Project Payback:
A Community Virtual Power Plant

Grid Modernization Based on Local Resources

By
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Canadian Association for the Club of Rome (CACOR)

- Interesting IR photo of 2% energy loss
- Distant Generator to local load

The Presentation Content

- Objective: To establish a Virtual Power Plant (VPP) in Ontario, Canada to demonstrate how the planet and people can thrive
- Describe VPPs and their usefulness and benefits
- Demonstrate how VPPs can unlock a new revenue stream by facilitating participation in energy markets
- Describe energy trading while time shifting loads
- How the Ontario Ultra Low Overnight electricity rates are a policy designed to smooth demand and supply

Value and Growth of Electricity

- Value of electricity in people's lives is critical to survival, communications, transportation, health and comfort
- Electric Vehicle and Vehicle to Grid (V2G) deployment is projected to grow annually by 30% in 2025
- Rooftop Solar, home batteries and BESS are combining with solar and wind farms and other DERs to become large microgrids which are also aggregating into massive Virtual Power Plants
- This surge is driven by substantial financial benefits, grid reliability, efficiency, decentralization, aging grid infrastructure, sustainability, mitigation of and adaptation to climate change

What is Happening on Ontario's Electrical Grid?

Growth of Ontario's annual grid energy demands is estimated at 75% growth to 2050. (From 2008 to 2016, residential electricity costs rose by **71%)**

- Disruption forces driven by
  - electrify everything (housing, industry, transportation)
  - consumer participation and cost savings
  - grid energy efficiency, sustainability and reliability
  - regulatory support and policy initiatives
  - increased public awareness in future proofing their homes
- VPPs are systems that respond to this opportunity

The Constraints of Nuclear Energy

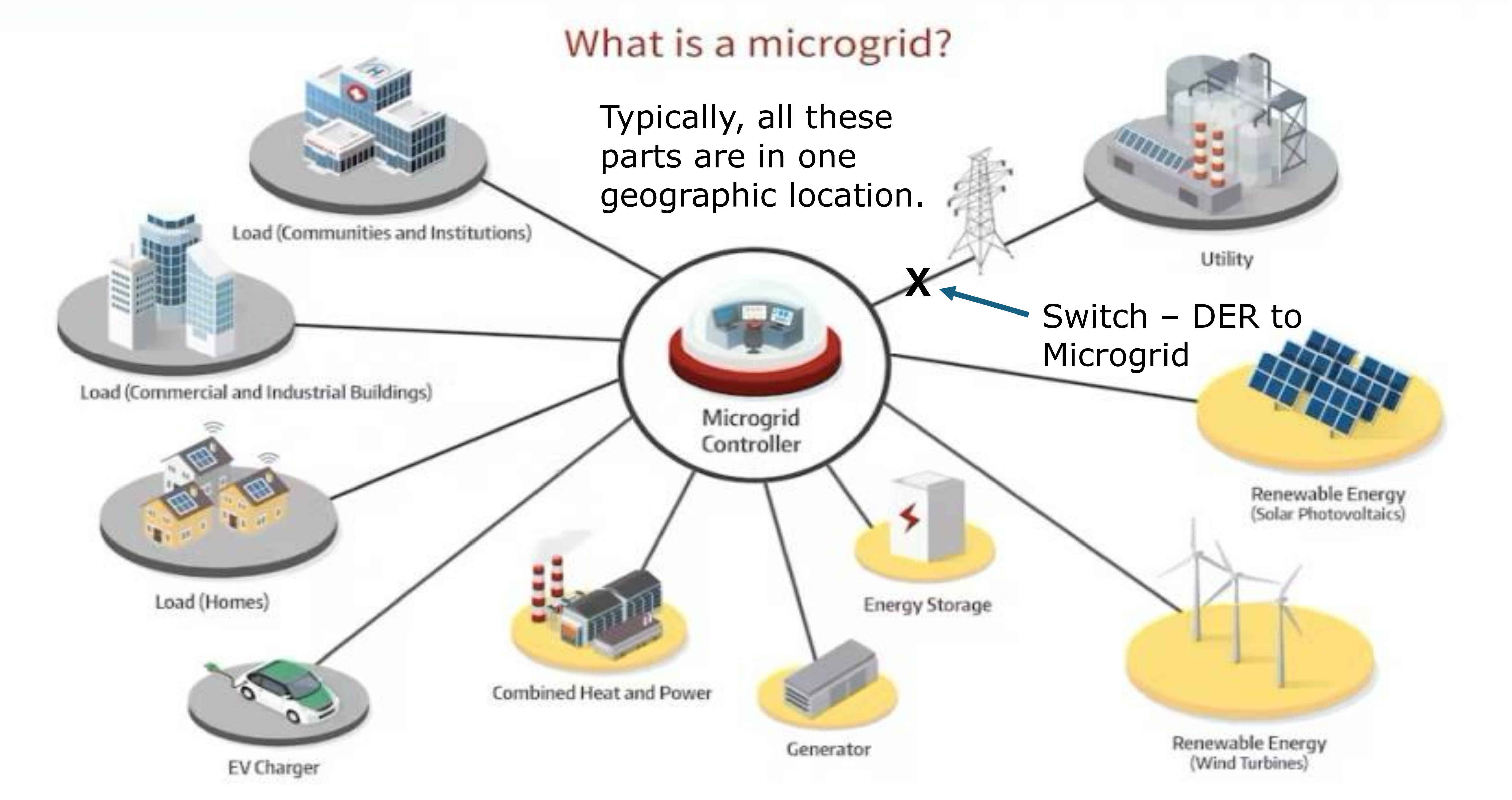
- Mainly inflexible and “fixed reactor output is always on or off” with limited reactor control
- Dumping some of the steam into turbines provides ramping down/up electricity generating flexibility
- Utilities seek means to absorb excess power and heat providing more flexibility
- Moving household demands to after peak hours will assist in use of this excess nuclear-electrical energy
- Home, EV and utility batteries help smooth energy demand to match the “fixed” supply

