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ELECTRIFICATION OF HOMES WITHOUT AN ELECTRICAL SERVICE UPGRADE

PASSIVE HOUSE ALBERTA

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Project Abstract

Utilizing a grant provided by the Alberta Eco Trust in December 2021, Passive House Alberta initiated a multi-year project with a focus on 'Building Better/Retrofitting Wiser.' The project was designed to explore potential stepping stones to Mass Electrification and Deep Energy Retrofits (DER) on residential buildings in Alberta through the use of load devices and "smart" electrical panels.

Electrification has the potential to significantly reduce greenhouse gas emissions (GHG), as the electricity can be supplied from renewable, non-GHG emitting sources. When a home is electrified as part of a DER, all the systems (including space and water heating and cooking appliances) are switched from running on fossil (natural) gas to electricity.

Unfortunately, to allow the electrification of a home, the existing electrical service connection most often is increased from 100 amps to 200 amps to meet the increased need for peak electrical power. If one house on a city block goes from 100 to 200 amps, the increase can be absorbed within the existing electrical infrastructure. However, once many more buildings upgrade, the infrastructure must also be upgraded, as the utility must ensure the electrical grid can supply the total rated electrical power to each house. These infrastructure upgrade costs would be passed on to customers, making electrification more costly, and more GHG emissions would be produced due to the necessary manufacture and installation of any added infrastructure.

There are ways to help minimize or eliminate the need to increase the existing service. One is using Load Share Devices which connect two loads to one circuit breaker. For example, the electric range and supplementary electric resistance heat for a heat pump could connect into a load share device, allowing homeowners to use either piece of equipment at any time (but not both at once). As this method prevents two major loads from operating at once, it cuts their combined power infrastructure requirement in/up to half.

A second way to control the peak electrical load from a building is by using a "Smart Electric Panel". This allows homeowners to control and monitor each individual circuit on the panel, and, via software the total peak load can be set or limited to 100amps by prioritizing the circuit loads.

The final option explored was how to install a large renewable energy system, such as a Solar Photovoltaic (PV) system without requiring a service upgrade. Splitter type devices and panelboards with larger busbars were found to accomplish this cost effectively.

This project explored the use of these devices to optimize electrification and minimize potential infrastructure improvement costs on a small number of Calgary homes. The goal was to maintain the original 100-amp electrical service using off-the-shelf Load Share Devices, "Smart" Electric Panels, and Splitters as alternatives to increasing the size of the homes electrical service.

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About Building Electrification

Full Building Electrification is when a building is disconnected from the fossil fuel (methane gas / natural gas or propane) distribution network and all building systems are switched over to run on electricity. Individual appliances can also be electrified, but this report will deal only with full electrification. The main goal of electrification is the potential reduction of greenhouse gas emissions (GHG) from operating the building. These GHG savings will occur faster in areas with low-carbon electricity generation and slowly over time as all of Canada's grid eventually decarbonizes. In colder climates, like most of Canada, building envelope improvements are strongly recommended prior to electrification. Although the processes noted below apply to both new construction and renovations, renovations are the focus of this report.

Optimized Electrification and Costs

Optimized Electrification refers to the electrification of a building while maintaining the existing electrical service connection. At a residential building scale, Optimized Electrification means maintaining the existing (most often 100-ampere, 240-volt (24 kW)) electrical connection. This is important because if too many buildings on a street all upgrade to a 200-ampere, 240-volt electrical connections, the electrical distribution network on that street may not be able to accommodate the additional peak demand, even after factoring in accompanying building envelope upgrades. To avoid the need for costly upgrades to the electrical distribution network infrastructure, which are passed on to all homeowners in the form of "fixed electrical-utility connection fees," a pathway for Optimized Electrification using a 100-ampere, 240-volt connection is needed.

In addition to affecting electrical infrastructure costs that are shared by all homeowners, there are also direct costs for a homeowner to install a larger electrical service to their home. If the home is fed by overhead electrical lines and the closest electrical transformer has available spare capacity, the cost from the utility can be very low or free. The cost to supply and install a new 200-ampere electrical panelboard and remove the existing 100-ampere electrical panelboard is around $4,000- $7,000 and includes a new electrical wire mast, new larger wires, labour, and electrical permit. If the electrical lines are fed underground and the transformer is far away or at capacity, the utility upgrade costs can increase to $30,000 or more.[1]

Overall, electrification and the options for Optimized Electrification that will be explained in this report are some of the most cost-effective options currently available for both the homeowners and society in general.[2]

This report utilizes the work of Redwood Energy in California and their Watt Diet Calculator[3]

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[1] Shoshana Pena et al., "Service Upgrades for Electrification Retrofits Study Final Report," *NV5.com,* May 22, 2022.

[2] Lacey Tan, Mohammad Hassan Fathollahzadeh & Edie Taylor., "The Economics of Electrifying Buildings: Residential New Construction," *RMI.org,* 2022.

[3] Watt Diet Calculator, *Redwood Energy,* 2022.

Watt Diet

The Watt Diet is a process that assists in reducing the peak electricity that a home or building draws from the grid. The peak electrical draw is calculated following the current Canadian Electric code. An Electrical Engineer or Certified Electrician should perform the calculation.

Appliance Swapping

Appliance swapping is often the first step of the Watt Diet and building electrification, where large electrical draw appliances are replaced with lower-consuming models, or gas appliances are converted into electric units.

The electric resistance dryer can be a simple first swap, replaced with a condensing dryer, a heat pump dryer, or an all-in-one washer and condensing dryer. Doing so may reduce the annual electrical consumption by up to 50%, depending on the model selected.

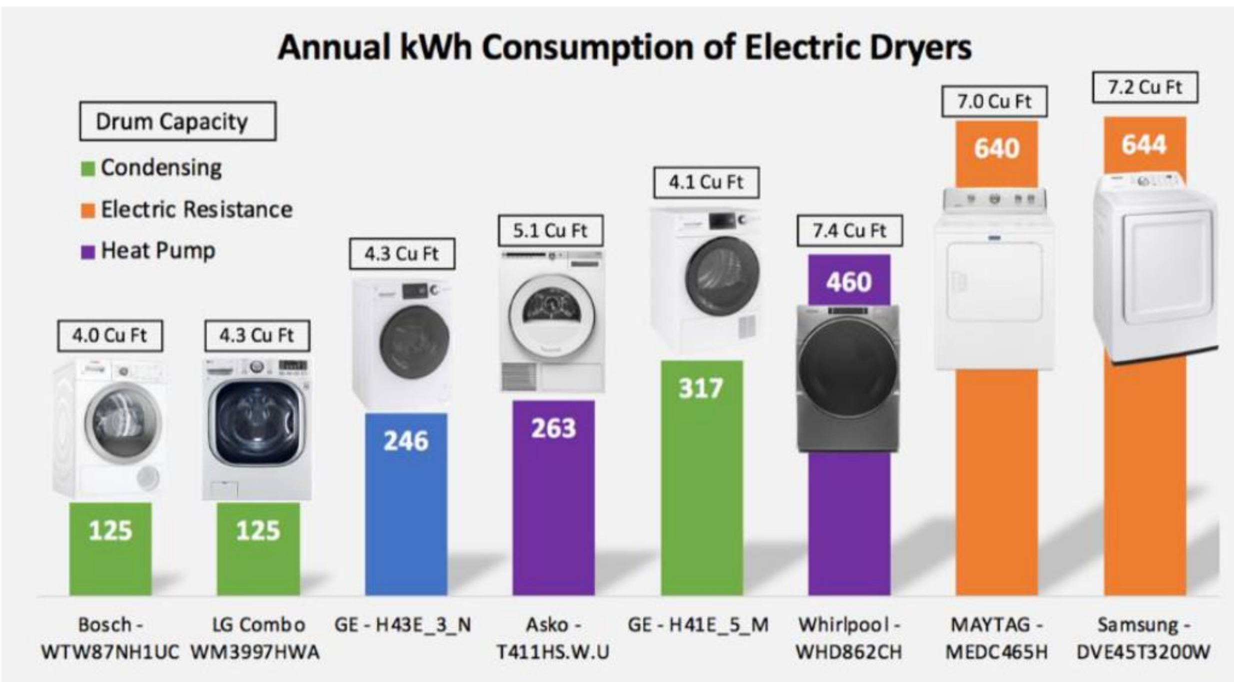


Photo: Comparison of Electric Dryer Annual kWh Consumption, courtesy of Redwood Energy: [RedwoodEnergy - A Pocket Guide to All Electric Retrofits of Single Family Homes]

Specific to electrification without a service upgrade, condensing and heat pump dryers that only need a 15-ampere, 120-volt electrical connection are preferred to those with a more typical 30-ampere, 240-volt connection as the savings on the peak load are substantial.

Most homes with a gas range will still have a plug for an electric range. The key when electrifying a gas range is to select an electric range, and not a separate electric cooktop and electric wall oven. The reason for this is due to an electric range requiring only one 40-ampere, 240-volt plug; an electric cooktop and wall oven each require dedicated 40-ampere, 240-volt plugs.

The electric range has built-in controls such that the cooktop and oven elements cannot both draw full power at the same time. Furthermore, induction cooktops are more efficient, safer, and produce less harmful gases and particulates during cooking than electric resistance or gas models. Induction cooktops are also less prone to burning food as the cooking surface remains cool.

Additional Loads

When a building is electrified, several new electrical loads are added to the electrical panelboard and will need to be accounted for and addressed to enable Optimized Electrification. These additional loads typically include:

- **Space Heating**: Increasingly, heat pumps are being used for space heating and space cooling and they can be either an air source or ground source type.

