CONSTRUCTING A CERTIFIED NET-ZERO HOME

Builder Success Story
Cedarglen Homes

CASE STUDY SCOPE

As building code requirements in Canada increase to meet the rising need for greenhouse gas (GHG) reductions, the quantity of higher performing homes will also increase. With this comes a period of learning amongst trades professionals, homebuilders, and homeowners. Trades professionals and homebuilders will require new knowledge on how to construct these types of homes, and homeowners will require the knowledge to understand and operate them. Canada's construction industry is nearing a shift from traditional design and construction to higher performing homes.

This case study was developed to document the process that Calgary based homebuilder Cedarglen Homes experienced in successfully constructing a certified Net-Zero Home. It was created to report on both the success and difficulties the team experienced throughout their process in order to guide future projects across Canada. The case study was funded by building material manufacturer Owens Corning.

Whenever mentioned, the term Net-Zero refers to homes that produce as much clean energy as they consume annually, using on-site renewable energy systems. Up to 80% more energy efficient than typical new homes, Net-Zero Homes are extremely well built with extra insulation, high-performance windows, and excellent airtightness to minimize heating and cooling needs. Appliances, lighting, and mechanical systems are all as energy efficient as possible.
Source: CHBA's Net-Zero Labeling Program

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Figure 1: Aerial view of the Net-Zero Home, illustrating limited south-facing roof-space for solar system installation. Source: Cedarglen Homes

GENERAL HOME INFORMATION

Cedarglen modified an existing 1000 square feet (93 square meters) single storey home design for the construction of this Net-Zero Home. The original design has been revised to accommodate Net-Zero elements such as increased insulation and high performance heating, ventilation, air condition (HVAC) systems. For the purpose of this case study, the original design of the home will be referred to as the benchmark.

The bungalow with detached garage resides in central-north Calgary community of Livingston bordering the city's edge. The home is oriented with the front door facing directly north. This site was intentionally selected as it presented non-ideal conditions for solar energy generation which typically reduce the Net-Zero potential of a home. In Canada, the sun resides to the south so to achieve optimal solar-gains, the largest area of roof-space should be oriented south. With this in mind, one of the key goals of this case study was to demonstrate that a high efficiency, or in this case Net-Zero, home can be achieved on a less-than-ideal site.

NET-ZERO DESIGN CHANGES

This section of the case study details any changes made to the design of the home in order to meet CHBA's (Canadian Homebuilders' Association) Net-Zero certification. Exterior building assemblies were improved upon from the benchmark design to achieve Net-Zero performance. The three main features that were focused on to achieve Net-Zero certification were increased insulation values, increased air tightness, and the installation of high-performance HVAC systems.

Building Assemblies

The following section compares the exterior wall, roof, below-grade foundation and slab-on-grade assemblies between the Net-Zero and benchmark homes. The largest contributor to improving the home's thermal performance was the use of increased insulation. This added insulation impacted the Net-Zero Home's interior square footage as wall thickness increased, which will be addressed in more detail in the Impacts on Design, Construction & Cost section of this case study.

Figure 2: Exterior photo of the Net-Zero Home in January 2022. Source: primary

ASSEMBLY	BENCHMARK HOME	NET-ZERO HOME
Roof Assembly	Asphalt shingles, OSB, insulation (type not specified), polyethylene vapour barrier, interior insulation **Nominal R-value: R-42.74**	Asphalt shingles, OSB, fibreglass insulation (type not specified), polyethylene vapour barrier, interior gypsum **Effective R-value: R-58.43**
Exterior Wall Assembly	Vinyl cladding, OSB or exterior gypsum, batt insulation, polyethylene vapour barrier, interior gypsum **Nominal R-value: R-22.97**	Vinyl cladding, strapping, Thermafiber® RainBarrier® ci High Compressive Plus (110) Mineral Wool Insulation , OSB or exterior gypsum, fiberglass batt insulation, polyethylene vapour barrier, interior gypsum **Effective R-value: R-30.31**
Below Grade Foundation Assembly	Concrete, batt insulation, polyethylene vapour barrier **Nominal R-value: R-13.4**	Dimple membrane, FOAMULAR® C-300 Extruded Polystyrene Rigid Insulation, concrete, fiberglass batt insulation, polyethylene vapour barrier **Effective R-value: R-27.16**
Basement Slab Assembly	Polyethylene vapour barrier, concrete **Nominal R-value: R-2**	Spray foam insulation, concrete **Effective R-value: R-13.17**

Table 1: Assembly comparison between benchmark home and Net-Zero Home.

Figure 3: Photo of living room ceiling with pot-lighting taken during blower door test 1. Source: primary

AIR TIGHTNESS

Air tightness throughout the entire home was increased and given special attention during the installation of the polyethylene vapour barrier. Figure 3 demonstrates the air-sealing of the pot-light system in the living room. This photo was taken during the first blower door test, performed prior to the installation of gypsum and finishes. The second blower door test was performed upon completion of the home.

Potential “problem spots” where air-tightness could be improved were identified during this first blower test, and were either mended on the spot or noted for later repair after the blower test was done. This assessment was performed by a Registered Energy Advisor (CACEA member) and Cedarglen team. Common areas where improvement was needed included around electrical and mechanical openings, membrane lapping, and assembly connections (e.g. wall to ceiling.)