A Pilot Project Proposal

- Pilot Project could be in any community in the province or the entire province
- Main considerations are affordability, reliability, resilience, equity, and decarbonization (sustainable)
- Emphasis in this presentation is affordability, but it is hard linked to the other considerations - all benefits come in a single package
- Aggregation of Solar PV generation paired with home batteries, but thermostat controls are also used

Virtual Power Plant
"the energy system of the future"

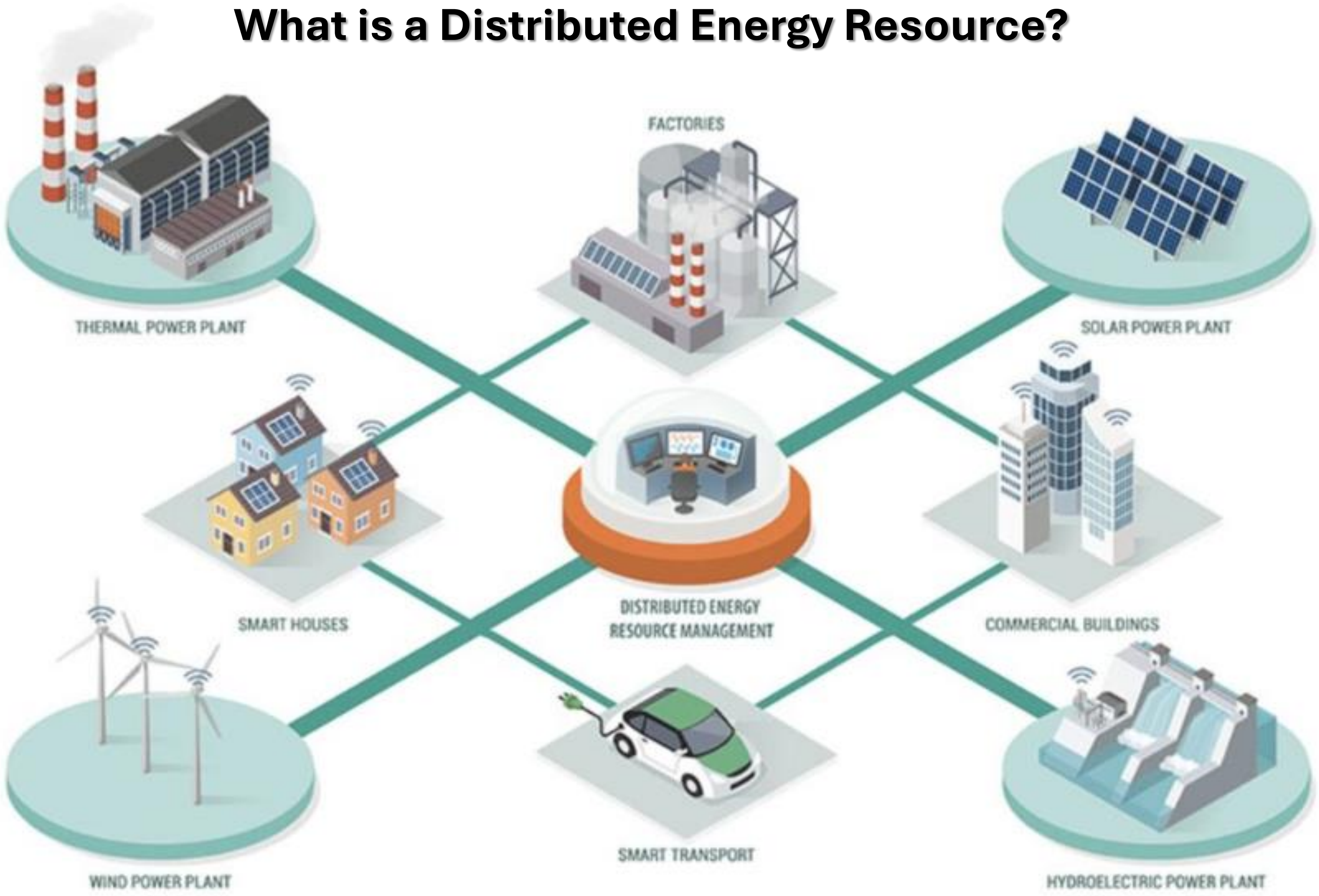
- VPP consolidates and streamlines customer clean 24/7 energy
- Reduces grid strain (transmission and distribution) and growth
- Controlled by the utility for peak load shaping and cost savings
- Financial Benefits
  - Local Microgrid and DER **owners** are paid for each kWh delivered.
  - **Utility** can delay upgrading distribution infrastructure (towers , poles, transformers, wire gauge) as demand growth is reduced
  - **All customers** get reduction in electricity cost escalations due to less costs for building grid infrastructure and no need for rushing construction of new centralized generation plants (nuclear, gas turbines, hydro)



Typically, all these parts are in one geographic location.

Switch – DER to Microgrid

What is a Distributed Energy Resource?



The Decentralized Grid

- The decentralized grid is:
  - an electric network of distributed energy resources and end-use customers (loads)
  - interact with each other and/or with the central grid
  - to improve efficiency, lower costs, reduce emissions, enhance both local and system resilience,
  - provides greater local control and energy independence
  - capture more of the economic benefits locally
  - capture local health benefits from these energy assets.

