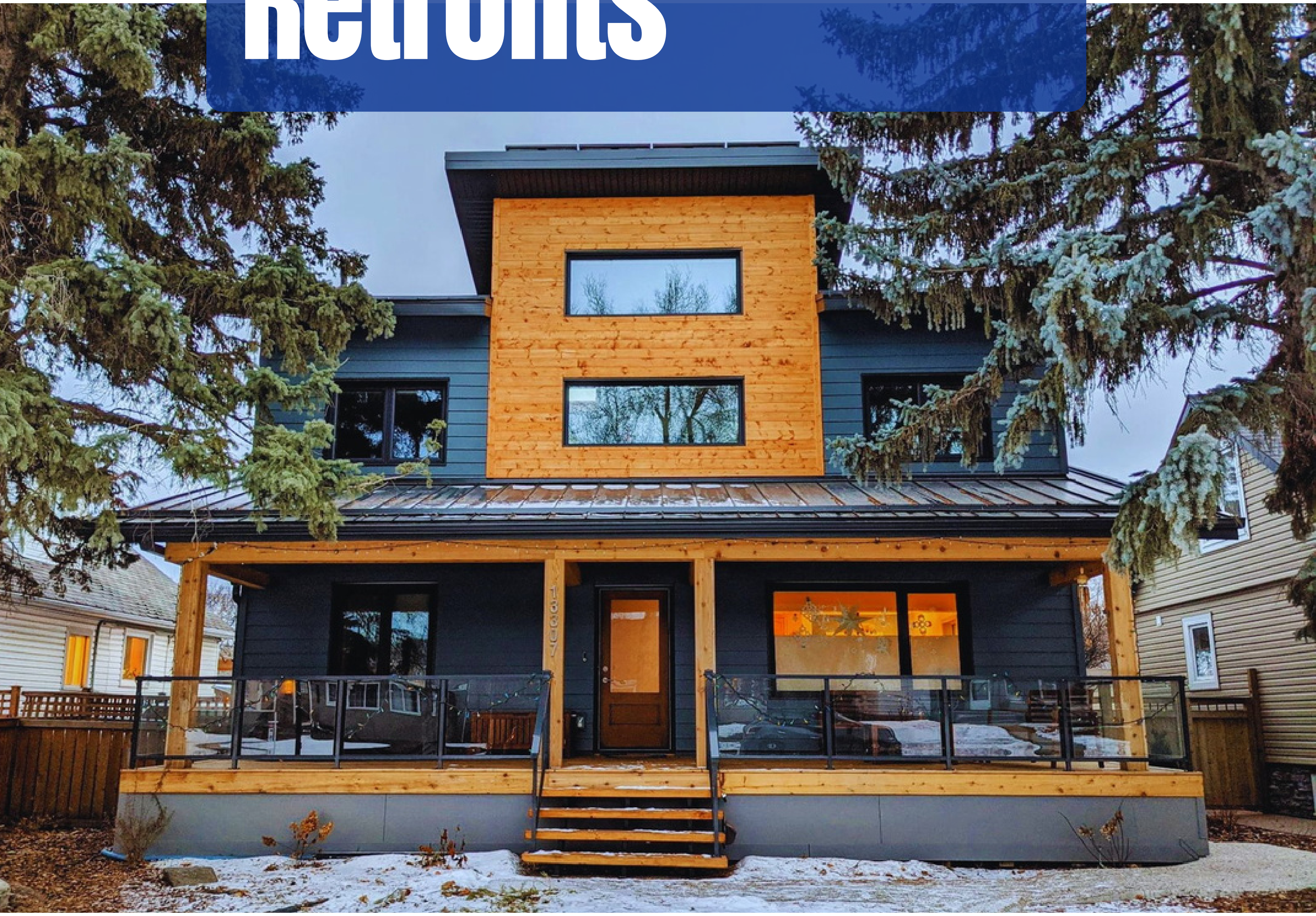
A Guide to Deep Energy Retrofits



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ACKNOWLEDGMENTS

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SAIT's Green Building Technologies (GBT) applied research group began in 2008, bringing SAIT and Green Building Technology researchers together with industry partners to identify and develop environmentally friendly technologies, processes, programs, systems and services that will fundamentally change the way we build, educate and develop skilled labour.

Our Partners

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- Retrofit Canada
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DISCLAIMER

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WHO IS THIS GUIDE FOR?

This guide is primarily for building professionals whose work provides opportunities for energy efficiency upgrades and effective **Deep Energy Retrofits**:

- General Contractors
- Designers
- Project Managers
- Energy Consultants (Advisors)
- Architects
- Tradespeople

The guide will also be useful to homeowners and building owners, educators, and advocates. It is intended to provide information associated with deep energy retrofits and to help users identify a pathway for retrofitting to net-zero emission performance for existing single-family homes. Although focused on single-family homes, the principles described herein are applicable to other building types.

Purpose of this Guide

Define **Deep Energy Retrofits (DER)** and explain how they support Canada's emission reduction goals.

Provide process considerations through a general **Retrofit Roadmap.**

Provide guidance through content and case studies.

MAJOR SKILL GAPS IN RESIDENTIAL CONSTRUCTION have created demand for educated professionals to improve home energy efficiency through Deep Energy Retrofits.

Energy use in housing contributes a significant portion of Canada's carbon emissions. Inefficiencies of existing homes are a major contributor to these emissions. Tearing down every existing inefficient home and rebuilding new would result in large amounts of waste, emissions and embodied carbon.

Deep Energy Retrofits offer one solution to extend the life of the building and reduce carbon emissions and landfill waste.

Canada has set a goal to get to Net-Zero Carbon Emissions by 2050.

Most of the houses that will exist in 2050 already exist today and are not net-zero ready. The residential construction industry's best opportunity to diminish operational emissions and electricity consumption is to adopt **Deep Energy Retrofits** of existing homes, massively scaling up retrofit offerings over the years to come.

This is achieved by first reducing reliance on emissive activities to minimize new emissions and then implementing methods of capturing carbon dioxide from the atmosphere.

Due to the correlation between energy generation and emissions, net-zero from a household's perspective refers to reducing our energy demand and producing as much clean energy on-site as is consumed over a year.

Reducing emissions is the most applicable and affordable strategy for achieving net-zero. This can be done by building new homes that are constructed to a higher standard than current code, or renovating the existing housing market to improve operational efficiency.

A **Deep Energy Retrofit** can make any existing home energy efficient, decreasing its overall energy demand so that it can get all of its energy needs from renewable sources.

"Achieving net-zero emissions means our economy either emits no greenhouse gas emissions or offsets its emissions, for example, through actions such as tree planting or employing technologies that can capture carbon before it is released into the air."

- Government of Canada

What is net-zero ready?

"A CHBA Qualified Net-Zero Ready home that is labeled under the program is a home that is recognized by CHBA (...) to be a home that has a renewable energy system designed for it that will allow it to achieve Net-Zero Home performance, but the renewable energy system is not yet installed."

- Canadian Home Builders Association (CHBA)

CHAPTER 1: WHAT IS A DEEP ENERGY RETROFIT?

1 DEFINING DEEP ENERGY RETROFITS

A **Deep Energy Retrofit (DER)** is a change or series of changes that lower the energy needs of the building enough that the remaining energy needs can be provided by emissions-neutral sources. The most readily available form of renewable energy is electricity from hydro, solar photovoltaics or wind. Renewable gas and green hydrogen can be zero emissions sources as well, however, these resources are not yet readily available.

Transforming existing buildings to near net-zero – at least for the initial ones as the green building sector scales up capacity – will be challenging and expensive if not carefully planned. **DERs** represent a substantial departure from the piecemeal, low-hanging fruit approach to energy upgrades currently encouraged and supported by typical government and utility programs. In some cases, designers may consider each component or system of a house individually. For example, they may design the building envelope without considering the mechanical system.

To make a home net-zero ready, we must recognize that a house is a complex system with many sub-systems that work together to ensure optimum performance and comfort (refer to **Section 4 - House as a System** to learn more).

Deep Energy Retrofit Benefits

Improved Comfort / Healthier Living

Upgrading the building envelope by adding continuous insulation and making it airtight is like wrapping it in a warm coat. Reducing air leakage and installing a heat recovery ventilator (HRV) makes it possible to have healthy fresh air and ideal humidity – even in the middle of winter.

Make necessary repairs anyway / Extend useful life of the building

DERs are a great opportunity to look after neglected maintenance in an efficient and cost-effective way. Exterior re-cladding using the best building science, extends the life of the building for many maintenance-free decades. Updating old heating systems with new technologies - for example, heat pump systems provide effective and efficient heating & cooling.

Energy savings & security / Increased resale value

DERs protect you from high energy bills and the rising cost of carbon. The multitude of home improvements that come with **DERs** can help increase the resale value of the existing home.

Green House Gas Reduction / Energy Efficiency / Peace of mind

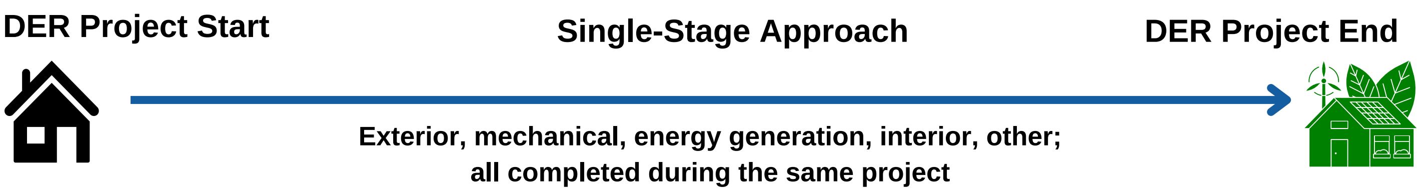
Canada's goal to be net-zero by 2050 means we have to make the homes we live in today net-zero ready. **DERs** are a solution that gives homeowners a practical and tangible opportunity to do their part to reduce emissions.

1 RETROFIT BUDGET AND TIMEFRAMES

Before starting any **DER** project, it is crucial to emphasize that they are a significant investment in time and money. As a result, there are two main **DER** categories: **"One-Shot"** and **“Multi-Stage”**. Keep in mind the retrofit project should always start with an energy audit and building assessment in order to develop a plan so that all of the upgrades are completed in the most efficient manner, and ultimately enable a home to be net-zero ready.

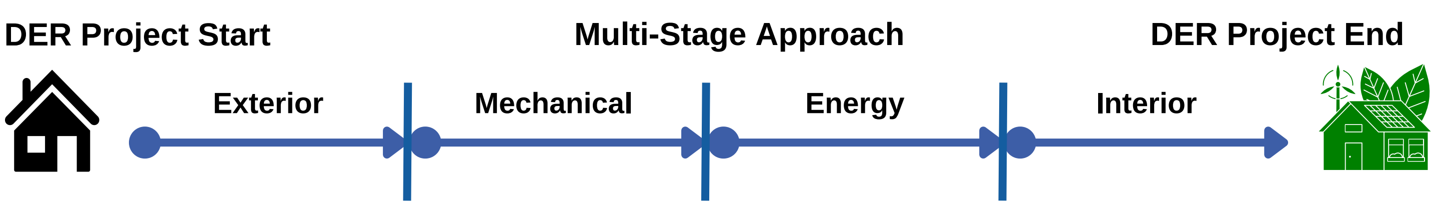
Single-Stage DER

A **"Single-Stage" DER** considers all construction upgrades and improvements simultaneously (i.e. in 'one-shot' rather than over time, resulting in a more **significant upfront capital cost** and potential homeowner relocation until the project is complete. For example, panelized retrofits with an HVAC system upgrade exemplify a one-shot approach. However, in the long-term there may be more return on investments through net-zero rebates, government incentives and increased property values.



Multi-Stage DER

"Multi-Stage" DER projects are planned and executed in stages to make the building net-zero ready. The multi-stage approach may apply to homeowners with limited funds, **allowing costs to be spread out over a longer timeframe**. The incremental steps of a multi-stage **DER** follow a detailed plan so that the improvements are carried out in a defined way, aligned with construction best practices as the homeowner secures additional project funds. If completing a Multi-Stage **DER**, refer to **Section 4 - House as a System** to learn more about approaching a **DER** using this method.



1 BEWARE OF PIECEMEAL RETROFITS

A piecemeal retrofit differs from a properly planned, Multi-Stage retrofit because it does not incorporate a comprehensive plan to make the home net-zero ready. The lack of an overarching retrofit plan often results in higher costs and more work overall when compared to an adequately phased or single-stage retrofit. Preparing an existing home to be net-zero-ready is significantly more complex. For example, retrofits can begin by replacing the doors and a few windows, and then at a later date, the remaining windows and exterior cladding. However, without adding extra insulation before the cladding, this would prohibit further thermal comfort improvements. This piecemeal, unplanned approach may never get you to net-zero. Care must be taken to ensure upgrade work does not "lock-in" inefficiency or create re-work down the road when the next stage of work is implemented.

Reasons to avoid Piecemeal Retrofits

1. Piecemeal retrofits make it challenging to achieve net-zero and ensure proper performance and comfort within the building during and after the retrofit work is completed.
2. They can cost significantly more than retrofitting through a cohesive and carefully phased plan.
3. Some portions of work may need to be re-done multiple times. For example, if you re-insulate your attic without addressing airtightness, you may have to remove all the new insulation before taking that step.
4. The overall retrofitting process will take longer, presenting inconvenience to the occupants.