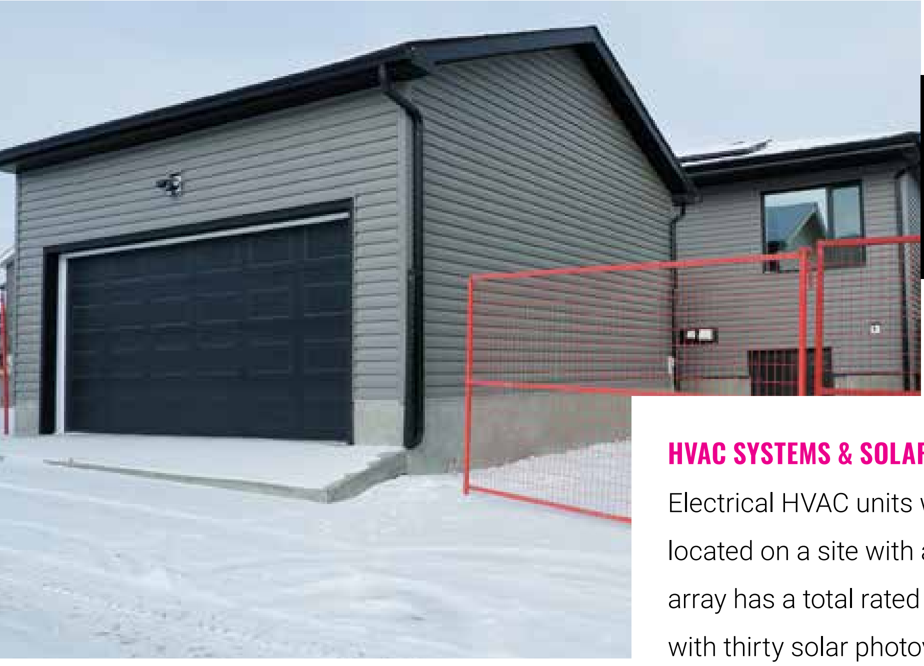


Figure 4: Photo of home from the rear with view of heat pump. Source: primary

HVAC SYSTEMS & SOLAR ARRAY

Electrical HVAC units were selected for the project. Despite being located on a site with a non-optimal solar orientation, the home's solar array has a total rated capacity of 10.8 kW. The system was designed with thirty solar photovoltaic (PV) panels. Six panels are located on the south-facing slope of the roof, fourteen on the east, and ten on the west. A solar invertor/generator of 7.6 kW size has been installed along side the solar array. No solar was installed on the detached garage unit.

This amount of energy generation is sufficient to sustain all of the home's electrical HVAC units and provide the needed energy for the home's other electrical needs. The units installed include:

- A cold-climate Mitsubishi heat pump with electric back-up for extreme cold temperatures.
- A Lennox HRV unit with defrosting capability and sensible efficiency of 85%
- A 40-gallon (182 liters) Rheem heat pump water heater rated at 3.75 UEF (energy efficiency)

Figure 5: Photo of home from the side with view of solar array on roof. Source: primary.