  With current cold climate Air Source Heat Pumps (ccASHP) technology, in most Canadian climates a supplementary space heat source is needed below -25°C as the unit can no longer meet the required heat load. Depending on the equipment, the ccASHP and supplementary heat source may be on a different circuit or the same circuit. The advantage of them being on the same circuit is that only the larger of the ccASHP and supplementary electric resistance heat source loads need to be accounted for in calculating the capacity of the electrical service to the house. If they are on separate circuits, then both need to be accounted for in calculating the capacity of the service. The advantage of separate circuits is that load sharing of the supplementary heat load is possible. These loads are often in the 5-9 kW range, depending on the size of the house and the building envelope upgrades performed.

  The next generation of ccASHP becoming available are predicted to perform at -30°C and at that time supplementary heat may not be required in many regions of Canada.

  As ground source heat pumps use the stable temperature of the ground, they most often do not require supplementary heat.

- **Domestic Hot Water Heating**: The use of heat pumps for Domestic Hot Water (DHW) heating is also increasing. Either a split-type heat pump with an outdoor condenser unit and separate indoor storage tank, or a Hybrid Heat Pump Hot Water Tank (HPHWT) where all the equipment is located inside the building, can be used. In either case, the largest load needs to be accounted for. These loads are in the 3.6 kW to 7.2 kW range, but newer 120-volt, 15-ampere Hybrid HPHWT are coming to market with a 1.5 kW load. To reduce the effect on peak power consumption, consider purchasing a 15-ampere, 240-volt model over a 30-ampere, 240-volt model.

- **EV Charging**: At-home electric vehicle (EV) charging is an increasingly desired option for homeowners and several options and sizes are available. Loads for EV chargers can vary from 1.5 kW for a level 1 charger up to 9.6 kW for a level 2 charger.

- **ERV or HRV**: To help ensure excellent indoor air quality, an Energy Recovery Ventilator (ERV) or Heat Recovery Ventilator (HRV) should be installed if one is not already present. The load of these devices is generally under 15 ampere and 120 volts or 1.8 kW.

Load-Share Devices

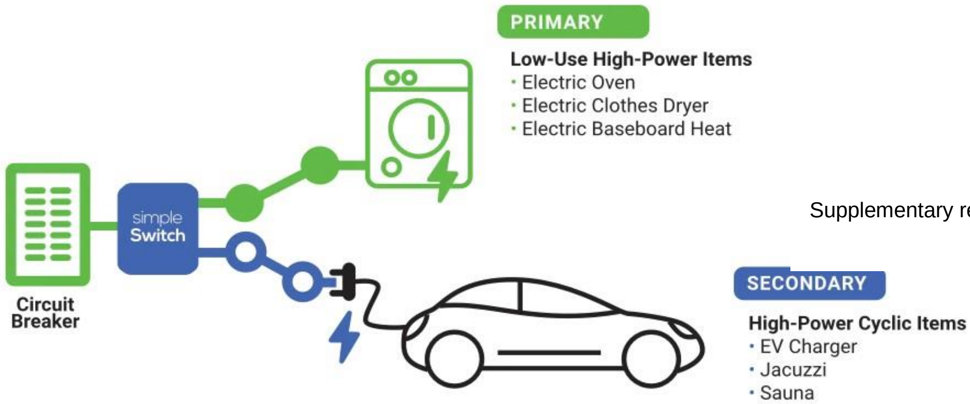
To add the large loads discussed above to an existing 100-ampere, 240-volt electrical panelboard, one must calculate the effect that these loads have on the site's service capacity according to the Canadian Electrical Code Rule 8-200. The code only considers circuit demands that are greater than 1500 W and not all larger “new” loads are counted 100%. Rules 8-106 and 8-500 also exempt EV charger loads from having to be counted if a load share device or energy management system is used to control the electric vehicle charger.

Depending on the existing panelboard loads and the energy-efficiency building envelope upgrades that have been performed to lower the space heating and DHW demand, Load Share Devices or Smart Electric panelboards may be needed.

A Load Share Device allows for additional electrical loads to be added to an electrical panelboard without going over the maximum capacity of the site's service (which includes the electrical panelboard, and the conductors feeding the site from the electricity distribution system). It does this by controlling and limiting the peak load that is drawn from the circuit so that the main circuit breaker is not tripped. Load Share Devices are available as units with a primary and secondary priority switch or as circuit-pause control devices, as described below:

Load-Share Devices with a Primary and Secondary Side

With these devices, the appliance plugged or connected to the primary side always has electricity. Any appliance plugged or connected to the secondary side only has electricity when the primary side is off. These devices work best when the primary and secondary side appliances have similar peak-demand ratings but different peak use times, however, additional breakers can be connected downstream of the Load-Share Device if appliances of different peak-demand ratings are connected. A Load Share Device that always provides a small amount of power (100 watts) to both appliances are advantageous as internal clocks or displays won’t need resetting when the electricity is switched off. Confirm with the device manufacturer whether their product provides this option.



Supplementary resistance heater

Photo: Example of a Load Share Device with Primary and Secondary connection from Simple Switch[4]

Examples of this type of Load Share Device available in Canada include:

- **AC Dandy Load Miser**: D-LM — AC Dandy Products Ltd. The Load Miser has hard-wired connections to connect a primary and secondary appliance to one existing circuit breaker, is made in Alberta, and costs approximately $810 +GST depending on the peak-demand rating of the unit. Many larger electrical supply stores carry this product.

- **NeoCharge Smart Splitter**: The NeoCharge is plugged into an existing high-demand outlet, and then the primary and secondary appliances are plugged into it. The advantage is that an electrician may not be required IF the plug sizes all match, and the appliance cords reach the existing high-demand outlet. It is important to order the correct electrical plug type. This device is made in the USA and can be purchased directly from the manufacturer for $500 to $600 USD + shipping and duty or from Sun Country Highways for $999 CAD + GST (NeoCharge Smart Splitter)

  Contact: Chiel Borenstein, Head of Partnerships
  Email: chiel@neocharge.io
  Cell: 602-317-9366
  NeoCharge

[4] Energy Load Management Simplified, *simpleSwitch Canada*, 2023.

- **LoadShare Technologies Inc DIVVEE**: The DIVVEE (loadsharingtechnologies.com) has a hard-wired primary and secondary connection to an existing circuit breaker, is made in British Columbia, has a local representative in Alberta, and costs $930 + GST.

  Contact: Derek Ginnell, Principal
  Email: dginnell@amagency.com
  Cell: 587-335-1766
  LoadShare Technologies Inc.

- **Simple Switch**: The 240 (simple-switch.ca) has a hard-wired primary and secondary connection to an existing circuit breaker, is made in Seattle, has a local distributor in Alberta, and costs $900 + GST.

  Contact: Patrick Kitt
  Email: patrick@simple-switch.ca
  Phone: 825-777-7577
  Cell: 780-707-9777
  Simple Switch Canada Ltd.

Circuit Pauser, Load Share Devices

These devices power a connected appliance while monitoring the demand on the main electrical service. If the demand goes over a certain threshold (generally 80% of rated capacity) the load share device will pause the power to the connected appliance until the main electrical service demand drops below the threshold for a set amount of time (generally 15 minutes).

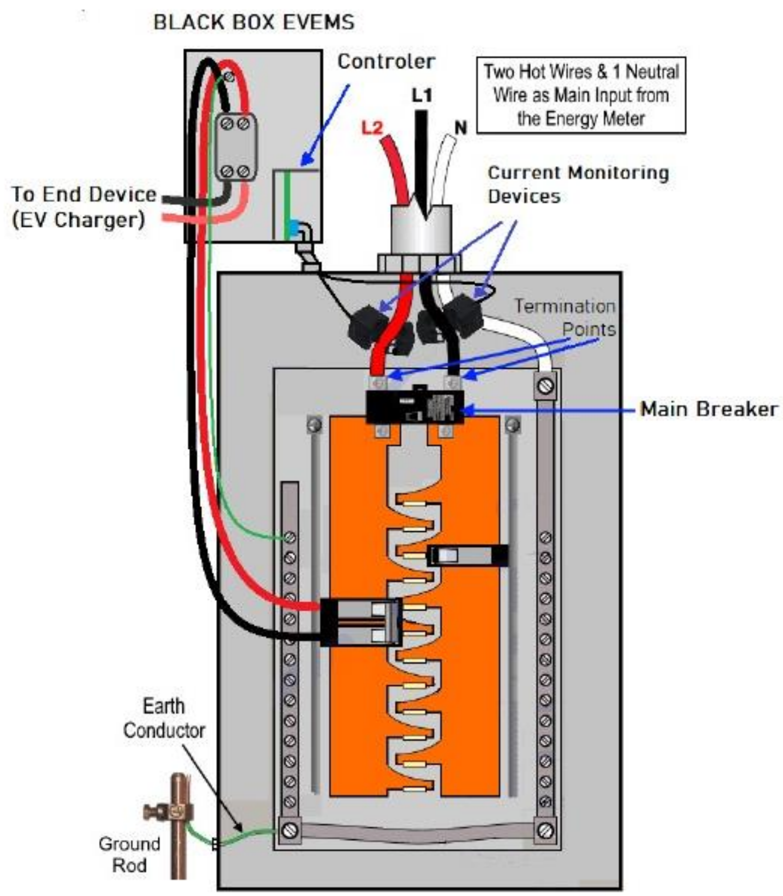


Photo: Example of a Circuit Pauser from Blackbox [(blackbox-in.com)](blackbox-in.com)

Examples of this type of device available in Canada include:

- **DCC Electric**: DCC-10 (dccelectric.com). The DCC Electric line of energy management products allows for the hard-wired connection of a high-load device (often an EV Charger) to an existing electrical panelboard, and only activates the new load when the main electrical connection is below 80% for 15 minutes. The DCC-10 costs approximately $1,250 and has a circuit breaker built into the unit, while the DCC-12 is approximately $945 and uses a power relay.