Reasons to complete Multi-Stage Retrofits

1. Assess and plan out the full DER project, then plan stages and transitions needed between the different improvements to prevent re-work and lost efforts.
2. By spreading retrofits costs out over time, borrowing costs can be reduced, therefore lowering the total cost, which reduces the need for additional credit.
3. With smaller scopes of work at each stage, occupants can likely stay in the home during the retrofit process.

CHAPTER 2:
A DEEP ENERGY RETROFIT ROADMAP

2 A DEEP ENERGY RETROFIT ROADMAP

There are many ways to complete **DERs** because there are so many different building types, shapes, ages, starting conditions, and climate zones.

The most cost-effective pathway for any building requires careful planning that takes into account the current energy consumption of the building, such as where that energy is going and what can be done about it, the maintenance and repairs it may need independent of energy considerations, and the availability of renewable energy sources.

For example, **DERs** often include reducing the building's energy needs through improvements to the thermal resistance and airtightness of the building envelope (exterior walls, roof, foundation, windows, and doors), electrification of the building's mechanical systems (heating, hot water, and cooking) and tapping into a renewable energy source (solar). Because there are so many options to evaluate, determining the most cost-effective solution set can be complicated. This guide includes a Retrofit Roadmap based on a house-as-a-system approach to simplify that journey.

The Roadmap outlines an integrated design process where an energy model of the existing building and an existing condition assessment of that building are brought together with construction to dial in a plan for the most effective set of upgrades and changes that will make that building net-zero before 2050.

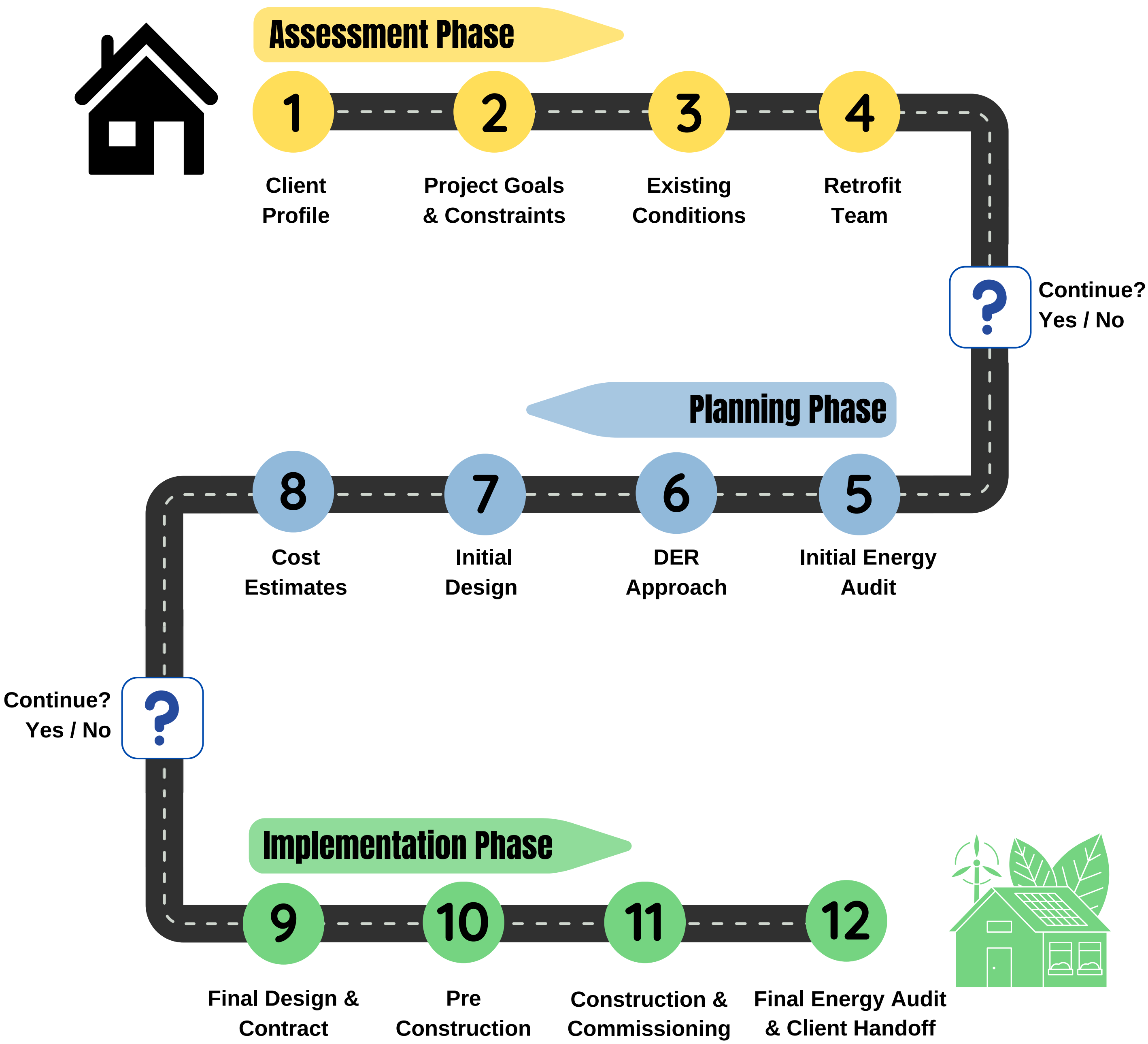
Aligning Deep Energy Retrofit Goals with Traditional Renovations

Tyler Hermanson of 4 Elements Integrated Design Ltd. has provided some great context for how a **DER** project can align with traditional renovations:

"While there are some homes that should not conceive of a DER project, the reality is that very few homes are a totally bad candidate. Most will not be ideal but workable, and some will be easy. We have to stop separating out DER from traditional renovations (kitchen, bath, style) as likely these needs are going to weave into the initial needs that drive a DER.

We are human after all, and everyone has NEEDS and WANTS and will mix a little of both in. To gain traction and wide adoption the masses have to pick this up, and DER becomes something you do because you are renovating your house anyway, not the sole driver."

2 FOLLOWING THE ROADMAP



2 ROADMAP: ASSESSMENT PHASE

The Assessment Phase is a critical first step in the **DER** process, and in many ways, this is similar to the steps taken for traditional renovations.

The initial phase of a **DER** focuses on learning and getting to know the client, their proposed project, and aligning project goals to understand the scope of work from the customer's perspective.

Secondly, the building and site should be fully assessed in order to understand all existing conditions, so that the most relevant retrofit strategies and building science principles can be applied to the retrofit project. And finally, you will need to build the project team (i.e. retrofit team) to capture the needed expertise for a successful project.

The Assessment Phase of a **DER** is further detailed within the following 4 steps.

1 - Client Profile

An important aspect to the success of any construction project, not just **DERs**, is understanding the client and what they value. Knowing this offers the opportunity to educate the client on home improvement opportunities they may not be aware of. This can help align their needs with the appropriate **DER** home improvements, while still achieving their desired outcome.

Get to know the client

Why are they renovating?

What are their short term and long term goals?

Is there input from others that needs to be considered (i.e. family members)?

Will accessibility (i.e. wheelchair) be a consideration in the future?

What part of the project is most important to them?

Do they know anything about DERs and the multiple benefits?

How can a DER be incorporated into their traditional renovation?

How much are they able to invest in the initial assessment and planning?

2 ROADMAP: ASSESSMENT PHASE

2 - Project Goals & Constraints

Understanding the motives behind why a client decided to do a **DER** will help you realize the project goals. By first identifying goals, you can envision the desired project outcomes, and then use these objectives to define what success looks like for the project. This sets the stage for identifying opportunities that bridge traditional renovations with a deep energy retrofit.

At this point, it is very important to recognize any constraints there may be with completing certain aspects of the project. One of the largest constraints in any household upgrade project is the budget. Other constraints can include project timelines and occupancy (i.e. can the work take place with occupants in the building?). Addressing these constraints and restrictions is essential for planning and determining the type of **DER** schedule that can be used (i.e. Single-Stage or Multi-Stage).

3 - Existing Conditions

Performing a thorough analysis of the existing conditions of the building and the site will help determine the feasibility of completing the **DER** goals laid out with the client. The assessment of existing conditions is crucial because it will determine necessary pathways or restrictions that may affect the process of competing the retrofit and achieving the client's goals. In certain scenarios, existing conditions may greatly increase the cost of the project, or they may deem that the project should not proceed due to specific circumstances. The earlier information is discovered and accounted for, the better the project team can prepare and budget accordingly. The following list are examples of existing conditions that should be assessed, that are critical to informing the **DER** plan:

- Structural conditions: What is the condition of the foundation? What is the condition of the above grade envelope? Are there structural damages, and to what degree?
- Year built and materials used: Past construction eras used materials that are harmful to humans. Are there toxic materials that need to be remediated? **See CAUTION note below**.
- Complexity of the building: Different building types (i.e. bungalows, duplexes, townhouses, bi-levels, multi-unit, etc.) will represent different constraints to consider.
- Complexity of the site: Does the site have limited access? Are there slopes or areas of the yard that must be protected or not used during construction? Are there overhead powerlines or underground utilities that will affect cost and the retrofit approach?
- Required replacement - end of life: Are there systems that have reached end of life and need replacement (i.e. roofing, siding, windows, doors, mechanical systems, etc.)?
- Thermal comfort: Are there areas of the home that are drafty or seasonally uncomfortable? How old are the windows and doors? Is the furnace old or inefficient?
- Exposure for solar PV energy: Does the roof have access to solar energy for on-site solar PV generation? Is it a complicated roof for solar PV installation? Are there trees or neighbouring buildings that shade the roof?

2 ROADMAP: ASSESSMENT PHASE

3 - Existing Conditions *continued...*

Identifying the building's year of construction can help a contractor identify relevant construction practices, and potential pitfalls associated with that era of construction, such as hazardous materials. Emphasis on the varying approaches to construction methods, building science, and materials used during the original construction of a home can have a significant impact on the overall **DER** strategy and cost.

CAUTION: HAZARDOUS MATERIALS

During the assessment of the existing conditions, there is a need to consider the construction material used in the past. A test should be conducted for hazardous material (i.e. asbestos, lead paint, lead pipes) and old / outdated building materials that will need to be replaced (i.e. poly B piping, outdated electrical wiring).

The remediation of hazardous materials and / or replacing outdated materials can be costly. Therefore, discovering early on whether the project will need to incur a remediation cost or replacing outdated materials, will help determine the achievable retrofit project goals and plan based on the remaining budget.

2 ROADMAP: ASSESSMENT PHASE

4 - Retrofit Team

Every **DER** project is unique and is a complex process requiring thorough assessments (i.e. existing conditions, energy, etc.), design advice, construction permits, financing and other documentation.

For a successful **DER** project, it is imperative to have an **integrated team** of consultants, each bringing their applicable skills to different project stages, who also understand each others scopes of work. If participants are brought in as early as possible, then there are less chances for costly errors (in both price and energy efficiency) further along in the retrofit process, leading to a more efficient and comprehensive **DER** project.

From homeowners to contractors, or even a consulting company, having an overarching **DER** manager provides experience and leadership throughout the entire process of a **DER** project. Preferably, a **DER** project will be managed by a trained professional or a company, who is knowledgeable in building science principles, residential energy efficiency, energy auditing, and best practices from a construction management perspective. Furthermore, a **DER** manager will ideally have the required expertise to develop a comprehensive retrofit plan that achieves the owner's goals within the allocated budget.

Ultimately, the scope and size of the **DER** project will determine how many consultants will need to be engaged, with larger or more complicated projects requiring a larger group of integrated consultants.

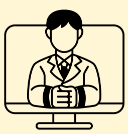
Vetting the Retrofit Team

- **DER** experience: It is highly recommended to engage with professionals that have **DER** experience and / or training. For example, the CHBA has a directory of qualified **net-zero renovators**.
- Multiple quotes and testimonials: Due diligence should be taken to acquire multiple quotes (valid for 2 months) for price comparisons, and don't hesitate to ask to connect with past clients to ensure good workmanship.
- Insurance: Verify that contractors have commercial general liability and vehicle insurance.
- WCB: Verify that contractors are in good standing with the Workers' Compensation Board (WCB) of Alberta.

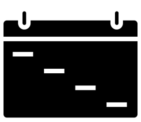
2 ROADMAP: ASSESSMENT PHASE

4 - Retrofit Team *continued...*

Beyond the Client, the following list outlines primary consultants that could participate in a **DER**, however a project does not require an independent representative for each role. Some participants may manage multiple functions depending on their expertise, retrofit experience and availability.

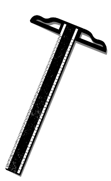


Energy Advisor / Auditor
- A professional that assesses the building's energy efficiency rating by completing energy models / analysis and airtightness tests.
- An advisor can also support the insurability of a project by certifying the process with an EnerGuide rating, CHBA Net-Zero certification, or Passive House EnerPHIt certification.

