# Residential Energy Storage – Innovation Report

## Project Summary

ENMAX Power, a subsidiary of ENMAX Corporation, is a regulated Alberta-based electric utility. As the Distribution Facilities Operator (DFO), ENMAX Power owns, operates, and maintains the electrical distribution system in and around the City of Calgary.

This project assessed the effectiveness of aggregated behind the meter energy storage as a non-wires solution (NWS) to enable electrification, optimize existing grid assets, and contribute to reducing emissions from residential customer homes.

This project was the first of its kind in Alberta and demonstrated how behind-the-meter flexible energy products can be coordinated to help customers meet their electrification and sustainability goals, while also enhancing reliability and resilience of the local distribution system.

### Project Scope

This project saw ENMAX partner with five residential customers in a neighbourhood where distribution equipment was approaching its rated capacity due to increasing electric vehicle (EV) and rooftop solar adoption.

ENMAX installed an 18kWh home battery system at each home that was scheduled to charge and discharge at fixed times during the day. This schedule shifted excess solar energy generated at these homes from mid-day to early evening when grid demand is highest. The batteries were set to always maintain at least 50% of their charge to be used as household backup power in the event of an unplanned grid power outage.

## Project Findings

### Battery Technology & Installation

The batteries available to ENMAX for this pilot were **Generac 18kWh PWRCell** home energy systems. These Lithium-ion batteries were installed in the participating homes' attached garages, floor-mounted against a wall. The systems occupied a space approximately two feet wide, six feet high, and ten inches deep for the battery, plus an inverter panel eighteen inches wide, twenty inches tall and six inches deep. Locating the battery in the garage required new conduit and circuits to be run from the garage to the home's main panel.

- **Key Findings:** Ideal installation locations will depend on the home layout, access to the electrical panel, and equipment specifications.
    - Installation requirements are subject to local building and electrical code rules which may exceed manufacturer or Canadian Electric Code requirements
- **Recommendations:** Installations should be performed by a manufacturer-certified battery installer.
    - Those installing battery energy storage systems must coordinate with local codes offices and the electric utility to confirm permit, installation, and interconnection requirements for their solution prior to installation.
    - **Insight:** Recognizing that home battery and EV charging adoption is steadily increasing, homebuilders might consider rough-ins to make the garages EV- or Battery-ready. Specific rough-in requirements should be confirmed through the latest local codes and standards.

**Fig 1**: Generac PWRCell Battery and inverter.

## Battery Energy Storage for Home Back-up Power

Installing a battery capable of whole-home backup required installing an automatic transfer switch that would allow the home to completely isolate from the grid. The installation required an eight-hour power outage, coordinated with the utility, to facilitate installing the transfer switch at the meter base.

While the battery capacity was sufficient to provide whole-home backup, an energy management system would be needed to coordinate power flow within the home to ensure instantaneous demand did not exceed the inverter rating. For this pilot, ENMAX and the homeowners opted to instead install a critical loads panel that supplied only essential appliances and a selection of lights and outlets within the home. The critical loads panel was more cost-effective and enabled the battery to successfully provide emergency back-up power to the home.

During the pilot, the participating homes experienced two unplanned outages lasting less than two hours total. Four of the five home batteries performed as designed, restoring power to the homes less than five seconds after grid power was lost. At the fifth home, the battery inverter experienced communications issues caused by compatibility challenges with their existing solar system. The battery inverter recognized the outage, but a protection setting prevented the battery from supplying power back to the home during the outage. This setting operated as intended by not exporting power to the home when the battery inverter could not validate the state of power flow from the solar inverter. This outcome could be mitigated if the two systems were DC coupled (e.g. shared a single inverter) or through the addition of a home energy management system.

Some customers reported dissatisfaction that the batteries could only support select loads within the home and would prefer a whole-home backup solution to the critical load panel. Notably, the Generac 40-amp inverter could not provide backup power for one homeowners' Level 2 electric vehicle charger and their critical appliances without a home energy management system to balance the system demand.

- **Key Findings:** the 18kWh Generac battery has sufficient capacity to supply an entire home's power needs during unplanned grid outages, however the battery inverter rating can limit the extent of back-up supply available.
  - The duration of back-up supply will vary for each home based on the battery's state of charge, and the home's electric demand during the outage.
  - A critical loads panel, or a home energy management system can enable back-up support during grid outages, provided there is sufficient anti-islanding protection to prevent back-flow to the grid during such outages.
  - The optimal solution will depend on the customer's needs and expectations of power reliability.
  - Homes with multiple inverters (e.g. solar and battery) may experience compatibility issues that could impede battery back-up
- **Recommendations:** whole-home back-up can be achieved if the home has an energy management system to balance electric load within the home.
  - Installers must confirm anti-islanding protection requirements with the local electric utility, electric codes office prior to installation.
  - A critical loads panel can enable back-up for critical appliances, lights and outlets at a lower cost to the homeowner.
  - The specific technical requirements to enable whole-home backup will depend on battery and inverter ratings and capabilities, the home's panel capacity, and local utility, electric, and building code requirements.

