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BESS Microgrid Integration for Remote North American Communities

Introduction

This clean energy microgrid project targets a remote Canadian community with a peak demand of 10 MW, currently reliant on diesel infrastructure. The initiative began with a comparative market analysis between the U.S. and Canada, ultimately selecting Canada due to its favourable conditions, including six active funding programs that support the deployment of rural and Indigenous clean energy.

To reduce fossil fuel usage and enhance reliability, a hybrid model is proposed featuring:

- An installed capacity of 29MW solar farm
- 8.32MW of grid-forming battery energy storage
- Dedicated substations and contingency switching between community and genset substations, enabling ring-loop redundancy

In the longer term, an augmentation scenario prepares the system for scalable interconnection with the provincial grid or neighbouring microgrids. While existing diesel generators remain available for emergency support, they are not included within the project scope or costing.

This strategic design represents a forward-thinking approach to community-driven energy resilience, carbon reduction, and long-term economic sustainability.

The following key questions are considered:

1. What are the main benefits and potential risks of replacing or supplementing existing power sources with a BESS microgrid in remote communities?

2. What are the technical and logistical challenges involved in integrating BESS microgrids into remote communities? How can they be overcome?

3. Is the regulatory (environmental, permitting) landscape suitable for this project? How should the project accommodate members of the remote communities as key beneficiaries in the planning, operation, and long-term governance of BESS microgrid projects?

Market Selection (US and Canada)

Both Canada and the United States are actively advancing microgrid development, but they differ in scale, focus, and policy frameworks. A comparison based on the latest insights is provided in Appendix 1. Canada is currently more favourable for remote and community-based microgrids, particularly in light of its goals to reduce diesel use. The U.S. remains a leader in scale and innovation, but the "Beautiful Bill" has presented a setback to clean energy developers relying on federal support.

Canadian government funding programs

Appendix 2 summarises major Canadian funding programs that support renewable energy, energy storage, and microgrid development, particularly in remote and Indigenous communities. It highlights available incentives, eligibility criteria, and the increasing trend in investments aimed at reducing diesel reliance and empowering local communities through clean energy initiatives.

Existing Microgrids Projects in Canada

Appendix 3 highlights several real-world Canadian microgrid projects, detailing their locations, technology mix, and outcomes. These examples showcase the successful

deployment of BESS and renewables in remote regions, illustrating improved grid reliability, reduced emissions, and potential models for future community energy solutions.

Remote Communities in Canada

According to the most recent data from Natural Resources Canada (2025), there are approximately 280 remote communities in Canada, with over 239 primarily diesel-based energy systems, collectively consuming an estimated 870 GWh/year. Refer to Exhibit 1 for a list of remote communities and their primary energy source.

Currently, there are 6 communities reported with renewable sources, some include a mix of microgrids and BESS. Refer to Exhibit 2 for the list. Exhibit 3 lists four additional remote communities that could potentially serve as our target customers for the deployment of a BESS microgrid, with projects scheduled for development.

MicroGrid Connection to Grid

The proposed initiative focuses on a remote, stand-alone Microgrid, not connected to the main electrical grid due to the absence of a precise location, broad project scope, high connection costs, and the need for energy independence provided to the remote community. Refer to Exhibit 4 for a breakdown of grid-connected vs off-grid microgrid features.

Risks and Safety

Considerations for Risk, as elaborated in Appendix 4, include permitting with sovereign nations, logistical challenges for remote areas, extreme weather conditions (such as blizzards, wildfires, and flooding), cybersecurity concerns, fire safety risks, and technical support/labour response times.

With a robust risk mitigation plan ensuring that security, communication, and training are adhered to throughout the entire life cycle of the plan, in close coordination with the

communities the microgrids will serve, resilience and security can be assured for years to come, alongside reduced GHG emissions and energy costs.

System Overview

The deployment and operational strategy of an MGC with a 10 MW peak demand, initially powered by a 4 MW biomass plant and 10 MW of internal combustion (ICE) generators, is detailed in Appendix 5. A hybrid upgrade with a 10MW solar farm and 8.32MW/35MWh BESS is also included. The hybrid scenario integrates advanced grid-forming BESS modules, significantly reducing diesel reliance, enabling energy balancing, and resulting in substantial fuel cost savings—especially during winter peaks when BESS is cycled daily and summer periods when ICE generators can be fully displaced. The BESS employs sophisticated design features for safe electrical conversion, thermal management, and system optimisation, while flexible control modes—including current and voltage regulation—ensure seamless switching between grid-connected and islanded operation and robust frequency, voltage, and black-start functions. Comprehensive microgrid control, including primary (droop), secondary (PI), and tertiary (economic dispatch) layers, alongside dynamic voltage regulation and fault management, positions the system for resiliency, scalability, and efficient integration of renewable generation.

BESS Sizing

For our systems, we have selected to go with an 8MW/8MWh @ Beginning of Life – 1C or 8MW/32MWh @ Beginning of Life -.25C. See Exhibit 29 for BESS sizing chart and Exhibit 30 for usable energy graph.

Financing

As elaborated in Appendix 9, the proposed Power Purchase Agreement (PPA) structure for off-grid microgrid deployment in remote communities is tailored to prioritise local reliability, affordability, and community oversight. In this model, a fully islanded microgrid powered by solar PV and BESS delivers electricity directly to residents and essential

services, with no connection to the centralised grid. The PPA formalises energy delivery terms between the operator—either a utility, community organisation, or public-private partnership—and local users, with pricing pegged to the avoided cost of diesel (typically CAD $0.56–$1.12/kWh) and structured for affordability and long-term cost recovery over a 10-year term. Service guarantees focus on local resilience features such as fast frequency response, black-start capability, and high system uptime rather than market-based incentives. The agreement emphasises predictable, lower energy costs, environmental benefits, opportunities for local training, and energy sovereignty, backed by inclusive governance involving utilities, Indigenous leadership, and provincial regulators.

Bill of Supply

The major cost components and inclusions (such as battery containers, power conversion systems, EMS panels, commissioning, warranty, spare parts, service, and logistics) along with quantities and, where available, pricing information, are shown in Exhibit 3.7. The Levelized Cost of Energy (LCOE) calculation is provided in Appendix 6. Utilisation scenarios in Exhibit 38 show that the more the battery is utilised, the lower the LCOE gets, making the system more cost-efficient; however, further consideration should be taken due to asset degradation that may shorten battery life. Replacing diesel with clean energy reduces environmental impact while dramatically lowering energy costs. Remote Canadian communities' energy costs are shown in Exhibit 39. The project focuses on installing an 8MW/8MWh solar and battery microgrid—excluding diesel costs—and estimates that its LCOE is substantially lower than traditional diesel, offering both cost and environmental benefits for remote communities.

The cost of traditional diesel power generation in remote Canadian communities can exceed CAD $1/kWh, driven by high fuel prices, seasonal delivery constraints, and operational inefficiencies. Liquefied Natural Gas (LNG) offers a cleaner alternative, with lower fuel costs and reduced emissions, but it requires significant infrastructure upgrades. In contrast, hybrid systems combining battery energy storage (BESS) and solar photovoltaic (PV) offer long-term cost stability and near-zero emissions, with

Levelized Cost of Energy (LCOE) estimates ranging from CAD $0.08 to $0.45/kWh depending on utilisation. Transitioning to renewables not only reduces environmental impact but can significantly improve energy affordability and resilience for remote communities.

Return on Investment (ROI) Calculation

The ROI Calculation shown in Appendix 7 provides a comprehensive financial assessment of incorporating a Battery Energy Storage System (BESS) into a microgrid alongside photovoltaic (PV) solar and biomass generation. It evaluates BESS-driven cost savings and environmental benefits across summer (high solar) and winter (reduced solar) scenarios, with a blended case offering a year-round view. Results show that annual net savings are highest in summer, with a rapid payback period of just over 2 years, while winter conditions lengthen payback to about 4 years. In the combined seasonal case, fuel savings approach $2.9 million CAD annually, achieving a payback in just 1.3 years and an annual ROI exceeding 75%. Sensitivity analysis reveals that scaling up PV resources or resizing BESS components can further boost ROI and accelerate payback, while hybrid diesel-biomass solutions remain sustainable with marginally longer returns. The analysis highlights the strong financial and environmental case for BESS in microgrid settings, particularly when system components are optimised for local conditions.

Long Term Service Agreement (LTSA) Plan

The LTSA plan (Appendix 8) outlines the comprehensive maintenance, monitoring, and performance framework necessary to ensure reliable long-term operation of the BESS microgrid system. Key elements include regularly scheduled preventive and corrective maintenance, remote diagnostics, and real-time system optimisation; strict performance guarantees for system availability (≥98%) and battery capacity retention; spare parts strategies and emergency response protocols; operator training and capacity building (including community-specific needs); and detailed reporting on key performance indicators. The agreement is tailored to address remote deployment challenges, with specialised cold-weather and access adaptations, and is structured for a contract duration of 5–15 years with renewal options.

Conclusion

With a favourable regulatory framework and a dispersed, remote population eager for resilient energy and a reduced carbon footprint, the Canadian market is poised to enter as an integrator of BESS systems, enabling microgrid functionality in conjunction with established cogeneration of energy. The very challenges that remote communities face, such as logistics issues, permitting/regulatory hurdles for development, and investment latency, are key reasons that introducing energy storage solutions makes sense for these communities. With a robust risk mitigation plan, integration of iBESS systems of 8MW/8MWH (1C) and 8MW/32MWh (.25C) allows low CAPEX investments to optimise existing energy infrastructure to meet the energy demands of remote communities throughout the year, despite weather and logistics challenges on the OPEX side. As our feasibility studies show, there are many communities that could directly benefit from our deployment/integration of BESS systems to reduce diesel consumption and provide ROI within as little as 2 years in the right scenario.

The challenge we face as developers is to propose and package our services to the right off-takers of this energy in a timely and concise manner, considering the challenges that remote communities face. As we look to round out our investment options, we will need to focus on the following key questions to arrive at solid project proposals:

1. What are the main benefits and potential risks of replacing or supplementing existing power sources with a BESS microgrid in remote communities?

2. What are the technical and logistical challenges involved in integrating BESS microgrids into remote communities? How can they be overcome?

3. Is the regulatory (environmental, permitting) landscape suitable for this project? How should the project accommodate members of the remote communities as key beneficiaries in the planning, operation, and long-term governance of BESS microgrid projects?

Exhibits

Exhibit 1 – Canadian remote community overview chart

Region	# of Remote Communities	Primary Energy Source	Estimated Annual Energy Consumption (GWh)
Yukon	9	Diesel + Hydro	~25
Northwest Territories	25	Diesel + Hydro	~120
Nunavut	25	Diesel	~180
British Columbia	50	Diesel + Hydro + Biomass	~90
Alberta	10	Diesel	~20
Saskatchewan	15	Diesel	~35
Manitoba	17	Diesel + Hydro	~40
Ontario	30	Diesel	~100
Quebec	35	Diesel + Hydro	~110
Newfoundland & Labrador	63	Diesel + Hydro	~150

Exhibit 2 – remote communities with existing renewable energy sources established

Community	Province/Territory	Renewable Source(s)	System Type	Diesel Offset
Watson Lake	Yukon	2.85 MW Solar + BESS	Microgrid (Sāde Solar Initiative)	~25% of annual diesel use
Anahim Lake	British Columbia	Solar PV (largest off-grid in BC)	Standalone Solar + Diesel Hybrid	~66% reduction in diesel
Colville Lake	Northwest Territories	Solar + Battery + Diesel	Hybrid Microgrid	~50% diesel reduction
Fort Severn First Nation	Ontario	Solar + Wind + Battery	Community Microgrid	~30–40% diesel offset
Old Crow	Yukon	Solar + Battery	Off-grid Microgrid	Seasonal diesel shutdowns possible
Ramea	Newfoundland & Labrador	Wind + Hydrogen + Diesel	Wind-Hydrogen-Diesel Hybrid	Demonstration-scale integration

Exhibit 3 – remote communities with upcoming renewable energy generation projects

Community	Province/Territory	Project	Technology	Expected Impact	Expected Completion
Watson Lake	Yukon	*Sāde Solar Initiative*	2.85 MW Solar + 5.3 MWh BESS	Offset ~25% of diesel use; enable full generator shutdown during summer	**Summer 2027**
Anahim Lake	British Columbia	*Anahim Lake Solar Farm*	3.8 MW Off-grid Solar + BESS	~66% diesel reduction (~1.1M litres/year)	**October 2025**
Multiple Sites	National (Phase 2)	*Global Initiative Pilot Projects*	Solar, Wind, Microgrids	5 pilot deployments in remote Indigenous communities	**2026–2027 (phased)**
Northern Ontario	TBD (Wah-ila-toos pipeline)	*Feasibility & Pre-construction*	Solar + Storage Microgrids	Several First Nations preparing for capital deployment	**2026–2028 (rolling)**

Exhibit 4 – comparison of grid-connected vs off-grid connection pros and cons to microgrids

MicroGrid Connection to Grid

	Grid-Connected MG	Off-Grid (Isolated) MG
Reliability	Can draw power from the grid during local generation shortfalls	Fully self-reliant; ideal for areas with no grid access or frequent outages
Cost Efficiency	May reduce energy costs by selling excess power to the grid or using grid power when cheaper	Higher operational costs due to need for full energy independence
Resilience	Can island during outages and reconnect when grid is restored	Always operates independently; resilient to grid failures
Regulatory Complexity	Requires interconnection agreements, compliance with utility regulations	Fewer regulatory hurdles but must meet all local safety and reliability standards
Capital Investment	Lower upfront cost if grid is used as backup	Higher initial cost due to need for full generation and storage capacity
Revenue Opportunities	Can participate in demand response, ancillary services, and net metering	No access to grid-based revenue streams
Maintenance & Operations	Shared responsibility with utility in some cases	Full responsibility for all system components or shared responsibility
Scalability	Easier to scale with grid support	Scaling requires significant investment in local generation and storage

1

Public

Public

Regulatory & Incentive Alignment	Eligible for more funding programs (e.g., **SREPs, CERRC**) that prefer or require grid connection	May have limited access to incentive programs unless targeting remote-only funding streams
Use Case Suitability	Best for urban, peri-urban, or industrial sites with grid access	Ideal for remote, islanded, or Indigenous communities with no or unreliable grid
National Security	Vulnerable to grid-wide cyberattacks or cascading failures; less control over energy sovereignty	Greater energy independence; ideal for defense, critical infrastructure, and remote security-sensitive sites