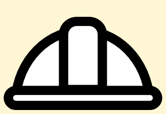


General Contractor / Builder
- Serves as a project manager and local contact for all construction requirements.
- Manages trades, aligning timelines for construction, assuring project quality and value.

Building Science Consultant
- Has detailed training in building envelopes, moisture management, building code, and can apply all of these to the design process.
- Vital in initial steps of a **DER** to help specify current conditions of a building and the feasibility of a retrofit project.



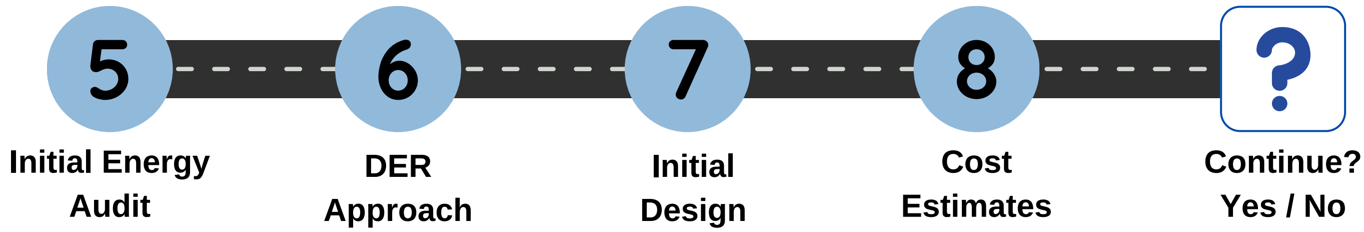
Architects, Engineers, and Designers
- Provide professional input on the design process and can establish legal certification and insurable standards.
- Designers provide the needed drawing support, and engineers may be necessary to ensure structural design changes or a detailed mechanical system design.



Subcontractors / Trades
- Identifying early in the project the subcontractors and trades that will be performing the on-site work ensures they know what will be expected of them and in what stages of the project they will be involved.

Other potential team members / participants could include:
- Building owner / operator
- Occupants
- Governing authorities
- Utility providers

2 ROADMAP: PLANNING PHASE



The next phase of a **DER** project begins the formal planning and design process, and prepares the project to start the work. This phase relies heavily on the integrated team identified above, and professional fees for design and planning start to be incurred.

At this point, an energy audit, initial design and cost estimates are conducted to provide the homeowner with a clear picture of the expected scope of work, rough price and timeline. A **DER** project should expect independent costs for Energy Advisory services, and design details, especially if architectural drawings are required.

In the following section, we will address key design considerations for **DERs** and available options for increasing envelope performance, which will assist in the pursuit of our net-zero goals.

The end of this DER phase is the homeowner's approval to proceed and to start attaining the required construction permits for construction to begin.

5 - Initial Energy Audit

Engaging an Energy Advisor, is the first step in collecting important information that will guide your retrofit goals. The EnerGuide Rating System (ERS) is the Government of Canada's energy performance rating and labeling program, which includes a designation for homes. The ERS for homes is carried out by Energy Advisors who work under a national system to consistently measure the energy consumption and efficiency of homes and provide standardized reports. This assessment includes an energy model to calculate energy consumption within the existing home, air tightness testing, combustion spillage risk assessment, and identifies key areas for improvement.

An energy model of a home takes many things into account, including:

- Physical space and size
- Geographic orientation
- Building envelope design
- Windows and doors (sizes, orientation and thermal performance)
- Heating and Ventilation systems
- Building air leakage rate
- EnergySTAR Appliances
- Thermal Bridges
- Shading

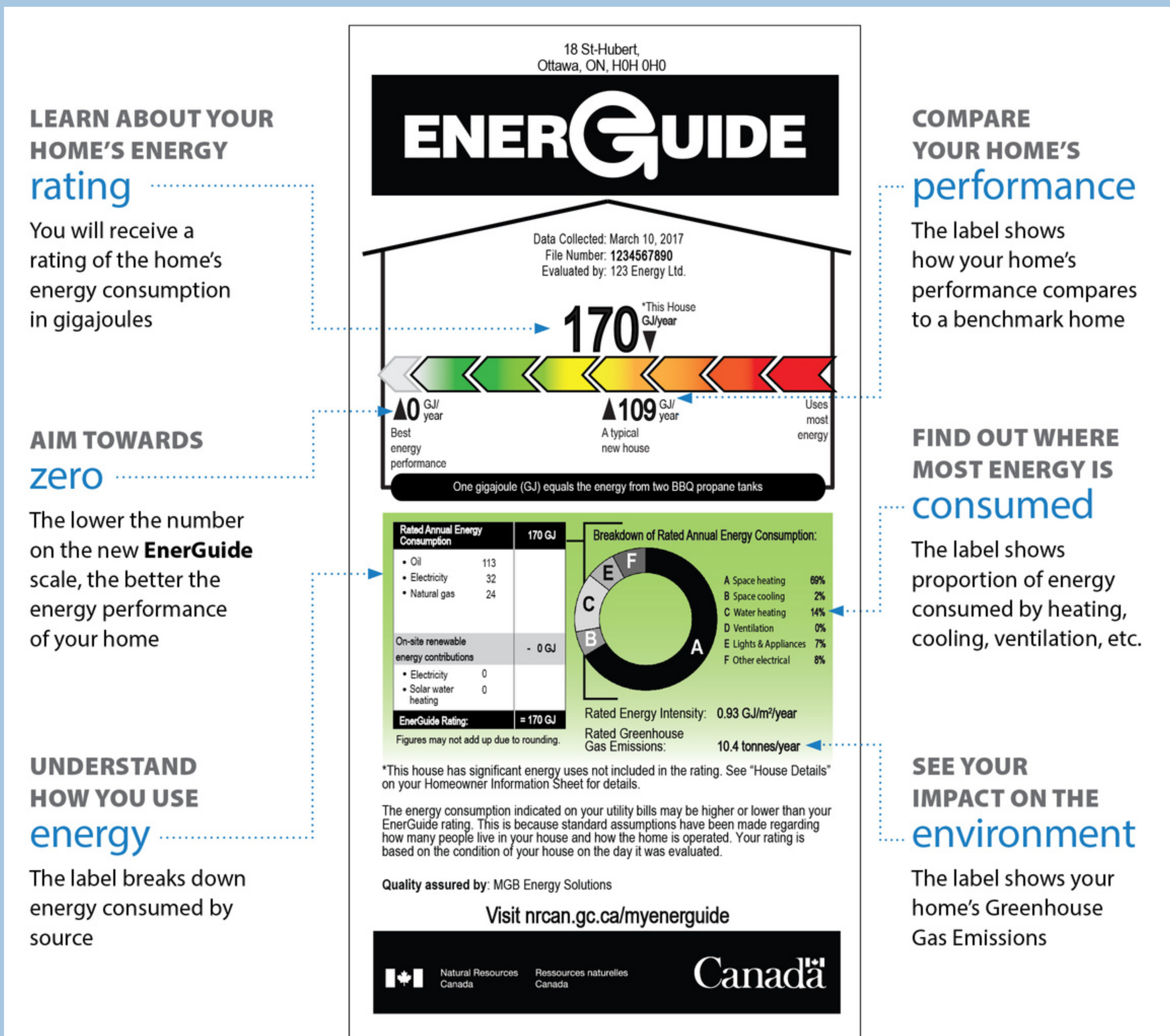
2 ROADMAP: PLANNING PHASE

5 - Initial Energy Audit *continued...*

The ERS may be part of the **DER** project's building permit requirements and may also be required by household improvement loan and grant programs. The EnerGuide label is also used by third party certification programs such as CHBA Net-Zero, LEED for Homes and ENERGY STAR.

Below is an example EnerGuide Rating System label for homes.

EnerGuide Label for Homes



2 ROADMAP: PLANNING PHASE

5 - Initial Energy Audit *continued...*

Air Tightness Testing

Since air leakage makes up a large portion of energy loss within Canadian homes (20% to 40%), air tightness testing with a blower door is an essential step during the home's energy audit. This test uses a calibrated fan at a standard pressure of 50 pascals (Pa), simulating a windy day, to measure the flow of air (i.e. air leakage) through the building's envelope. The air leakage of a home is measured in air changes per hour at this standard pressure (ACH50), indicating the number of times per hour the entire volume of air within the home leaks out. A higher ACH50 value signifies increased air leakage in the home. This test provides valuable information on how the home's envelope is performing and where locations for air sealing exist.

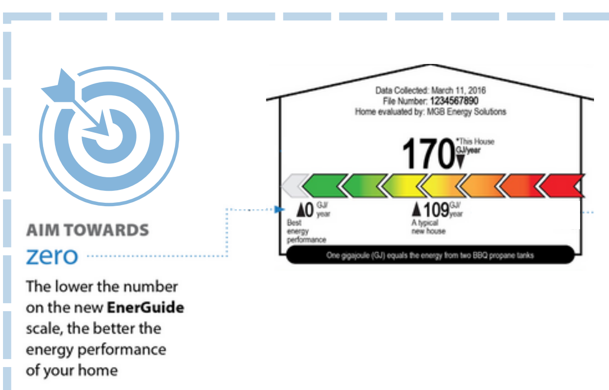
DER Target Performance

Household energy efficiency improvements can be viewed as a road, and homes are moving down the road towards the requirements of Canada's 2050 Net-Zero Emissions goals for a low carbon future. The objective should be for all **DER** projects to include the most effective combination of energy efficiency improvements within the available budget, using appropriate expertise, techniques, materials, and equipment, so that the home's overall energy consumption is reduced to levels where on-site renewable energy systems are possible in providing the annual energy required.

However, targets for each **DER** project will vary by homeowner goals, building code requirements, and optional certification programs.

The following codes, standards and programs provide varying energy performance targets that can be referenced for **DER** projects:

- National Building Code of Canada Section 9.36
- ENERGY STAR
- CHBA Net-Zero Home Renovation Label
- Enerphit (Passive House Retrofits)
- Passive House



2 ROADMAP: PLANNING PHASE

6 - DER Approach

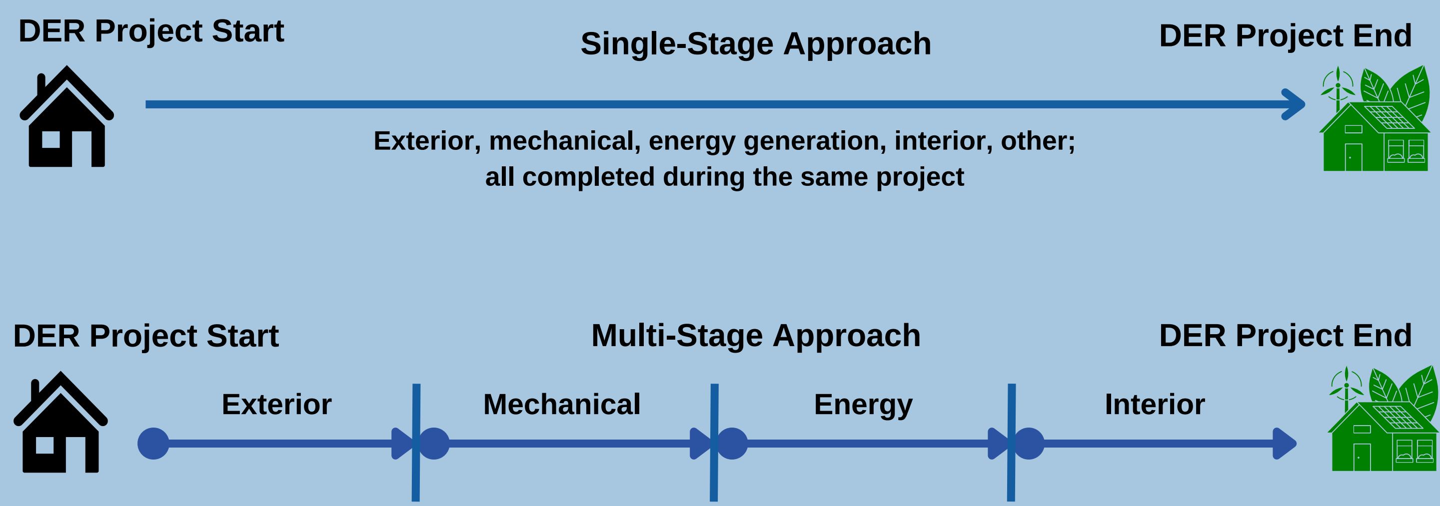
Successful and cost-effective construction projects are generally the result of a well-integrated team which implements open communication from the early stages of planning through to construction. Therefore, another key to successful projects is ensuring the entire **DER** team is on the same page regarding the project's goals, working together to achieve the best result.

In the best case scenario, a "One-Shot" **DER** is done to make the building airtight, super-insulated, properly ventilated and net-zero ready. As mentioned earlier in the guide, many circumstances may require the **DER** to be planned in a "multi-stage" fashion.

A major question that will need to be answered is **"what do we do first?"** There are many different factors that can affect how we answer this question. Sometimes the starting point will be dictated by what has to be done (window & cladding replacement, failing heating system, etc.). Building envelope upgrades should be done before mechanical upgrades when staging a **DER**. A properly designed envelope needs to correlate with a correctly-sized mechanical system to meet the building's heating, cooling, and ventilation loads.