### Retrofitting Energy Storage to Homes with Existing Solar Microgeneration

Retrofitting a battery installation at a home that already includes a solar PV system can leave the home with two independent inverters. Having two independent inverters increases system cost and complexity. Having solar power converted from DC to AC power at the solar inverter, and then converted back to DC power to charge the battery also adds additional losses that impact the overall system efficiency.

- **Key Finding:** compatibility between battery and solar systems and their respective inverters may vary by manufacturer. When assessing system compatibility it is critical to consider the make and model, as well as the capacity of the solar and battery systems.
- **Recommendation:** while it is possible to retrofit a battery and inverter system in homes with an existing solar inverter, it is more practical and efficient to install DC-coupled systems where the battery and solar system share a single inverter.
  - A DC-coupled system optimizes energy efficiency and reduces overall costs to owners.
  - When installing solar and battery, or retrofitting batteries to an existing home with solar, it is critical to confirm compatibility between systems with a certified installer and/or the manufacturer.

### GHG Reductions

The project was originally expected to reduce GHG emissions by up to 44%, offsetting grid consumption at times where the electricity mix was at its highest carbon intensity. The final GHG emissions were calculated to be approximately 36.4% per year.

Causes of GHG reduction variance include:

- The carbon intensity of the grid varies significantly from hour to hour based on the actual grid supply mix.
    - It was impractical for ENMAX to manually dispatch the batteries based on the actual carbon intensity. Doing so would also compromise other project goals related to optimizing grid assets.
- While the pilot demonstrated that batteries can be fully charged by rooftop solar alone, without requiring excess power from the grid to supplement rooftop solar microgeneration, they often required some grid power to supplement power generated by the home's rooftop solar microgeneration.
    - The home's ability to self-supply its battery charging energy varies based on available sunlight, instantaneous household demand, real-time grid carbon intensity, and season.

**Key Findings:** The GHG emissions potential of a battery is capped by the battery capacity and number of charge and discharge cycles per day.

- The net emissions impact on a per-household level would vary depending on household consumption patterns.
- The per-household GHG reductions potential would be inversely proportional to the magnitude of the household demand. Essentially: the more power a home draws, the more likely it would require grid power to supplement net household load including battery charging.
    - Conversely: a lower demand, or higher-efficiency home is more likely to have higher GHG reductions potential.

## Customer Financial Considerations

As expected, this pilot did not lead to positive or negative cost impacts to participating customer electricity bills. The batteries were scheduled such that they always charged and discharged the same amount every day, leaving the household with no net difference in consumption. The absence of time of use rates in Calgary during the pilot period meant customers had no opportunity to maximize financial benefits by exporting power during times of high Power Pool prices.

During initial outreach many customers expressed disinterest in participating in the pilot as there was no opportunity to decrease their electric bill. They also expressed that the prospect of home backup was not appealing since Calgary experiences a very high degree of reliability.

These findings seem to indicate most homeowners would be unlikely to adopt such technologies in the near term. However the emergence of time-varying rates could lead more homeowners to consider adopting batteries to maximize solar export benefits and minimize costs during peak rate period.

The emergence of Vehicle-to-grid (V2G) capable EVs and retail aggregators in Alberta may also remove up-front financial barriers and create incentives for customers to adopt battery or V2G systems. This project's findings are generally applicable to V2G systems, but further research is needed to understand the opportunities, constraints, and practicality of those solutions.

## Energy Storage as a Non-Wires Solution to Enable Electrification

Based on household data, a solar, battery, and energy management solution might be applied to enhance a home's electric capacity as an alternative to a service upgrade. A similar approach might be applicable to in-fill developments where the existing property’s electrical capacity is limited. For these solutions to be achieved, the battery energy storage system would likely need to be paired with a home energy management system with protection settings approved by the local electric utility and electric inspections office.

While these solutions are technically possible, the benefits, feasibility, and practicality will vary for each home.

## Grid Impacts

The project successfully demonstrated how customer devices can contribute to optimizing grid asset utilization. By normalizing variances in a home's electricity consumption the pilot was able to decrease peak power exports through ENMAX distribution transformers during times of high solar generation. That excess solar energy was stored until the early evening hours when it was exported to offset household demand, and in turn decrease total demand on distribution transformers.