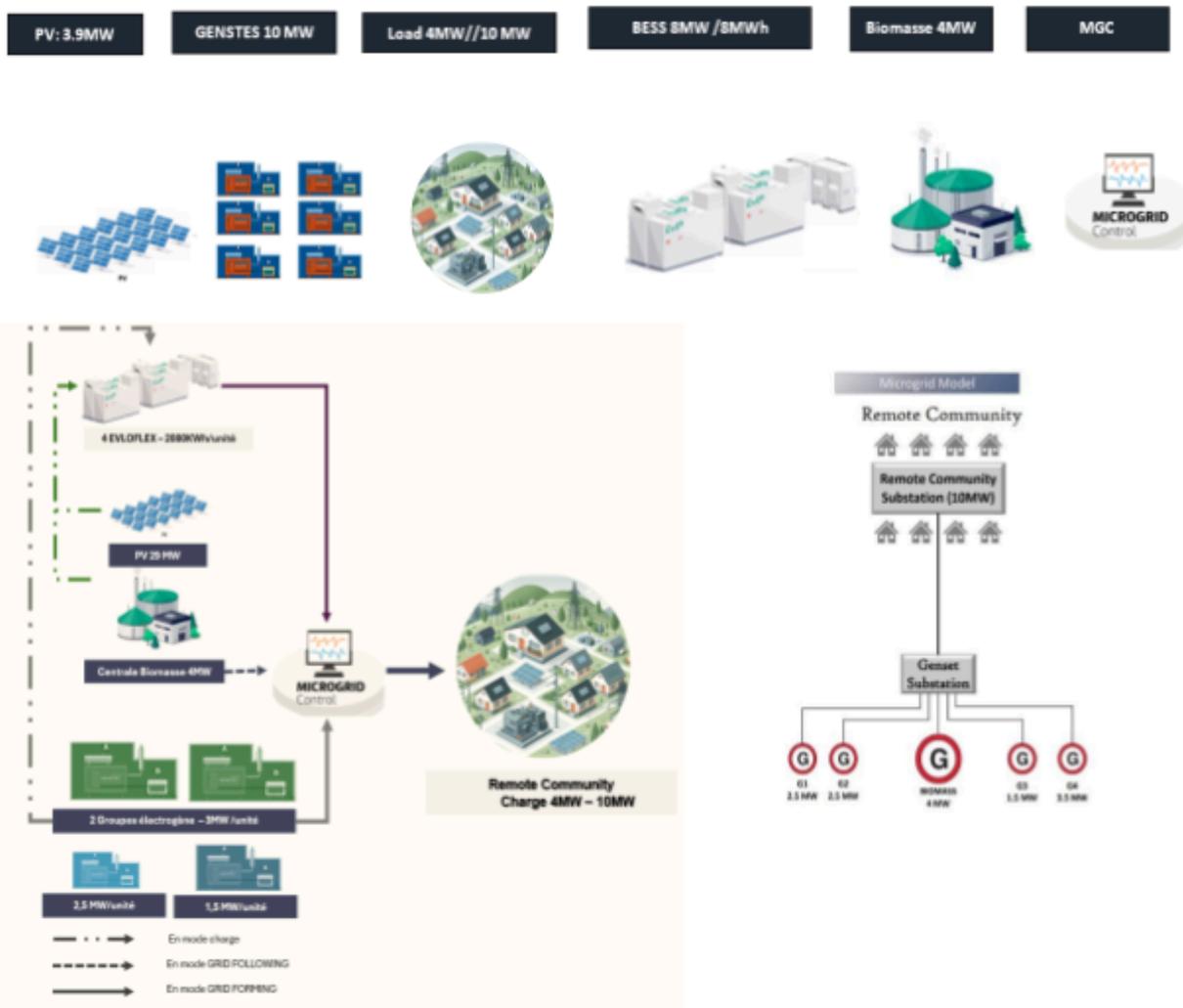**Exhibit 5 – illustration of original microgrid disposition for our base case**

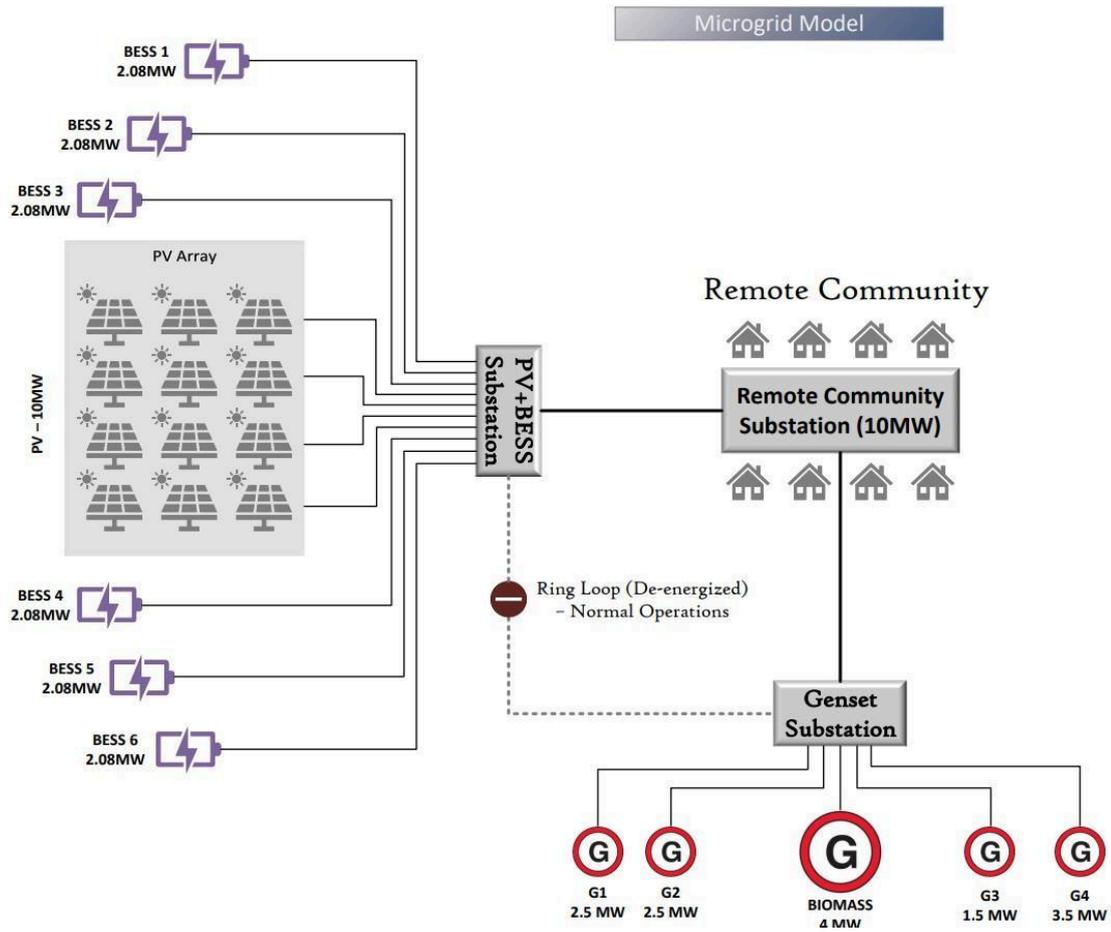## Exhibit 6 – illustration for microgrid in hybrid case

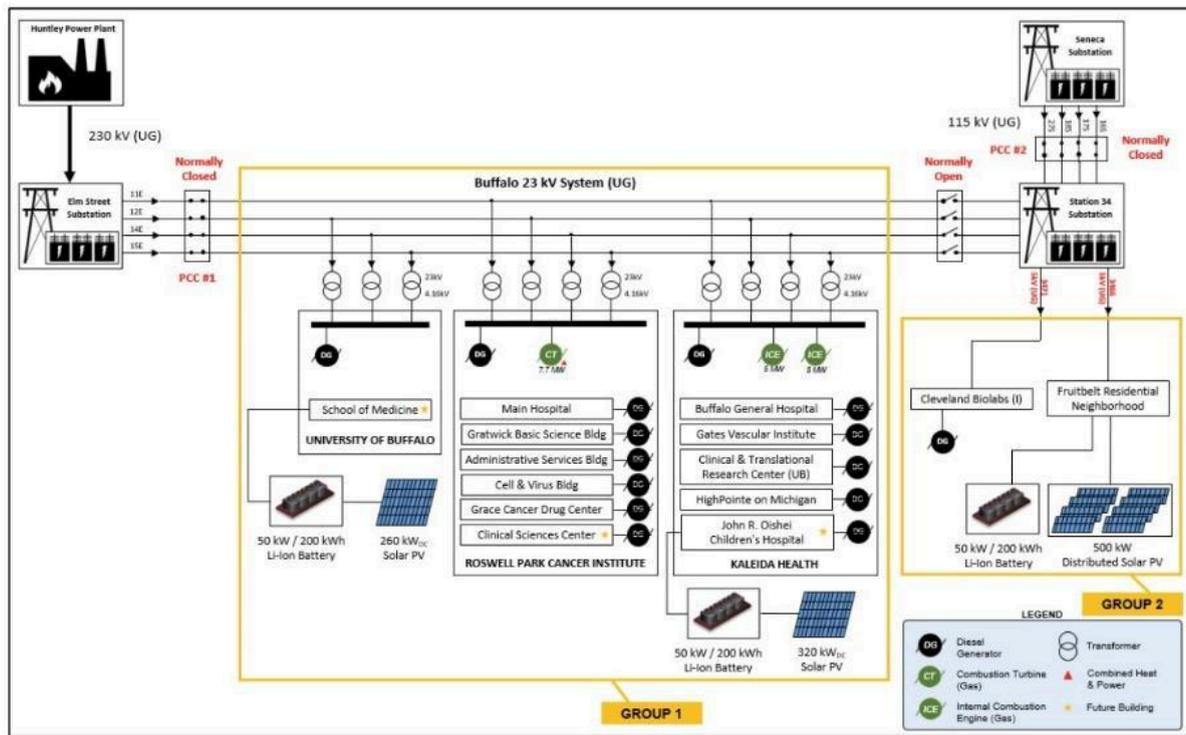## Exhibit 7 – real world example of microgrid design resembling our proposal

Exhibit 8 – illustration of ESS li–ion DC blocks connected to step up transformer
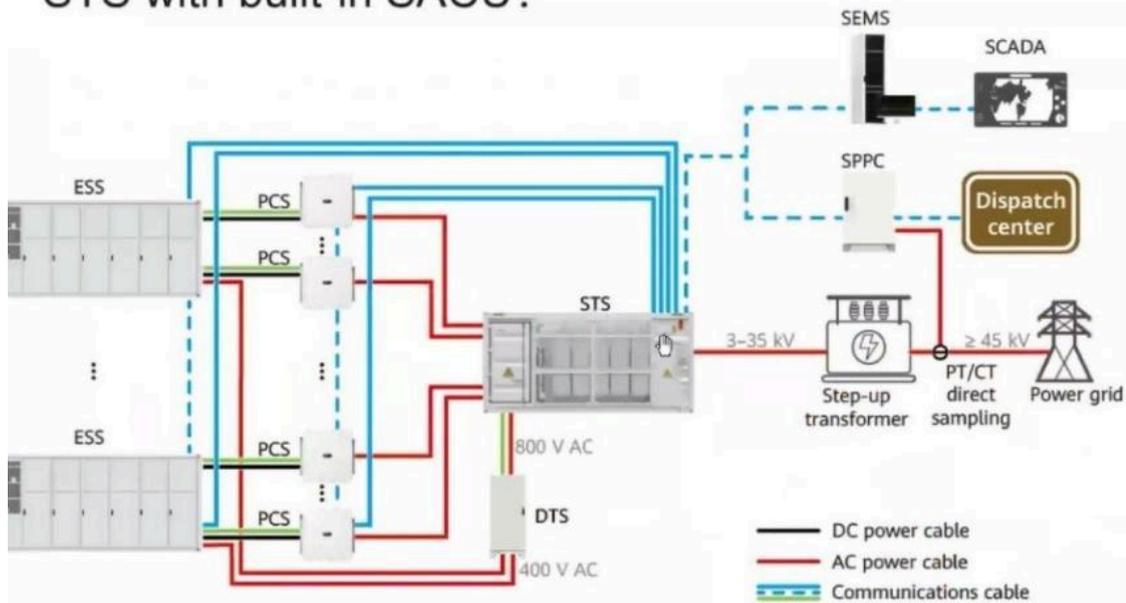

STS with built-in SACU:

Exhibit 9 – Peak load in winter graph

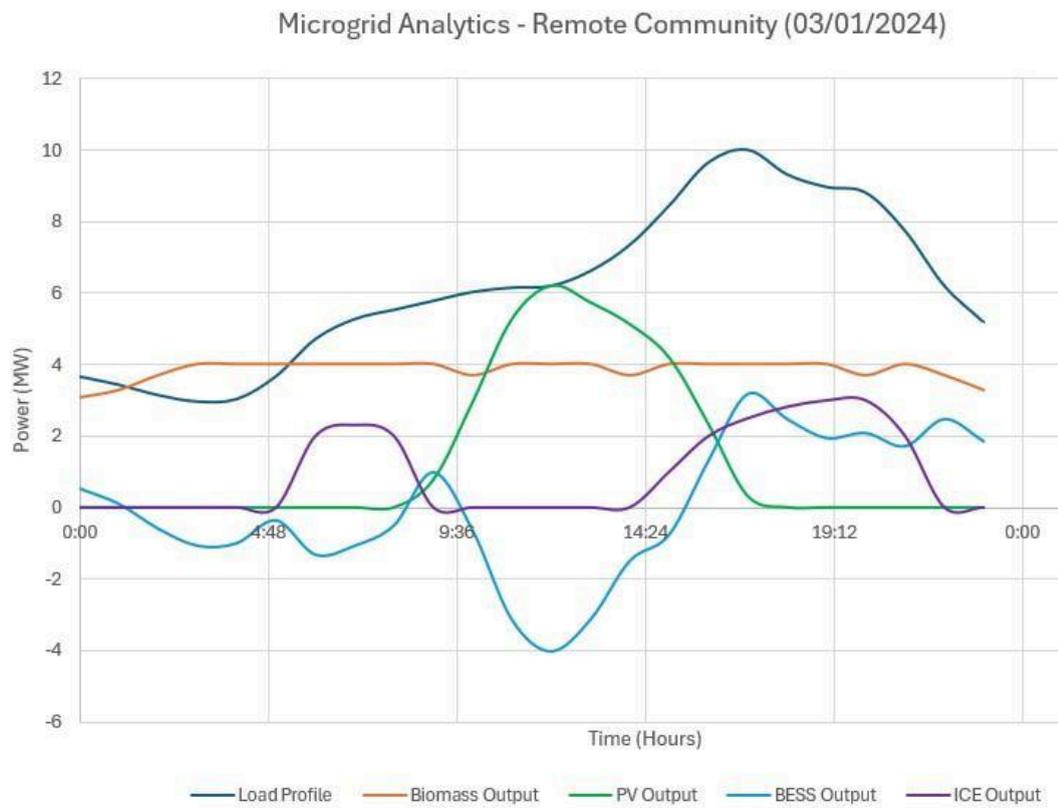Microgrid Analytics - Remote Community (03/01/2024)