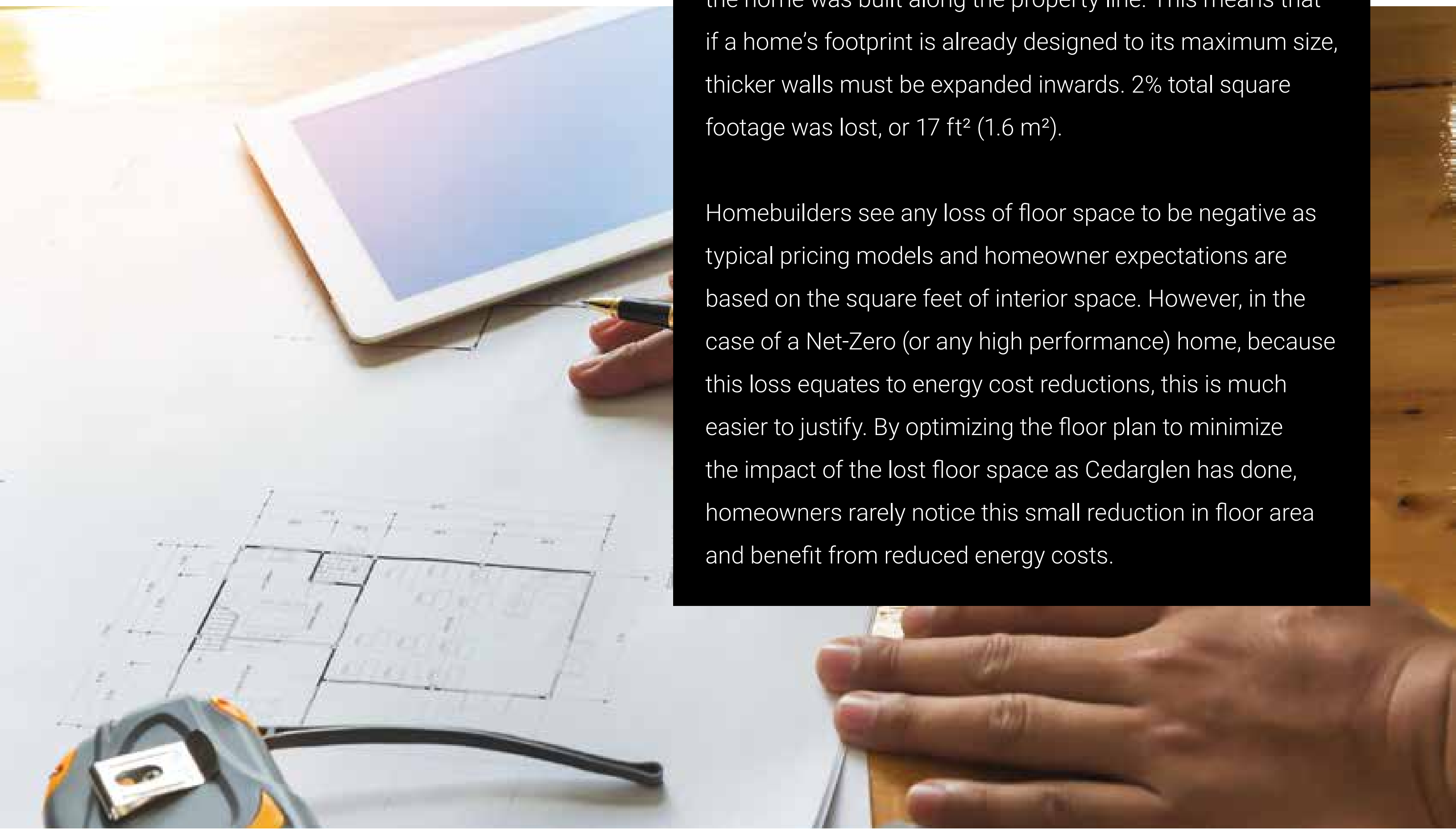
IMPACTS FROM SHIFTING TO NET-ZERO

The following section of the case study documents the impacts of designing and building for Net-Zero, both in terms of successes and difficulties. They have been selected to be features to inform future high performance projects, and serve as a "lessons learned" piece. Relatability to these topics can greatly vary regionally, however some apply to most parts of Canada based on building code policy and conditions.

Loss of Interior Square Footage

Increasing insulation typically leads to increasing wall thickness. As a result, either walls are built outwards, or in cases where it is not possible, interior square footage is lost. In the case of this Net-Zero Home, the latter occurred as this home was built on a zero-lot line lot where one side-wall of the home was built along the property line. This means that if a home's footprint is already designed to its maximum size, thicker walls must be expanded inwards. 2% total square footage was lost, or 17 ft^2 (1.6 m^2).

Homebuilders see any loss of floor space to be negative as typical pricing models and homeowner expectations are based on the square feet of interior space. However, in the case of a Net-Zero (or any high performance) home, because this loss equates to energy cost reductions, this is much easier to justify. By optimizing the floor plan to minimize the impact of the lost floor space as Cedarglen has done, homeowners rarely notice this small reduction in floor area and benefit from reduced energy costs.



Aligning with Trades Partners

The Cedarglen construction team expressed some difficulty in aligning with certain trades professionals in the construction of the Net-Zero Home. The difficulties arose when ensuring all construction quality met the Net-Zero parameters and requirements outlined during the design. In particular, framing trades found some difficulties with this regard due to the changes in framing approach required to align with the updated design of the home.