The Manotick Microgrid

Consists of:

- rooftop solar array – 5.5 kW maximum production
- three Tesla "Powerwall 2" NMC (nickel, manganese, cobalt) batteries – 40 kWh storage
- two electric Vehicles – Tesla model 3 (80 kWh NMC battery) and Mitsubishi i-MiEV (14 kWh NMC battery)
- Ground Source Heat Pump – shelter heating and cooling plus hot water
- Tesla Powerwall control system with Smartphone App

Most homes are not this well equipped but could be

Virtual Power Plants

Virtual power plants (VPPs) are an aggregation of small-scale distributed energy resources including:

1. Microgrids
2. solar energy systems,
3. electric vehicle batteries (EVs), EV bi-directional chargers
4. demand response devices such as water heaters, thermostats, appliances

VPP's and their collaborating DER technologies can grow and adapt with dynamic grid needs

Virtual Power Plants
(defined in prose)

- A Virtual Power Plant (VPP) is used to sustainably decarbonize part of an electrical grid. It decentralizes energy management to many locally controlled regions with cost reductions. This permits aggregation and growth of any source or load.
- Reliability is delivered by the ability to isolate local outages. With great flexibility, they can collect millions of dispersed generation devices and billions of consumption loads. Managing both supply and demand at the nano scale greatly advances efficiency and resiliency.
- A VPP then conducts energy and load shifting with the grid and delivers stable energy and services. Customizable algorithms streamline operations, affordability, and infrastructure maintenance.
- Multiple VPPs are ideal for future demands of Electrifying Everything. This includes deployment of bi-directional electric vehicle chargers, heat pumps, and data centers.

How Basic Financial Benefits are Determined

Comparison of two homes which provides:

- operational costs before and after adding solar panels
- both before and after expenditures are changing in real time

"**Microgrid**" home same design as the traditional home

- only electric energy financing as no fossil fuels are burned
- Dr. Art Hunter resident

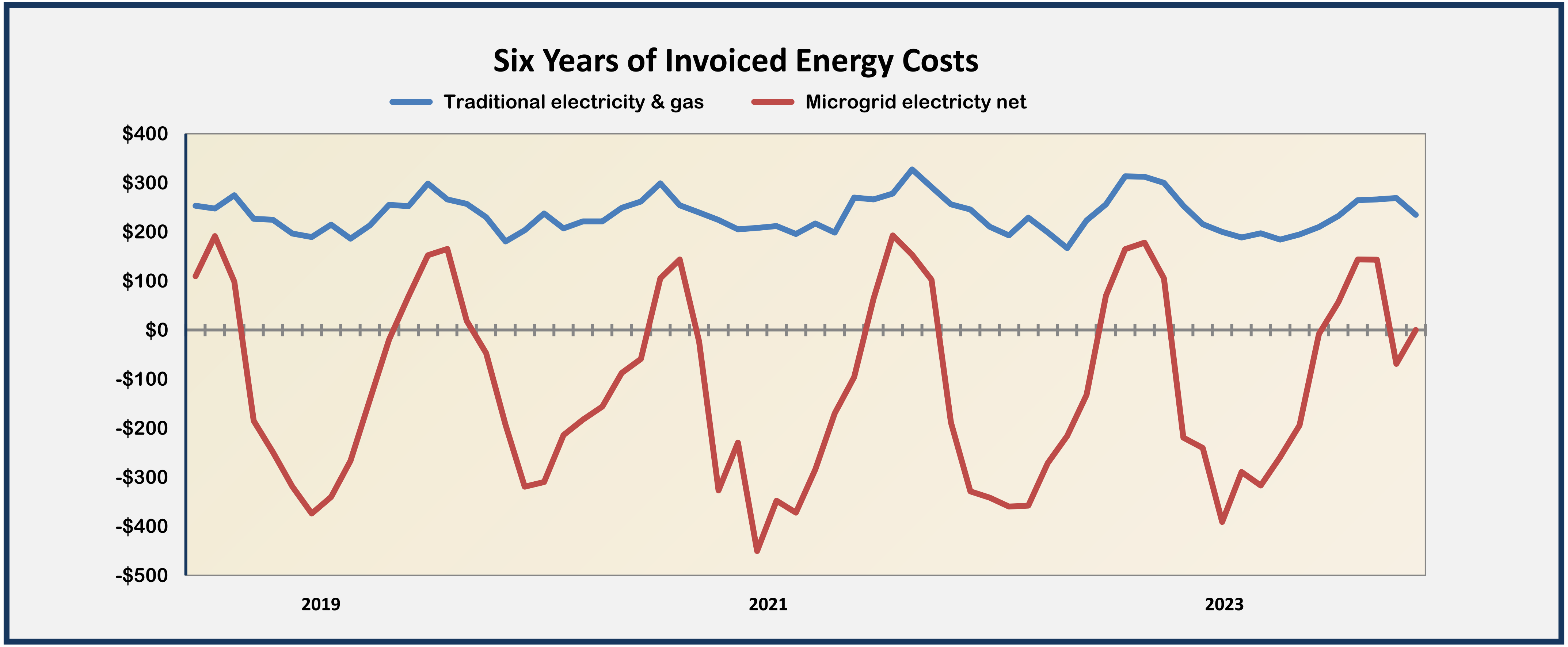
"**Traditional**" same original home design in same location as the Microgrid home