  The DCC-9 is a larger capacity unit intended for multifamily buildings and can connect to a larger main electrical feed. It also energizes the connected circuit if the draw on the panelboard is less than 80% for 15 minutes. If connecting several smaller level 1 EV chargers or other loads is desired, you could connect them to a sub-panelboard so each is protected by a breaker and then connect the sub-panelboard to the DCC-9, which would energize the sub-panelboard when capacity is available. DCC-9 EVEMS for Electric Vehicle Charging in Condos and Apartments (dccelectric.com)

- **The Blackbox Energy Manager**: The Blackbox Circuit Pauser (EVEMS - Electric Vehicle Energy Management Systems – Black Box Innovations (blackbox-in.com)) costs approximately $845, depending on the demand capacity. It monitors the total panelboard demand; when the main electrical connection is below 80% it activates the connected load.

- **Simple Switch**: The 240M (simple-switch.ca) is a Circuit Pauser, made in Seattle, has a local distributor in Alberta, and costs approximately $1,077 + GST.

  Contact: Patrick Kitt
  Email: patrick@simple-switch.ca
  Phone: 825-777-7577
  Cell: 780-707-9777
  Simple Switch Canada Ltd.

Single Line Diagrams for both types of Load Share Devices are included in Appendix A.

Smart Electrical Panelboards

If more than a single appliance or load needs to be connected, or if more control, monitoring and circuit-by-circuit billing is needed, then a Smart Electrical Panelboard may be a more appropriate solution than a Load Share Device.

Full electrical panel board replacement examples include:

- **Koben Genius Energy Hub**: GENIUS - KOBEN (kobensystems.com). Designed and made in Canada, this load center can control up to 24 circuits and up to 400 amperes. It provides utility-grade billing plus circuit-by-circuit control, monitoring and prioritizing. The cost is between $4,500 and $6,000 depending on size and quantity, plus delivery and programing. This load center integrates well with EV chargers, batteries, and other renewable energy equipment. There is an annual software connection fee for online access and continual monitoring of all the connected circuits. It does not have a main disconnect breaker so a separate one would have to be installed to meet code requirements.

  Contact: Vic Burconak, CEO & President
  Email: vic@kobensystems.com
  Phone: 416-479-7728 ext:101
  Koben Systems

- **Span Smart Electric Panelboard: SPAN® Home. Designed in the USA, with no Canadian** availability (at the time of writing). This panel provides circuit-by-circuit control, monitoring and prioritizing of loads as the main breaker load (100 amperes) is approached. Pricing is around $5,000 USD.

Smart Electrical Panelboard add-on to an existing electrical panelboard:

- **Lumin Smart Panelboard**: Lumin - home energy monitor. The Lumin Smart Panelboard is an add-on Smart Electrical Panelboard that can monitor, control, and prioritize up to twelve 120-volt circuits or six 240-volt circuits. Having received its Canadian certification recently, this device has limited **Canadian** distributors at the time of writing. The Lumin Smart Panelboard costs $2,500 USD. It must be connected to a standard electrical panelboard as it has no built-in circuit breakers. However, for the circuits it controls and monitors, it acts the same as a full-size smart panelboard.

  Contact: Phil Roth, Channel Sales Specialist, Solar + Storage
  Email: phil.roth@luminsmart.com
  Cell: 304-360-1323

Adding Electricity Generating Systems

Many buildings add electricity generating systems as part of the process leading to total electrification and increased resilience. Many of these generating systems use the solar photovoltaic process. As they are electricity generation they do not affect peak electrical consumption calculations. However, higher capacity generating systems may overload the panelboard's busbar, as they can increase the amount of electric current flowing in the electrical panelboard. As such, the systems are limited by the panelboard's rated busbar capacity. The busbar is equivalent to the wires as it distributes the electricity to each circuit breaker within the panelboard.

The ratings of the breakers feeding the panelboard are permitted to be greater than the busbar's capacity by up to 25% per the Canadian Electrical Code (CSAC22.1-21) Subrule 64-112 c) and d). For a 100-ampere main breaker on a panelboard with a 100-ampere busbar, a 25-ampere circuit breaker is permitted for the electricity generating system. Electricity generating systems are always considered “continuous” so you may only use 80% of that breaker's capacity (CE Code Subrule 8-104 6), which is 20 amperes. Therefore, an electricity generating system that produces a maximum of 4.8 kW (25 A x 240 V x 80%) of electric power is the largest that can be added directly to a 100-ampere busbar electrical panelboard.

If a larger electricity generating system is desired, several options are available:

- For new construction or renovations, installing a 200-ampere, 240-volt panelboard with a 200-ampere busbar and cable from the meter to the panel board, yet only installing a 100-ampere main circuit breaker is a “future proof” option. The 200-ampere busbar would allow a large Renewable Energy system ((200A x 125%-100A) x 80% = 120-ampers to be connected, while the 100-ampere main breaker limits the electrical service size from the grid. Electrical panelboards are rated based on the size of their busbar, a smaller main breaker may always be installed.

  One would not likely be able to install the full 120-ampere 240-volt of solar PV on a single-family home and stay below the 100% microgeneration production limit, but the cost difference from a 125-ampere to a 200-ampere panelboard is minimal and the labour to swap them with the existing panelboard is the same.

- A 200-ampere panelboard option was costed out to upgrade a 60-ampere electrical service to a 100-ampere electrical service. It cost only $350 more for a 200-ampere option as compared to standard 100-ampere equipment, and labour charges were the same.

- The Koben Genius has a separate connection point for large renewable energy systems and a 400-ampere busbar, so it is also an option.

For renovations, to avoid an electrical service or panelboard upgrade, there are at least four cost-effective and code-compliant options to use a splitter type device to split the incoming power feed into multiple feeds. The splitter's terminals and busbar would be sized to accommodate the rated current of the generating system plus the panelboard. Disconnects are required by CE Code Subrule 6-310 to protect the splitter and the generating system. Splitter Options include:

Meter Base with Dual Lugs

Meter bases can be ordered with two sets of lugs that split the incoming utility connection into two connections; both connections would have to be protected by a disconnect. Some brands of meter equipment, mainly Eaton, have “dual lug kits” that can be installed in compatible single lug meter bases. The dual lug kits can cost as low as $30, and the dual lug meter bases can be under $400.

Photo: Dual Lug for meter socket from Eaton

Photo: Dual lug meter base from Microlectric® (gescan.com)

Splitter Box and Meter Disconnect

A basic splitter box is simply an electrical box with incoming connection points and lugs for multiple outgoing connection feeds. Each outgoing feed and the splitter box itself need to be protected by its own disconnect. Each piece of equipment only costs a few hundred dollars, but you are adding at least two disconnects, the splitter box, conduit, and cable, so the total cost can add up.

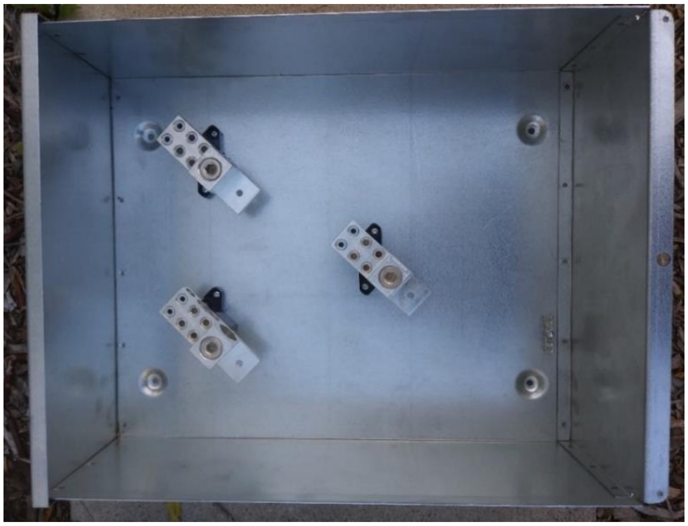


Photo: APS-400 400 ampere Splitter box with 3 connection points for incoming wires and additional lugs to split the service into multiple outgoing feed.

There are also custom splitter boxes that come with a disconnect breaker for the solar PV feed built into the splitter box. A disconnect would still be required before the splitter box.

Photo: Feed-Through, Splitter Box with Breaker from [(blackboxelectrical.com)](blackboxelectrical.com)

A BlackBox Splitter box was installed in a case study home in Edmonton: material cost was approximately $580 plus a few hours of labour. Each splitter box is semi-custom and comes in a 6” x 6” electrical box. This box was a bit small to be able to fit all 3 of the 100-ampere cables in, so if used again, a larger electrical box should be requested. For this situation, the most cost-effective way to add the disconnect before the splitter was to install a meter base with built-in disconnect for around $250 in equipment cost.

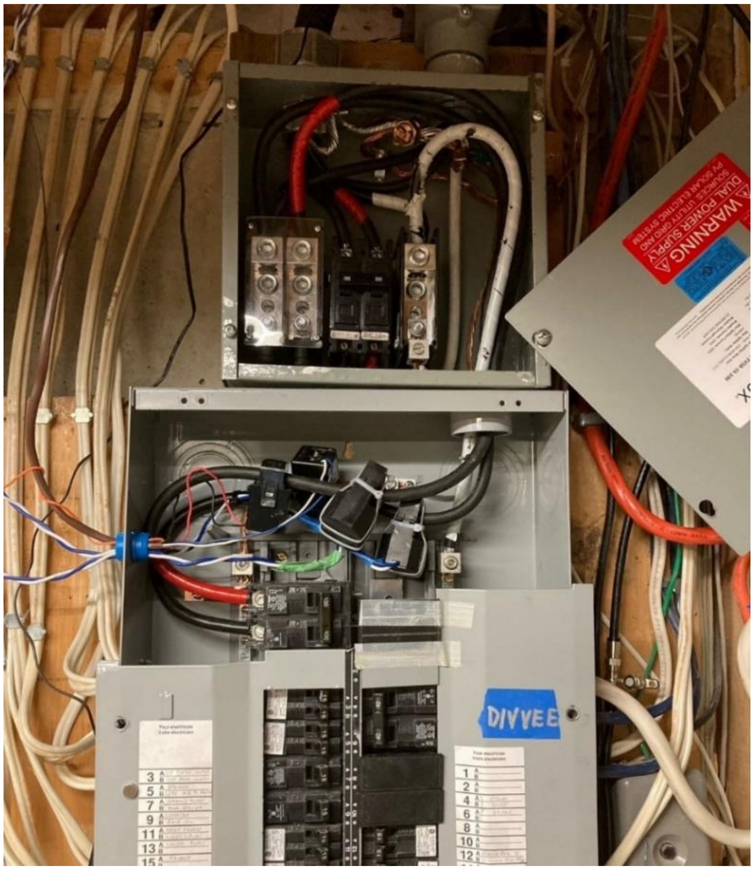


Photo: Blackbox Splitter Box with 100-ampere breaker for Solar PV system and electrical panel below. The feed from the meter with disconnect and the feed to Solar PV system both enter the splitter box from the top.