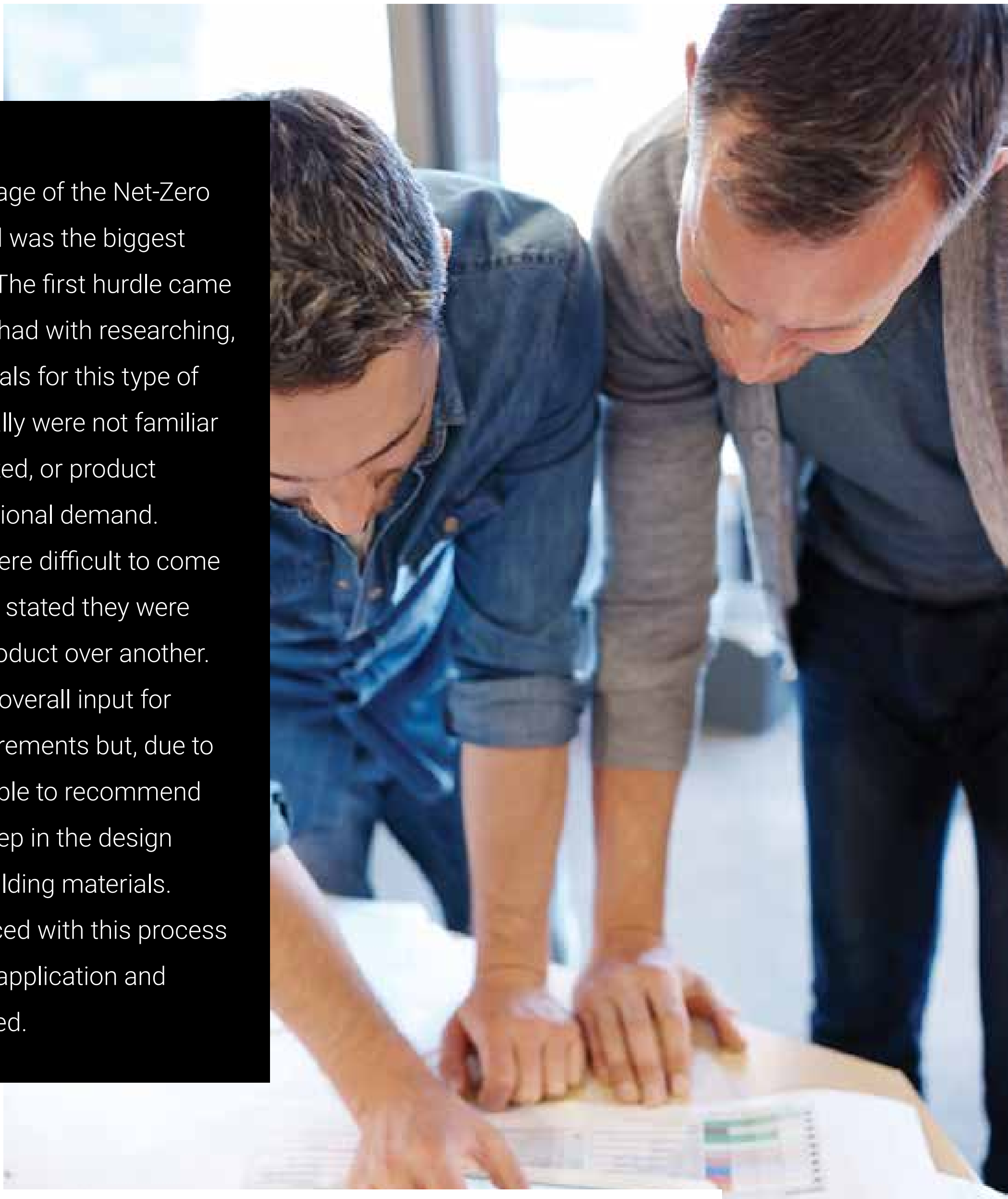
There were challenges related to framing needs to ensure proper pre-sealing at connections and transitions. This created a small delay in the construction timeline, though the project was completed on-time as anticipated but with additional challenges related to costs, as the builder was charged a premium for trades who were not familiar with the product and/or installation practices. As Net-Zero construction practices are still not considered typical or main-stream, this can occur within many different trades sectors, increasing costs to the homebuilder and therefore the homeowner.

Increased Testing and Verification

The team expressed an increased requirement for site-supervisors being on-site and planning ahead for testing and verification procedures, especially in regards to air tightness testing. Coordinating these tests required preparation to ensure required the parties (e.g. site supervisors) were on-site so that when opportunities to improve air tightness were identified, they could be addressed during testing. A major take-away the Cedarglen team gathered from the air tightness and blower door process was that having a clear plan for air tightness in future Net-Zero projects can assist the project to remain on schedule. This requires thinking through each step of the construction process to achieve the desired air tightness, especially regarding the sealing of difficult areas. Making the effort to do this will streamline the process and allow blower door testing to be performed more quickly and with minimal changes following testing.

Material Selection & Limitations

The team expressed that the design stage of the Net-Zero project required the most foresight and was the biggest change from their traditional process. The first hurdle came from the lack of experience their team had with researching, identifying, and locating desired materials for this type of build. Local trades and suppliers typically were not familiar with the building materials being selected, or product supplies were limited due to lack of regional demand. Furthermore, subject matter experts were difficult to come by, and the majority that were engaged stated they were not in a position to recommend one product over another. The Energy Advisor provided excellent overall input for design strategy to meet Net Zero requirements but, due to their third-party advisor role, was not able to recommend specific products. The most difficult step in the design process was the actual selection of building materials. The Cedarglen team was not experienced with this process and careful consideration towards the application and installation of each product was required.



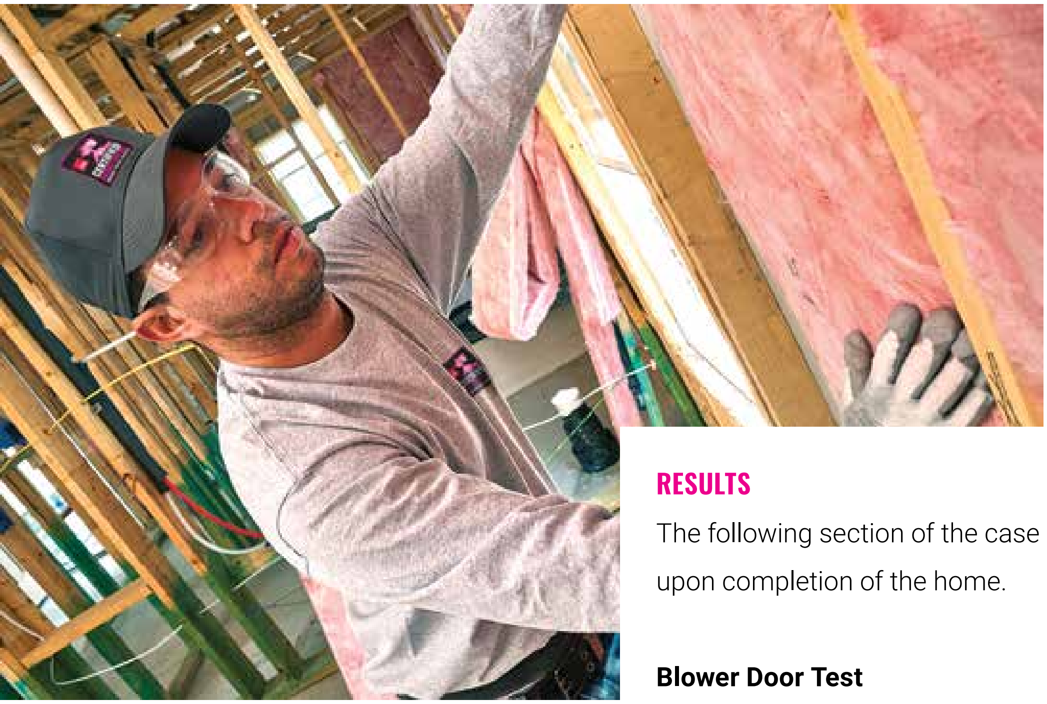
As a final note on design challenges, due to a lack of experience, the team had difficulty determining which information was accurate and which was marketing rhetoric regarding materials, wall assembly designs, and mechanical equipment during early design stages. The lack of real-world-application when it comes to the integration and performance of these types of products is key in determining their success post-construction.