- with electricity, natural gas & gasoline costs
- Dr. David Head resident

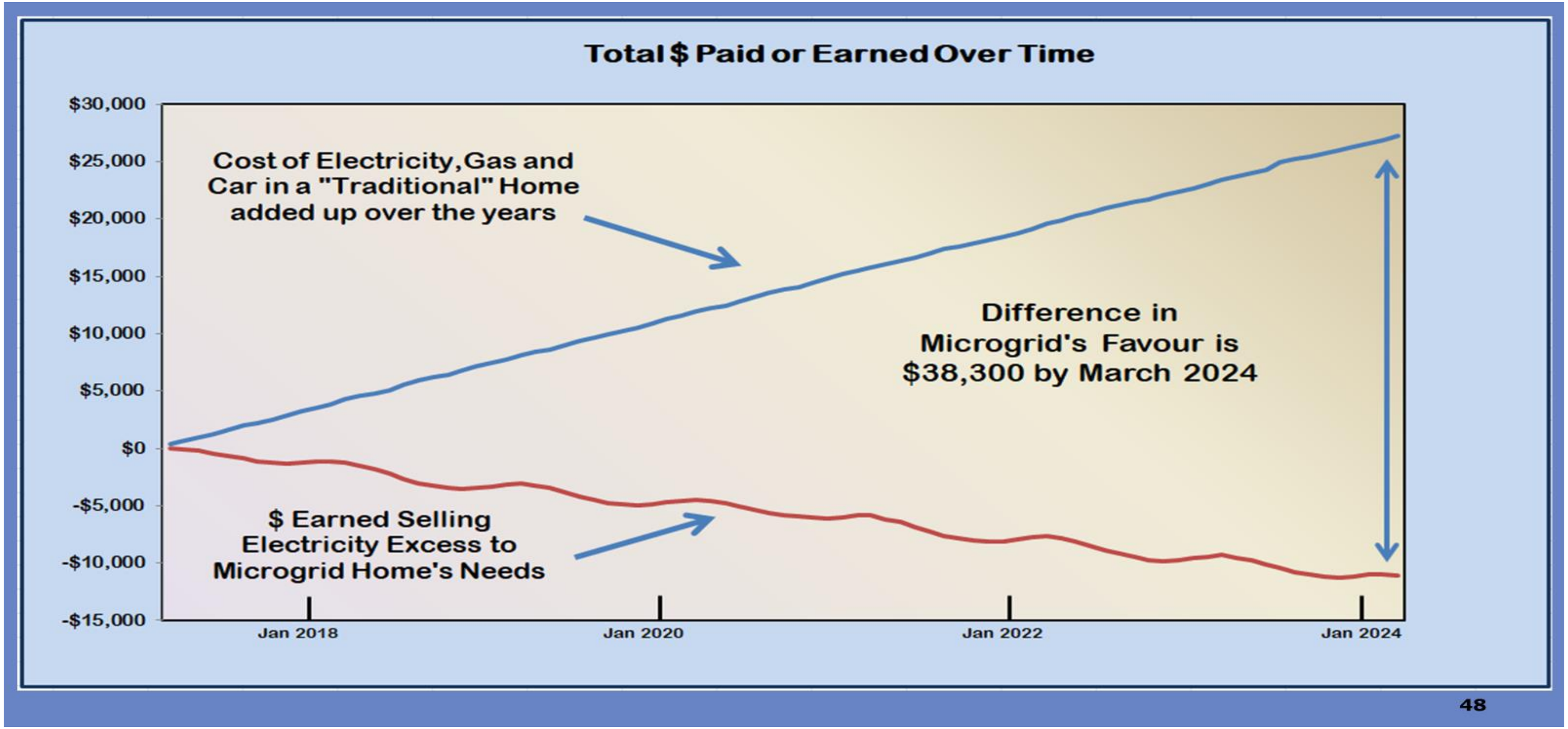
Payback Demonstration Project

- Demonstration project initiated in December 2023
- Use the Manotick Microgrid to mimic a Virtual Power Plant
- Objectives:
    1. Save money using optimized energy trading with the grid and load shifting to reduce electricity energy costs
    2. Save “energy credits” produced in summer for winter use

Microgrid vs Traditional Seasonal Costs



Payback over 7 Years



Observations

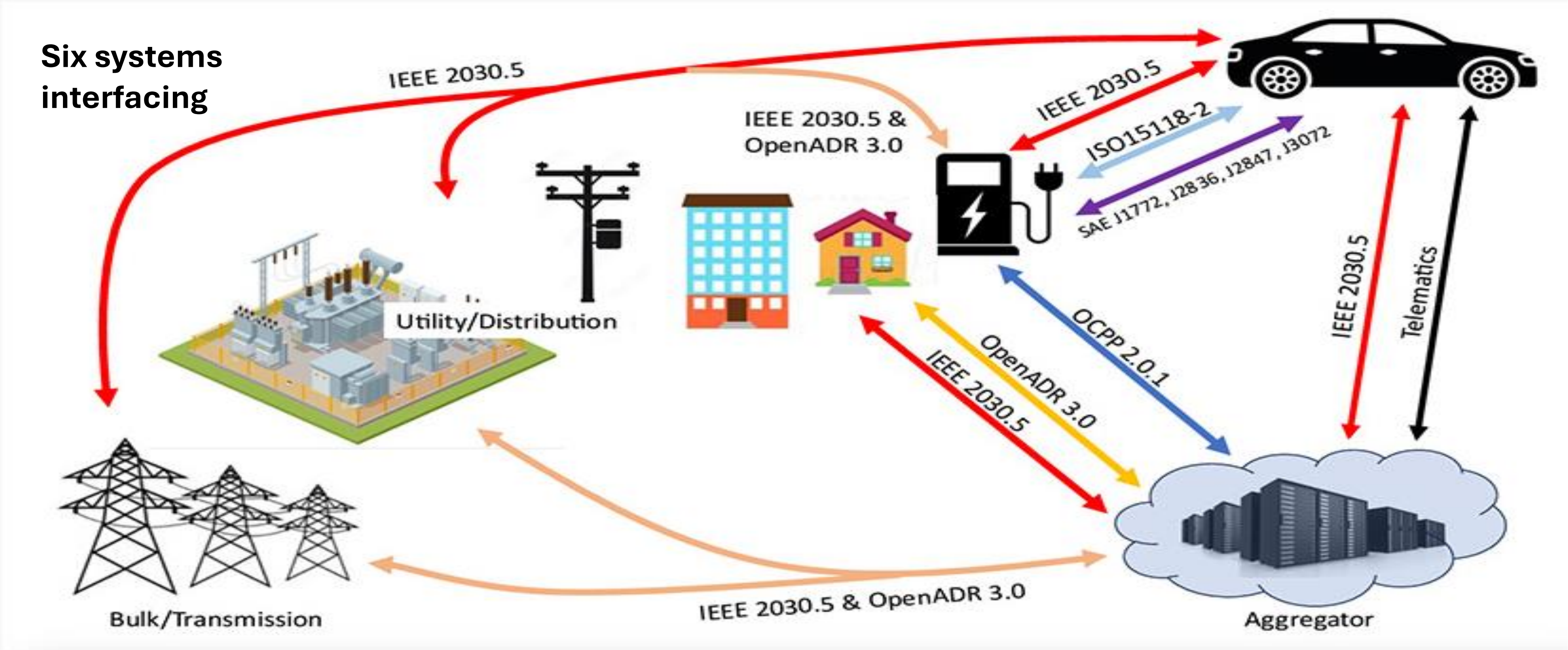
$22,000 was Installation cost of 5 kW Net Metering solar array

