Environment Canada
> * US EPA
> * CANMET

* The results reported relate only to the test samples as provided by the client.

* Samples will be kept for 30 days after the final report is sent. Please contact the lab if you have any special requirements.

* Additional information is available upon request.

SRC ANALYTICAL

Nov 15, 2012

422 Downey Road
Saskatoon, Saskatchewan, Canada
S7N 4N1
(306) 933-6932 or 1-800-240-8808

Building Performance, SRC
15 Innovation Blvd
Saskatoon, SK   S7N 2X8
 Attn: Brad Boyle, 12323

Date Samples Received: Oct-24-2012   Client P.O.:

42137   10/10/2012 14:00 to 10/17/2012 14:00 UMEX FORMALDEHYDE SAMPLER (ECHO-HAVEN OCTOBER) *MISCELLANEOUS*

Analyte	Units	42137
Organic Chemistry		
Formaldehyde	mg/m3	0.018

SRC ANALYTICAL

422 Downey Road
Saskatoon, Saskatchewan, Canada
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(306) 933-6932 or 1-800-240-8808

Building Performance, SRC
15 Innovation Blvd
Saskatoon, SK   S7N 2X8
  Attn: Brad Boyle, 12323

Date Samples Received: Mar-05-2012   Client P.O.:

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SRC ANALYTICAL

Mar 20, 2012

422 Downey Road
Saskatoon, Saskatchewan, Canada
S7N 4N1
(306) 933-6932 or 1-800-240-8808

Building Performance, SRC
15 Innovation Blvd
Saskatoon, SK   S7N 2X8
Attn: Brad Boyle, 12323

Date Samples Received: Mar-05-2012   Client P.O.:

8337   01/20/2012 12:00 to 02/28/2012 11:40 ECHO-V1 *PASSIVE CHARCOAL SAMPLER*

Analyte	Units	8337
Organic Chemistry		
Hydrocarbons	mg/m3	See below

The sample was desorbed using a suitable solvent and analyzed by GC/MS.

Compound	ug	Volume(L)	mg/m3
Ethyl benzene	7.89	1533	0.005
Methyl benzene	121	1621	0.075
Dimethyl benzene	34.5	1533	0.022
Trimethyl benzene	3.81	1533	0.002
Styrene	5.26	1505	0.004
Alpha pinene	31.7	1621	0.020
Beta pinene	3.81	1621	0.002
Camphene	13.27	1621	0.008
Delta 3 carene	21.84	1621	0.014
dl-Limonene	25.86	1621	0.016
1,1-Biphenyl	4.42	1621	0.003
Benzene oxybis	11.98	1621	0.007
Hexanal	4.48	1621	0.003
Acetic acid butyl ester	2.09	1621	0.001
Siloxane	10.31	1621	0.006
Hydrocarbons (C7-C15)	6.95	1493	0.005

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SRC ANALYTICAL

422 Downey Road
Saskatoon, Saskatchewan, Canada
S7N 4N1

Building Performance, SRC   Apr-03-2012
15 Innovation Blvd
Saskatoon, SK   S7N 2X8
   Attn : Brad Boyle, 12323

   Date Samples Received: Mar-05-2012   Client P.O.:

SRC Lab # 8298   Sample Type: RADON DETECTOR

SRC BUILDING PERFORMANCE - ECHO-R1 01/21/2012 12:00 to 02/28/2012 12:00 DETECTOR NO. K70127
CENTRAL BASEMENT-ECHO HAVEN

Analyte Name	Units	Results	Canadian Max. Acceptible Concentration
Radon-222	Bq/m3	70	200

Result is below the Health Canada Action Level for Radon in Air

Visit our website at www.cmhc.ca