Meter base with integrated Disconnect and Splitter

Some meter bases can be purchased with an integrated Disconnect and Splitter all in the same electrical box. This can save material and labour costs, but equipment options are more limited, and costs are closer to $1000. These types of meter bases are sometimes called “farm service boxes” as that is one of their most common uses.

Photo: Microlectric C02M series meter sockets with splitter 200-a-120-240-v-co2-series.pdf (tnb.ca)

Combination Service Entrance Device

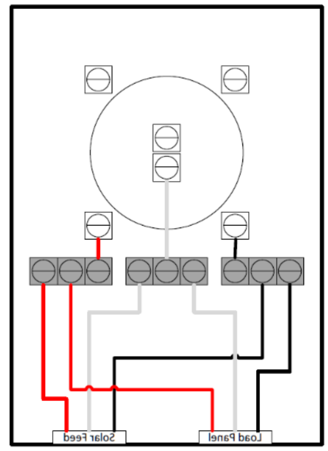
The final option explored was a Combination Service Entrance Device; these products have a meter base, a main disconnect with a branch circuit section, and feed through lugs downstream of the disconnect all combined into one electrical enclosure. The renewable energy generation connects directly to a branch circuit and the existing panelboard connects to the feed through lugs. Canadian availability may be limited, but prices may be under $750.

Photo: CSED from Square D Homeline 200-ampere 20-Space 40-Circuit Outdoor Ring-Type Overhead Service Surface Mount Main Breaker CSED Value Pack SO2040VP

The options listed above show that there are numerous ways that a large Renewable Energy System can be added without requiring a costly electrical service upgrade. For all situations, it is best to confirm which of the above options will be acceptable to local codes officials as acceptable or approved options have been found to vary from location to location. Equipment availability will also vary by location. Single Line Diagrams for the options are included in Appendix A.

Pre-Insulated Connector

A final splitter options would be the use of Pre-insulated Connectors such as those manufactured by Polaris which is part of NSI Industries. These connectors could be installed inside the existing meter base and function the same as a dual lug. The Polarise products are ULC rated and the Canadian Electrical Code clause 64-112 on Utility Interactive points of Connection (inverters) allows "the output of an interactive inverter to be connected to the line side of a service disconnecting means at a dual lug meter socket or other source(s)". The Pre-insulated Connectors would be a form of the "other sources" listed. Confirmation of acceptance of this option by utility providers and Authorities having Jurisdiction has not been confirmed at the time of writing this report.



Photos: Polaris Pre-Insulated 3 port Connector and schematic of the installation within an existing meter base. (Why Pre-Insulated Connectors are the Professional's Choice - NSI Industries)

Piloted Devices and Applications in Alberta

As part of the grant from Alberta Ecotrust, the following products were piloted:

1. An AC Dandy Load Miser (60-ampere, 240-Volt) was used to load share the electric Range (primary) with a supplementary electric resistance space heater (secondary). An electrical permit was issued by the City of Calgary for this use with no concerns raised.

2. A DCC-12 Energy Management System was used on two occasions and a BlackBox Energy Manager on another occasion to each add a 40-ampere, 240-volt EV charger to an existing electrical panelboard that was near capacity but had a circuit breaker free. Electrical permits were issued by the City of Calgary, the City of Edmonton, and the City of Airdrie with no concerns raised.

3. A Divee load share device was used with an electric range as the primary and a ccASHP as the secondary load. Electrical permits were issued and approved by the City of Edmonton for this use case.

4. A Koben Genuis smart electrical panel was installed in Calgary. Electrical permits were issued and approved for this use case.

5. A Blackbox Splitter box and Meter base with disconnect were installed in Edmonton to connect a large solar PV array while maintaining the 100-ampere service and panelboard. Electrical permits were issued and approved by the City of Edmonton for this use case.

6. A dual lug meter base and separate disconnect were used to connect a 6 kW solar PV system expansion. Electrical permits were issued and approved by the City of Calgary.

Device installation comments and feedback:

- An electrician should perform a panel capacity calculation, not all connected loads on the panel count as it is assumed not all will be on at the same time. The Electrical Service Load Calculator for Single Dwellings in Canada (blackboxelectrical.com)[5] can be used as an estimate.
- A certified electrician and an electrical permit are required.
- The load share installation cost varied from $400 to $700, depending on whether any additional electrical work or adjustments to the electrical panelboards were required.
- Most of the devices have a voltage transformer with strong electromagnets in them, so extra care needs to be taken during the installation to ensure no metal fragments are left in the devices, especially when the "knock outs" are removed from the electrical boxes. On one occasion a metal fragment was left in the device, and it made a humming sound until removed. Vacuuming (not blowing) out the devices is recommended by some suppliers after all connections are made to reduce the possibility of this occurring.
- The Blackbox splitter came in a 6" x 6" electrical box, which makes connecting the 100-ampere rated cables a tight fit. A larger electrical box should be requested. Cost was $580 with a 100-ampere circuit breaker for the solar PV system. Installation was an hour or two but did require a shutdown of power to the building.
- The Genius is very adaptable to various system needs. It is easy to integrate multiple power sources such as solar, wind, battery storage, or generator input. The busbars are rated for 400-amperes. This device can be used in single or three phase power systems. In both cases the system has built in surge protection for the whole panel. The energy management system is good for managing bigger loads using a priority sequence and to understand visually which loads on your system are using the most power as all the circuits are monitored for consumption when on a dedicated circuit breaker.
- The Genius panel does not have a disconnect, which is required by code. This means between the load side of the electrical meter and the panel, a fused disconnect needs to be added. What was done for the grant project was bring the main service into a new 100-ampere panel first, which had a main disconnect that met CEC requirements. The Genius was then a sub-panel with all the home circuit breakers. This increased the cost of an already expensive piece of equipment.
- The limitation of the Genius is that it only accommodates 24 circuits with full monitoring and any 240-volt load takes two circuit spaces. The Genius panel currently only takes Square D Type QO circuit breakers, which do not have "space saver" 240-volt circuit breakers. There are 120-volt space saver circuit breakers but then two circuits are monitored as one. Lastly, no manufacturer currently makes a "space saver" arc fault protection circuit breaker, so in new construction where many circuits need arc fault protection, one may run out of circuits quickly. Arc faults are not currently needed in panel upgrade/retrofit situations.

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[5] Electrical Service Load Calculator for Single Dwellings in Canada, Blackbox *Electrical*, 2022.

Electrification Process of Pilot Homes in Alberta

Several homes undertook the process of a Deep Energy Retrofit and Electrification, and they highlight how retaining the 100-ampere, 240-volt electrical service is possible.

Home 1: Single family home, built prior to 1970.

Existing Conditions:

- Typical single-family home with an existing 100-ampere panelboard that was previously upgraded from a 60-ampere panelboard.
- Fossil fuel / natural gas furnace, hot water tank, and clothes dryer.
- A 30-ampere, 240-volt electric dryer circuit was on the panelboard but not used.
- A 40-ampere, 240-volt electric range circuit.
- A 20-ampere, 120-volt electric clothes washer circuit.
- The 100-ampere electrical panelboard had circuit breaker space available.
- The house is connected to the electrical distribution network by an overhead line from the alley.

Electrical panelboard after electrification:

- The 30-ampere, 240-volt electric clothes dryer circuit was removed, and the breaker space was reallocated.
- The 15-ampere, 120-volt furnace circuit was reallocated to the ERV.
- A 2 ton Daiken ccASHP air handler system was added:
    - 20-ampere, 240-volt circuit for the outdoor condenser unit.
    - 30-ampere, 240-volt circuit for the interior air handler with a 5 kW integrated supplemental heater.
    - Internal controls were commissioned to not allow the compressor and supplemental heater to both turn on at the same time.
- 30-ampere, 240-Volt hybrid HPHWT was added as the 15-ampere, 240-volt model was not available.
- A 15-ampere, 120-volt circuit was added for an all-in-one washer and condensing dryer.
- A 20-ampere, 120-volt kitchen countertop circuit was added.

Impacts:

- Full electrification was targeted and was achievable after building envelope upgrades that reduced total energy consumption from 134 to 49 GJ/yr. were completed.
- The existing electrical panelboard and 100-ampere electrical service were retained.
- A load share device was not required as the ccASHP air handler and its supplementary resistance heater shared the same circuit and are controlled internally to the unit.
- A Large Solar PV system will be added to the roof, connected via one of the approved options listed above, to bring the home as close as possible to net zero on-site energy.

- A Circuit Pauser load share device can be used in the future if an EV charger is desired.

Home 2: Single family home with legal secondary suite.