The last hurdle the team experienced with regards to building materials came from supply chain issues, with delays to the schedule and need to substitute some materials with alternatives.

High Performance Preparedness

As a homebuilder, Cedarglen has already been including many Net-Zero friendly features in all of their homes including HRVs for ventilation, triple-pane windows, and insulating around rough openings with low-expansion injection foam. Having substantial experience with these products and construction processes, they saved costs in these regards as they have established relationships with these buildings material suppliers and trades professionals. Furthermore, they anticipate the costs of these materials to go down in the future as newer high efficiency products become more abundant in the market.

The key lesson confirmed is that by becoming a Net-Zero homebuilder, Cedarglen is preparing for the future, with the added benefit that their clients seek them out for their use of higher quality materials and processes to create higher performing homes with a focus on keeping them affordable.



RESULTS

The following section of the case study details the results observed upon completion of the home.

Blower Door Test

A blower door test was performed on September 7th, 2021, with a result of 2.39 ACH50. The test was performed before cladding was complete and the interior was ready for boarding. This was rated as a good level of air tightness for a pre-drywall level of construction for this size of home. The HRV was fully sealed at the time of testing.

The final blower door test completed in November 2021 revealed an air tightness of 0.87 ACH50.

Thermal Radar Analysis

On December 2nd, 2021, the SAIT Green Building Technologies Research Team visited the home for a final visit. At this time, the home was essentially complete and an infrared thermometer was brought to assess potential thermal penetrations post-construction. Typical thermal behavior was observed around window frames and assembly connections as seen in figures 6. It should be noted that it is normal for corners to display cooler temperatures as shown in figure 7.

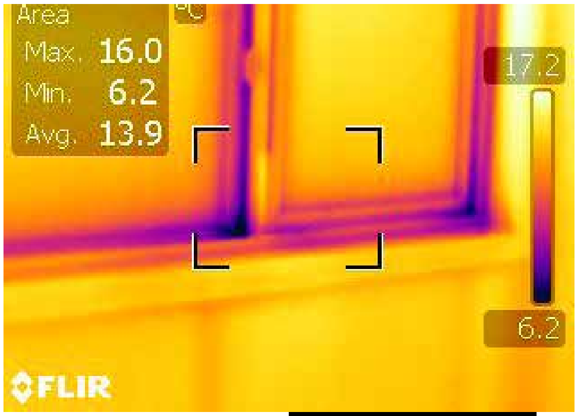


Figure 6: Thermal penetration observed around window frame on main level.
Source: SAIT

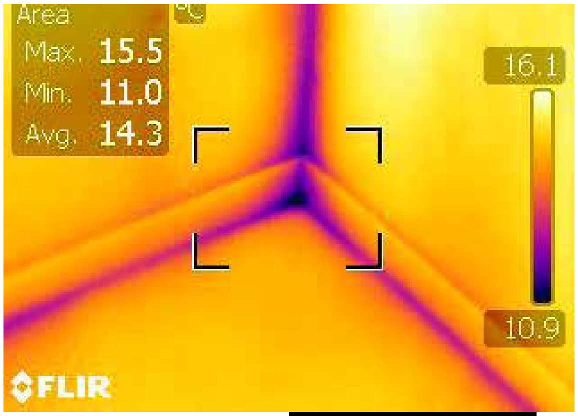


Figure 7: Thermal penetration observed between wall and floor assembly connections on main level.
Source: SAIT

More minor thermal penetrations were observed at certain sections of the main-level exterior wall, such as where more framing was present around electrical fixtures. Overall, the home was observed as above average with fewer thermal penetrations than typical homes of similar size.