Exhibit 10 – analysis of BESS + PV plant vs solely ICE generator use during the day in winter with and without hybrid BESS+PV plant
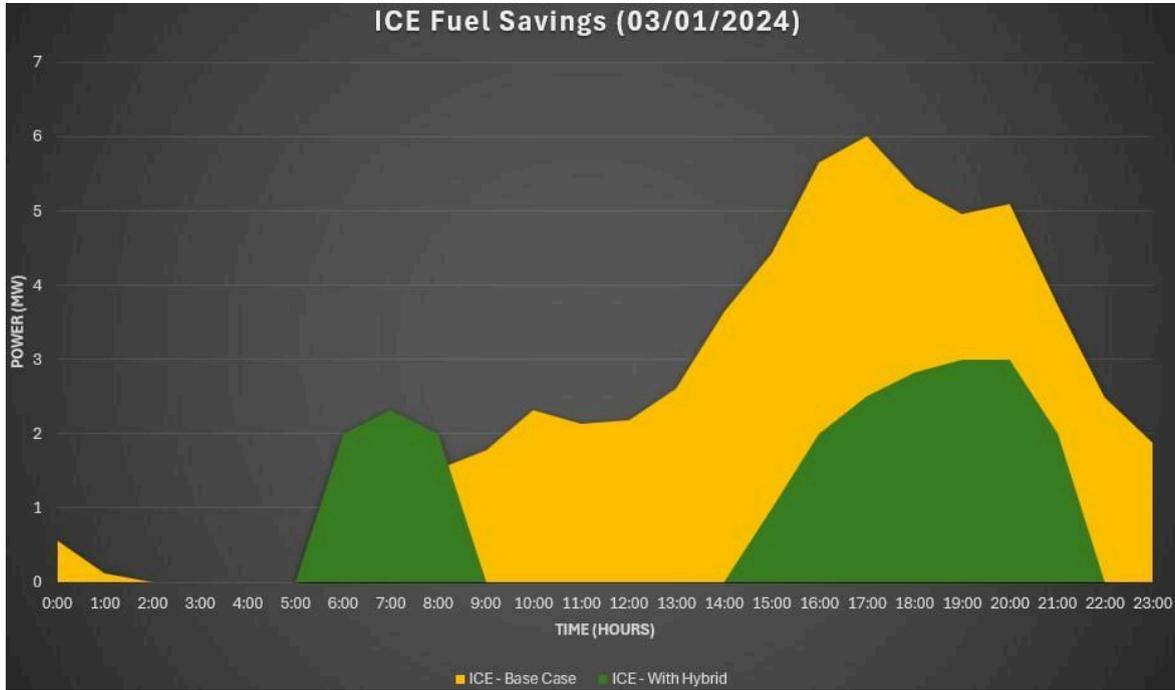
Exhibit 11 – analysis for low load in summer (06/21/2024) taken from Canada's IESO's website
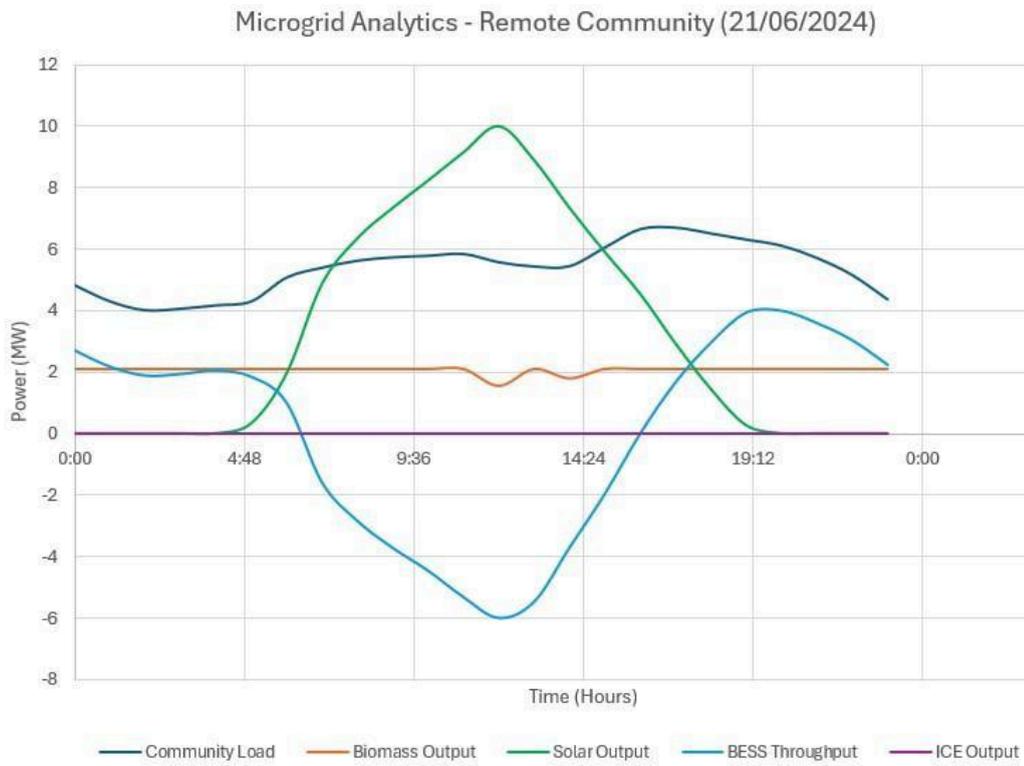
Exhibit 12 – analysis comparing ICE generators during a summer day with and without the hybrid BESS+PV plant

ICE Fuel Savings (21/06/2024)
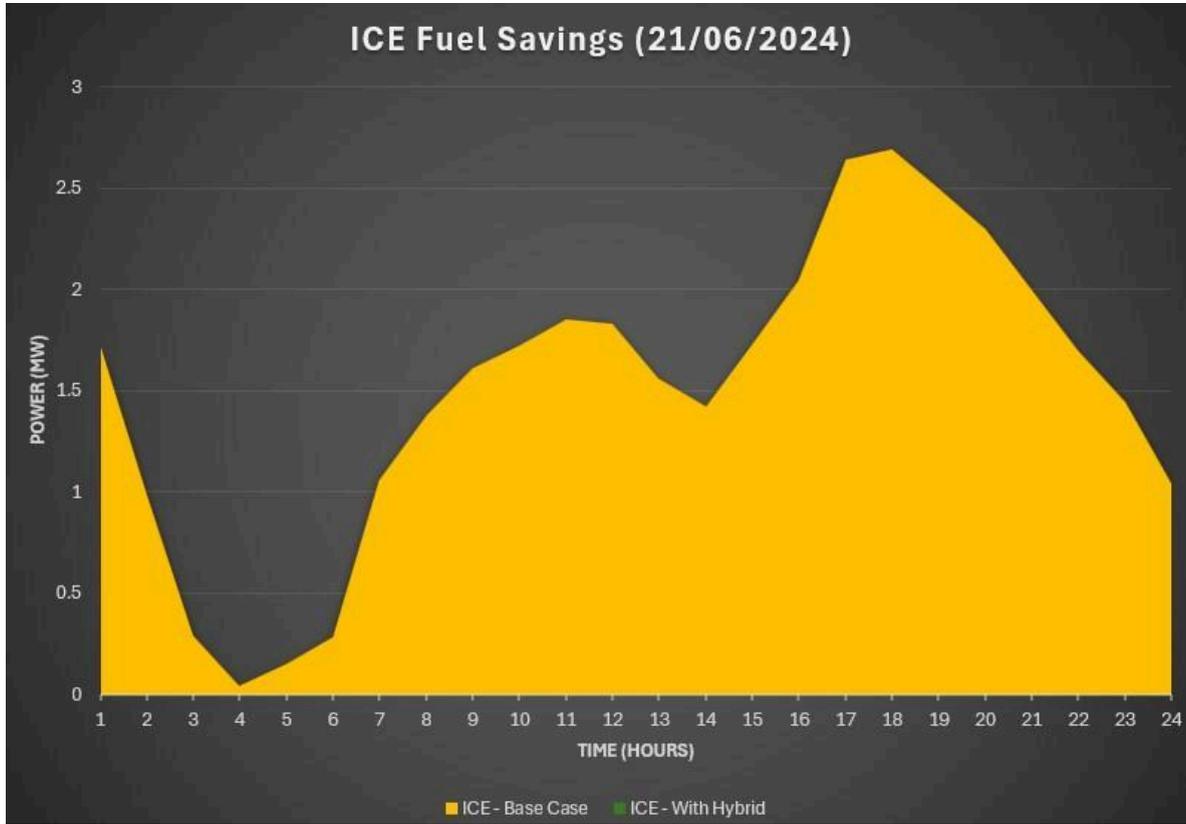
Exhibit 13 – illustration of microgrid controller logic
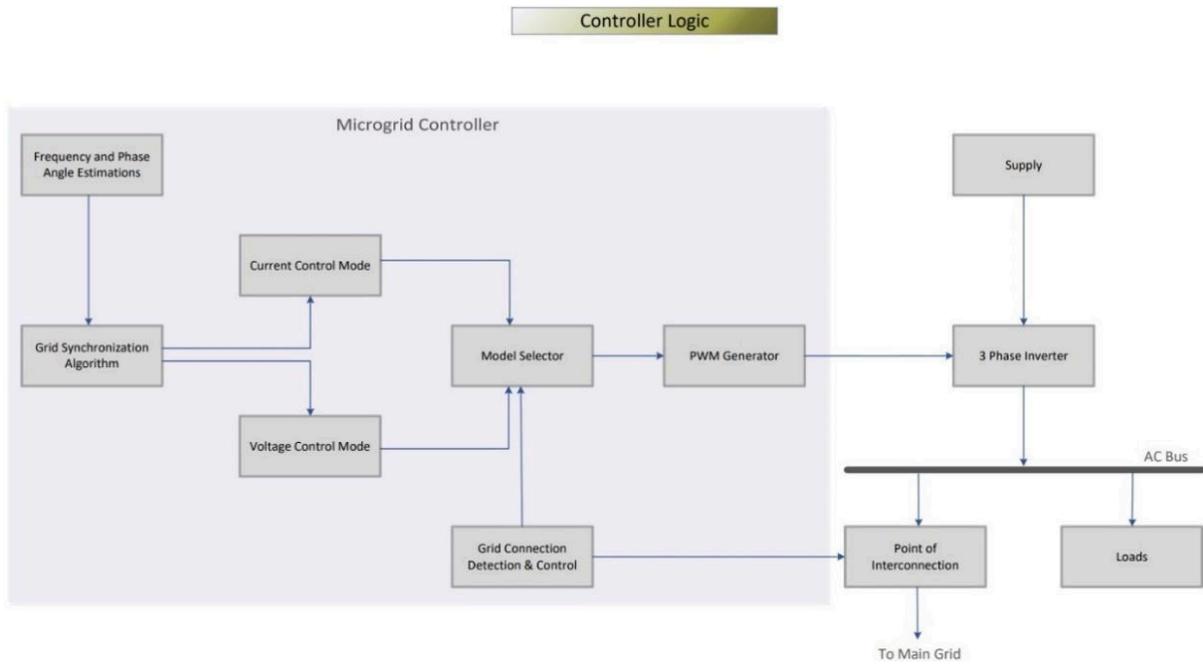
Exhibit 14 – block diagram representation of current control mode
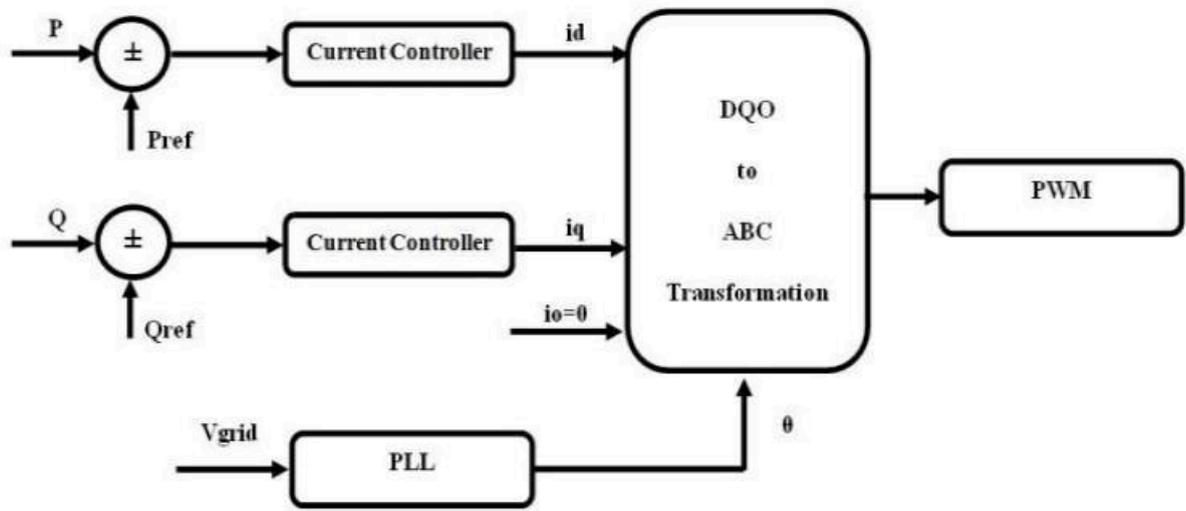
Exhibit 15 – tertiary control algorithm logic between main grid and microgrid

Include Transmission and Distribution Management System (TDMS) with all SCADA, Generation & Transmission (EMS), and Distribution Management Systems (DMS) required to monitor and control the entire project.