Existing Conditions:

- The secondary suite is used as a home office and is currently not rented.
- There was an existing 100-ampere, 240-volt main panelboard that fed a 50-ampere, 240-volt sub panelboard.
- Meter was in an awkward location right next to the back door.
- Both existing electrical panelboards had limited spare circuit breaker space.
- There was a 30-ampere, 240-volt electric clothes dryer circuit, two 20-ampere, 120-volt kitchen counter plug circuits, and a 15-ampere, 120-volt ERV circuit.
- There were two 40-ampere, 240-volt electric range circuits; one in the main house and one in the secondary suite.
- The secondary suite range's circuit breaker was smaller than the rating on the range, so if the oven was used it could have tripped the breaker. Both range's circuit breakers were on the main electrical panelboard, located outside the secondary suite's space.
- The home uses a condensing on-demand fossil fuel / natural gas combination boiler for both space heating (via fan coils) and a tank for domestic hot water. The combination boiler is not near the end of its life.
- The house is connected to the electrical distribution network by an overhead line from the alley.

Electrical Panelboard and Electrification:

- Due to the limited spare breakers on the electrical panelboard, incorrect breaker sizing, non-ideal breaker locations, mechanical equipment with significant service life remaining, and a limited budget, full electrification was not targeted at this time.
- Maintaining the 100-ampere, 240-volt electrical service was also not possible if both electric ranges were retained.

Impacts:

- A new larger main electrical panelboard with a 200-ampere, 240-volt service feed was installed on the outside of the home in a more convenient location. It feeds the two existing panelboards as sub-panelboards. The electrical line provider did not charge to upsize the line to 200-amperes.
- A chase was installed below the new wall siding covered in new trim. This space will allow for future runs of electrical as needed for future solar PV or replacement of the combination boiler.
- A 80-ampere wire was run to a weather-tight box under the front deck to allow for future EV charging controlled by a circuit pauser.

- An energy monitoring system is being installed to monitor energy use; using its data, a plan for full electrification will be created for when the fossil fuel appliances reach their end of life.
- Energy modeling showed that removal of the 2nd range and replacement with a two-burner induction cooktop and oven that connects to the existing 20-ampere kitchen counter plug plus the installation of a condensing dryer would allow the home to run on a 100-ampere electrical service, however the free cost from the line provider for the electrical service upgraded provided value to the homeowner.

Home 3: Single family home with legal secondary suite and workshop in the detached garage.

Existing Conditions:

- The basement secondary suite is used as a rental suite.
- There was an existing 100-ampere, 240-volt main panelboard in the home with spare breaker space.
- A 30-ampere, 240-volt electric clothes dryer circuit, two 40-ampere, 240-volt electric range circuits and three 20-ampere, 120-volt kitchen plug circuits.
- The house was connected to the electrical distribution network by an overhead line from the alley.
- The garage/workshop had only a single 15-ampere circuit, fed from the house.

Electrical Panelboard after Electrification:

- Full electrification was targeted by the homeowner, and achievable after building envelope upgrades that reduced total energy consumption from 152 to 49GJ/yr. were completed.

- The overhead electrical service needed to be moved to accommodate the installation of 8-inches of exterior continuous insulation to the home, so it was relocated from the house to the garage to also remove the overhead wires. This allowed easy upgrading of the electrical circuit service to the garage/workshop, which will be used as an art studio.

Impacts:

- Due to the two electric range loads and future garage workshop loads, the existing 100-ampere, 240-volt service could not be maintained and was upgraded to a 200-ampere, 240-volt service.
- A 200-ampere panelboard with 225 busbar was added to the garage near the meter base.
- A 50-ampere, 240-volt plug was installed in the garage for future load sharing of an electric kiln and EV charger.
- A second 30-ampere, 240-volt circuit was added in the garage/workshop/art studio for an air source heat pump to heat the space. Supplementary heat was not added as the garage is not occupied all the time.
- The electrical service was trenched underground to the house.
- The existing house panelboard was upgraded to 150-ampere, 240-volt.

- A 30-ampere, 240-volt breaker was added for the hybrid heat pump hot water tank as a 15-ampere, 240-volt model could not be sourced.
- A 20-ampere, 240-volt circuit was added for the home's ccASHP outdoor condenser, plus a separate 60-ampere, 240-volt circuit for the air handler and supplementary electric resistance heater element. Both circuits are controlled by the ccASPH and the system was commissioned so that the supplemental heat and compressor cannot both turn on at the same time.

Photo: Daiken Multi-position Heat Pump Air handler indoor unit

Photo: Daiken ccASHP outdoor Unit

- An existing 15-ampere, 120-volt circuit was reallocated to the new ERV.
- The clothes washer was new enough to keep, but a new hybrid heat pump electric clothes dryer was installed. Unfortunately, the Whirlpool HybridCare™ Heat Pump Dryer model purchased has an electric resistance heater element (the hybrid portion) in the unit, so it still required the 30-ampere, 240-volt connection even though it uses much less power in heat pump mode. The unit was bought to test the heat pump dryer unit's performance and reliability. However, given the electrical requirements and the implications on electrification, they are not recommended if they have the electric resistance element in them and a higher electrical demand.

- An Emporia Vue Gen 2 Energy Monitoring system was installed to monitor the energy use; one on each of the garage and house panelboards.
- A roof mounted 15.41 kW solar PV system was installed on the home and garage roof to bring the home as close to net zero on-site energy as possible and connected at the bottom of the garage and home electrical panels. The 225-ampere busbar was sufficient with a 150-ampere main breaker.

Home 4: Recently built single family home.

Existing Conditions:

- Typical single-family home built recently in 2010.
- Existing electrical service and panelboard were rated at 125-amperes, but a 100-ampere main breaker was installed.
- Building envelope still had lots of service life remaining.
- Fossil fuel (natural gas) furnace and hot water tank, nearing the end of service life.
- A 30-ampere, 240-volt electric dryer circuit.
- A 40-ampere, 240-volt electric range circuit.
- A 40-ampere, 240-volt connection to the garage.
- A 60-ampere, 240-volt hot tub circuit.
- The electrical panelboard had some spare circuit breaker space available.
- The house is connected to the electrical distribution network by an underground line, the transformer is located adjacent to the lot.

Electrical Panelboard after Electrification:

- The 30-ampere, 240-volt electric dryer remained but they are looking into an all-in-one washer and condensing dryer.
- The hot tub was removed, and its circuit was reused for a ground source heat pump air handler, which replaced the furnace. The existing ductwork was reused.
- A High Efficiency Electric Hot Water tank was installed on a 20-ampere, 240-volt circuit; the ground source heat pump provides preheating of the water to the tank.
- A Circuit Pauser load-share device was used to control the 40-ampere, 240-volt garage circuit which had an EV charger added to it.

Photo: DCC Electric Circuit Pauser Installation

Impacts:

- Full electrification was targeted by the homeowner, and achieved through air sealing of the building via AERObarrier and the addition of a ground source heat pump that reduced total energy consumption from 143 GJ/yr. to 62 GJ/yr.
- The existing 100-ampere, 240-volt electrical service had to increase to 125-ampere as the electrical load calculation resulted in a peak load of 104-amperes.
- A 9.6 kW solar PV system was mounted to the roof and modeled to bring the home to net zero on-site energy. All the splitter and dual lug options were proposed to connect the solar PV system. However, the only option acceptable to the local code official at the time was to replace the existing 125-ampere, 240 panelboard (which had sufficient capacity to remain) with a new 200-ampere panelboard and a 125-ampere main breaker.
- An ERV was not installed, but the bath fans and air handler fan are now all controlled via a humidistat to ensure high indoor air quality was achieved and indoor relative humidity levels did not go above 35% when the outdoor temperature was below -25°C.
- Bath fans were upgraded to more powerful and quieter units.
- Indoor air monitoring has been installed.

Home 5: Single family home and workshop, built in 1979.

Existing Conditions:

- Typical single-family home with an existing 100-ampere, 240-volt panel board.
- Fossil fuel (natural gas) furnace and hot water tank. Original mechanical equipment, no upgrades have been done.
- A 30-ampere, 240-volt electric dryer circuit.
- A 40-ampere, 240-volt electric range circuit.
- Basement workshop has 3, 15-ampere, 120-volt circuits. Equipment is not all run at the same time.
- The main electrical panel had older breakers and was upgraded to a newer 100-ampere model.
- Electrical service is underground from the front of the lot.
- Cladding of the home was replaced in 2018 prior to the creation of the net zero on-site Energy and Electrifications plan.

Electrical panelboards after full electrification:

- new 100A subpanel was added next to the utility room with the following loads:
  - 30-ampere, 240-volt ccASHP outdoor condenser
  - 40-ampere, 240-volt ccASHP Air Hander with integrated supplementary resistance heat
  - 30-ampere, 240-volt for 2nd ccASHP outdoor condenser
  - 40-ampere, 240-volt for 2nd ccASHP Air Hander with integrated supplementary resistance heat
  - 30-ampere, 240-volt hybrid HPHWT, as the 15-amp 240-volt model was not available.
- Existing 15-ampere, 120-volt furnace circuit re-allocated to the HRV circuit.
- A 15-ampere, 120-volt condensing dryer was installed.

Impacts:

- Full electrification was achieved using two ccASHP, increased attic insulation, and slightly improved air tightness via caulking and sealing of gaps that reduced the total energy consumption from 156 GJ/yr. to 80 GJ/yr.
- The existing 100-ampere, 240-volt electrical service was successfully retained using two load share devices:

- A Circuit Pauser load share device was used to pause the electricity to the 2nd ccASHP circuits when the main panel breaker reached 80% capacity.