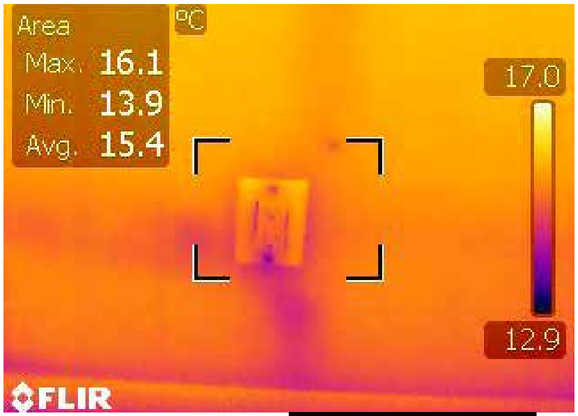


Figure 8: Minimal thermal penetration observed from framing surrounding an electrical fixture.
Source: SAIT

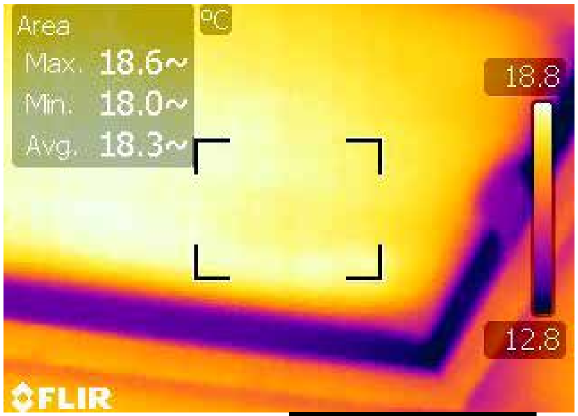


Figure 9: Thermal leakage observed around the attic hatch.
Source: SAIT

NET-ZERO CERTIFICATION & ENERGY RATING

On December 9th, 2021, the home received an EnerGuide rating of 0, indicating that it generates as much energy as it consumes on an annual basis. Its rating intensity was reported as 0.22 GJ/m²/yr. Figures 10 and 11 illustrate the home's energy usage and heat loss:

On December 15th, 2021, the home was successfully certified under the CHBA Net Zero Home Labelling Program.

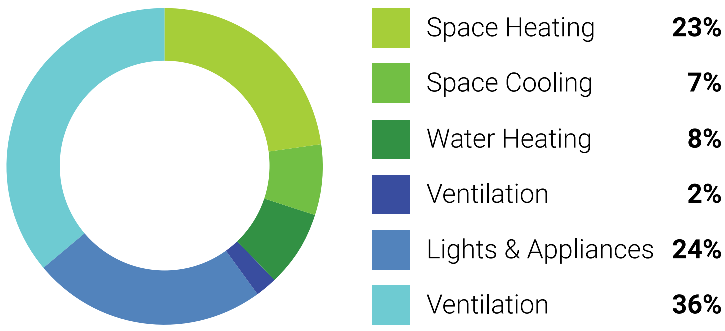


Figure 10: The home's energy usage. Source: EnerGuide.

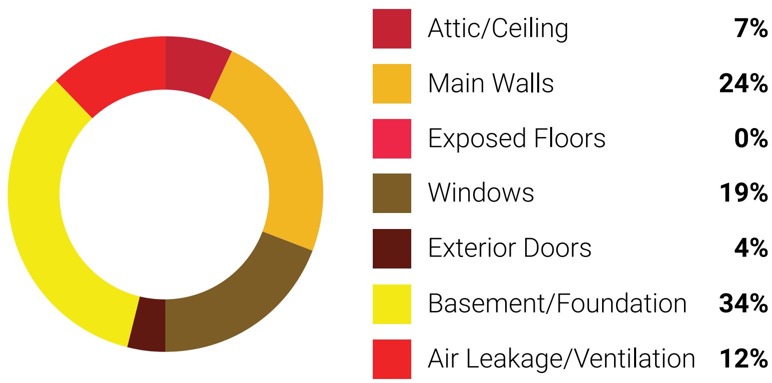


Figure 11: The home's heat loss. Source: EnerGuide.