Significant Microgrid earnings in the summer and some costs in the winter

Over time energy earnings (sell) far exceeds the costs (buy)

Traditional home has far less seasonal variation but always has a cost without any earnings

EV Smart Charge Management



Multiple communication pathways and protocols between EVs, charging infrastructure, aggregators, buildings, distribution systems, and bulk power transmission systems. Courtesy: Lawrence Berkeley National Laboratory

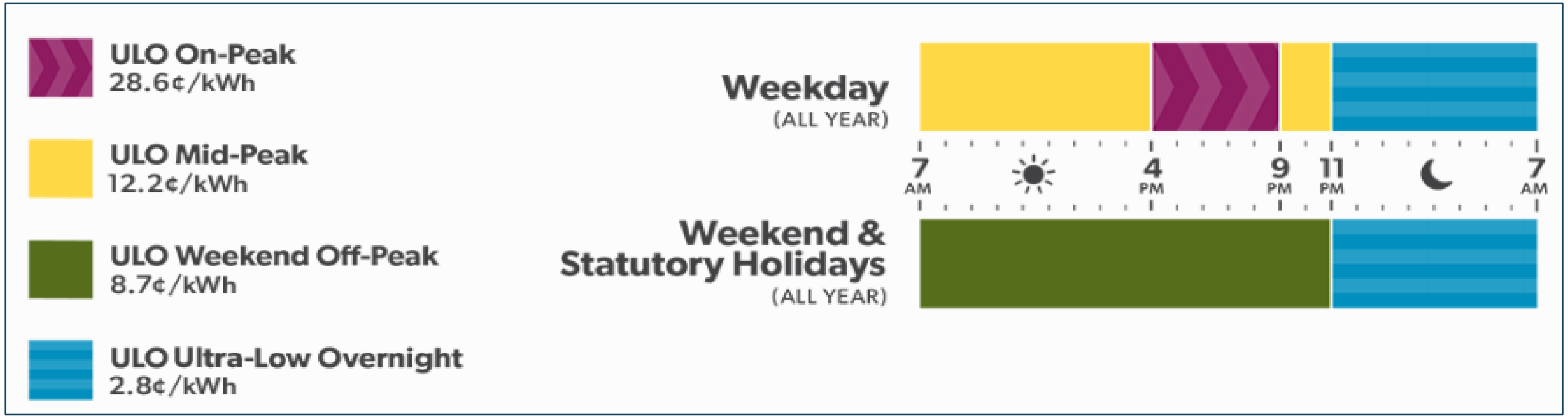
EV Smart Charge Management

- There are no uniformly adopted standards for EV bidirectional power flow protocols with:
    1. home and public charging infrastructure,
    2. utilities,
    3. the grid
- no requirement to comply with any standard but EV batteries must be considered identical to home batteries or as mobile microgrids.
- “difficult” for vehicle manufacturers to determine how to build smart charge management into their vehicles

Encouraging Demand Shifting
(do it yourself energy management)

Regulated Ultra Low Overnight (ULO) Rate Structure in Ontario

- buying and selling dynamic pricing
- rates must target efficiency, effectivity, and equity
- rate structure to encourage solar producers to remain on the grid to prevent utility death spirals by defection
- rates are reviewed annually on 1 November



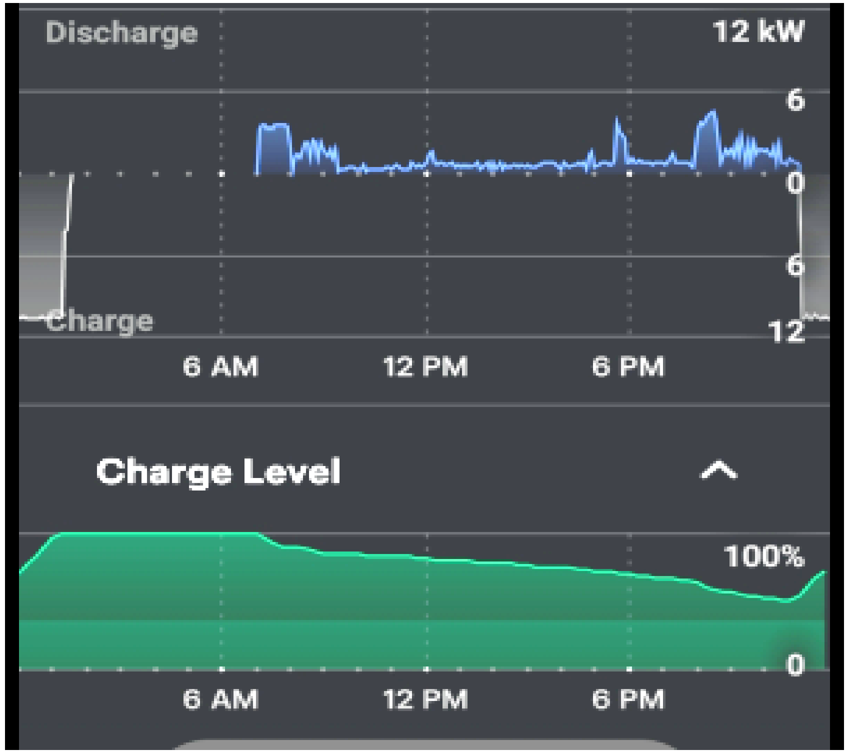
Energy Trading
daily and seasonally shifting

Energy Trading: buying electricity at utility's low $ rate and selling at high $ rates

- Daily time shifting = moving daily household loads, out of the Peak high-rate times using batteries
- Rate Shifting is permanently moving EV charging to the lowest energy rate using timers
- Seasonal Shifting is the process of accumulating energy credits from your local utility for use the following winter