Mechanical-first options that can be done consist of installing a hybrid (gas + heat pump) air handler if the furnace is approaching its end of life. The heat pump portion needs to be appropriately sized for the fully completed **DER** heat load. Gas will be the backup heat source until all the building envelope upgrades are completed. Then the gas line would be disconnected, but the new heat pump mechanical equipment remains.

Individual stages should be planned to minimize duplication of work between stages. Additionally, careful planning should be carried out to ensure the work of a later stage does not affect the order of operations.



2 ROADMAP: PLANNING PHASE

7 - Initial Design

The architectural and structural design of a **DER** considers data gathered in the earlier stages, such as the building assessment and energy modelling. With this information, the design and specifications of the project can begin. The info collected will allow the design team to better make decisions that will have the greatest impact on the final outcome and effectiveness of the **DER**. This includes, but is not limited to some of the following considerations:

- Heating & ventilation requirements
- Structural changes & requirements
- Insulation type & where
- New window positions (recessed in or out)
- Trees / landscaping (kept or removed)
- Soffit overhangs

7 - Initial Design: Durability Concerns

Residential **DERs** should aim to increase the thermal resistance and airtightness of the building enclosure, without compromising the durability of its assemblies.

The following are some common durability concerns:

- Bulk water entry due to improper detailing
- Condensation due to air leakage
- Material incompatibilities
- Condensation due to vapour diffusion
- Proper selection and alignment of product and material lifespans

2 ROADMAP: PLANNING PHASE

7 - Initial Design: Retrofit Building Science Considerations

There are many different options for making a high-performance wall. For **DERs**, applying exterior insulation is highly beneficial in terms of constructability and performance. Even though this is a common practice, things can go very wrong if proper building science principles are not considered.

One of the most important things to remember is to maintain or re-establish the quality and continuity of the four control layers, which are, **in order of importance**:

- Water control layer, consisting of the 'water shedding surface' (WSS) and the 'water resistive barrier' (WRB)
- Air control layer
- Vapour control layer
- Thermal control layer

Each of these layers needs to be maintained or redone if required. In most cases, in existing Canadian homes, the vapour control layer is the air control layer, which is on the warm side of a wall assembly (and often not very air-tight). Because of this, **DERs** with exterior insulation being added will often add a new air control layer.

An important consideration is the possibility of creating two vapour control layers when installing certain types of insulation. This needs to be avoided or appropriately planned for as two vapour barriers can cause moisture to get trapped in the wall, with no ability to dry, which can lead to water damage issues (i.e. rotting).

When using exterior insulation products that will create a vapour barrier, ensure sufficient insulation is installed to move the dew point (where moisture will condense) out from the existing wall and into the exterior insulation. Double vapour barrier risks can be minimized by using fibrous exterior insulations which are vapour open.

When selecting a wall assembly, the key building science principle to remember is air tightness first, vapor control second. The vapor control layer is concerned with controlling the movement of moisture via diffusion through solid materials, so if it is 95% present, it is 95% effective. The air control layer is concerned with controlling the flow of air through a hole in the building fabric. As it is driven by air pressure, air will flow preferentially towards a leak, so a 95% complete air barrier is NOT 95% effective. When air flows through a hole, it also brings significant moisture.

Other things to consider when adding exterior insulation to a **DER** include, but are not limited to:

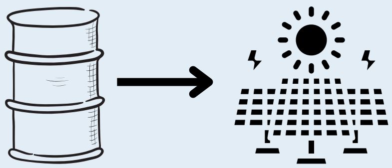
- Water management - must ensure proper water drainage for the wall system
- Local code requirements - everything done to the assembly must meet local building codes
- Fire rating requirements
- Maximum lot coverage / setbacks, etc.

2 ROADMAP: PLANNING PHASE

7 - Initial Design: Electrical Considerations

Electrification, also known as fuel switching, means that fossil fuel consumption within the home is eliminated, by switching all systems (i.e. heating, hot water, cooking, etc.) to those that only use electricity. The primary purpose of electrification is to reduce the greenhouse gas emissions associated with fossil fuel combustion within the building. However, there are several considerations that need to be addressed with electrification, one of which is the **amperage** of the electrical service within the home.

Electrification



The electrical service of new homes is typically 100-amps, however older homes undergoing a **DER** may only have a 60-amp service, which means that 'electrifying' the home will require an electrical service upgrade, especially with the addition of more systems using electricity. It is essential to engage early with local electrical utilities if the amperage of the electrical service will need to increase as part of the **DER**. Furthermore, depending on the mechanical systems and appliances installed within a **DER**, electrification may require a greater than 100-amp service (i.e. 150-amp or 200-amp), which will also have cost implications for installation.

See **Chapter 4, At-Home Energy Use** for further information on 'electrification'.

8 - Cost Estimates

The process of generating cost estimates and determining the final build cost is typically an iterative process with the “Initial Design” stage of the roadmap. This means that initial plans will be made, estimated costs calculated for those plans, and then changes to the initial plans might need to be done, depending on the client’s acceptance or desire to adjust the final cost.

Cost estimates related to a **DER** project will follow the same principles as a standard renovation budget and will form the basis of a contract for construction. This includes costs for materials, equipment, labour, builder's fees (i.e. overhead), GST, and most importantly for a **DER** project, there should be funds set aside for possible contingencies.

Similar to approaching the cost estimate of a traditional renovation, certain contingencies are key within a **DER** project budget, because it is unknown what is actually hidden behind walls (and within attics) until the construction work begins. The existing conditions of the home and site were evaluated during the "assessment phase", however, it is quite common for a renovation project to uncover unforeseen situations that will require replacement, removal or remediation, which comes with costs that may not have been planned for.

2 ROADMAP: PLANNING PHASE

8 - Cost Estimates *continued...*

Additionally with **DERs,** there are further cost contingencies to consider. Since the project will be carried out with superior components (i.e. higher-end windows, advanced building envelope), energy efficient appliances (i.e. fridge / freezer, washer / dryer, stove top, etc.) and newer to market mechanical systems (i.e. heat pumps), it is noted that these will also come with higher costs. Therefore, general contractors & builders should be aware that a **DER** project will inherently have higher cost estimates than a traditional renovation, and should be transparent with their clients.

8 - Cost Estimates: Cost-Effectiveness

It is important during planning to evaluate the cost-effectiveness of different retrofit strategies. This means comparing costs with the extent of potential energy savings and other realized benefits. In determining cost-effectiveness, the added cost for specific energy improvements (i.e. added insulation and higher-performance windows) should be focused on. This allows a view of the true cost of a **DER** beyond work that is needed independent of energy-saving strategies (replacement of old / outdated cladding and windows).

The added costs of a **DER** may be recovered over time through annual energy savings but this should not be the only consideration. Value is also received through the added comfort, health, environmental benefits, and durability of a **DER**.

Less & Walker (2015) found that, on average, deep energy retrofits in the U.S. were cash-flow neutral on a monthly basis. However, variability was large, with some projects substantially reducing net-monthly costs and others substantially increasing net-costs. Questionable cost-effectiveness is thus seen as a barrier to widespread implementation of deep energy retrofits.

It is important during the planning stages of a deep energy retrofit to consider the various benefits and not focus solely on utility savings.

2 ROADMAP: PLANNING PHASE

8 - Cost Estimates: Financial Incentives

Incentives for home energy improvements vary across Canada. However, most rebate and incentive programs must align with insurable work, meaning professional engagement with a certified Energy Advisor and licensed professionals and trades are required as a minimum standard for application.

On top of finding ways to reduce renovation and ongoing operating costs, experienced retrofit professionals will ideally know about local incentive, rebate and financing programs. Some may even do the rebate / incentive management on the owner's behalf. Below are some options for national and municipal incentives currently offered in Canada.

Canada Greener Homes Grant

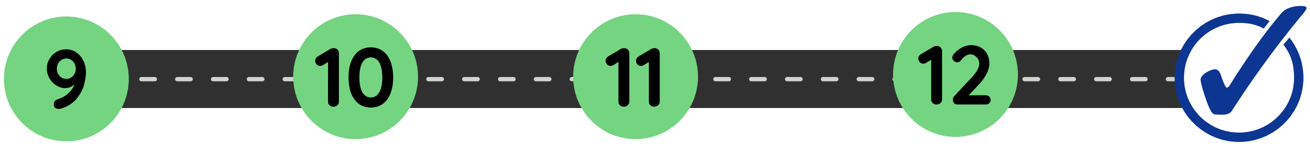
- Natural Resources Canada (NRCan) funding for household efficiency improvements.
- Grants from $125 to $5,000 - To get a part of your costs back for eligible home retrofits.
- Up to $600 - As a maximum contribution toward the total costs of your 'before' and 'after' retrofit EnerGuide evaluations.
- Interest-free loans of up to $40,000, with a payback term of 10 years to assist homeowners undertake major home retrofits.

Municipal Clean Energy Improvement Programs (CEIP)

- Example of a financing model available in some Canadian municipalities that homeowners can use to upgrade their home’s energy performance or install renewable energy systems with no money down.
- Repaid on a property's municipal tax bill over a length of time.
- Investment of improving a home to be directly tied to the assets overall value.
- See https://ceip.abmunis.ca/residential/locations/ for a list of Alberta municipalities with Clean Energy Improvement Programs.

Always check within the area of the DER project what incentive programs are available. There are incentive options for household efficiency improvements offered at the federal, provincial and municipal level.

2 ROADMAP: IMPLEMENTATION PHASE



Final Design & Contract | **Pre Construction** | **Construction & Commissioning** | **Final Energy Audit & Client Handoff**

The final phase of the **DER** process requires specific design and construction considerations that account for the home's unique variables and the retrofit's location. Although similar retrofit solutions may apply to similar homes of identical construction eras, the reality is that each project is unique and will require specific design solutions to achieve the best retrofit outcome.

This phase of the **DER** will focus pre construction activities and develop a timeline for project objectives. Risk assessment plays a vital role in successful construction outcomes, confirming goals, identifying risks, and developing mitigation strategies. It will touch on the work that needs to be done after the planning phase but before any hammers are swung. Lastly, this section highlights the high-level processes in the construction and commissioning of a **DER**.

9 - Final Design & Contract

The first step in the implementation phase is to take the client approved initial plans and finalize them for possible permit applications, distribution and use, and confirm that the project still meets the initial project goals. If the builder has been brought in already as part of the integrated design process, then they should be familiar with the project goals and understand the path forward. The following are some considerations within the detailed final design:

- Architectural / Structural Design: Working drawings, Real Property Report, envelope upgrade plan, component / material / installation details and specifications.
    - If required: permit drawings, structural and mechanical engineering review, energy model based on final design.
- Utility Planning: Electrical upgrade design / planning / pricing, utility consultation, electrical engineering (if required).
- Building Capture (if a panelized retrofit): Digital capture and site measurements, verify digitized accuracy, panel drawing and dimensions.

At this point it would be valuable to start bringing in the trade sub-contractors so they can understand the integrated delivery process and what is expected of them.

2 ROADMAP: IMPLEMENTATION PHASE

9 - Final Design & Contract *continued...*

There are different contract delivery methods that can be utilized to execute a **DER**. Each of these has factors that must be considered to determine what is best for each project and the associated team.

Integrated Project delivery

When planning a **DER**, using Integrated Project Delivery (IPD) can help manage liability and costs. IPD fully integrates project teams throughout the design and construction process to take advantage of the knowledge of all team members to maximize the project outcome. The benefit of IPD is that this approach engages the key team members who will execute the work right at the start of the design phase. This helps minimize issues during construction. In addition, IPD projects often utilize contracts that reduce change orders and share a profit pool among stakeholders.

Fixed price contract / Bidding

Another approach to contracting trades and relevant labour is the more traditional method of single-contract bidding. Competing quotes are obtained from different professions and suppliers and are agreed upon with a signed contract at a fixed price.

Cost / Plus

An initial bid is not used with a cost-plus contract, and the contractor invoices all project expenses with an agreed-upon profit.

Design / Build

Design-build is a form of project delivery where an owner contracts, under a single contract, with one entity (a design-builder) to provide and take contractual responsibility for both the design and construction services.

2 ROADMAP: IMPLEMENTATION PHASE

10 - Pre Construction

- **Permits**
  - Confirm which construction permits will be required. It is likely that there will be more than one type of permit required for the **DER** project, such as:
    - Building
    - Gas
    - Electrical (will also cover on-site renewables, for most jurisdictions)
    - Plumbing (may be needed)
    - Development permit: depending on the project scope, a development permit may be required. Always confirm with the municipality where the project is located which permits are required.

- **Order Major Components**
  - Lead times - some components will need to be ordered earlier since they will take longer to get delivered
  - Windows / doors
  - Mechanical equipment
  - Specialized lumber products

- **Homeowner / Occupant / Tenant Engagement**
  - Will the tenant be moving out for the duration of the retrofit? Will they be living in a different area of the home?
  - Ensure the tenant understands the construction process and how they will be affected.
  - Does there need to be site protection or containment for areas of the home that aren't being retrofitted, so they don't get damaged or filled with dust?
  - Putting more thought into making the retrofit process easier for the tenant / client goes a long way.

- **Final Construction Schedule**
  - Ensure time of year and weather implications have been considered.