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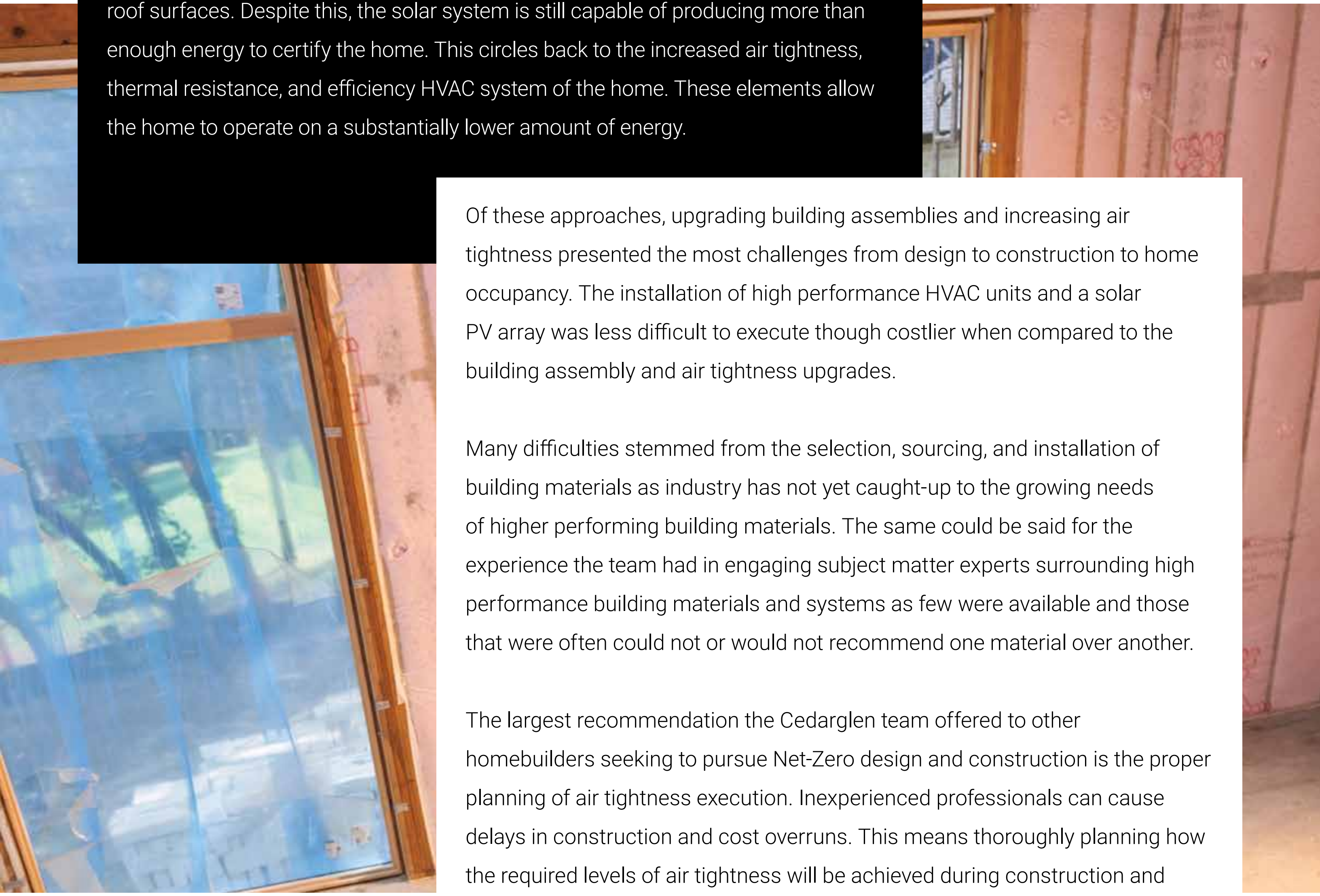
CONCLUSION

The Cedarglen team successfully executed a certified, single storey Net-Zero Home located on a non-solar optimal plot. This was achieved through the following:

- Increased thermal performance of exterior building assemblies by installing 51 mm (2") Thermafiber® RainBarrier® ci High Compressive Plus (110) Mineral Wool Insulation as the above-grade exterior insulation
- Increased thermal performance of below grade building assemblies by installing 51 mm (2") FOAMULAR® C-300 Extruded Polystyrene Rigid Insulation as the exterior foundation insulation exposed to the soil
- Increased air tightness measures
- The installation of high-performance electrical HVAC units
- The installation of a solar PV array on the home's roof

The holistic approach to this project was integral in it successfully achieving Net-Zero certification. This refers to the house working as a whole system through increased air tightness and thermal resistance resistance, efficient HVAC units and the solar array working in tandem. As a reminder, this home was built on a non-solar optimized lot, with the majority of PV panels having been installed on the east and west facing roof surfaces. Despite this, the solar system is still capable of producing more than enough energy to certify the home. This circles back to the increased air tightness, thermal resistance, and efficiency HVAC system of the home. These elements allow the home to operate on a substantially lower amount of energy.