The TDMS fully integrates with each subsystem, substation, the Solar generation, the ICE and the BESS local control systems through relevant interfaces.
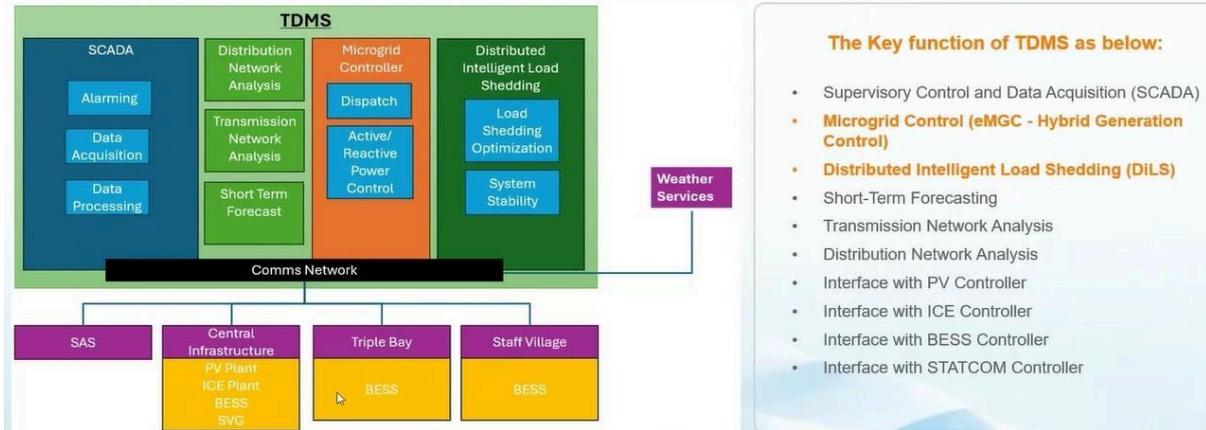
Exhibit 16 – intentional islanding detection sequence
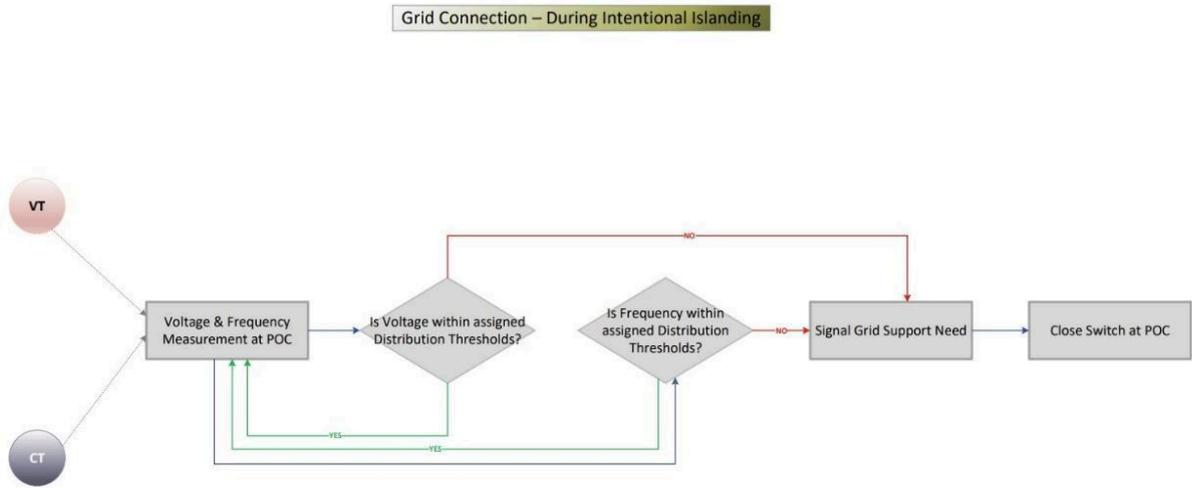
Exhibit 17 – microgrid frequency droop regulation graph
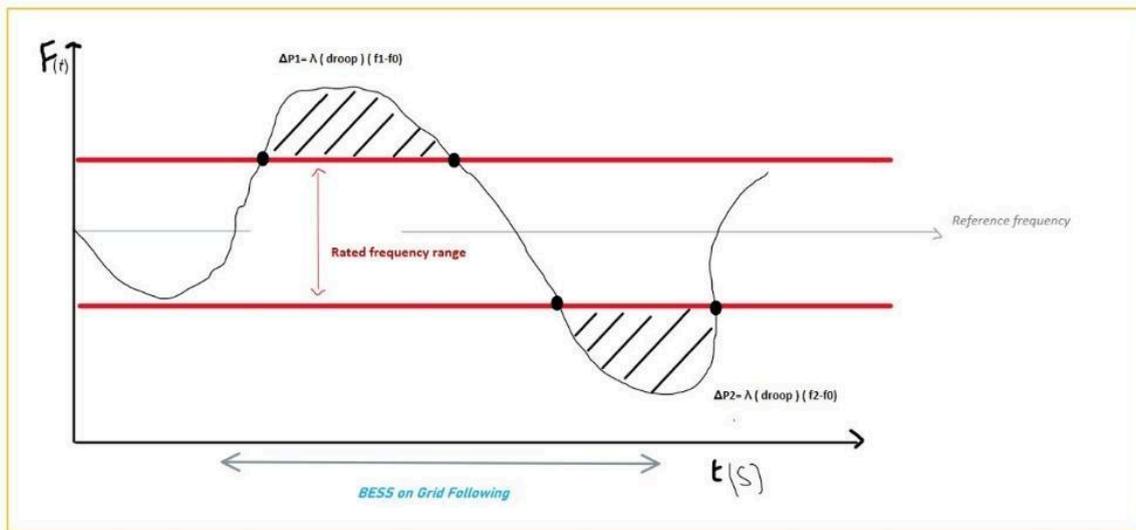
Exhibit 18 – frequency fluctuation for droop and inertial control
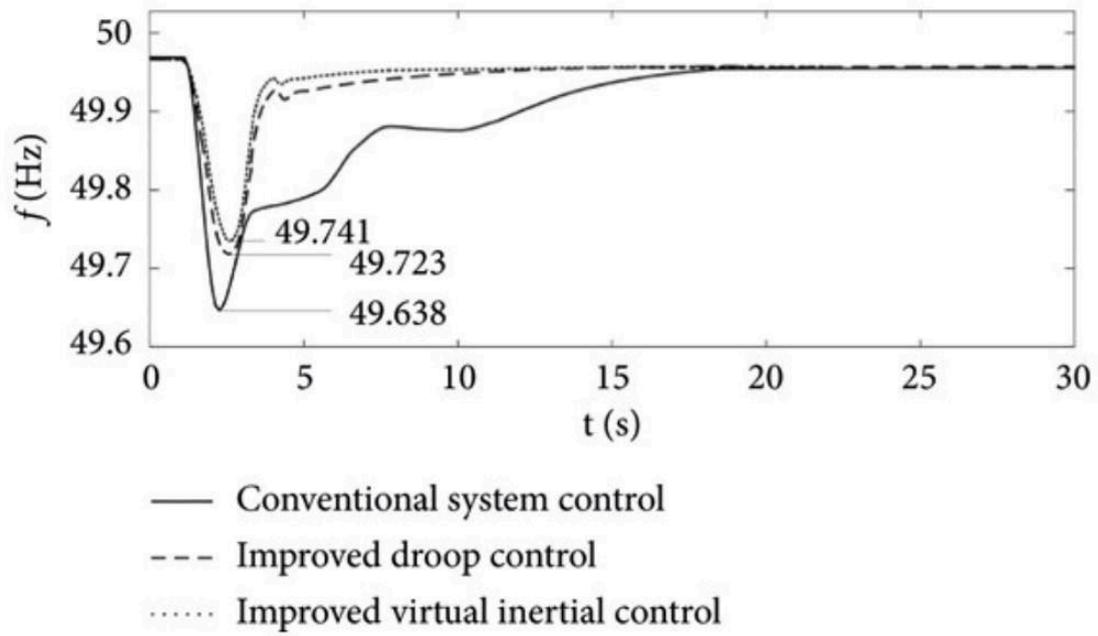
Exhibit 19 – grid forming (GFM) vs grid following event (GFL)
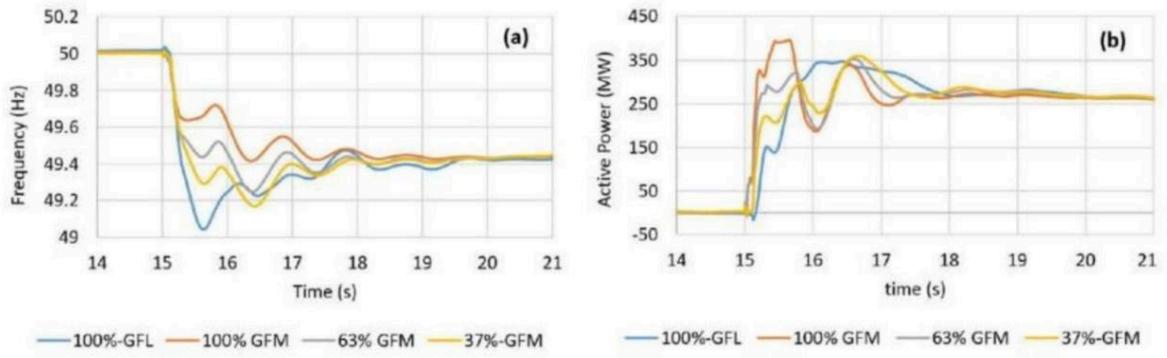
Exhibit 20 – automated generation control (AGC)
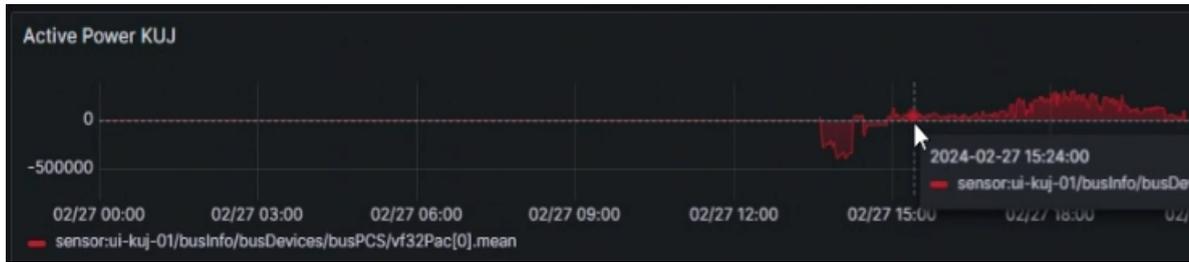
Exhibit 21 – SOC management logic
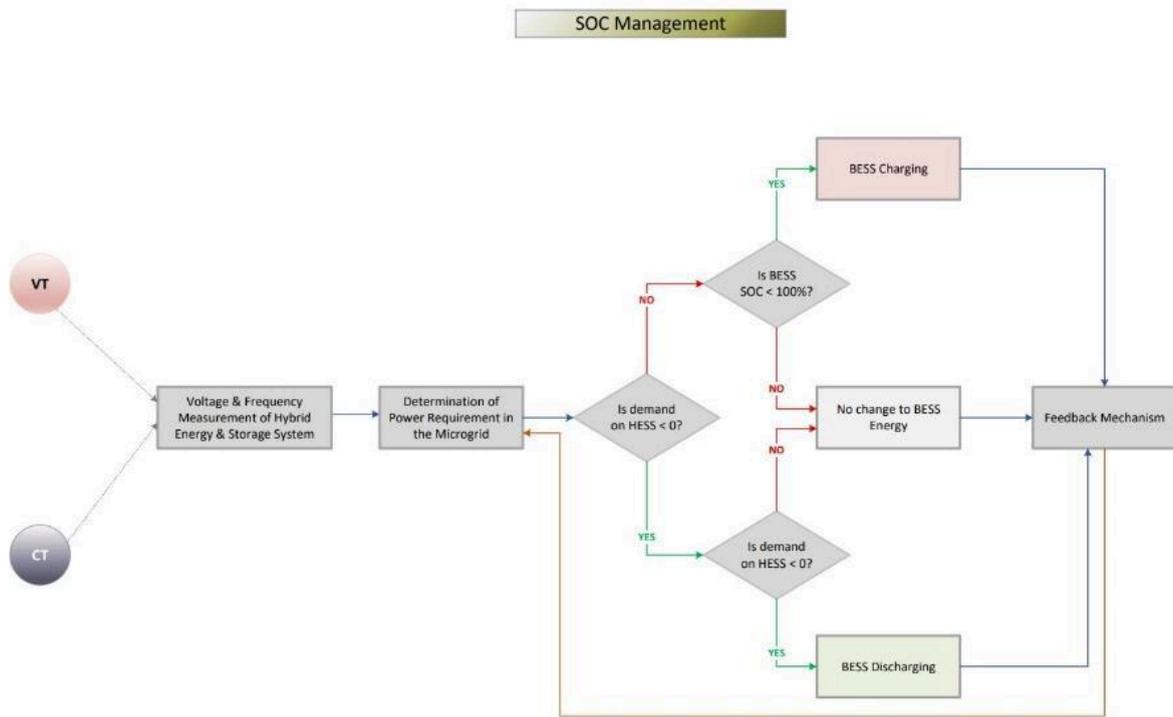
Exhibit 22 – Biogas reactive capability curve
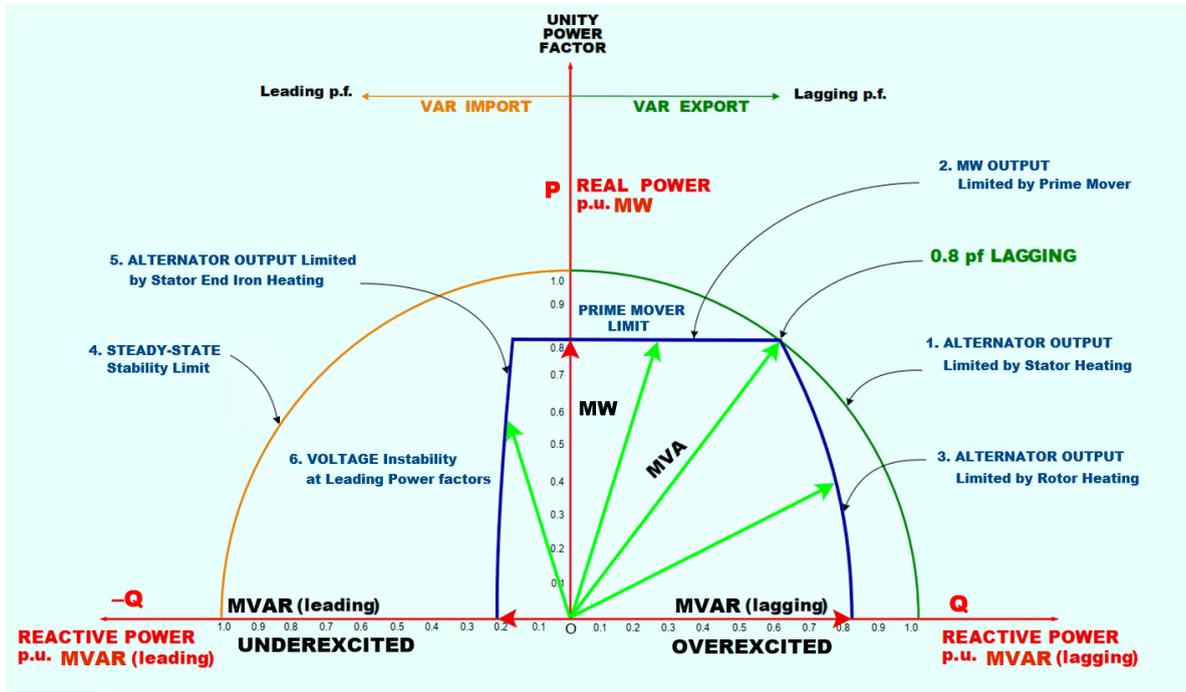
Exhibit 23 – supply leading reactive power vs supply lagging reactive power