Dual Use Battery Energy Trading
daily time shifting

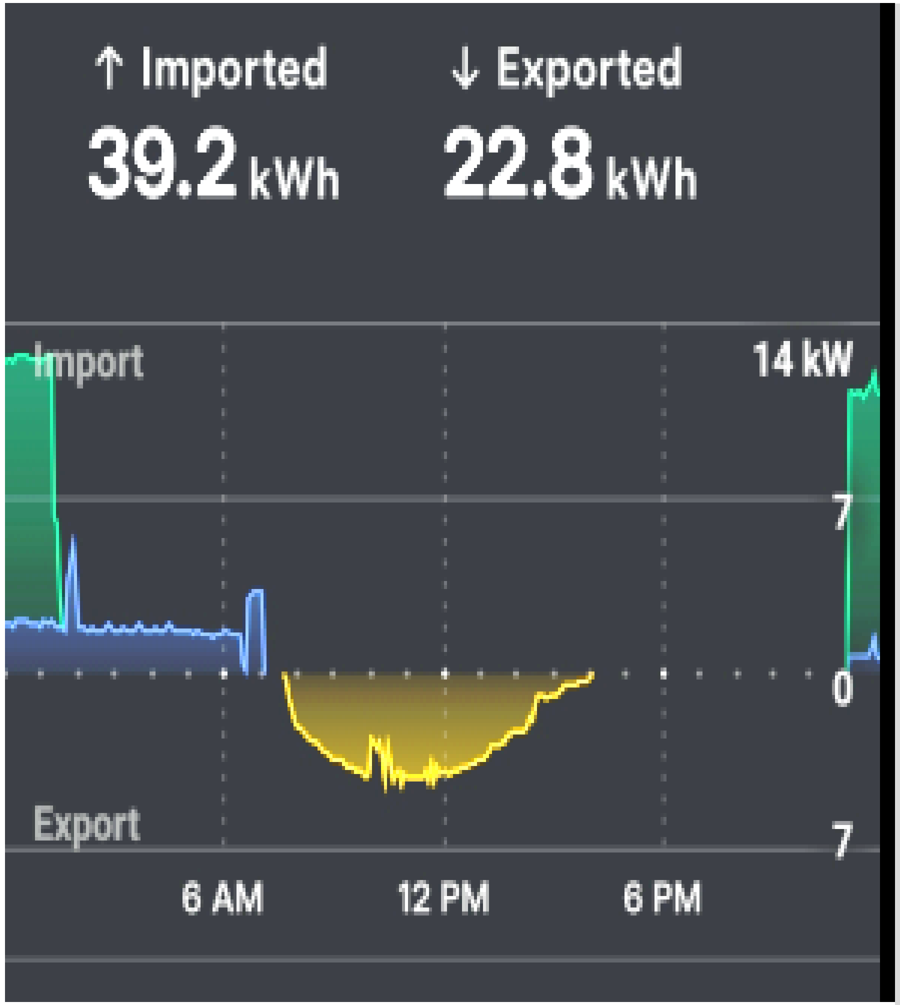
Energy Trading: Battery discharge at high energy $ rate and charge at low energy $ rate



- Top **blue** curve is battery discharge from 7 a.m. to 11 p.m. It is set to an all-day window when high rates apply
- Discharge was 18.5 kWh or about 46% of battery capacity.
- Will not wear out an NMC battery at 17C.
- Recharge (white) from 11 p.m. to 1:30 a.m. at $0.028/kWh.
- Lower **green** curve is State of Charge level over time
- **66% capacity for energy trading, 33% grid outage standby - always ON settings**

Grid Imports/Exports

Energy Trading earned $2.44 this day



- Home load for 7 hours from 12:00 a.m. to 7 a.m. overnight import from grid at ULO rates (**blue**) and battery charging (**green**)
- At 7:45 a.m. the sun rose and exported all to the grid until 4 p.m. (**yellow**) = $2.78
- At 4 p.m. to 11 p.m. no grid energy trading action after sunset
- At 11 p.m. the grid importing ULO rates came back into force for battery charging and home loads (**green** and **blue**) = $0.34

Hydro One Buy (usage) and Sell (generation)

August 2024

What is my Ultra-Low Overnight (ULO) usage breakdown?

Jul 17/24 to Aug 16/24	Usage (kWh)	Rate (¢)	Amount
ULO On-Peak	28.3704	28.6	$8.11
ULO Mid-Peak	72.834	12.2	$8.89
ULO Weekend Off-Peak	38.7366	8.7	$3.37
ULO Ultra-Low Overnight	435.5142	2.8	$12.19
		Total	$32.56

What is my Ultra-Low Overnight (ULO) generation breakdown?

Jul 17/24 to Aug 16/24	Usage (kWh)	Rate (¢)	Amount
ULO On-Peak	66.4746	28.6	−$19.01
ULO Mid-Peak	346.7382	12.2	−$42.30
ULO Weekend Off-Peak	187.2018	8.7	−$16.29
ULO Ultra-Low Overnight	0.0852	2.8	$0.00
			Total $77.60

Date ending	Month #	Prior accrued	Monthly addition	Total
16-Apr-24	1	$ -	$ 10.71	$ 10.71
14-May-24	2	$ 10.71	$ 30.50	$ 41.21
15-Jun-24	3	$ 41.21	$ 54.55	$ 95.76
17-Jul-24	4	$ 95.76	$ 46.29	$ 142.05
16-Aug-24	5	$ 142.05	$ 42.05	$ 184.10

Your transaction history

Directly from Hydro One billing history – Connection fee only

Date	Transaction
Sep 11, 2024	Payment received for $35.97
Aug 22, 2024	Billed amount $35.97
Aug 12, 2024	Payment received for $37.05
Jul 23, 2024	Billed amount $37.05
Jul 11, 2024	Payment received for $13.40
Jun 21, 2024	Billed amount $13.40

Mathematical Model Design

Balance supply and demand with Energy Trading using

- Home battery and its mobile microgrid
- Electrical grid acting as an external battery