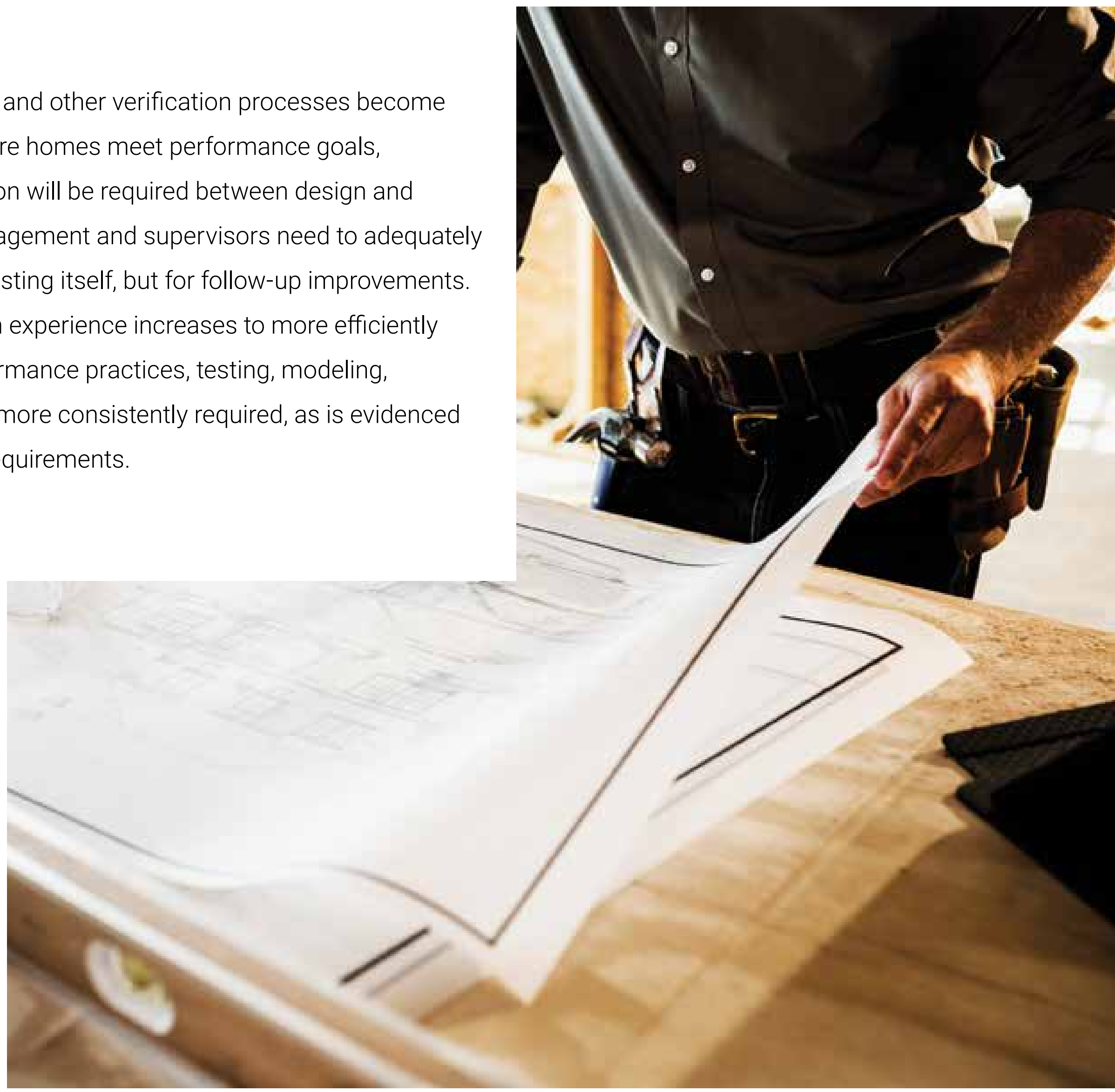
Of these approaches, upgrading building assemblies and increasing air tightness presented the most challenges from design to construction to home occupancy. The installation of high performance HVAC units and a solar PV array was less difficult to execute though costlier when compared to the building assembly and air tightness upgrades.

Many difficulties stemmed from the selection, sourcing, and installation of building materials as industry has not yet caught-up to the growing needs of higher performing building materials. The same could be said for the experience the team had in engaging subject matter experts surrounding high performance building materials and systems as few were available and those that were often could not or would not recommend one material over another.

The largest recommendation the Cedarglen team offered to other homebuilders seeking to pursue Net-Zero design and construction is the proper planning of air tightness execution. Inexperienced professionals can cause delays in construction and cost overruns. This means thoroughly planning how the required levels of air tightness will be achieved during construction and engaging trades early on to integrate them in the process. This goes beyond simply designing a high-performance wall assembly, and speaks to how sealing and tightness can be completed on-site during construction and how issues can be addressed post-testing.

As building code requirements increase to meet high performance levels and goals, design and construction practices will need to adapt. Engaging educated trades professionals will be integral in efficiently achieving these high-performance levels and goals, especially at earlier stages in industry adoption when such practices are newer. We anticipate that trades learning curves will be steeper in the coming years and many professionals will seek to train and expand their skill-sets to support high performance construction such as Net-Zero. An experienced team will become increasingly important in the efficient and successful execution of high performance homes.

As testing, energy modelling, and other verification processes become more common place to ensure homes meet performance goals, a different type of coordination will be required between design and construction activities - management and supervisors need to adequately plan ahead for not only the testing itself, but for follow-up improvements. Furthermore, as construction experience increases to more efficiently execute and meet high performance practices, testing, modeling, and verification will become more consistently required, as is evidenced in increasing building code requirements.



APPENDICES

Appendix A: Supplementary Photos

This appendix offers additional images taken at all stages of the project, and are meant to offer additional information on the journey Cedarglen experienced in achieving Net-Zero certification. All images in this appendix are provided and owned by the SAIT Green Building Technologies Research Team.

Figure 12: Photo of double flashing and insulation detailing around attached deck at rear of home. Source: SAIT

Figure 13: Photo of exterior 51 mm (2") Thermafiber® RainBarrier® ci High Compressive Plus (110) Mineral Wool Insulation and strapping below vinyl cladding. Source: SAIT

Figure 14: Below-grade to above grade wall transition showcasing 51 mm (2") Thermafiber® RainBarrier® ci High Compressive Plus (110) Mineral Wool Insulation and 51 mm (2") FOAMULAR® C-300 Extruded Polystyrene Rigid Insulation. Source: SAIT

Figure 15: Below-grade exterior insulation showcasing 51 mm (2") FOAMULAR® C-300 Extruded Polystyrene Rigid Insulation Source: SAIT

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