Exhibit 24 – PQ curvature of the BESS
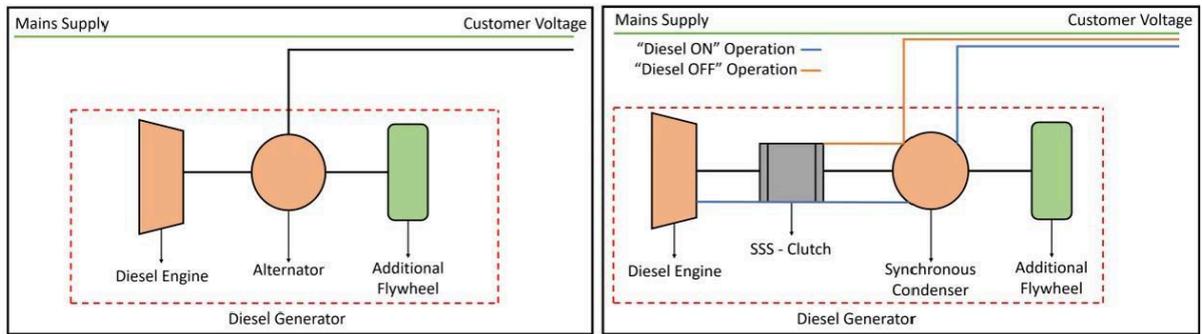
Exhibit 24 – PQ curvature of the BESS
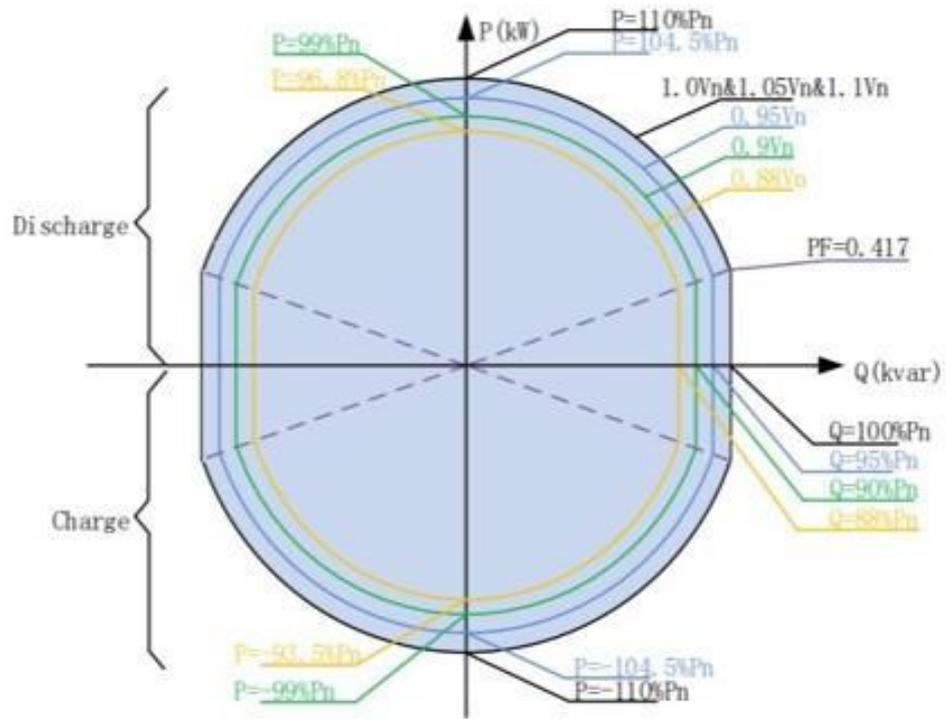
Exhibit 25 – grid forming mode injection/absorption of power damping
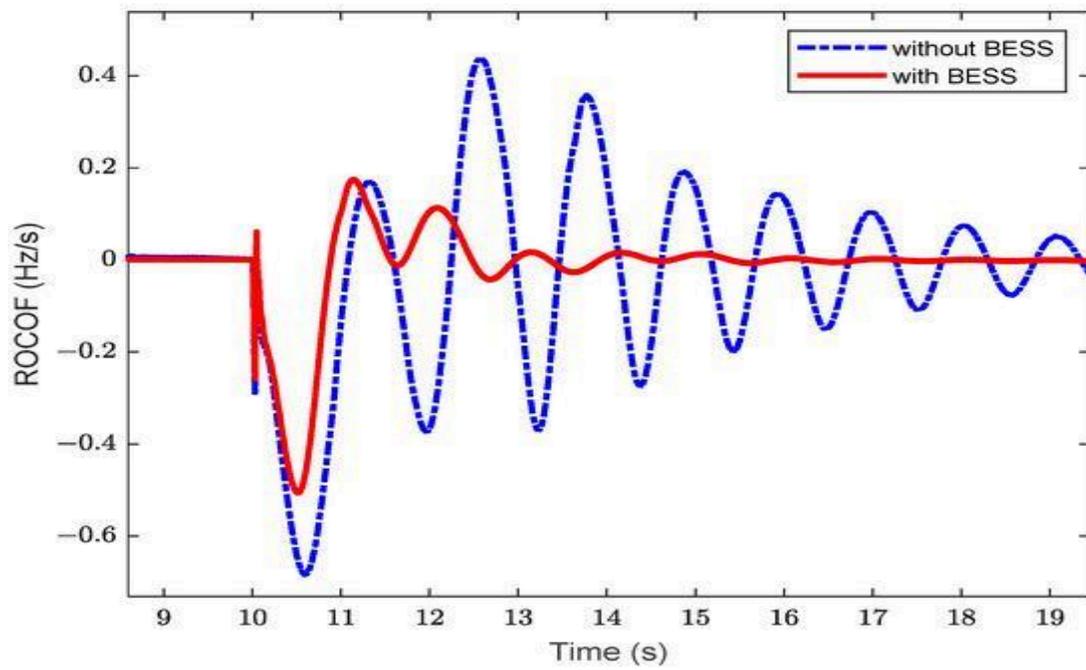
Exhibit 26 – post–grid stabilization sequence diagram
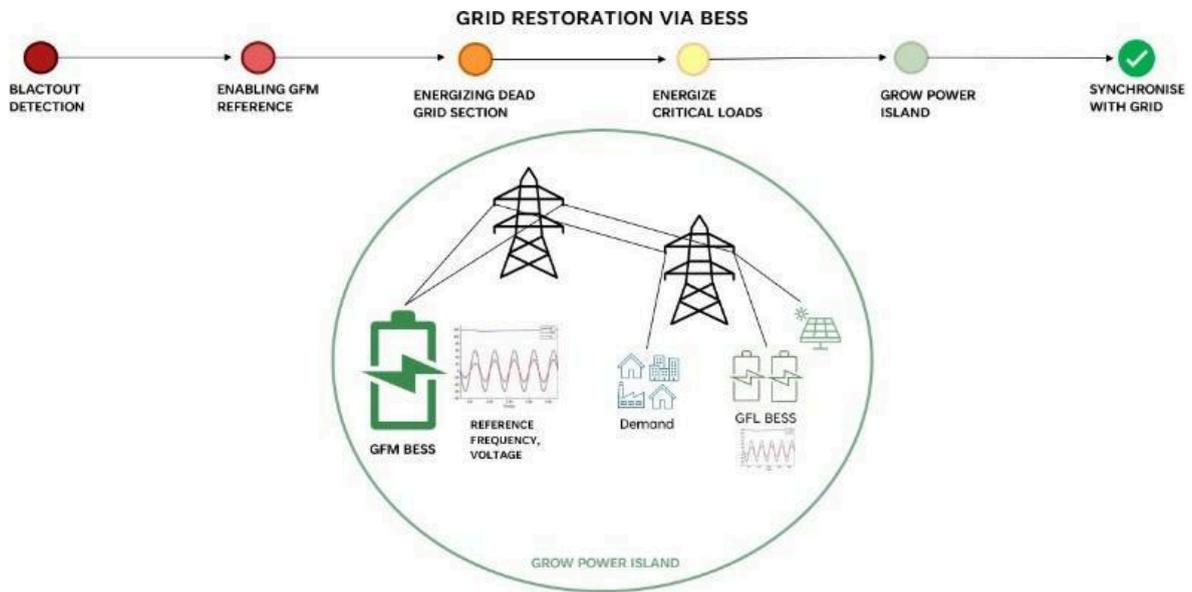
Exhibit 27 – microgrid load restoration sequence graph
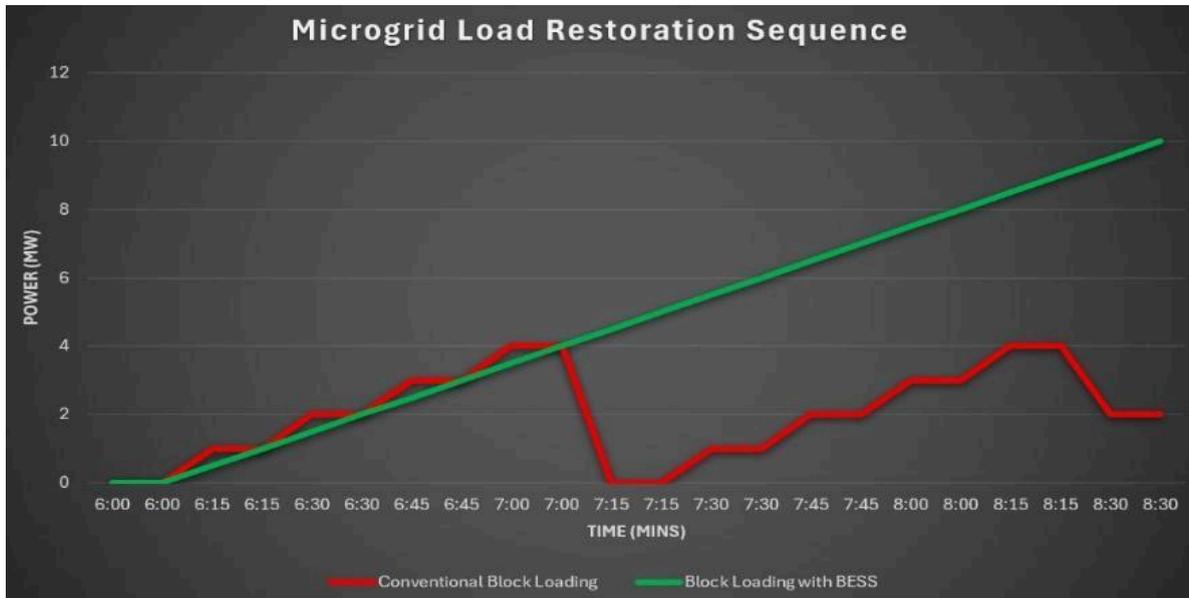
Exhibit 28 – BESS stacking services diagram
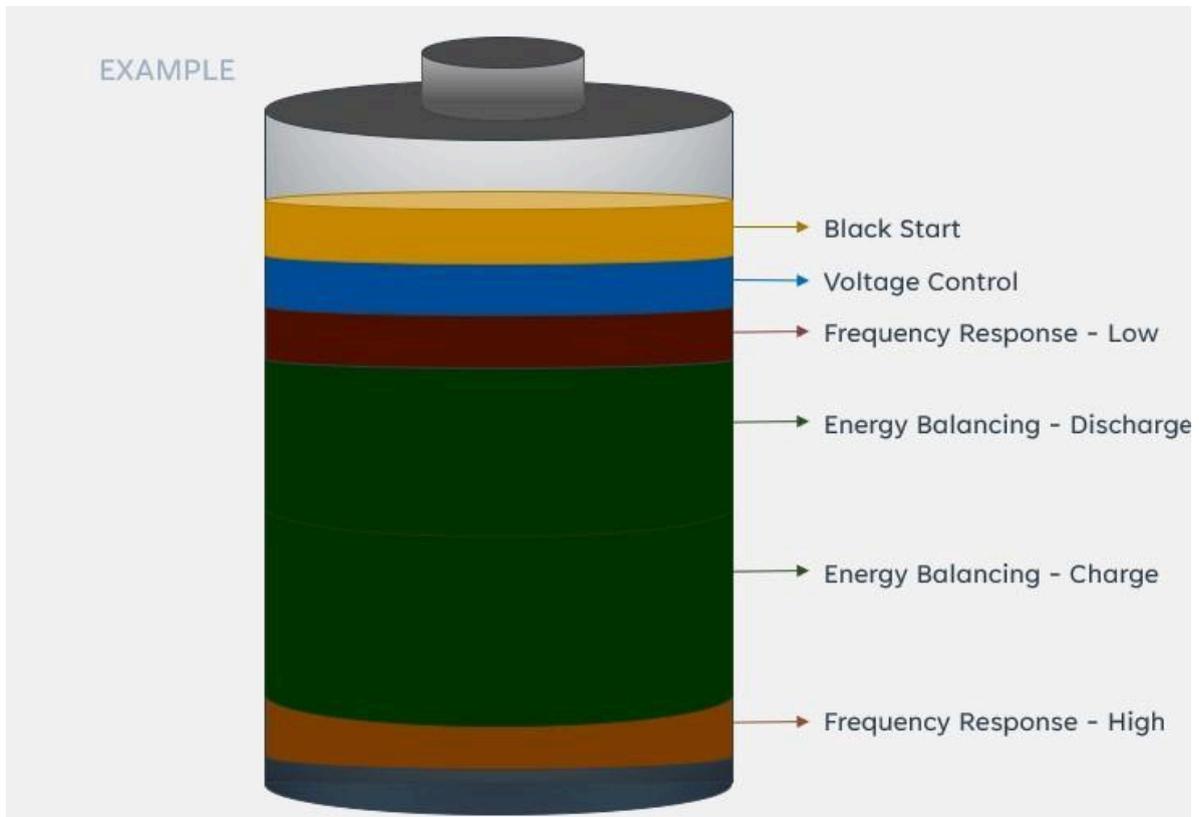
Exhibit 29 – BESS sizing chart & specs

8 MW / 8MWh @ BOL - 1C / 8MW / 32 MWh @ BOL – 0.25C	
Assumptions	
Minimum network voltage	**95%**
Operating Voltage	**690V**
Minimum Power factor	**0.95**
Yearly cycles	**365**
Lifespan	**10 years**
Battery SOH at EOL	**85.1 %**
Beginning of Life (BOL)	
Max Useable Power at POI	**4.61 MW**
(considering P.F. and min network voltage & efficiencies)	
Useable Energy at POI	**8.68 MWh**
End of Life (EOL)	
Max Useable Power at POI	**4.61 MW**
(considering P.F. and min network voltage & efficiencies)	
Useable Energy at POI	**7.36 MWh**
Assumed balance of plant efficiencies[1]	
AC & DC Cable	**99.50%**
Auxiliary XFMR	**98.00%**
Step-Up XFMR	**99.37%**