- **Site Preparation**
  - Protect public infrastructure (i.e. sidewalks) and prepare surrounding area of building and landscape for construction work.
  - Ensure all OHS requirements for public safety, worker safety and municipal safety standards are in place.

2 ROADMAP: IMPLEMENTATION PHASE

11 - Construction

Moving from pre construction to construction is exciting since this is where all the details of the "Planning Phase" gets put into practice and the **DER** site work gets started. Below is additional information on site-built methods compared to panelized methods, followed by a generalized **DER** construction order of operations.

11 - Construction: Site-Built Methods

"Site-built methods" refers to retrofits where all of the construction takes place on-site, which is how the majority of traditional renovations are done. Typically, with **DER** projects, homeowners can remain in their homes during the construction phase with little disturbance or relocation. However, in retrofits requiring extensive interior work or very invasive exterior work, homeowners may want to find another residence during the retrofit.

11 - Construction: Site-Built Options

Below are some material options that can be used when constructing a site-built **DER**. The use and application of these materials will have been determined during the planning phase, however, the following are some considerations during construction.

There are several different types of **exterior insulation** that could be used in a **DER**. Some examples include:

- Blown-in Insulation (Dense Packed Insulation)
- Mineral Fibre
- EPS (expanded polystyrene) & GPS (graphite polystyrene - EPS core embedded with graphite)
- XPS
- EIFS

2 ROADMAP: IMPLEMENTATION PHASE

11 - Construction: Site-Built Options *continued...*

Blown-in Insulation (Dense Packed Insulation)

Blown-in insulation can also be added to the exterior of an existing wall assembly. If blown-in insulation is used, a cavity must be built that the insulation can be blown into, allowing for the proper density to be obtained. There are several techniques to making this cavity, such as using a Larsen truss or I-joist outriggers with a membrane around the exterior to hold the insulation. Strapping will often be used over the membrane to ensure it isn't bulging and affecting the siding installation.

The easiest option for installing blown-in is from the interior. This allows for more of a controlled environment and flat surface for the installers. This oftentimes isn't an option, though, if the interior of the home is not being completely renovated as well. If it is being installed from the exterior extra equipment may be needed, such as scaffolding or man lifts. The insulation must also be protected from weather conditions which can have an adverse effect on it, therefore try to get the insulation permanently covered as soon as possible.

The installation of blown-in insulation is also an important factor. A qualified and experienced installer should be hired to install the dense-packed insulation as it needs to meet a certain density so it will not settle. Improperly installed blown-in insulation can lead to issues down the road, mainly gaps of insulation at the top of the cavity.

2 ROADMAP: IMPLEMENTATION PHASE

11 - Construction: Site-Built Options *continued...*

Mineral Fibre, EPS, GPS, XPS

Rigid board-type insulation is attached using strapping and structural screws or pre-made clips and brackets. An engineer or architect may be required to design the fastening system, which would have been done in the planning / design phase. This is to ensure it can support the loads of the exterior cladding and any other special requirements, such as fire rating.

If using the strapping and structural screw method, care must be taken to ensure the screws are hitting solid backing (stud, blocking, etc.) within the structural assembly of the wall (framing). Depending on the thickness of the insulation that is being added, this can become increasingly difficult. If a screw misses, it is advisable to leave that screw in and add a new one that connects to structure. Removing screws that have missed will create an unnecessary open hole in the wall assembly, which could include leaving a small hole in the air-tight layer.

EIFS

One solution available for externally focused **DERs** is the Exterior Insulation and Finish System (EIFS). EIFS is a multi-layer exterior cladding system that incorporates continuous insulation, the water control layer and the finished surface in an integrated composite material system. An EIFS installation in a **DER** typically consists of removing the existing cladding system down to the structural sheathing, replacing any damaged sheathing, and then installing the following components:

1. Liquid Applied Air and Moisture Barrier
2. Cementitious Adhesive
3. Rigid board insulation (typically EPS)
4. Reinforcing mesh
5. Base coat and then finish coat

There are many considerations needed to ensure the proper installation of an EIFS system and this work should only be undertaken by properly trained crews.

2 ROADMAP: IMPLEMENTATION PHASE

11 - Construction: Site-Built Options *continued...*

Air Sealing

When completing a site-built **DER**, air sealing is done on-site in the existing conditions. Variables to consider that may affect the air sealing process include, but not limited to:

- Cold weather, which can lead to the worker rushing, tapes and sealants not sticking correctly, etc.
- Adverse weather conditions like rain, snow, hail, wind, forest fire smoke, which can affect worker efficiency and scheduling.
- Site conditions like uneven ground, workers not being fully equipped with proper tools / machinery for the site conditions, etc.

Extra attention to detail is needed to ensure air sealing is done correctly.

11 - Construction: Panelized Method

A **panelized** retrofit is an efficient approach that uses digital imaging technology to capture the precise dimensions of a building to pre-fabricate airtight and well-insulated panels. The prefabricated panels are delivered to the project site and installed on the outside of the building.

Steps of the **panelized** method include:

1. Digital Capture (Photogrammetry)
2. Design Panels
3. Build Panels
4. Prepare Building
5. Installation
6. Finishing and detailing

2 ROADMAP: IMPLEMENTATION PHASE

11 - Construction: Panelized Method *continued...*

The following images depict panel installation for a **DER** of a 1,950-square-foot, 1940s home. This project, located in Edmonton, Alberta, was the first panelized **DER** of a single-family home in North America.

11 - Construction: Panelized Options and Building Science Considerations

Panelized retrofits generally consist of wood-framed panels that include structure, insulation and an airtight weather barrier. In some cases, windows may be pre-installed. In rare cases, cladding is installed before the panels are put on the house. The panels are most often installed in a "cladding-ready" state so that the final appearance of the building will not reflect all of the panel connections.

The lowest row of panels is typically supported by brackets or a ledger on the building's foundation wall. The upper panels bear on the lower panels, and upper retainer brackets secure and align the upper portion of the panel with the existing wall structure.

Joints between panels are typically treated by sealing the panels with an air barrier tape. Gaps are often filled with batt insulation.

2 ROADMAP: IMPLEMENTATION PHASE

11 - Construction: Order of Operations

Every **DER** project will differ, but the following list provides a suggested approach to the order of operations and considerations for each step of the construction process.

Knowing when inspections are required for each permit is also crucial, as they should be properly incorporated into the order of operations. Different municipalities will have different required inspections, therefore due diligence should be taken to understand the requirements of the local authority. Lastly, it is highly suggested to carry out continual quality control checks throughout the construction process.

1. **Site Preparation and Protection**
    a. Required safety measures
    b. Utility locates
    c. Recycling/waste containers
    d. Services turned off (with consideration whether there will need to be power or water from another source)
    e. Refer to section '10 - Pre Construction'
2. **Excavation (if required)**
    a. Foundation for built addition
    b. Foundation wall exterior insulation
    c. For ground source heating
3. **Demolition (if required)**
    a. Confirm extent/scope
    b. Assess what can be re-used, salvaged/re-sold, re-purposed, recycled, or disposed of
    c. Plan for unforeseen circumstances (i.e. structural components, mould, vegetation, etc.)
4. **Structure/Envelope Framing**
    a. Re-framing/framing (as needed)
    b. Confirm that window/door rough openings, wall, roof, and other assemblies are correct. Note: The added insulation of DERs can lead to costly re-work if not considered when framing
    c. Additional framing after control layers are installed (if needed)
5. **Window & Door Replacement/Installation**
    a. Confirm proper installation details are followed and executed properly
6. **Mechanical Rough-in**
    a. HVAC, electrical, plumbing, security systems, home management systems, ground source heating, on-site renewable energy system, etc.
    b. If penetrating the air control layer, it **MUST** be properly sealed (at the very least, notify the DER manager)

2 ROADMAP: IMPLEMENTATION PHASE

11 - Construction: Order of Operations *continued...*

7. **Control Layer Installation**
    a. The control layers should have all been established at the design phase. During implementation phase it is critical to follow the details and discuss any concerns
    b. Confirm each control layer component is installed, as per manufacturer's specifications
    c. Continually inspect for errors, discontinuity, and damage
    d. Water control layer: ensure proper installation to allow necessary drainage of any possible moisture
    e. Air control layer: advised to have an individual 'in charge' of the air control layer to ensure continuity, who is reported to for any cuts and punctures. Should perform an air-tightness test to confirm adequate air sealing and fix any issues before this layer is covered up
8. **Exterior Finishing**
    a. Siding and exterior trim installation, following manufacturer's specifications
    b. Maintain the quality/integrity of any affected control layer
9. **Interior finishing**
    a. Maintain the quality/integrity of any effected control layer
    b. Finish carpentry, paint, cabinetry, flooring, etc.
10. **Construction Wrap-up**
    a. Interior finishing repairs
    b. Final clean up
    c. Equipment commissioning
    d. Final energy audit
    e. Financial incentive follow-ups (as required)
    f. Finalize additional electrical systems (i.e. security, home energy management/monitoring etc.)
    g. Operational and maintenance considerations: homeowner education, window coverings and operation, equipment maintenance and servicing requirements
    h. Landscape restoration and clean up

11 - Construction: Quality Control

On top of the inspections required for construction permits (i.e. electrical, gas, plumbing, etc.), ongoing quality control and continual engagement with all members of the project is needed to ensure that the **DER** follows the project plan and design.

Moreover, continual quality control inspections help to confirm the building components and equipment are properly installed at each stage, following sound building science principles, while taking extra precautions to adequately seal any envelope penetrations along the way.

2 ROADMAP: IMPLEMENTATION PHASE

11 - Commissioning

Another step near the end of the construction stage is the commissioning of all newly installed equipment (i.e. mechanical / HVAC, solar PV, appliances, other) to ensure they are operating as designed. In an air tight house, this is an important step since HVAC systems that aren't operating properly (i.e. air balanced) can have an adverse affect on the health of the building's occupants. Ensuring that all equipment and appliances are operating efficiently is also key, since energy efficiency is a primary goal of a **DER** project.






12 - Final Energy Audit

Once construction is fully complete, it is strongly recommended that a final energy audit is performed to verify the project has achieved the goals set with the client in the planning phase. Doing the post-construction energy audit is important and will provide metrics that show the building's energy efficiency improvement resulting from the **DER.**

This is also a requirement of many financial incentive programs that may have been used to finance the retrofit project.

2 ROADMAP: IMPLEMENTATION PHASE

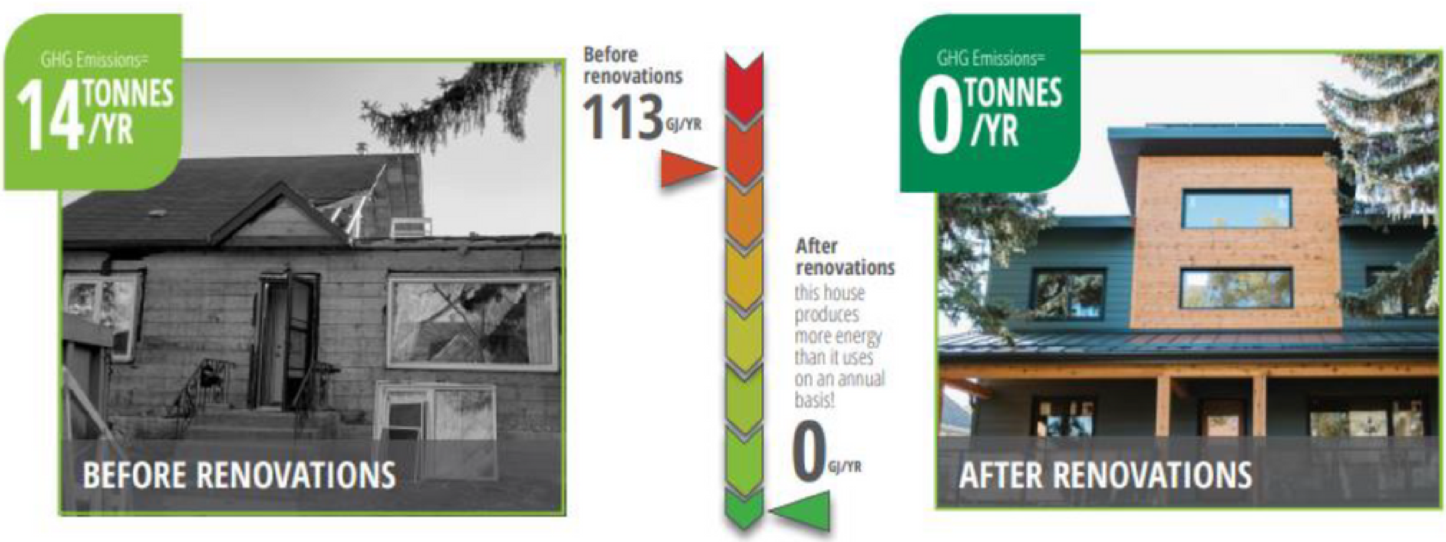
12 - Client Handoff

During the client handoff, a final walk through should be performed to identify any outstanding deficiencies.

Lastly, another factor in the success of a **DER** project is client education, especially as it relates to the newly installed equipment and appliances. The **DER** manager / builder should ensure that homeowners have been shown how to use all new equipment, and are provided with all necessary documentation (i.e. manuals) for ongoing operation and maintenance procedures.