Trading using these storage “batteries” is highly strategic

- Design and develop strategy to minimize homeowner costs
- Use previous experience to predict energy credits
- Correct this prediction with actual measurements
- Use AI to learn the trading quantities for the next prediction and correction

Virtual Power Plant "Simulator" Mathematical Model

Use previous measured facts

Prediction: model suggests energy flows and energy credits of December 2024 to be the same as December 2023

A rough estimate in the prediction

weather, monthly collected solar energy and monthly home power consumption never the same each year

Math model

applies a "correction" to reduce uncertainty in the "prediction"

Correction

based on actual utility measurement for the prior month with AI learned correction adjustments

Model termed a "Predictor-Corrector Simulation"

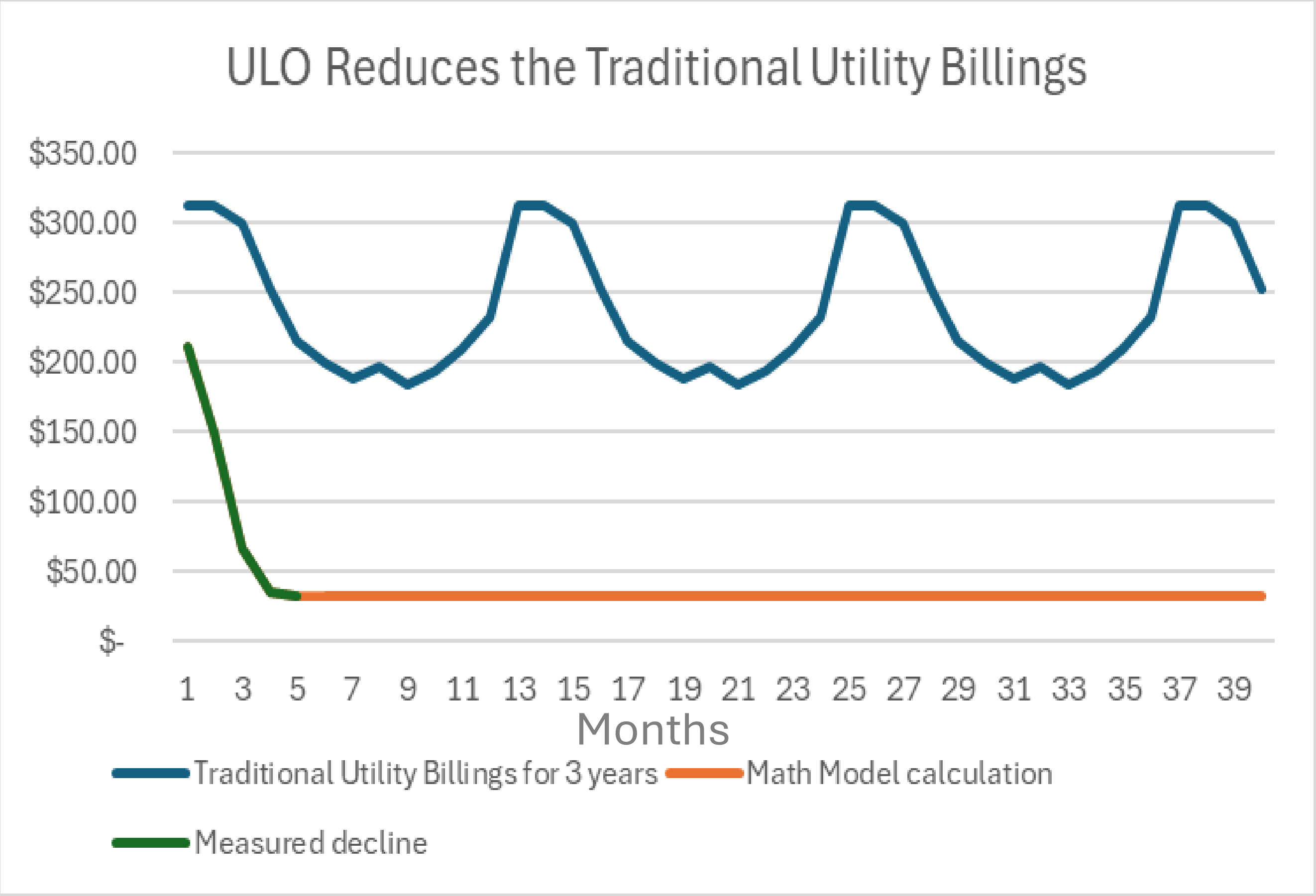
ULO + 5 kW Solar Generation Reduces Utility Billings

Blue: billings on tiered rate over three years for **traditional home** (rates unchanged over 24-hour period)

Green: utility data for **microgrid home** show a rapid decline in the first 3 months of ULO rate plan