Exhibit 30 – BESS useable energy chart
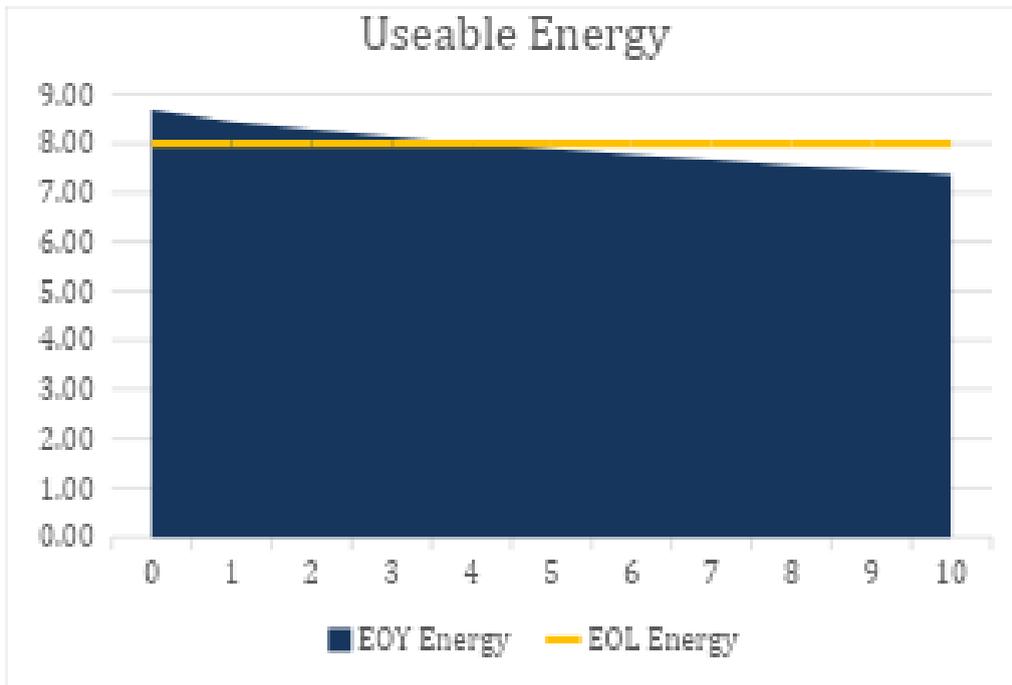
Exhibit 31 – ROI payback curve (all scenarios)
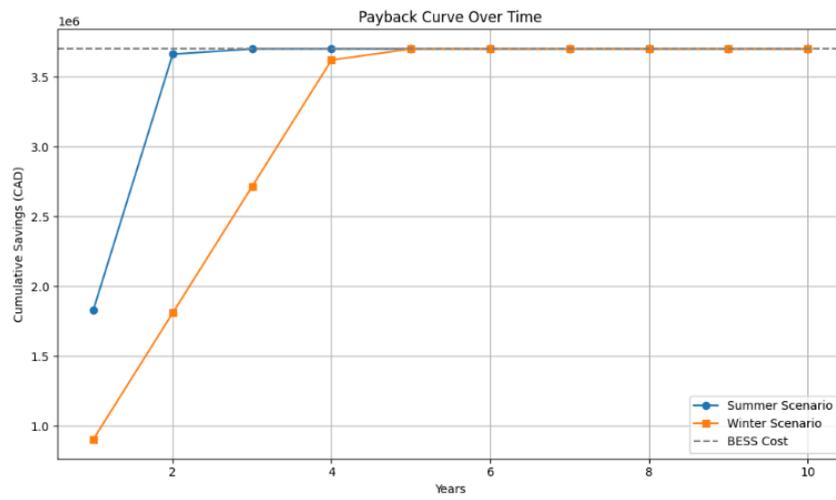
Exhibit 32 – ROI payback curve (mixed seasonal scenario)
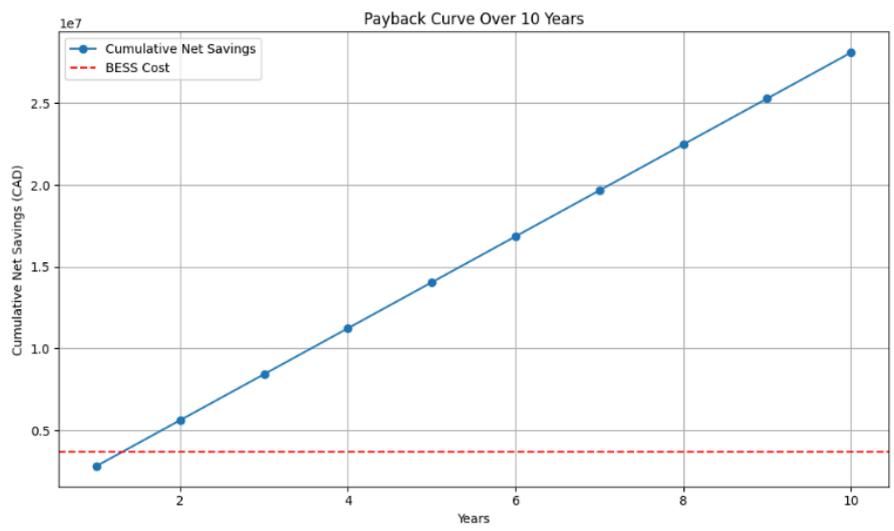
Exhibit 33 – ROI comparison by scenario
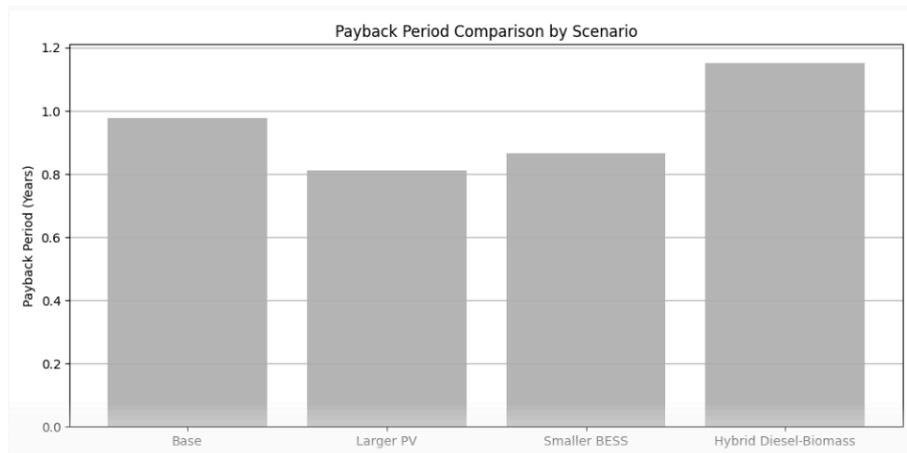
Exhibit 34 – PCS sample data sheet (EPC CAB1000)

CAB1000 / AC

Up to 1500 VDC
Utility Grade Storage Inverter
Scalable from 1 to 6 MW

Return on Investment
- 99% max conversion efficiency
- Low shipping & installation cost
- Easy to move - no crane required

Modular / flexible configuration
- Configurable up to 6 MW
- Individual AC connections or combined throat
- Modular 1-1.5 MW blocks

Simple O&M
- Easy to maintain
- Modular design with low component count
- Extended warranty available

Advanced Technology
- High DC side short circuit capability
- Advanced grid support features including 4-quadrent control and VSG
- Fast seamless transition and fast response time
- Blackstart
- Harmonic dampening

One inverter for all uses
- Frequency regulation (FFR)
- Renewables capacity firming
- Load leveling (Energy time shifting)
- Parallel UPS functionality
- Synthetic inertia
- Micro-grids
- Bi-direction DC source

CAB1000 Overview

The CAB1000 scalable platform has been developed to offer a straightforward and simple solution to developers of Utility-grade energy storage systems for both UL and IEC markets.

CAB1000 offers a scalable and modular building block for systems of all sizes. With world-class power density and easy to install design, your energy storage system will be commissioned quickly and safely.

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January 2023

epcpower

CAB1000/AC - 3L.2 | Model 50-100181
Bidirectional Energy Storage & Microgrid PCS

epcpower

AC						
	AC configuration | max. cables per phase (1)	3-wire (3P3W) | 6 x 600 kcmil or 6 x 300 mm²				
	Nominal AC voltage (+/- 10%) (2)	480 VRMS	600 VRMS	630 VRMS	660 VRMS	690 VRMS
	Nominal AC current (export/import)	1255 ARMS				
	AC export/import capacity @ 40°C (3)	1043 kW	1304 kW	1369 kW	1435 kW	1500 kW
	Max overload capacity @ 40°C, starting from 66% full load (8)	120 % for 2 sec and 110 % for 5 min				
	Reactive power capacity (4), (5)	Power Factor 0,8...1 leading/lagging				
	Allowed grid short ckt. current ratios	Current mode: >4 | Voltage mode: all				
	Max. fault current allowed from AC source	100 kA (AC RMS) throated version | 180 kA (AC RMS) non-throated version				
	Normal frequency range	50 / 60 Hz (configurable)				
	Harmonic distortion	UL1741 / IEEE 1547, <2% TDDI at rated power per IEEE 519 <3% according to VDE-AR-N 4110/4120				
	Efficiency (@ 690 VAC): Peak | CEC | Euro	98.8% | 98.4% | 98.5%				
DC	DC voltage range, maximum (6)	720 - 1500 VDC	900 - 1500 VDC	945 - 1500 VDC	990 - 1500 VDC	1035 - 1500 VDC
	DC voltage range, at nominal power (6)	761 - 1200 VDC	951 - 1500 VDC	999 - 1500 VDC	1046 - 1500 VDC	1094 - 1500 VDC
	Recommended minimum battery voltage	1,65 x nominal AC voltage				
	Maximum DC current	1400 ADC				
	Max. fault current allowed from DC source	180 kA (with internal DC fuses, per input)				
	Number of DC inputs | max. cables per pole	1 | 8 x 600 kcmil or 8 x 300 mm²				
	Max. deviation of DC voltage between parallel units	150 VDC				

Environmental		
	Ambient temperature (operation)	-20°C to 60°C (-40°C as option)
	Ambient temperature (storage)	-40°C to 60°C
	Relative humidity	5 to 100% non-condensing
	Protection degree	Outdoor: IP55 / NEMA 3R. Salt fog kit available for coastal sites.
	Max elevation	3,000m+ [9,842 ft.+] (Consult EPC for any higher elevation)
	Max noise level (A-weighted equivalent)	<70 dB @ 3m
	Seismic	ICC-Es AC 156 Sds @ 1.35 G
	Altitude derating (current)	10% per 1,000m above 1000m elevation
	Temperature de-rating	1.7% per degree °C from 40-55 °C

Cabinet		
	Maximum dimensions (H x W x D)	mm: [2281 x 1000 x 1636] in.: [89.8 x 39.4 x 64.4]
	Weight	1370 kg [3020 lb.]
	Mounting	Pad mount / skid mount
	Cooling	Hybrid liquid / air, temperature controlled

Certifications		
	Safety	UL 1741 | C22.2 No. 107.1-16 | IEC 62477-1, IEC 62909-1
	EMC	FCC Part 15 subpart B | IEC/EN 61000-6-2, 6-4 | EN 55011 | CISPR 32; CISPR 11 | IEEE C37.90.2
	Utility interconnect	UL 1741 (SB) | IEEE 1547-2018 | CA Rule 21 | Hawaii Rule 14 | AS4777.2 | VDE-AR-N 4110/4120/4130 | EN 50549-2

Protections		
	AC disconnection	Contactor
	DC disconnection	Motorized disconnect
	AC fuses | DC fuses (7)	2 x 1000 A, 200 kAIc (24kA SC min) | 3 x 750 A, 210 kAIc (20kA SC min)
	AC | DC surge protection (SPD)	Type 2 (Optionally Type 1-heavy duty) | Type 1-heady duty
	Safety features	F-stop, AC / DC overvoltage, AC timed overvoltage, inst. & timed overcurrent, overtemperature (both instantaneous and time-overload), condensation, etc.
	Ground fault detection (optional)	IMD

Control		
	Control interface	CAN, Modbus TCP/IP
	Command latency	1 ms (CAN), 3 ms (Modbus TCP/IP)
	Response time; (time to accomplish full power step)	down to 2 ms; adjustable longer via parameters
	On-off grid transitions (optional)	Yes | UPS mode available
	Black-start capable (optional)	Yes; requires external control power
	Grid-tied control modes	Voltage mode | PQ (power) | DQ (current) | cos φ (pf) | STATCOM
	Grid-support functions	Active/Reactive control | Volt/VAR | Hz/Watt | Volt/Watt | L/HVRT & L/HFRT | Inertia | ramp rate, etc.
	Islanded control modes	V&f | droop control | VSG | Ok to parallel with other sources
	Island overload avoidance	active inrush limiting for starting large loads
	Control power voltage	208 V 1-ph 60 Hz or 240 V 1-ph 50 Hz
	Self-consumption: Abs. Max. | Typ. 100% load, 30C | 50% load, 30C [standby]	2400 W | 1500 W | 1200 W [160 W]

Exhibit 35 – DC block specs

EVLOFLEX BESS specifications

System performance
- Configurable energy for 1.65 MWh, 2 MWh, or 2.5 MWh
- Grid frequency of 50Hz and 60Hz (configurable on the PCS)
- Cooling system HVAC air cooled
- Battery chemistry: Lithium-iron phosphate (LiFePO)
- Front-of-meter or behind-the-meter configuration

Safety features
- Meets NFPA855 standards
- UL9540 certification
- UL9540A tested (cell, module, unit)
- Active ventilation on all our products per NFPA 69
- Fast-acting H2 gas detector

Enclosure & environment
- Enclosure dimensions, excluding HVAC: 6.1 x 2.44 x 2.90 m (20 x 8 x 9.5 ft)
- Operating temperature range: -40°C to +55 °C (-40°F to 131°F)
- Rating meets IEEE 693 requirements for seismic events

Energy Management System EVLOGIX
- Powerful EVLO-tailored IoT infrastructure
- Onsite and remote supervision and control
- Utility-grade SCADA security for industrial operations
- Compatible with all industrial protocols for connecting to external entities

Exhibit 36. Efficiency of PV+BESS systems

Power Technology	Efficiency (%)	Required Throughput (MW)	Installed Capacity (MW)
PV	35	10	29
BESS	89	6.5	8.32

Exhibit 37. Bill of supply

8MW/8 MWh @ EOL			
Supply of BESS1 – (CAPEX)	Qty	Price (CAD)	$/kWh
DC BLOCK– Battery containers and selected options	4	3 700 000.00 $	To be calculated
Power conversion systems EPC Power CAB1000 3L.2	4		
EMS panel (to be installed in Owner's building), including software	1		
PCS Option: Arctic Package (–20°C to –40°C) and Black–Start	Included		
EMS panel option: Local HMI	Included		
Factory acceptance test	Included		
Commissioning and Site Acceptance Tests (See Appendix C)	Included		
Optional – (CAPEX)			
5 Years Extended Warranty	1	TBC	
Spare parts	Lot	TBC	
Service – (OPEX)			
Long term service agreement	TBC	TBC	
Training	–	TBC	
Logistics			
Delivery to site – DDP	Lot	TBC	

Note: The prices provided are for informational purposes only for the case study and in no way reflect the actual BESS equipment used in this document

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Exhibit 38. Replacing diesel with clean energy reduces environmental impact while dramatically lowering energy costs.