If the **DER** is planned to be a rental, then it is important that the tenants are educated and also shown proper equipment operation and maintenance procedures.

12 - DER Complete



CHAPTER 3:
DER CASE STUDY

3 DER CASE STUDY

Project Profile / Case Study Submission
1955 single family bungalow with legal basement suite + heated studio in garage, retrofitted & electrified to NetZero readiness for 15.41 kW solar PV design. Primary upgrade is site framed exterior 8" Larsen wall with dense packed cellulose, and 2" mineral fibre to exterior of garage.

A	Building Profile			
	Address	Highwood, NW, Calgary, AB		
	Year Built	1955	**Type of building**	Single-Family (bungalow)
	Floor Area (m^2)	218.8	**Structure Type**	Wood-Framed
	Climate Zone	7a	**Foundation Type**	Concrete (Full Basement)
	Retrofit Phasing	Multi-Stage	**Retrofit Type**	Envelope and Mechanical

B	Project Goals	Comments	Priority
	Reduce Energy Consumption	Reduce to Net-zero ready	x
	Achieve Net-zero or Net-zero Ready	Achieve Net-zero ready	x
	Increase Thermal Comfort	Reduce chill in 400sf addition with crawlspace, add cooling in summer	x
	Improve Indoor Air Quality	Control radon without dedicated fan, replace gas range & fireplace for reduced CO2	x
	Reduce GHG Emissions	Electrification	x
	Repair and/or Renew Exterior	Renew exterior	
	Improve Home Value	Long term durability with increased curb appeal, and energy target resilience	
	Other Typical Renovation Goals	Make garage art studio more comfortable/efficient	

3 DER CASE STUDY

C	Stakeholder Profile			
	Builder	SNAP Building Inc.	**Energy Advisor**	Tyler Hermanson – 4 Elements Integrated Design Ltd.
	Project Manager / Retrofit Coach	Steve Norris (SNAP Building Inc.)	**Designer / Architect**	N/A
	Building Science Advisor	Cory MacDermott - Beacon High Performance Homes	**Mechanical Engineer**	N/A
	Funding Source (if applicable)	SSRIA	**Structural Engineer**	N/A

1	Retrofit Checklist		
	Retrofit Type	**Initial Assessment**	**Retrofit Improvement**
		Envelope	
	Airtightness - Penetration Sealing	Appliance venting, ceiling penetrations	Chimneys, fans, vents removed, ceiling penetrations sealed
	Wall Insulation	~R6 original walls, R20 in the addition	+ R30 (8" blown / dense packed cellulose)
	Ceiling Insulation	~R8 wood chip & fibreglass	R60 (17" blown / dense packed cellulose)
	Foundation Insulation	R12 interior walls, nothing on exterior	Crawlspace & perimeter insulated, 18" of exposed foundation above grade insulated with 4" XPS (R20)
	Window / Door Replacement	Windows: 7 original windows, 2 double glazed, 2 triple glazed Doors: 2 exterior doors	Windows: 7 originals replaced, 2 double glazed Doors: 2 exterior replaced
	Other	Crawlspace not air sealed	Crawlspace 90% air sealed, R8 added under heat run, 4" XPS added to exposed foundation, perimeter skirt re-insulated 4" XPS
2		**Mechanical and Electrical Systems**	
	Ventilation	Furnace / bath fan ventilation only	Panasonic 100CFM ERV
	Heating	Natural gas furnace	Air source heat pump (ASHP)
	Cooling	N/A	Air source heat pump (ASHP)
	Hot Water	Natural gas hot water tank	Air source heat pump with electric back-up hot water tank
	Electrical Service Amperage	100-amp	200-amp (local transformer had capacity - minimal upgrade charges)
	Renewables	N/A	Solar PV: 15.41 kW
	Other		

3 DER CASE STUDY

3	Energy Performance			
		Initial	**Goal / Actual**	**% Improvement**
	Annual Electricity Consumption (kWh/a)	7,500 kWh/a (27 GJ/a)	15,278 kWh/a (55 GJ/a)	N/A
	Annual Natural Gas Consumption (kWh/a) / (GJ/a)	34,444 kWh/a (124 GJ/a)	0 kWh/a (0 GJ)	100%
	Energy Use Intensity (kWh/m2/a)	192 kWh/m2/a (0.69 GJ/m2/a)		
	Annual Heating Demand (kWh/m2/a)	27,778 kWh/m2/a (100 GJ)	6,389 kWh/m2/a (23 GJ)	77%
	Annual Cooling Demand (kWh/m2/a)	0 kWh/m2/a (0 GJ)	833 kWh/m2/a (3 GJ)	N/A
	Air Leakage Rate (ACH50)	5.74	2	65%
	Other	No renewables	Solar PV: 15.41 kW	

4	Carbon Emissions			
		Initial	**Goal / Actual**	**% Improvement**
	Annual Operational Carbon Emissions from Electricity Consumption (KgCO2e/a)	6100 KgCO2e/a	0	100%
	Annual Operational Carbon Emissions from Natural Gas Consumption (KgCO2e/a)	6500 KgCO2e/a	0	100%
	Embodied Carbon in Retrofit Materials			
	Embodied Carbon in Retrofit Processes			

3 DER CASE STUDY

5 Lessons Learned

BUILDING ASSESSMENT
- Be realistic about amount of demolition required
- Include asbestos testing
- Identify potential additional scope that might be requested (ie. decks, lighting changes, landscaping, interior reno, etc.)

ENERGY MODELLING
- Doesn't account for accessory building loads, secondary suites, etc. that could prevent actually being "Net Zero"
- Multiple heat pumps - i.e. HWT, Dryer in mech room

OPTIMIZATION
- Was a bit "token" - many decisions were based on values and gut feeling vs. data

DESIGN
- Account for additional wall thickness - impacts windows near corners, deck ledgers, secondary suite staircases, side yard setbacks, driveway width, entry landings
- Consider improving window size, location, basement adds, etc.

BUDGETING
- Assess "hidden" labor costs
- Removing perimeter obstructions - bushes, decks, etc.
- Should assess potential scope creep issues (or opportunities!)

SCHEDULING
- Lead time for all supplies is critical
- Compile material ordering/delivery as much as possible
- Would be difficult in winter without tight scheduling
- ATCO/Enmax timelines

ATTIC/ROOF
- Assess potential HRV runs before removing bath fans
- Open up chimneys to assess time needed for removal
- How to seal/insulate wall/roof connection
- Electrical access will be limited

WALLS
- Do exploratory demo early to assess wall assembly
- Do asbestos testing early for any materials to be removed
- How much existing cladding will be removed...all?!
- Don't leave windows with large performance gap

FOUNDATION
- Hard surface obstructions that prevent insulation
- Is it worth insulating? What is finishing plan

HVAC
- Understand peak heating load early to right-size equipment
- Need to evaluate mechanical room(s) for new equipment including duct runs
- Very difficult to get ERV/HRV ventilation runs to bathrooms
- Homeowner education - difference of heat pump operation (lower setbacks, slower heat, control ice, defrost cycles, etc.)
- Consider heat pump runoff solutions
- Using existing ductwork can be challenging to get correct distribution and can be noisy depending on fan speed, duct configuration

PLUMBING
- Had to move sink drain/vent for ERV run to main bath
- ATCO - $1400 to completely remove, free to shut off/remove meter

ELECTRICAL
- Evaluate trench digging between garage/house
- Transformer capacity
- Where to run new power & solar lines
- Exterior boxes - extensions or rerouting?
- What should be addressed prior to:
- Attic insulation
- Wall insulation
- Soffit installs
- Replace wiring where appropriate
- In attic where deeper insulation hides runs
- Dedicated circuits - i.e. electric fireplace
- Make lighting/power changes at same time

INTERIOR FINISHING
- Account for miscellaneous drywall repairs, trim, paint

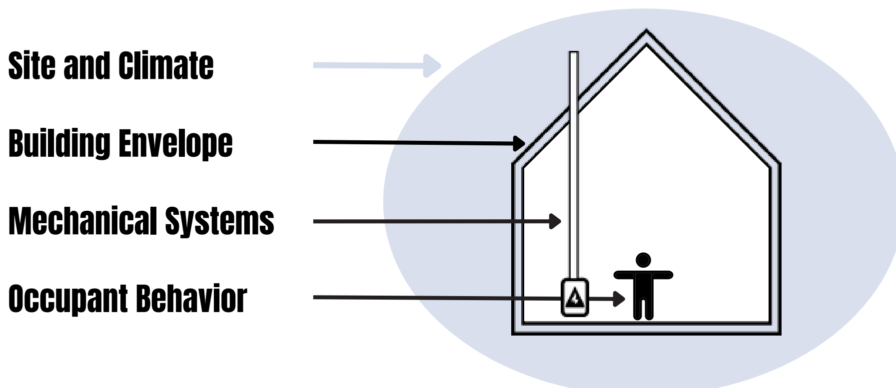
SOLAR
- Need to clarify kW vs kWh calculation
- Potential additional costs - bird screening, black clamps, etc.
- Carefully evaluate tree shading
- Future shading obstructions
- Panel size differences

CHAPTER 4: RESIDENTIAL ENERGY EFFICIENCY 101

4 HOUSE AS A SYSTEM

When beginning a **DER** project, treating the house as a "system" can help one understand how the building is influenced and interacts with the home's environment and occupants.

Building professionals must consider the interaction of several sub-systems within a house. For example, the airtightness of the envelope determines the degree to which air enters or exits through the structure. In addition, occupant habits and external weather conditions requires appropriate ventilation to prevent high moisture conditions. The following factors, amongst others, must be considered in the balanced design of a mechanical ventilation system:



Examples of How Retrofits Impact Other Building Systems

Benefit:
Air sealing makes a home less drafty and more comfortable, and helps reduce space conditioning costs.

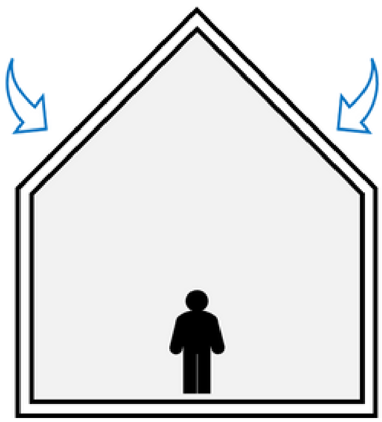
Consideration:
Improved airtightness can notably reduce the uncontrolled ventilation levels in a home (i.e., a leaky house), and can result in higher humidity levels and pressure imbalances. In severe cases, back drafting of combustion appliances and organic growth can result in hazardous indoor air quality within the home if proper ventilation isn't taken care of after a home is made air tight.

Benefit:
Insulation improves thermal comfort, can reduce heating & cooling costs, while also reducing indoor condensation and subsequent deterioration.

Consideration:
Increasing insulation without making airtightness improvements can significantly lower the effectiveness of the insulation and potentially lead to condensation and organic growth within insulated envelopes and assemblies.

4 HOUSE AS A SYSTEM

Site and Climate



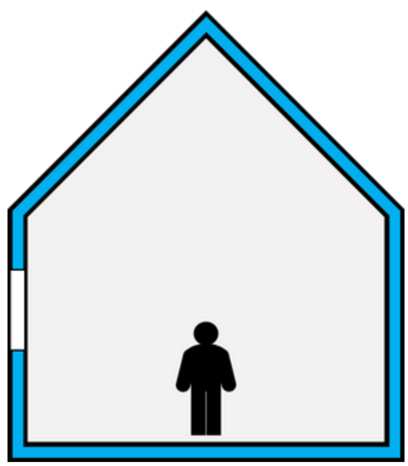
The primary purpose of a house is to separate and protect its occupants from the environmental elements, providing a centralized zone to 'house' their basic needs. The structures we build are vulnerable to all environmental factors, such as temperature, rain, wind, hail, snow, animals, and ultraviolet light. Therefore, considering each element and decision when designing a new home, or completing a renovation or **DER**, can offer an advantage in creating the structure we plan to build.

Local and micro climate factors can create unique effects to a building due to factors like exposure, elevation, and adjacent landscape and structures. Across Canada, different geographic locations have different climate zones associated with their respective average annual heating (and cooling) requirements. These various zones determine thermal performance requirements within local building codes.

Building Envelope

This guide has referenced the term "building envelope" in previous sections. The building envelope (often referred to as the building enclosure) is the division between conditioned and unconditioned space. It is where most building science considerations take place and is a crucial system to ensure the proper temperature control, ventilation, and overall comfort of occupants. Ideally, it is resistant to air, water, heat, light, and external noise. In order of importance for durability, the building envelope consists of:

- a water control layer
- an air control layer
- a vapour control layer
- a thermal control layer.

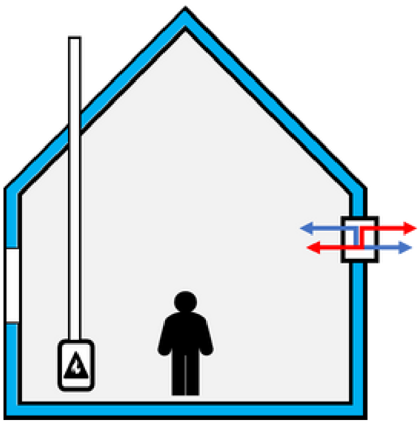


A well-constructed building envelope should avoid air leakage, vapour diffusion, and condensation, and ensure materials are compatible with each other.