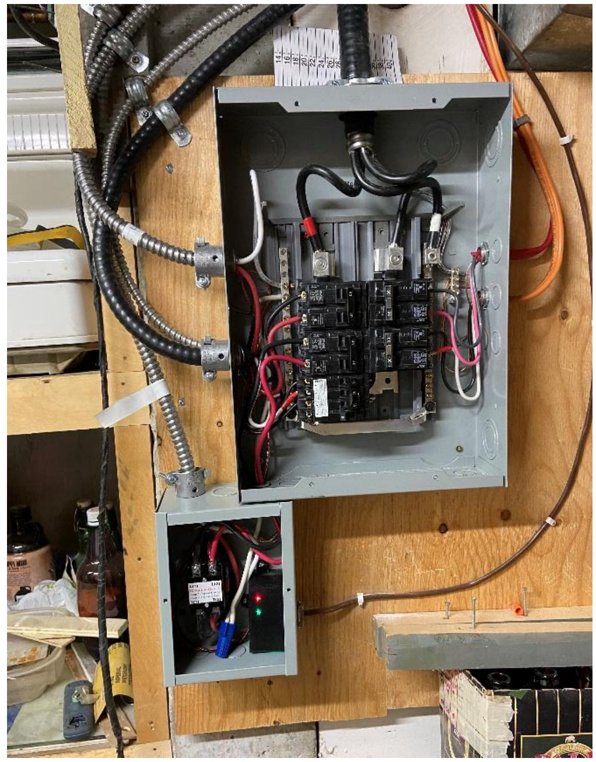

Photo: BlackBox Circuit Pauser installation

- A load share device was used to connect an EV charger as the secondary with the Range as the primary appliance.

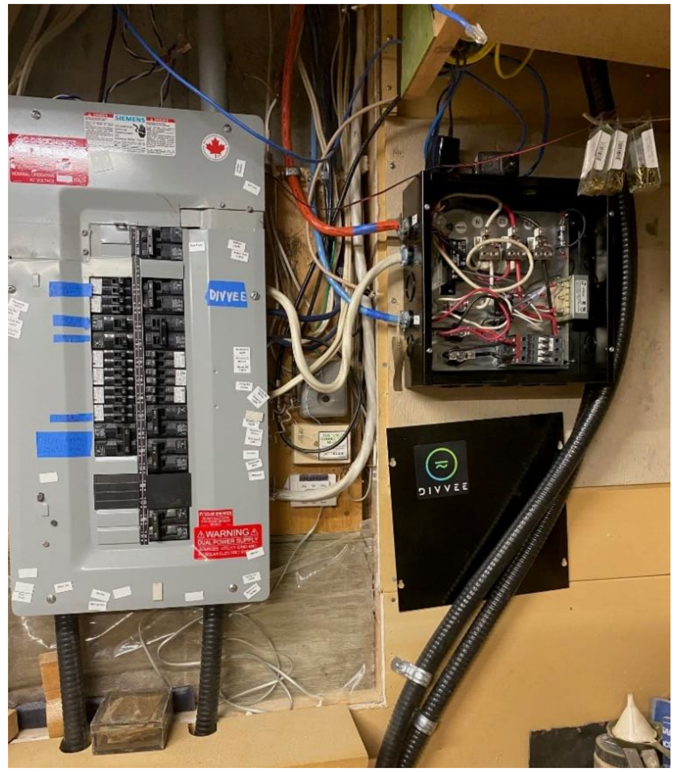

Photo: Divvee Load share device installed

- Two 8 kW ccASHPs were required to replace the existing furnace as building envelope improvements were not that extensive. The units act as load share devices as they internally control when the air handler and supplementary resistance heat turn on.

- A 21.1 kW roof mounted solar photovoltaic (PV) array was added using a splitter box with a 200-ampere busbar to bring the home close to net zero on-site energy. The splitter box was protected by replacing the existing meter base with a combinate meter base and disconnect.

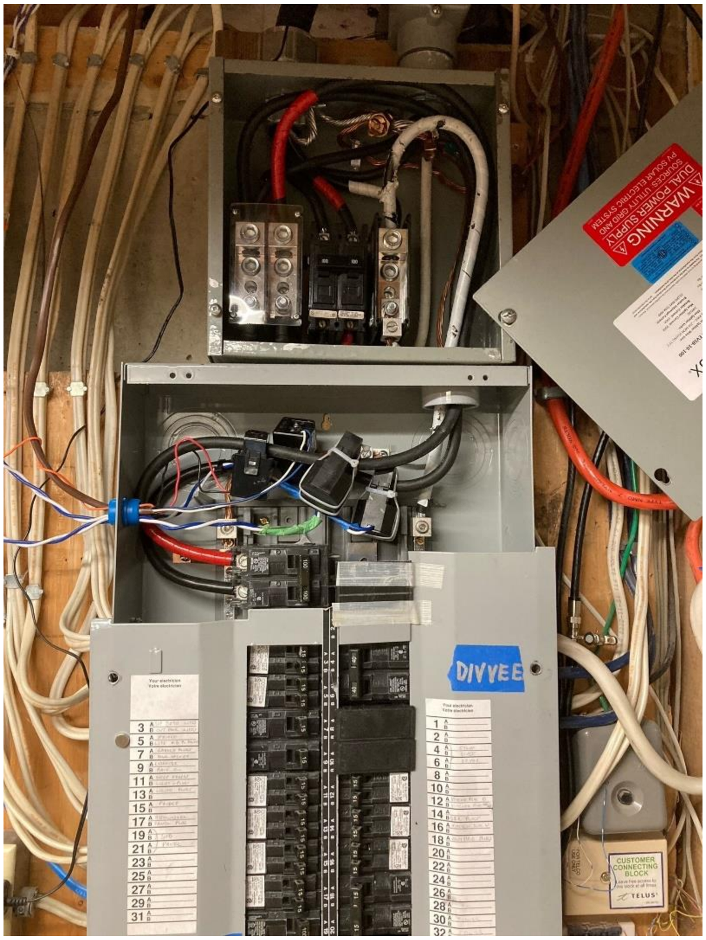

Photo: Black Box Splitter box installed above the main panel.

Home 6: Single Family Home built prior to 1970, Smart Electrical Panel.

Existing Conditions

- 1969 split level home with 2x4 walls, insulated to that era's requirements.
- Some original double pane windows and some newer double pane windows that were of moderate quality.
- The original 100-ampere panelboard was poorly located in a non-code compliant location above a toilet in a bathroom.
- The panelboard had several lightly loaded circuits but no spare breaker space.
- Natural gas furnace and hot water tank.
- A 30-ampere, 240-volt electric dryer circuit.
- A 40-ampere, 240-volt electric range circuit.
- A 20-ampere, 120-volt electric clothes washer circuit.

- The house is connected to the electrical distribution network by a buried line from the alley through a nicely landscaped backyard.

Electrical panelboard after electrification

- A Koben Genius Smart electrical panel was installed as a sub panel to a new 100-ampere main panel, and placed in an accessible and code compliant location as the Genius has no main breaker disconnect.
- Where possible, existing wires were run to the Genius, but if not, the original panel was modified to act as a junction box.

Photo: Koben Genius Smart panel installed as a sub panel

- A 2.5 ton Daiken ccASHP air handler system was added.
    - 50-ampere, 240-volt circuit for the interior air handler and with a 5 kW integrated supplemental heater.
    - 35-ampere, 240-volt circuit for the outdoor condenser unit.
    - Internal controls do not allow the outdoor condenser and supplemental heater to both turn on at the same time.
- 30-ampere, 240-volt hybrid HPHWT was added as the 15-ampere, 240-volt model was not available.
- The 15-ampere, 120-volt furnace circuit was reallocated to the ERV.
- 50-ampere, 240-volt EV charger circuit added.
- The Genius allows each of its 24 circuits to be monitored, controlled, and prioritized using a 1-high to 5-low scale. This ensures that when the total electrical consumption approaches the 100-ampere breaker size, circuits with a lower priority get turned off.
- The EV charger, dryer and HPWHT circuits were all marked low priority (5).

Impacts:

- Full electrification was targeted and was achievable as part of a Deep Energy Retrofit that reduced total energy consumption from 148 to 43 GJ/yr.
- The ASHP air handler and its supplementary resistance heater shared the same circuit and are controlled internally to the unit.
- In the future, a solar PV system will be added to the roof to bring the home as close as possible to net zero on-site energy. The Genius has a dedicated connection point for the solar PV and a 400-ampere bus bar.

KOBEN

GENIUS HOME
Technical Site Survey Report
Site Inspection

Panel Information

Panel ID/Name	Dan Henne + Lisa Listgarten 2211 Paliswood Pl SW, Calgary	Floor No	Basement			
Incoming Voltage, #phases & Amps	100 A	Specific Location	Electrical Room			
Alternative Source #phases, Amp Allowance per this Panel	None	Available space	Min Required L 33.86" (86 cm) W 21.65" (55 cm) D 9.53" (21.7 cm)		Load Control	Priority (1-5)

GENIUS Circuit Mapping (1 - High, 5 - Low)

CB Number	Circuit Name/Function	3 Pole C/B Amp rating	2 Pole C/B Amp Rating	1 Pole C/B Amp Rating	Control or Monitor-only	Assign Priority
1 (Tandem)	1a: Dishwasher			15	c	3
	1b: South kitchen counter-Left left upper outlet		15			
2 (Tandem)	2a: South Kitchen- right left and left left bottom, sink light				c	1
	2b: Microwave			15		
3 (Tandem)	3a: Fridge			15	c	1
	3b: South Kitchen counter- Left right upper and lower outlet		15			
4 (Tandem)	4a: South Kitchen counter- Left right upper and lower outlet				c	3
	4b: Dining light, living ceiling, living interior plug, foyer/closet light			15		
5 (Tandem)	5a: Basement main light and interior outlets			15	c	1
	5b: Exterior basement plugs			15		
6 (Tandem)	6a: Basement bathroom lights			15	c	3
	6b: Basement bedroom light, int plugs, bathroom plug			15		
7 (Tandem)	7a: Kitchen pots and island			15	c	3
	7b: Exterior outlets living room and outside light			15		
8 (Tandem)	8a: Under sink socket, south kitchen			15	c	1
	8B: West kitchen outlet			15		
9 (Tandem)	9a: laundry plugs washing machine			15	c	3
	9b: Master bedroom all, NW bedroom all			15		
10 (Tandem)	10a: Upstairs bathrooms, hallway light and smoke detector			15	c	3
	10b: Garage lights and plugs			15		
11 (Tandem)	11a: Office lights, Ext SW plugs, main floor bath lights, hall lights, Laundry light			15	c	3
	11b: Transformer, crawlspace			15		
12 (Tandem)	12a: Garage door, Garage outside lights, Garage outlet left			15	c	3
	12b: ERV			15		
13 / 14	Heat pump indoor unit		50		c	2
15 / 16	Hot Water Tank		30		c	5
17 / 18	Heat pump outdoor unit		35		c	2
19 / 20	Range		40		c	1
21 / 22	Dryer		30		c	5
23 / 24	EV car charger		50		c	5