Utilization Rate	Annual Cycles	Annual Energy (MWh)	Total Energy (10 yrs)	LCOE (CAD/kWh)
Low (0.5x/day)	183	1,464	14,640	0.2527
Moderate (0.75x/day)	274	2,192	21,920	0.1688
Base Case (1x/day)	**365**	**2,920**	**29,200**	**0.1267**
High (1.5x/day)	548	4,384	43,840	0.0844
Aggressive (2x/day)	730	5,840	58,400	0.0633

Exhibit 39. Remote Canadian communities' energy costs:

Fuel Type	Avg Cost (CAD/kWh)	Details
Diesel	$0.56–$1.12	High OPEX, emissions, delivery issues
LNG (Alternative)	$0.25–$0.50	Cleaner but infrastructure-dependent
Hybrid BESS + PV	$0.08–$0.45	Renewable, scalable, climate-adapted

Exhibit 40. Payback Curve Over 10 Years: Mixed Seasonal Results

Metric	Value
Winter Fuel Savings	$979,020 CAD
Summer Fuel Savings	$1,905,120 CAD
Total Annual Fuel Savings	$2,884,140 CAD
Annual Maintenance Cost	$74,000 CAD
Net Annual Savings	$2,810,140 CAD
Payback Period	1.32 years
Annual ROI	75.95%

Exhibit 41. Payback Curve Over 10 Years Sensitivity Analysis

Scenario	ROI (%)	Payback Period (Years)
Base (Current Setup)	102.41	0.98
Larger PV (+20%)	123.29	0.81
Smaller BESS (−20% cost, −10% savings)	115.46	0.87
Hybrid Diesel–Biomass (−15% diesel use)	86.75	1.15

Exhibit 42. LTSA Plan: Service Schedule

Frequency	Component	Task
Monthly	Battery Module	Visual inspection, SoC drift analysis, cooling fan check
	PCS & Inverter	Alarm log review, MPPT behavior sampling
Quarterly	System Communication	Ethernet/Modbus signal testing, SCADA interface check
	EMS/Microgrid Logic	Validate islanding, reconnection, and diesel genset support logic
Annually	Battery Diagnostics	SoH test, impedance sweep, firmware patching
	System Integration	Black start simulation, PV/load-following test (if applicable)
Seasonal	Climate Resilience Check	Snow/ice shield check, heater/HVAC tests, environmental sealing

Exhibit 43. Remote Deployment Provisions

Category	Adaptation
Cold Weather	Battery heaters, HVAC redundancy, systems rated for -40°C or colder
Access Limitations	Adjusted SLA windows, local spares, satellite communications
Seasonal Isolation	Preventive work scheduled around freeze-thaw seasons; overstocking before winter
Wildlife & Hazards	Rodent-proofing, permafrost-resistant enclosures, firebreaks
Cultural Alignment	Community consent, Indigenous involvement in O&M, and culturally appropriate training
Grid Independence	Fully autonomous islanding tested semi-annually; backup diesel or hydro interface tested quarterly

Exhibit 44. Remote Deployment Provisions

Category	Adaptation
Cold Weather	Battery heaters, HVAC redundancy, systems rated for −40°C or colder
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Grid Independence	Fully autonomous islanding tested semi-annually; backup diesel or hydro interface tested quarterly

Appendices

Appendix 1. Insights for market selection (US and Canada)

- United States: Larger Scale & Diverse Applications
    - Scale: Over 575 microgrids were operating in the U.S. by 2022, with a total capacity of 7,000 MW, and an additional 3,000 MW under construction 1. The U.S. now tracks over 4,870 microgrid projects in various stages, with total capacity expected to exceed 10 GW by 2026 (Wood Mackenzie, 2025).
    - Drivers: Resilience after natural disasters, energy independence, and decarbonization.
    - Government Support: Strong federal and state-level initiatives, including 53 microgrid-related bills across 21 states in the past six years
    - Policy Shift: As per Pillsbury Winthrop Shaw Pittman LLP (2025) The "One Big Beautiful Bill" (2025) introduces early sunsets and phase-outs for many clean energy tax credits, including:
        - Section 45Y/48E (Clean Electricity Credits) ending for solar/wind after 2027 unless construction begins soon.
        - Transferability restrictions and foreign content limitations that may deter investment.
    - Impact: While existing projects are protected, long-term certainty is reduced, especially for new utility-scale or commercial microgrids relying on federal incentives.
    - Technology: High integration of solar + storage, hydrogen, and smart microgrid controls.
    - Use Cases: Urban resilience, military bases, universities, and commercial campuses.
- Canada: Targeted, Community-Focused Development:
    - Focus: Emphasis on remote, Indigenous, and northern communities—around 300 communities are not connected to the North American grid 1.

- o Government Incentives: Programs like SREPs and CERRC provide significant funding for clean energy and microgrid projects, especially in rural and Indigenous areas.
  - o Grid Emissions: Canada's grid is already 83% emissions-free, so microgrids are often used to replace diesel in off-grid areas rather than decarbonize urban grids.
  - o Innovation: Projects like EVLO's large-scale battery deployment in Quebec show leadership in storage and resilience.
- Feasibility
  - o Canada is highly feasible for microgrids in remote and Indigenous communities, with strong government backing and a clear need.
  - o The U.S. is more feasible for urban, commercial, and industrial microgrids, with a broader market and more diverse applications.
- Advancement
  - o The U.S. leads in scale, diversity, and private sector involvement.
  - o Canada excels in policy-driven, community-focused innovation, especially in clean energy transitions for remote regions.

Appendix 2. Funding – Available incentive from Canadian government

Smart Renewables and Electrification Pathways Program (SREPs):

- Budget: $4.5 billion

- Focus: Supports grid modernization, energy storage, and renewable energy technologies.

- Eligibility: Projects led by utilities, Indigenous communities, and other stakeholders.

Support Includes:

- Funding for transmission and distribution infrastructure

- Energy storage systems

- Indigenous-led clean energy projects

- Timeline: Active until March 31, 2036

Clean Energy for Rural and Remote Communities (CERRC)

- Target: Indigenous and remote communities

- Funding Example: Over $11 million announced in 2025 for 15 projects across Canada

Project Types:

- Solar PV and battery storage

- Biomass and bioenergy systems

- Energy efficiency upgrades

- Feasibility and engineering studies

- Goal: Reduce diesel reliance, improve energy security, and support Indigenous self-determination

 Canada Infrastructure Bank (CIB):

- Clean Power Initiative: $10 billion in financing

- Purpose: Low-cost loans for clean electricity and infrastructure projects, often in coordination with SREPs

 Wah-ila-toos (Clean Energy Hub):

- Target: Indigenous and remote communities seeking clean energy solutions

- Funding Example: Provides coordinated access to multiple federal programs; recent projects include solar and BESS in northern communities

Project Types:

- Feasibility studies and planning
- Clean energy system design and installation (e.g., microgrids with solar and battery)
- Capacity building and community engagement
- Infrastructure upgrades for renewables
- Goal: Simplify access to clean energy funding, foster Indigenous energy sovereignty, and reduce reliance on fossil fuels (Government of Canada, 2024)

NRC IRAP Clean Technology Program:

- Target: Canadian small and medium-sized enterprises (SMEs) developing innovative clean technologies for commercialization
- Funding Example: Offers up to 60−80% reimbursement of eligible R&D costs, capped at $500,000 over 24 months

Project Types:

- Early-stage clean tech R&D and prototyping
- Demonstration and scale-up of proven technologies
- Commercialization support and market readiness
- Collaborative innovation with ecosystem partners
- Goal: Accelerate the development and adoption of clean technologies that deliver measurable environmental benefits and economic growth (National Research Council Canada, 2025)

Global Initiative on Transitioning Remote Communities to Renewable Energy:

- Target: Remote and off-grid communities worldwide, including Indigenous and isolated populations
- Funding Example: Canada contributed $500,000 in 2025 to support Phase 2 activities in partnership with IRENA

Project Types:

- Development of case studies on successful renewable energy business models

- Country-level assessments of renewable energy potential in remote areas

- Technical workshops and training for community members and policymakers

- Knowledge-sharing platforms for planning, installation, and maintenance of clean energy systems

- Goal: Support global energy equity by helping remote communities transition from diesel to renewable energy, improve energy access, and build local capacity through international collaboration (Government of Canada, 2025).
  As evidenced by the above, there is a real trend of investment by Canadian utilities in BESS microgrid projects for remote communities:

- Reducing Diesel Dependence

  o Many remote and Indigenous communities in Canada still rely heavily on diesel generators for electricity. Diesel is expensive to transport, especially by air or seasonal roads, and poses environmental and safety risks.

- Improving Energy Reliability

  o BESS helps stabilize microgrids, manage peak loads, and provide backup power during outages. In islanded mode, BESS ensures continuous power supply even when disconnected from the main grid.

- Enabling Renewable Integration

  o Canada is expanding solar, wind, and biomass in remote areas. BESS allows communities to store excess renewable energy and use it when generation is low (e.g., at night or in winter).

- Lowering Long-Term Costs

  o While upfront costs are high, BESS reduces fuel consumption, generator wear, and maintenance costs. Our previous analysis showed payback periods under 2 years and ROIs over 70% in blended seasonal scenarios.

- Meeting Climate Goals

  o Canada has committed to net-zero emissions by 2050. Replacing diesel with clean energy and storage in remote areas is a key federal and provincial priority. Programs like NRCan's Clean Energy for Rural and Remote Communities support these transitions.

- Empowering Local Communities

o Microgrids with BESS give communities greater energy independence, local job creation, and resilience. Indigenous-led energy projects are increasingly supported through co-development and capacity-building programs.

Appendix 3. Existing Microgrids Projects in Canada

We can reference multiple existing and upcoming microgrid projects existing in Canada for feasibility into expansion efforts as developers, such as the following sites:

Parent, Quebec

Company: Hydro-Québec

Location: Parent, Quebec

Project: Grid-connected

BESS Size: 4 MW / 20 MWh

Purpose: Serve as sole source of grid power during outages

In the remote community of Parent, Quebec, all residents and businesses depend on a single transmission line for electricity. When this line required major upgrades in 2021, maintaining uninterrupted power supply became a critical challenge. To address this, EVLO—a subsidiary of Hydro-Québec—deployed a cutting-edge 4 MW / 20 MWh battery energy storage system (BESS) using its proprietary lithium iron phosphate (LFP) technology.

As the largest energy storage installation in Quebec to date, the system ensured continuous power delivery throughout the upgrade process. Beyond that, it now plays a key role in enhancing grid reliability by acting as a backup power source during outages. This not only ensures consistent service but also reduces the community's dependence on diesel generators, helping to lower greenhouse gas emissions and noise pollution.

Waterton, Alberta – FortisAlberta Microgrid Project

Company: FortisAlberta

Location: Waterton, Alberta

Project: Grid-connected microgrid

BESS Size: 1.5 MW / 5.2 MWh

Funding: Supported by Emissions Reduction Alberta through the BEST Challenge

 Purpose: Provide backup power during outages and improve grid reliability in a remote national park townsite

This project combined solar PV (324 kW) with a battery energy storage system and advanced controls to create Alberta's first utility-scale microgrid. It offers up to 4 hours of backup power, reduces reliance on diesel, and serves as a model for non-wire alternatives in remote communities.

Designed to improve grid reliability in a remote area prone to outages, replacing the need for diesel generators and long distribution feeders and served as a non-wire alternative and a model for future microgrids in Alberta (Emissions Reduction Alberta, 2023)

Goal: Improve grid resilience, reduce diesel reliance, and provide a replicable model for sustainable microgrids

Bella Coola, BC – HARP Project (Nuxalk Nation)

Company: BC Hydro (in partnership with GE, Powertech, and the Nuxalk Nation)

Location: Bella Coola, British Columbia

Funding: Collaborative funding via Indigenous Clean Energy initiatives and innovation programs

Project: Off-grid hybrid microgrid

BESS Size: Vanadium redox battery (capacity not publicly specified)

Purpose: Store intermittent hydro power and reduce diesel use in an isolated Indigenous community

As per GE Newsroom, 2010, the Hydrogen Assisted Renewable Power (HARP) project integrates run-of-river hydro, vanadium redox battery storage, and hydrogen fuel cells. It reduced diesel consumption by over 52,000 gallons annually and cut GHG emissions by 600 tons, while showcasing a replicable model for 30–40 other remote communities.

Appendix 4. Considerations for Risk

Permitting

Issues may arise with jurisdictional overlap for permitting AHJs. Remote indigenous or federal lands may require special permits or community agreements.

Environmental assessments must be conducted under more stringent lenses in ecologically sensitive areas.

- Noise attenuation: In urban areas, project may not operate within the AHJ's permitted noise levels at peak operation levels. In more rural areas, this concern is mitigated with no neighboring restrictions on noise.
    - o Per Canada Occupational Health and Safety Regulations, Part VII – IPG-074, prescribes that the noise exposure level (Lex, 8) of an employee shall not exceed 87 dBA for 8 hours in any 24-hour period. Any worksites near by the BESS installations must consider installation of noise attenuation methods such as acoustic barriers, which ultimately add to the CAPEX of the project.
- Environmental Impact Assessment: to be conducted by third-parties to be submitted at the time of the permit for AHJ review/approval.
    - o Must adhere to standards under the Canadian Environmental Assessment Act, 2012.
        - ▪ Community/public notice is required to be published with a 20-day public comment period upon completion of the study
        - ▪ The Canadian EPA mush decide if the environmental assessment is required within 45 days of the posting the notice of consideration to the registry.
            - Any comments received from the public w/in 20 days after posting the project description summary online get submitted to the agency
            - Minister of the Agency has 60 days to determine recommendations to the project, inclusive of mitigation to adverse environmental effects.

    o Environmental Review Process: An environmental review process (ERP) is in place for projects on reserve land to assess potential harmful environmental effects and their impact on Indigenous peoples' health, social and economic conditions. This process also seeks ways to reduce impacts and ensure compliance with federal laws, regulations, and standards.