Another aspect of the building envelope to consider is penetrations such as windows, doors, and utility connections. The constant fluctuations and transitions in the control layers presents challenges for potential gaps in protecting the building envelope and the overall success of the **DER** project.

4 HOUSE AS A SYSTEM

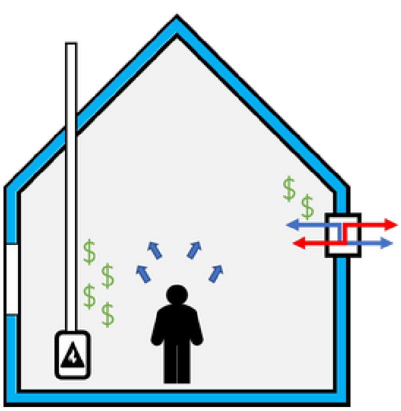
Mechanical Heating, Ventilation, and Air Conditioning (HVAC)



Mechanical systems, namely HVAC systems, are typically made for heating, cooling and controlling moisture. These systems are primarily responsible for conditioning the building's interior space and help to reduce the risk of moisture buildup, unhealthy indoor air quality, and uncomfortable living conditions. In addition, buildings rely on these components to move air through the home in a stable, even manner, traditionally seen as forced-air ventilation ducts in single-family homes.

These mechanical systems are a significant component of energy use in any residence, and directly correlates to the size of the home being conditioned. Therefore, it is essential to consider the load and efficiency of your mechanical systems relative to the airtightness and insulation levels of your envelope, as well as occupant behaviour.

Occupant Behavior



How an individual or family lives and interacts within a home notably impacts its performance. Impacts on system performance include temperature preferences, desired humidity levels, increased moisture in the air from cooking, bathing and breathing, use of appliances and electronic devices, and general wear and tear.

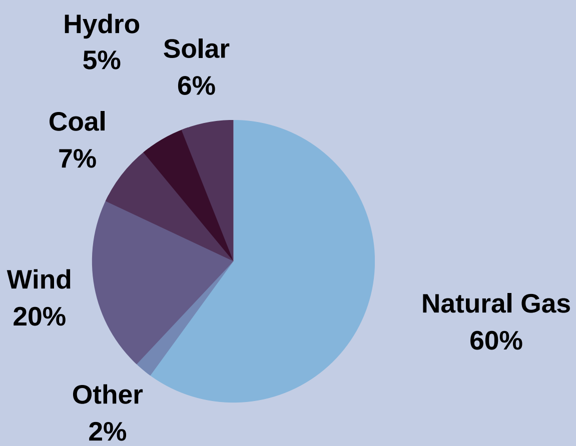
Accounting for occupant behaviour will help ensure occupant health and comfort, while maintaining the building's peak performance. However, this can be difficult, especially if the home's occupants change (i.e. the house was sold). This is where occupant education is important, whether it be current or new homeowners, so that information is conveyed and the occupants understand how to properly operate their home (i.e. the mechanical systems, appliances, etc.)

4 ENERGY LITERACY

Energy generation and transmission have been contentious topics in economic, political, and social circles due to the pollutant emissions (i.e., CO2) associated with different energy generation strategies. However, whether you are burning natural gas at home, or using electricity to power your lifestyle, most of the energy that is accessed from the utility grid in Alberta, as well as many other areas in Canada, currently relies on the burning of fossil fuels.

For this reason, there needs to be a high importance on using energy efficiently by reducing both consumption and reliance on heavy emissions generation sources.

Electrical Generation in Alberta



As of 2022, roughly 67% of electricity in Alberta is produced from fossil fuels – 60% from natural gas and 7% from coal.

Of note, in recent years, electricity generated by wind and solar has increased to 20% and 6%, respectively. The remaining 7% is produced from hydro at 5%, and other sources (i.e. biomass) at 2%.

-AESO, Understanding Electricity in Alberta

Electricity from the grid - is generated at power plants and distributed across grid infrastructure such as powerlines and transformers. Electricity is measured in Kilowatt hours (kWh). One kWh is equivalent to 1,000 Watts being consumed for an entire hour. Therefore, when turned on, a 100-Watt light bulb uses 1 kWh every 10 hours. (ATCO Gas, Energy 101)

Natural gas - is produced at upstream facilities, distributed by pipe to residential districts, and also combusted on-site to generate energy to transport to our homes. Gas meters measure the volume of gas that flows, measured in cubic feet or meters, and quantify the amount of energy in Gigajoules (GJ). One GJ of natural gas could heat 6000 gallons of water, enough water for 150 bathtubs.
(ATCO Gas, Energy 101)

1 GJ = 277.8 kWh

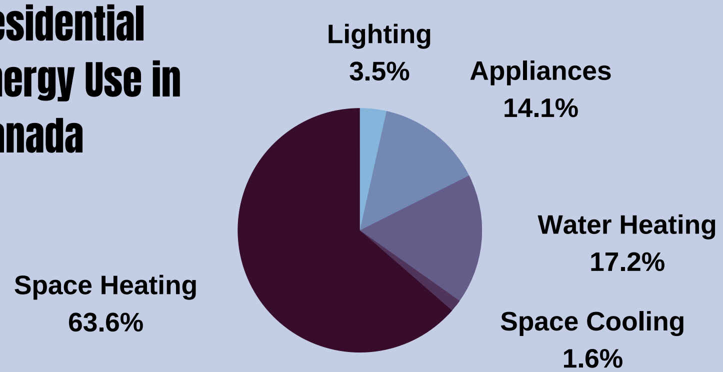
4 AT-HOME ENERGY USE

To access energy, Alberta utility providers charge consumers distribution and transmission fees, system maintenance fees, and a per-unit usage rate - kWh for electricity and GJ for gas.

The average home in Alberta uses 600 kWh of electricity and 10 GJ of natural gas every month (ATCO Gas, Energy 101). However, this differs from home to home and season to season. For example, Albertans use as low as 2 or 3 GJ of natural gas in the summer, but closer to 10 or 12 GJ a month in the winter due to increased home heating needs.

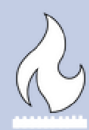
Space and water heating make up the vast majority of residential energy use within Canada. Traditionally, both systems run on fossil fuel, primarily natural gas, since burning fossil fuels emits thermal energy for use within the mechanical systems.

Residential Energy Use in Canada



-NRCAN, Energy Efficiency for Products

All appliances, lighting, TV's, computers, fans, air conditioning

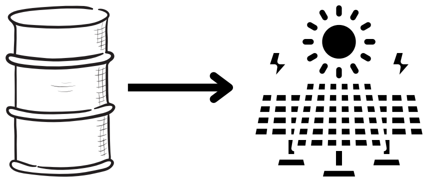


Space heating, water heating, cooking

Electrification of Homes (Fuel Switching)

As described earlier in the guide, electrification (also known as fuel switching), means eliminating fossil fuel consumption by only using electricity in a home. As the transitioning of household energy systems to full electrification becomes mainstream, essential appliances and mechanical HVAC systems will become more dependent on electricity (either produced on-site from renewables or from the electrical grid) than natural gas.

Electrification



4 AT-HOME ENERGY USE

Electrification of Homes (Fuel Switching) *continued...*

Older homes undergoing a **DER** that have a 60-amp service, will require, at the very least, an upgrade to the current requirement of a 100-amp service, 240-volt connection. If the current service in a **DER** project is 100-amp, the electrical service may need to be further upgraded to a 150-amp or 200-amp service, depending on the household electrical needs of the newly installed systems (i.e. mechanical: heat pump, ERV / HRV, hybrid heat pump hot water tank, etc.; appliances (i.e. electric / induction stove top); solar PV system; electric vehicle charger; etc.).

However, the installation of a larger household electrical service (i.e. 150-amp or 200-amp), which includes the removal of the existing electrical panel, installing a new electrical wire mast, new larger gauge wires, labour and electrical permit, comes with added costs. The cost of electrical service upgrade can range from approximately $7,000 in a simple overhead electrical line scenario to around $20,000 for a more complex underground electrical line scenario.

Furthermore, if many homes on a street all upgrade to a 200-amp, 240-volt electrical service, utility capacity may become a significant issue for electrification and the electrical grid may not be able to accommodate the additional peak load.

Therefore, to avoid additional costs to the **DER** project budget and to avoid costly upgrades to the electrical grid distribution infrastructure (which are passed on to homeowners in the form of "fixed utility connection fees"), a pathway for optimizing home electrification using a 100-amp, 240-volt service is needed.

This is where '**optimized electrification**' can play a role.

'Optimized electrification' refers to the electrification of a home while maintaining the existing 100-amp, 240-volt electrical service connection. Potential solutions to 'optimized electrification' include **Load Share Devices** and **Energy Management Systems**. For additional information on these solutions, reference the following: https://b2electrification.org/home-electrification-service-upgrade-not-required

4 BASIC ENERGY MANAGEMENT

Homes contain many devices and mechanical systems that operate consistently without user intervention. However, these devices have varying efficiencies, often decreasing as they age from the time of installation.

From the occupant's perspective, there are some things that you can do to consider greater efficiency in your home that don't require a **DER** or any professional involvement. However, a home's overall efficiency can see significant improvement by a **DER** that considers the house as a system and sets a high standard for energy efficiency and conservation.

Things to consider

Phantom Loads
Many electronics such as TVs, computers, microwaves, and coffee makers, among others, can consume small amounts of electricity even when turned off. These are known as phantom loads. Having controlled outlets, switches, or simply unplugging devices can help to minimize additional energy consumption from phantom loads.

Energy Star
Energy Star appliances consume less energy and should be an essential consideration when replacing old appliances such as fridges, freezers, clothes washers / dryers, dishwashers, and ovens / ranges.

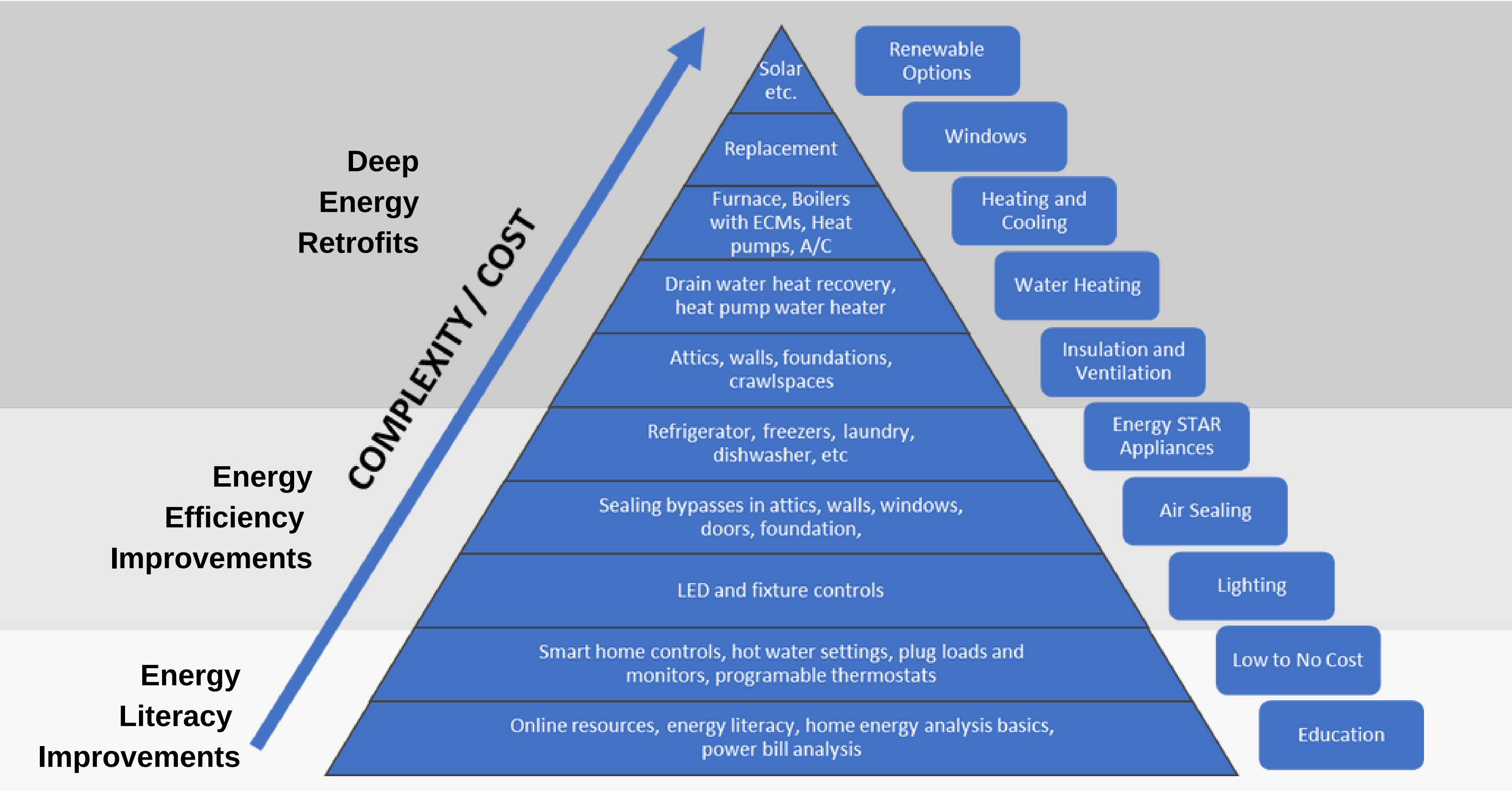
LED Light Fixtures
LED light bulbs consume up to 75 percent less energy than traditional incandescent bulbs. Implementing small changes such as replacing old light bulbs and turning off lights when not in use can make a noticeable difference in electrical consumption and monthly energy bills.