The pilot data suggests this effect could be further enhanced with the inclusion of a home energy management system capable of dynamic battery charging and home load optimization. Using the data generated from the pilot, ENMAX can model how an ideally coordinated system could act to optimize asset utilization. An ideal system would charge, and discharge batteries based on load conditions observed at the transformer, with the goal of minimizing variations.

The following figure shows actual grid conditions and battery performance for a distribution transformer with 18kWh of distributed battery capacity available. By targeting optimal grid performance batteries will tend to charge when high levels of solar are available, and discharge when demand is high but solar generation is not available. This coordination maximizes potential emissions reductions, while also optimizing grid asset utilization.

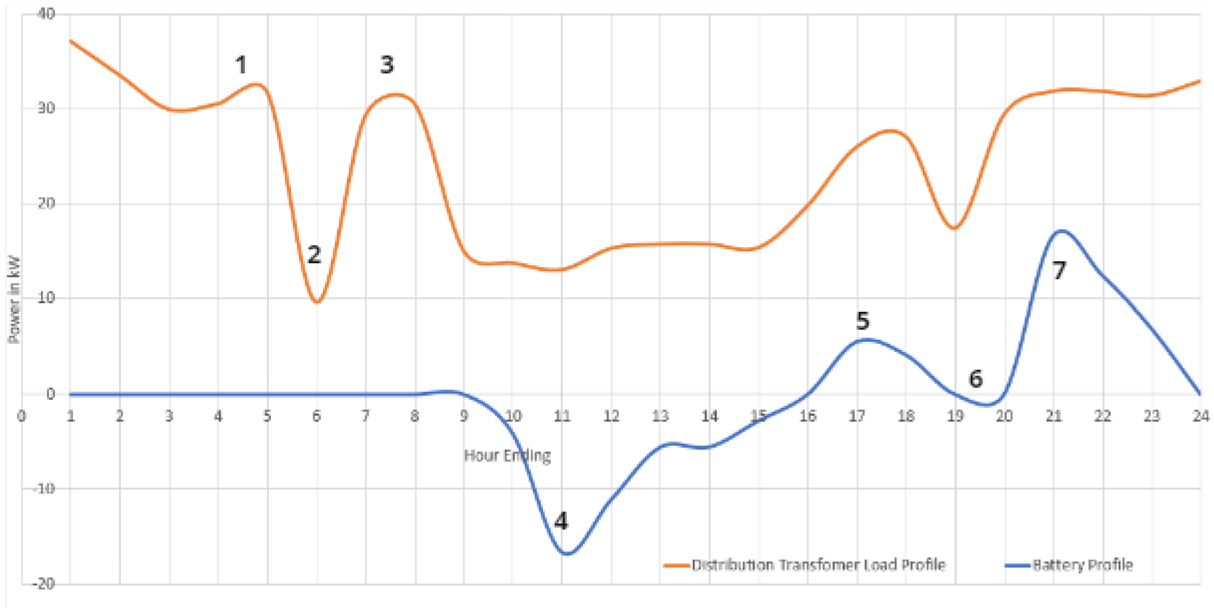


**Figure 2**: *Example of Distribution Transformer load vs. battery load with optimal battery cycling*

1. ENMAX data suggests this 5 a.m. load increase is due to scheduled EV charging on Tesla vehicles.
2. The steep decline from the end of scheduled overnight EV charging
3. Load increase from morning household routines drops off as solar panels begin to generate power.
4. Peak solar from homes leads batteries to charge to maintain level distribution profile. **Battery charging prevents reverse power flow on distribution transformer.** The battery charge tapers off as solar exports to the grid decrease, or when the batteries reach capacity.
5. **Grid demand increase leads the batteries to export, reducing peak demand on transformer**
6. Demand unexpectedly drops off (e.g. cloud break increases solar generation), batteries cease exporting.

## Policies and Regulations

Battery energy storage and inverter technology is progressing rapidly, and jurisdictions everywhere are continuing to adapt safety, electrical and building codes to these new technologies. Local codes can include mechanical and fire protection requirements that extend beyond those identified in the Canadian Electric Code. Many jurisdictions are beginning to adopt mechanical protection requirements for battery energy storage systems installed in garages to prevent accidental vehicle impacts, as well as processes to notify emergency services about the presence of energy storage systems.

- **Recommendation:** it is critical for battery installers to coordinate and comply with local electrical, and building permit offices, as well as their local electric utility to identify their latest installation, documentation, and interconnection requirements.