Photo: Koben Genius prioritization form

Generic Pathway for Home Electrification without a Service Upgrade

Step 1: Reduce or reallocate existing loads:

- Improve the building envelope to reduce the peak heating and cooling loads as much as possible.
- Replace the standalone electric resistance dryer with a condensing dryer or all-in-one washer and condensing dryer combo unit to free up electrical capacity.
- An all-in-one washer and condensing dryer reduces the load on the panel to only one 15-ampere, 120-volt circuit, with a price comparable to a high-end washer. A separate washer and condensing dryer would require two 15-ampere, 120-volt circuits.
- The added ERV or HRV reuses the removed fossil fuel furnace circuit.
- Install an electric range to replace the fossil fuel cooktop or separate electric cook top and a wall oven, as it has internal load controls and thus only needs one 40-ampere, 240-volt circuit.
- If there is a secondary suite in the home, consider the possibility of using a two-burner induction cooktop and a plug-in countertop oven instead of a 2^{nd} range. The countertop oven connects to the existing 20-ampere kitchen cooktop circuit and the two-burner induction stove may often run on a 20-ampere, 120-volt circuit. This configuration takes up much less of the electrical panelboard's capacity.

Step 2: Add new loads and load share as needed:

- The ccASHP often can reuse the electric dryer circuit freed up by installing the condensing dryer.
- Replace the furnace with air handler type ccASHP that reuses the existing ductwork.
- Some air handler ccASHP brands come with an integrated supplementary electric space heater and internal controls that control the peak electrical load to the larger of the two.
- For other brands or types of ccASHPs, load share the electric range as the primary appliance with the supplementary electric space heater as the secondary appliance.
- Use a Circuit Pauser load share device to add an EV charger or other large load.
- For a HPHWT try to use the 15-ampere, 240-volt models. These lower amperage models are less common, so order early. Buy a larger size tank than otherwise needed. This will not reduce the circuit breaker size but will reduce the energy used, as it should allow the unit to stay in heat pump mode most or all the time and run at a Coefficient of Performance above 3 using under 500watts. Set the tank to a higher temperature and use a tempering valve to bring the hot water supply temp down to the desired temperature. This provides more hot water capacity from the tank.
- Confirm with your Local Authority which method to connect the renewable energy system would be acceptable if the existing panelboard busbar does not have the capacity needed.
- If additional large loads need to be added such as workshop equipment, or you are connecting batteries and a back up generator, then a smart electrical panel may be required.

For individual and societal benefit, the results from this project indicate electrification without a service upgrade can be a viable, cost-effective, and attainable goal, even in cold climate Alberta.

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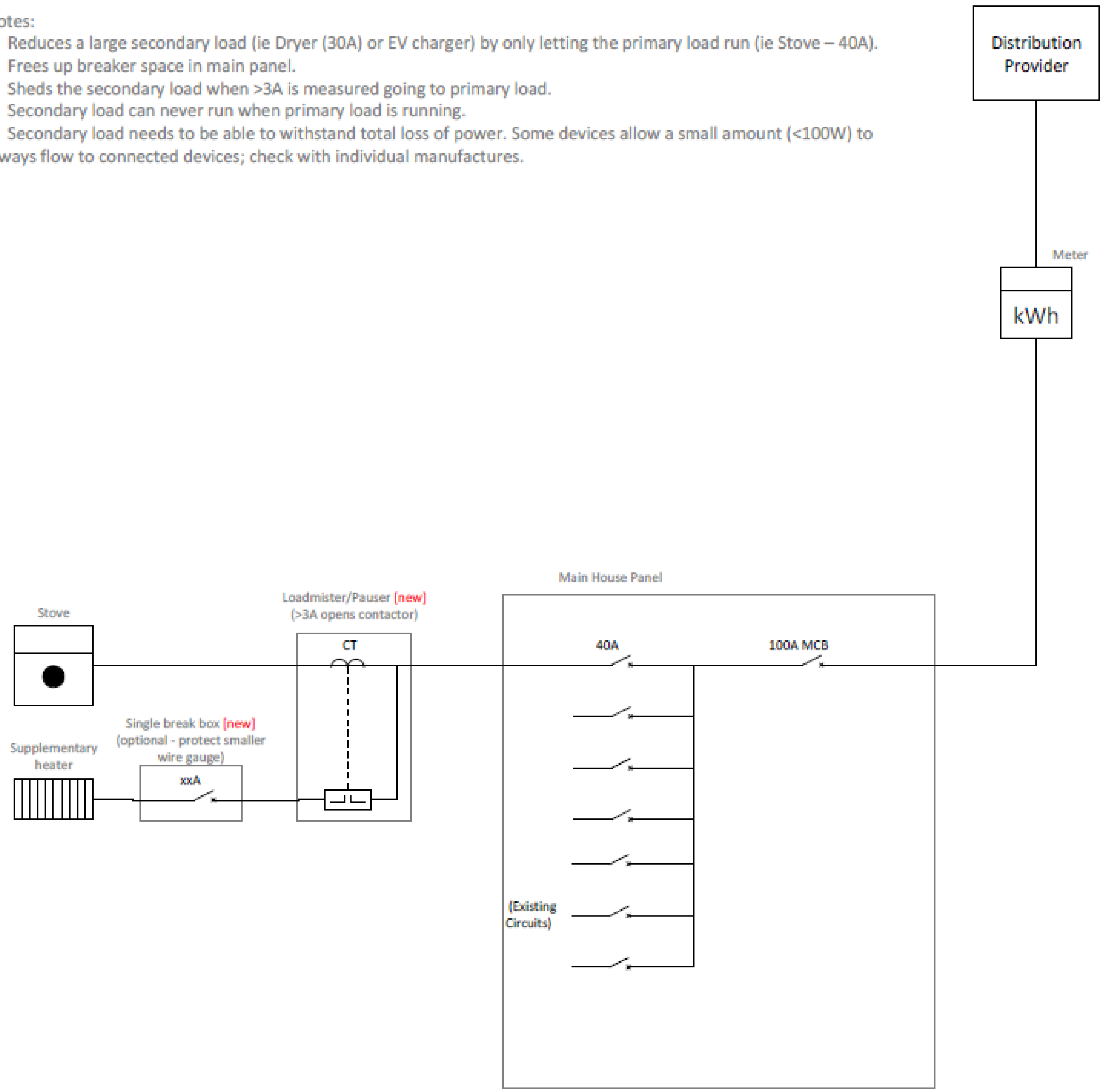
Appendix A: Single Line Diagrams

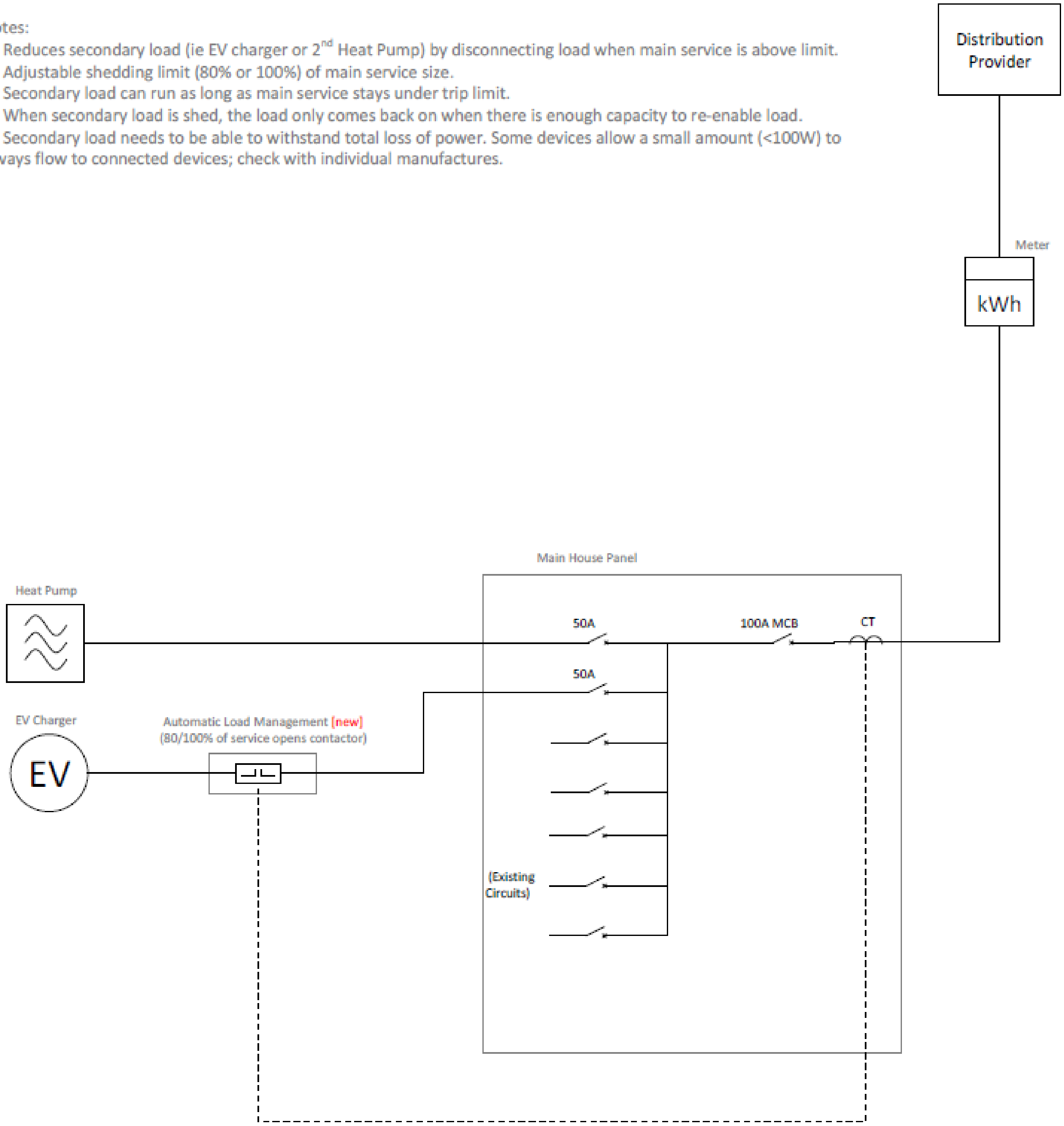
Load-Share Devices with Primary and Secondary Side