Shading Considerations
Using awnings or large overhangs can help mitigate the intensity of the sun's heat coming into the home and notably reduce the energy required to cool a home in the summer. Planting deciduous (leafy) trees on the home's south side (sunny side) can also help mitigate the amount of sunlight hitting the home throughout different times of the year. During summer, the leaves provide shade; and in winter, the bare branches let the warm sunlight through, passively heating the home.

4 ENERGY CONSERVATION

A typical reference in **DER** literature refers to the Pyramid of Conservation. The pyramid shows a progression in options in terms of complexity and affordability relative to the potential advancement from an inefficient building to a highly energy-efficient home. When planning strategies for energy conservation, the most effective use of time and money is to start at the base of the pyramid and work upwards. This mainly applies when the budget does not allow for an entire **DER.**

The Pyramid of Conservation (Residential Version)



-Minnesota Power

> **"The greenest unit of energy is the unit of energy that is never generated thanks to efficiency and conservation."**
>
> **- Amory Lovins, 1990**

APPENDIX

APPENDIX: TERMINOLOGY

Annual Energy Use: the total energy required to operate a home for an entire year. The metric is typically expressed in GJ / year or kWh / year, and includes energy used for all mechanical systems (i.e., HVAC, water heating), appliances, and lighting.

Annual Heating Demand: The total energy used to heat a home for an entire year. It is most often expressed in kWh / m² / year.

Building Envelope: The division between the conditioned and unconditioned space of a home or building.

Constructability: Ease of construction.

Digital Capture: Produce accurate measurements of the existing building using a digital device and software (Camera, Drone, Lasers, Sensors, Computers, etc.).

Electrification: The process of replacing technologies that use fossil fuels (coal, oil, and natural gas) with technologies that use electricity as a source of energy.

Embodied Carbon: Accounts for the total emissions used to source, manufacture and transport materials used to construct a building as well as the construction methods employed to erect the structure and the end-of-life demolition.

Energy Audit: Testing and analysis of a building's energy efficiency. Most commonly determined using a blower door test and energy modelling analysis.

Energy Efficiency: The rate at which energy is converted and captured from one form and / or use to another.

Energy Use Intensity / Rated Energy Intensity This metric takes the annual energy use and applies it to the total area of a home. It is expressed as GJ / m² / year or kWh / m² / year, and this shows efficiency over floor area of the home but tends to favor larger homes.

Geothermal: Relating to or produced by the internal heat of the earth.

High-Performance Home: Home that goes above and beyond minimum building standards, specifically in the areas of energy use, air quality and thermal comfort.

Integrated Project Team To be brought together. In terms of construction, bringing everyone involved in the project together.

Mitigation: Action of reducing the severity, seriousness, or painfulness of something.

Mechanical Load: Amount of stress a home's entire mechanical system causes to the grid or on-site energy-producing devices.

Net-zero: In terms of national carbon emissions, targeting net-zero means negating an equal amount of greenhouse gases to the amount produced by human activity. This is achieved by first reducing reliance on emissive activities to minimize new emissions and then implementing methods of absorbing carbon dioxide from the atmosphere.

Net-zero ready: “A home that is recognized by CHBA and NRCan’s EnerGuide Rating System to be a home that has a renewable energy system designed for it that will allow it to achieve Net Zero Home performance, but the renewable energy system is not yet installed."- CHBA.

Operational Emissions: Refers to all the energy used in managing and maintaining the function of a building. It can include heating, cooling, lighting, and any other power usage needed to run programs.

Panelized: A method of construction consisting of capturing the precise dimensions of a building to pre-fabricate airtight and well-insulated panels. As a result, these panels are delivered to the project site, then are later installed on the exterior of the building.

Peak Load: The maximum of electrical power demand. In Canada it usually occurs in the winter when everyone is running their heaters, but can also occur in the summer when using air conditioners.

APPENDIX: TERMINOLOGY *continued...*

Perm Rating: A standard measure of the water vapor permeability of a material. The higher the number, the more readily water vapor (in the gaseous state) can diffuse through the material.

Reference House: A comparative energy model of the same house built to the minimum requirements of the National Building Code, this represents a "typical home" and allows for comparison.

Retrofit: An act of adding a component or accessory to something that did not have it when manufactured.

Tenant: A person who occupies land or property rented from a landlord.

Thermal Bridge: An area or component of an object which has higher thermal conductivity than the surrounding materials, creating a path of least resistance for heat transfer.

Thermal Resistance: A heat property and a measurement of a temperature difference by which an object or material resists a heat flow. It is often expressed as the R-Value. It is the reciprocal of thermal conductance which is usually expressed as a U-Value.

Traditional Renovation: A renovation (or retrofit) that does not incorporate improved energy efficiency / net zero practices

Utility Capacity: The maximum output an electricity generator can physically produce, whether it is the grid or on-site energy producing devices.

Abbreviations

ACH: Air Changes per Hour
CHBA: Canadian Home Builders' Association
DER: Deep Energy Retrofit
EA: Energy Advisor
EIFS: Exterior Insulation and Finish Systems
EPS: Expanded Polystyrene Insulation
ERS: Energuide Rating System
ERV: Energy Recovery Ventilators (transfers heat and humidity)
GJ: Gigajoules
HRV: Heat Recovery Ventilator (transfers heat)
HVAC: Heating, Ventilation, and Air Conditioning
IPD: Integrated Project Delivery. Not to be mistaken with the construction term of IPD, which means Insulation / Poly / Drywall.
kWh: Kilowatt hours
NBC: National Building Code
NRCan: Natural Resources Canada
OHS: Occupational Health & Safety
PACE: Property Assessed Clean Energy
Pa: Pascales
PH: Passive House
PV: Photovoltaics
kWh: Kilowatt hours
NBC: National Building Code
NRCan: Natural Resources Canada
OHS: Occupational Health & Safety
PACE: Property Assessed Clean Energy
SEEFAR: Sustainable Energy Efficient Facility Asset Renewal
XPS: Extruded Polystyrene Insulation
WRB: Water Resistive Barrier

APPENDIX: RESOURCES

This guide has provided information for professionals and homeowners to use as a starting point when considering a residential **DER**. The following list includes additional resources that will help increase your knowledge of **DERs**.

Alberta Electric System Operator (AESO)
Understanding Electricity in Alberta
https://www.aeso.ca/aeso/understanding-electricity-in-alberta/

Alberta Municipalities
Clean Energy Improvement Program
https://ceip.abmunis.ca/

The American Institute of Architects
Integrated Project Delivery: A Guide
https://zdassets.aiacontracts.org/ctrzdweb02/zdpdfs/ipd_guide.pdf

ATCO
Energy 101
https://gas.atco.com/en-ca/products-services-rates/rates-billing-energy-savings-tips/energy-101.html#:~:text=The%20average%20home%20in%20Alberta,of%20natural%20gas%20every%20month

Building to Electrification Coalition
Home Electrification: Service Upgrade Not Required!
https://b2electrification.org/home-electrification-service-upgrade-not-required

Canadian Home Builders Association
Net Zero Homes
https://www.chba.ca/CHBA/BuyingNew/Net-Zero-Homes.aspx
Net Zero Renovations
https://www.chba.ca/CHBA/HousingCanada/Net_Zero_Energy_Program/NEW__Net_Zero_Renos/CHBA/Housing_in_Canada/Net_Zero_Energy_Program/Net_Zero_Renovations.aspx?hkey=b852ae22-f006-4b50-9ed6-7754cfbc6652
Renovators' Manual
https://www.chba.ca/CHBA/Publications/Renovators-Manual.aspx

City of Calgary
Residential Solar Calculator
https://www.calgary.ca/environment/programs/residential-solar-calculator.html

CHRON. Small Business
What Is a Cost-Plus Contract in Construction?
https://smallbusiness.chron.com/costplus-contract-construction-66735.html

c**ove.tool**
Energy Use and EUI
https://help.covetool.com/en/articles/2499676-energy-use-and-eui

APPENDIX: RESOURCES *continued...*

Green Building Advisor
Collection of Deep Energy Retrofit Articles
https://www.greenbuildingadvisor.com/collection/deep-energy-retrofits

London Energy Transformation Initiative (LETI)
Climate Emergency Retrofit Guide
https://www.leti.uk/retrofit

National Research Council of Canada
National Building Code of Canada 2020
https://nrc.canada.ca/en/certifications-evaluations-standards/codes-canada/codes-canada-publications/national-building-code-canada-2020

Natural Resources Canada
ENERGY STAR Certified Homes
https://natural-resources.canada.ca/energy-efficiency/energy-star-canada/energy-star-for-new-homes/energy-starr-certified-homes/5057
Canada Greener Homes Grant
https://natural-resources.canada.ca/energy-efficiency/homes/canada-greener-homes-initiative/canada-greener-homes-grant/canada-greener-homes-grant/23441

NORR
Understanding Operational and Embodied Carbon
https://norr.com/blog-series/our-journey-to-carbon-neutrality/understanding-operational-and-embodied-carbon/

OSLER
Integrated Project Delivery model in Canada: What you need to know
https://www.osler.com/en/resources/transactions/2018/integrated-project-delivery-model-in-canada-what-you-need-to-know

Passive House Canada
About Passive House
https://www.passivehousecanada.com/about-passive-house/
EnerPHit Certification
https://www.passivehousecanada.com/enerphit-certification/

Retrofit Canada
Case Studies
https://www.retrofitcanada.com/case-studies
Reasons to do a Deep Retrofit
https://www.retrofitcanada.com/news/top-5-reasons-to-do-a-deep-retrofit

U.S. Department of Energy - Energy Efficiency and Renewable Energy
Measure Guideline: Incorporating Thick Layers of Exterior Rigid Insulation on Walls
https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/incorporating-thick-layers-exterior-insulation.pdf

U.S. Department of Energy - Office of Scientific and Technical Information
A Path to Successful Energy Retrofits: Early Collaboration through Integrated Project Delivery Teams
https://www.osti.gov/servlets/purl/1169479

APPENDIX: REFERENCES

In order of appearance

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Canadian Home Builders' Association. (n.d.). How to Label Your CHBA Qualified Net Zero Homes. CHBA Net Zero Home Labelling Program. Retrieved June 1, 2023, from https://www.chba.ca/nzprogramrequirements

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The authors of this guide would like to thank the following partners for providing many of the photos used in the publication:
Retrofit Canada
4 Elements
SNAP Building
Solar Homes Inc.
CHBA

DER WORKSHEET P.1

Project Profile / Case Study Submission
Description:

A	Building Profile			
	Address			
	Year Built		Type of building	
	Floor Area (m^2)		Structure Type	
	Climate Zone		Foundation Type	
	Retrofit Phasing		Retrofit Type	

B	Project Goals	Comments	Priority
	Reduce Energy Consumption		
	Achieve Net-zero or Net-zero Ready		
	Increase Thermal Comfort		
	Improve Indoor Air Quality		
	Reduce GHG Emissions		
	Repair and/or Renew Exterior		
	Improve Home Value		
	Other Typical Renovation Goals		

C	Stakeholder Profile			
	Builder		Energy Advisor	
	Project Manager / Retrofit Coach		Designer / Architect	
	Building Science Advisor		Mechanical Engineer	
	Funding Source (if applicable)		Structural Engineer	

DER WORKSHEET P.2

Retrofit Checklist			
Retrofit Type		Initial Assessment	Retrofit Improvement
Envelope			
1	Airtightness - Penetration Sealing		
	Wall Insulation		
	Ceiling Insulation		
	Foundation Insulation		
	Window / Door Replacement		
	Other		

Mechanical and Electrical Systems			
2	Ventilation		
	Heating		
	Cooling		
	Hot Water		
	Electrical Service Amperage		
	Renewables		
	Other		

DER WORKSHEET P.3

3	Energy Performance			
		Initial	Goal / Actual	% Improvement
	Annual Electricity Consumption (kWh/a)			
	Annual Natural Gas Consumption (kWh/a) / (GJ/a)			
	Energy Use Intensity (kWh/m2/a)			
	Annual Heating Demand (kWh/m2/a)			
	Annual Cooling Demand (kWh/m2/a)			
	Air Leakage Rate (ACH50)			
	Other			

4	Carbon Emissions			
		Initial	Goal / Actual	% Improvement
	Annual Operational Carbon Emissions from Electricity Consumption (KgCO2e/a)			
	Annual Operational Carbon Emissions from Natural Gas Consumption (KgCO2e/a)			
	Embodied Carbon in Retrofit Materials			
	Embodied Carbon in Retrofit Processes			

5	Lessons Learned
	Describe any relevant issues and the associated lessons learned.