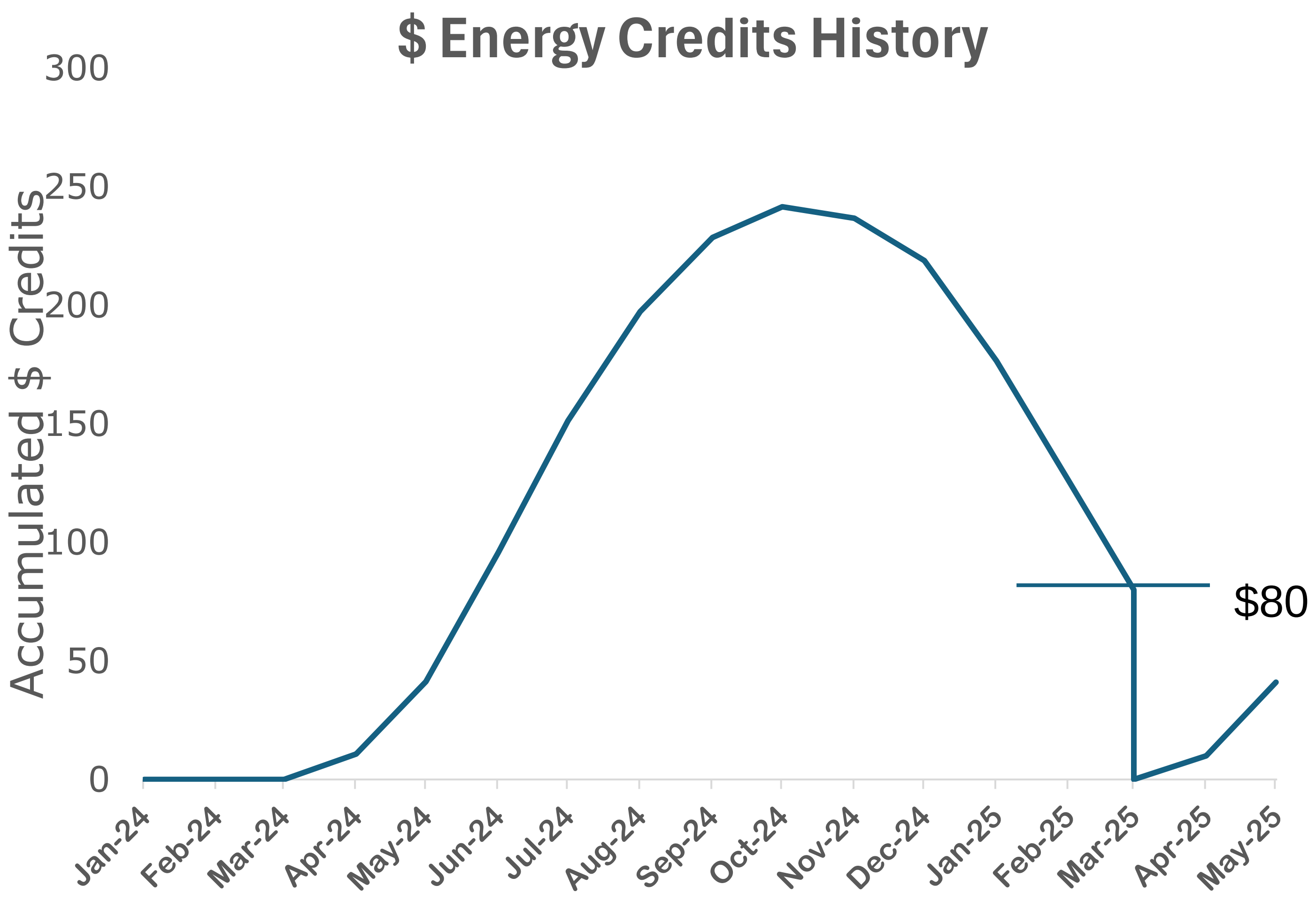
Orange: decline in next months to lowest possible billing – just utility connect fee ($36/mo)

Mathematical Model concludes billings will be just the utility connect fee into the future.



Energy Credit Accumulation and Use

1. First 3 winter months of 2024 there were no excess credits and aggregation reserve remained $0.0
2. Rapid growth of reserve through the summer due to excess earned credits
3. Autumn and Winter starts the consumption of credits
4. Reserve credits drop to low point of $80 in March 2025
5. The 12-month rule released the $80 credit back to the utility.
6. April 2025, credit reserve starts to grow again



Conclusions: Manotick microgrid mimicking a VPP

- Time shifting energy loads off peak rates using ULO is a savings, but not highly significant compared to the solar trading benefits
- Adding 5 kw of solar energy generation rapidly adds to savings with ULO because of daily energy rate variations
- Adding more solar power once optimum is reached will not improve savings as it is not possible to pay less to the utility, Hydro One, than the minimum monthly connection fee
- However, in the USA the utility also pays $2/kWh VPP peak demand participation

Virtual Power Plant Benefits
Win, Win, Win

- Financial Benefits (both grid supply expansion and demand reduction)
  - **WIN:** **Microgrid owners** may reduce utility payments to connection only ($36/month) and incentive participation of $2/kWh (about $600/year with complex rules)
  - **WIN:** Utility can defer future upgrades of **delivery infrastructure** (towers, poles, transformers, and wire gauge) as demand growth is reduced.

    US study "VPPs could help reduce annual power sector upgrade expenditures by $35 billion in 2030."
  - **WIN:** All customers and taxpayers receive reduction in electricity rate escalations as deferred future upgrades of distant **new generation plants** (nuclear, gas turbines, hydro).

    US study "deploying 80-160 GW of VPPs by 2030 could avert as much as $10 billion in annual new grid generator costs"

Microgrid Batteries - 7 Benefits

- Peak Shaving - Discharge during peak times to avoid or reduce demand charges
- Load Shifting - Shift energy consumption from one moment to another to avoid high prices
- Demand Response - Respond to utility signals when energy demand is high to earn money e.g. energy trading
- Backup Power - Use stored energy to power operations during a grid outage
- Solar Self Consumption – during daylight and at night (normal operations)
- Grid Services - Provide frequency and voltage support to the electrical grid
- Microgrid - Generate, store and manage energy with or without a connection to the grid for energy independence.

Rooftop Solar and Battery Expectations

- Owners want a fundamental value proposition from solar and batteries. Specifically:
  - a lower electricity bill from their solar,
  - access to grid outage backup power from their battery,
  - battery to be capable of time of use management (both load shifting and energy trading) with no additional costs
  - eliminate mechanical inertia time delays and energy losses

IESO Vital Requirements

- The IESO Grid managers are open to any technology that advances their three main goals.

1. Affordability
2. Reliability
3. Renewability

Virtual Power Plants
Pathway for Widespread Deployment

- VPPs requires progress on five imperatives:
  - expanding Distributed Energy Resource adoption with equitable benefits (increase public awareness),
  - simplifying VPP enrollment,
  - increasing standardization,
  - integrating into utility planning and delivered incentives visible on monthly billings,
  - integrating into wholesale markets.

The END of the Old Way


DEAR FUTURE
I'M READY...

Virtual Power Plant References

- The grid's new secret weapon: Your home – pv magazine USA