Notes:
1. Reduces a large secondary load (ie Dryer (30A) or EV charger) by only letting the primary load run (ie Stove – 40A).
2. Frees up breaker space in main panel.
3. Sheds the secondary load when >3A is measured going to primary load.
4. Secondary load can never run when primary load is running.
5. Secondary load needs to be able to withstand total loss of power. Some devices allow a small amount (<100W) to always flow to connected devices; check with individual manufactures.

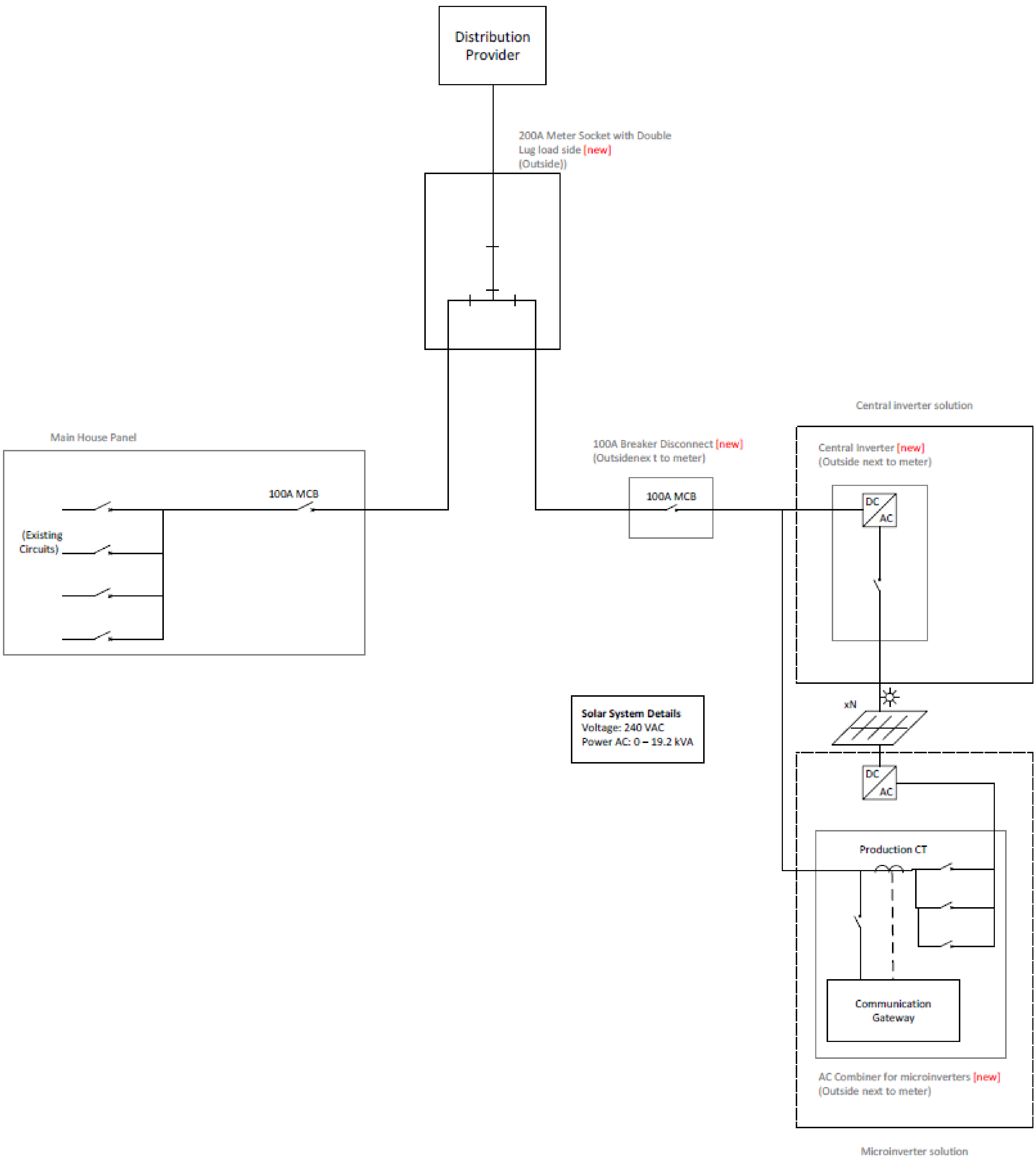


Circuit Pauser Load-Share Devices

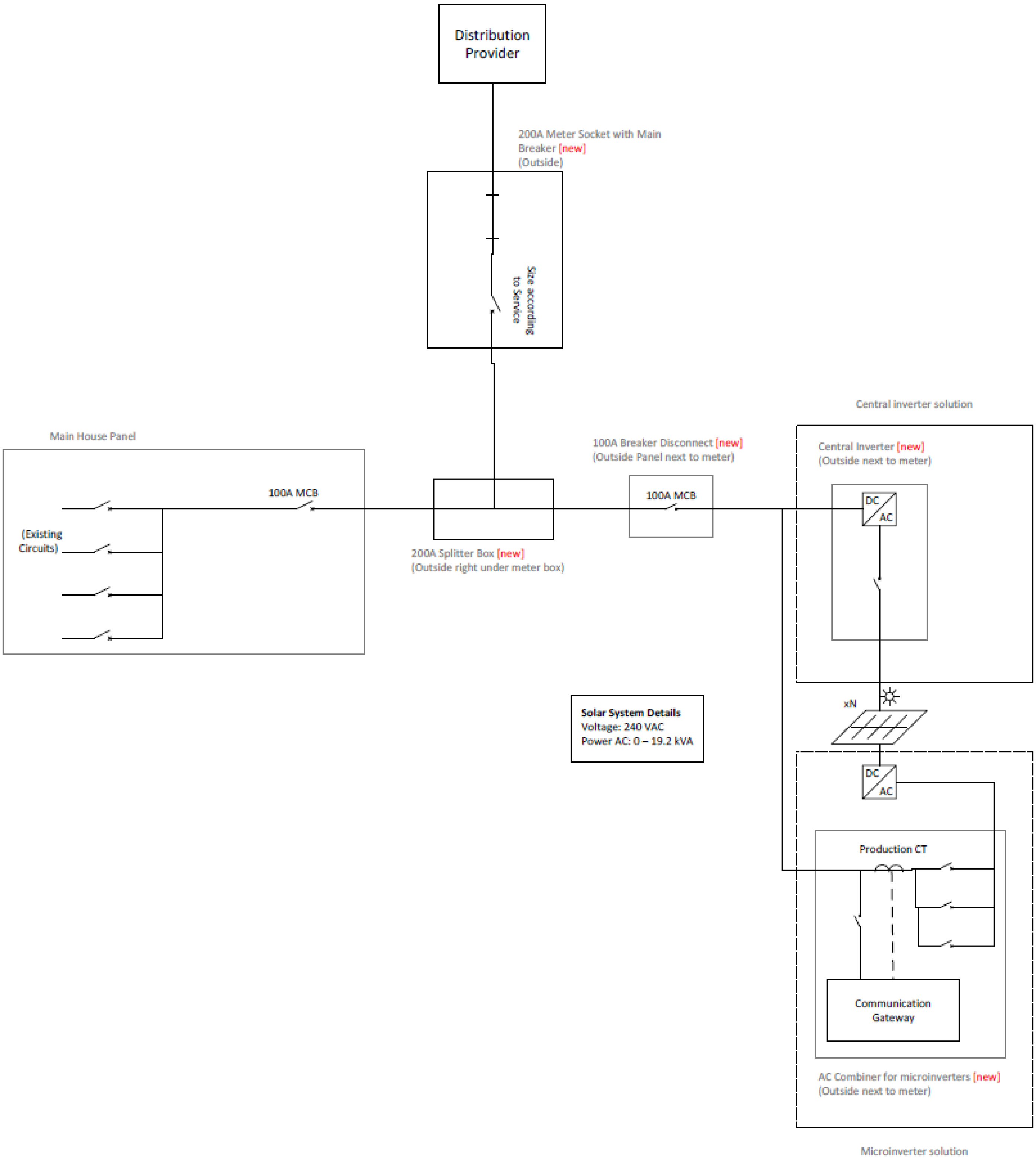
Notes:
1. Reduces secondary load (ie EV charger or 2nd Heat Pump) by disconnecting load when main service is above limit.
2. Adjustable shedding limit (80% or 100%) of main service size.
3. Secondary load can run as long as main service stays under trip limit.
4. When secondary load is shed, the load only comes back on when there is enough capacity to re-enable load.
5. Secondary load needs to be able to withstand total loss of power. Some devices allow a small amount (<100W) to always flow to connected devices; check with individual manufactures.



Option 1 – Meter Load Side Double Lug



Option 2 – Splitter Box with Meter Breaker



Option 3 – Combination Service Entrance Device (CSED)