- First Nation Community Review/Approval Canadian indigenous community permit requirements. Entering or working on Indigenous lands in Canada generally necessitates respecting the laws and protocols of both the Canadian government and the relevant Indigenous community. Considerations include:
    - o Respecting indigenous authority and the duty to consult
        - ▪ Self-governance: Many Indigenous communities in Canada have negotiated self-governance agreements that define their authority over their lands and resources.
        - ▪ Duty to Consult: The Canadian government, and in some cases provinces and territories, have a constitutional duty to consult with Indigenous groups when considering actions (including funding projects or issuing permits) that may adversely impact their established or potential Aboriginal and/or treaty rights. This is based on Section 35 of the Constitution Act, 1982.
        - ▪ Meaningful Consultation: This duty requires:
            - Providing notice and information about potential impacts.
            - Consulting on necessary studies to assess adverse impacts.
            - Engaging in good faith, being responsive, and taking Indigenous perspectives into account.
            - Attempting to minimize or mitigate adverse impacts.
            - Demonstrating a willingness to make changes based on consultation outcomes.
            - Consent: While not always legally required, securing free, prior, and informed consent is increasingly seen as crucial, especially for projects on Aboriginal title lands.

o   Navigating land use and development

- Lands-related Permits on Indian Lands: Permits are required for the use of specified reserve land for particular interests for a limited time.

- The federal Crown grants these permits based on a band council resolution or agreement with individual locatee(s).

- Negotiating terms and verifying proposed usage with the First Nation or locatee(s) are crucial steps before submitting the permit application.

- The process also involves departmental review and approval, registration in the Indian Land Registry, and sending the registered permit to the permittee, First Nation, and locatee(s) (if applicable).

- Impact Benefit Agreements (IBAs): These are legally binding contracts negotiated between Indigenous communities and resource developers. They outline the terms of the relationship, how impacts will be addressed, and how benefits will be shared.

- Entering reserve land: For activities like surveys, it is essential to obtain written permission from the Band Council or relevant authority to enter the reserve before commencing work.

- Construction: Construction projects on reserve land require permits, and adherence to the appropriate building codes is crucial to ensure safety and avoid potential liabilities.

In essence, navigating permit requirements related to Indigenous communities and lands in Canada requires a nuanced approach, acknowledging Indigenous self-governance, adhering to the duty to consult, and engaging in respectful and meaningful consultation processes. It's crucial to research the specific requirements of the relevant Indigenous community and consult with them directly to ensure compliance and build positive relationships.

Logistics

Many of these remote locations are inaccessible by road, with winter conditions notoriously harsh for air and sea travel. Extra consideration must be given for the following conditions:

- Limited site access: seasonal road closures, ferry-only access, or airlift-only delivery may delay maintenance or part replacement.
- Extended mobilization time: Technicians may require days—not hours—to reach the site, so response time SLAs should reflect this.
- On-site spares: Critical components (e.g., fuses, relays, BMS cards) should be stored locally to avoid long lead times.

Communications & Monitoring

With the remote location of these projects, it is paramount to assure continued remote monitoring and connectivity to the sites to mitigate adverse operation or failure modes.

- Connectivity constraints: Satellite or low-bandwidth internet may limit real-time monitoring or remote diagnostics.
- Edge computing: Deploy local data logging and control redundancy in case of communication loss.
- Cybersecurity: Remote sites are more vulnerable to physical tampering—ensure hardened enclosures and secure protocols.

Environmental Concerns

- Extreme temperatures: Cold climates may require battery heating systems.
- Wildlife & vegetation: Rodent-proofing, vegetation management, and fencing are essential for system integrity.
- Natural hazards: Design for seismic activity, flooding, or wildfires depending on geography.

Human Capacity & Training

With small populations, it is important to establish the following labor and educational systems:

- Local operator empowerment: Train community members or local staff to perform basic diagnostics and resets.
- Simplified HMI: Interfaces should be intuitive and multilingual if needed.
- Remote support protocols: Include video-assisted troubleshooting and escalation workflows.
- First responder Emergency Action Plans in case of fire
- Developer to submit at time of permit:
  - Emergency Action Plan with adherence to OSHA standards
  - Routine maintenance schedule per OEM recommendation for filter replacements, de-icing, liquid-cooling agent replacement, and all routine maintenance recommendations from NREL.
  - Decommissioning plan of the system per recommendations from DNV

Energy Security & Redundancy:

- Black start capability: Critical for remote sites with no grid fallback.
- Hybrid integration: Diesel gensets, solar, wind, and BESS must be coordinated for seamless transitions.
- Load prioritization: Define critical vs. non-critical loads in EMS logic.

Fire Protection and Suppression Risk Mitigation:

- System OEM to provide UL9540A results for AHJ review/approval at time of permit application.
- BESS to undergo Large Scale Fire Testing at certified NRTL under standard: CSA TS-800:24 (TS-800) to assure adequate system performance under conditions of external fires

- Under recommendations to NFPA 855, section 2.3, chemical-based suppression to be bypassed in lieu of external water supply for first responders to use for thermal suppression for explosion mitigation
    - Site selection to consider adequate water storage/capacity
- NFPA 68 compliance to meet vent deflagration to mitigate explosion in severe failure of thermal runaway propagation
- NFPA 69 compliance to assure industry standard

Electrical Protection for hazard/fault mitigation:

- System and site design to adhere to Canadian Electrical Code, CSA 22.1, for all medium voltage terminations, up-stream of grid line-side/bus taps, overcurrent protection, arc flash calculations/signage, and grounding designs of the systems.
- IFC 1207 ESS standards to be adhered to for site design requirements such as setbacks, clearances, and torquing requirements.
- For feeder protection, integration with SEL-751 relay for industrial and utility feeder protection, with conventional/low-energy analog (LEA) current and voltage input support, flexible I/O options, easy mounting, and fast settings.
- Compliance with EC 61850 Edition 2.1, IEC 60870-5-103, the IEC 62439 Parallel Redundancy Protocol (PRP), EtherNet/IP, the Rapid Spanning Tree Protocol (RSTP), the IEEE 1588 Precision Time Protocol (PTP), Modbus, DNP3, and other protocols.
- AC disconnect implemented within site design per Ontario Electrical Safety Code – Electrical Safety Authority Bulletin 64-6-4 Page 1 of 4 Bulletin 64-6-4PV rapid shutdown per Ontario Electrical Safety Association standards.

Robust Cybersecurity Plan for BESS Microgrid Risk Mitigation:

With increased threats to grid infrastructure, especially sites located on federal property/military installations, it is vital to integrate a thorough cybersecurity framework as part of the hardware/software to assure resilience for the microgrid users. The projects shall establish the following:

- Governance & Risk Management
    - Cybersecurity Framework: Align with NIST CSF, IEC 62443, and ISO/IEC 27001.

- Risk Assessment: Conduct a full threat and vulnerability assessment specific to BESS components (PCS, BMS, SCADA, etc.) and PLC (Microgrid Controller)
  - Use of EATON Microgrid Controller, leveraging ISO/IEC 3031 standard programmed with their Electrical Power Monitoring System (EPMS) software or Siemens Controller for Modbus Integration of PV optimizers, PLC, auxiliary systems, and BESS systems.
- Roles & Responsibilities: Define clear roles for cybersecurity leadership, IT/OT teams, and third-party vendors.

- Asset & Network Protection
  - Asset Inventory: Maintain a real-time inventory of all hardware, software, and firmware.
  - Network Segmentation: Separate IT and OT networks using firewalls and VLANs.
  - Zero Trust Architecture: Enforce least privilege access and continuous authentication.

- Access Control & Identity Management
  - Multi-Factor Authentication (MFA): Required for all remote and privileged access.
  - Role-Based Access Control (RBAC): Limit access based on job function.
  - Audit Trails: Log all access attempts and changes to critical systems.

- Monitoring & Threat Detection
  - Security Operations Centre (SOC): 24/7 monitoring of cyber threats and anomalies.
  - Intrusion Detection Systems (IDS): Deploy on both IT and OT networks.
  - SIEM Integration: Centralize logs and alerts for real-time analysis.

- Incident Response & Recovery
  - Incident Response Plan (IRP): Define procedures for detection, containment, eradication, and recovery.
  - Disaster Recovery Plan (DRP): Ensure rapid restoration of operations with minimal data loss.
  - Tabletop Exercises: Conduct regular simulations to test readiness.

- System Hardening & Patch Management

- o Secure Configuration Baselines: Harden all devices (PCS, BMS, SCADA, etc.) against known vulnerabilities.

- o Patch Management: Regularly update firmware and software with validated patches.

- o Removable Media Control: Restrict and scan all external devices.

- Data Protection & Privacy

  - o Encryption: Use end-to-end encryption for data in transit and at rest.

  - o Data Retention Policy: Define how long operational and user data is stored.

  - o Backup Strategy: Implement automated, encrypted backups with offsite storage.

- Third-Party & Supply Chain Security

  - o Vendor Risk Assessments: Evaluate cybersecurity posture of all suppliers.

  - o Contractual Security Clauses: Include cybersecurity requirements in all vendor agreements.

  - o Component Verification: Perform forensic checks on critical hardware/software.

- Training & Awareness

  - o Cyber Hygiene Training: Regular sessions for all staff on phishing, password hygiene, and incident reporting.

  - o OT-Specific Training: Specialized training for operators and engineers on securing industrial systems.

- Compliance & Auditing

  - o Regulatory Compliance: Ensure adherence to local and international standards (e.g., NERC-CIP, GDPR).

  - o Internal & External Audits: Conduct regular reviews of cybersecurity controls and practices.

  - o Continuous Improvement: Use audit findings and threat intelligence to evolve the security posture.

Appendix 5. System details

Base Case:

The purpose of this chapter is to clarify the specific use cases of the BESS in the context of an MGC (Microgrid Community) deployment, using data from IESO (Independent Electricity System Operator), and to highlight the necessary conditions for optimal BESS operation. The microgrid consists of a remote community whose anticipated peak demand is 10MW. It is currently powered by:

One 4MW Biomass Plant that's got a near constant output, except regular feed and maintenance when demand is low overnight. Refer to Exhibit 5 for illustration of our system overview.

● 4 Internal Combustion Engine (ICE) generators of various sizes with a total of 10MW

With Biomass assumed being operational all the time, a base case scenario would have the ICE generators running on top to supply load, a winter peak and a summer trough determine the range of generation that will be required.

Hybrid Case:

To complement the Biomass plant and ICE generators with clean energy & reduce the loading on the ICE engines, the Hybrid Case is an illustration of a Solar farm with a usable capacity of 10MW complemented by Grid forming BESS modules with an installed capacity of 8.32MW/35MWh (2.08MW each). The hybrid generator has its own AC substation. It has a separate connection to the remote community substation. There also is another connection to the genset substation that is normally deenergized for contingency purposes. When one of the connections has a fault or an outage, then this connection is switched closed. This acts like a ring loop. Refer to Exhibit 6 for illustration of hybrid case.

Augmentation Model:

Refer to Exhibit 7 for scenario where infrastructure is built in readiness to connect to the main interconnected system and in readiness to connect to other communities and grow the microgrid. The connections are left deenergized respectively and are only ever

switched if augmentation is deemed to be necessary. Refer to Exhibit 8 for a real-world example of a microgrid design that resembles the proposal.

The efficiency of PV+BESS systems is shown in Exhibit 36.

BESS Design:

The BESS design consists of ESS lithium-ion phosphate DC blocks; the various components are as listed below:

- PCS (Power Converter System): Converts DC power from ESS blocks to AC & vice versa, 1 PCS per DC block
- DTS (Distributed Temperature Sensing): The thermal management system reduces risk of thermal runaway
- SCS (Smart Transformer Station) Transformer Skid: intelligent power distribution node
- SACU (Sensor Acquisition & Control Unit: collects sensor data (voltage, current, temperature, etc.) and provides control signals for operation and protection within the BESS system. Refer to Exhibit 9 for a diagram of STS w/built-in SACU.
- SEMS (Smart Energy Management System): monitors controls and optimizes BESS at the Point of Interconnection
- SPPC (Smart Power Plant Controller)
- SCADA (Supervisory Control & Data Acquisition) : enabling monitoring & control at the dispatch centre
- Dispatch Centre : For operation of BESS
- Step Up Transformer : Stepping up from Medium Voltage to High Voltage
- VT – Voltage Transformer: Measure voltage at point of interconnection
- CT – Current Transformer: Measures current at point of interconnection

Analytics – Energy Balancing:

Scenario 1: Peak Load in Winter

This scenario is taken on the 3rd of January 2024; the load and renewable supply (solar) profiles were taken from real time metered outputs from Canada's Independent

Electricity System Operator (IESO)'s website and is extrapolated to mimic maximum remote community microgrid demand. This is a dynamic simulation of hourly profiles within a day. The supply graph mimics the supply curve characteristics on the same day; however, the maximum PV output is a fraction of its installed capacity (62%) against its full potential in peak summer (Scenario 2). The Biomass output remains very close to peak capacity apart from times when there will be feed interruptions, usually at times when consumption demand is low (overnight). The BESS throughput is used to mitigate the difference between supply and demand (charge during renewable generation & discharge when renewable generation output is zero overnight). As demand is higher in the winter and solar output is low for a very short period due to the location in the northern hemisphere, we observe that there is not enough capacity for BESS to charge & therefore not enough capacity to discharge at night. This will result in ICE generators running for certain periods in the day (i.e. morning peak & evening peak). This scenario ensures that BESS is cycled once in a day. Refer to Exhibit 9 for graphs. There is another analysis that compares ICE generators usage during the day in winter with and without hybrid BESS+PV plants. Refer to Exhibit 10 for comparison of scenarios.

Clearly the Base case runs more ICE generators than if hybrid generation were to be installed. The calculated power savings in this case is around **36 MWh** during the day. Assuming 1 Liter of diesel generates 5Kwh of electricity. Therefore 1 MWh should consume about **200** Litres of diesel. Therefore, the diesel required to provide for the difference would be **7,200** Liters a day. Assuming the price of diesel is **$1.47** (CAD) per liter, this will amount to about **$10,600** savings (CAD) in fuel per day in the winter.

Scenario 2: Low Load in Summer (High & long PV Penetration)

This scenario is taken on the 21st of June 2024; the load and renewable supply (solar) profiles were taken from real time metered outputs from Canada's Independent Electricity System Operator (IESO)'s website and is extrapolated to mimic summertime remote community microgrid demand and maximum solar output. This is a dynamic simulation of hourly profiles within a day. The supply graph mimics the supply curve characteristics on the same day, the assumption here is that the maximum PV output achieves its complete installed capacity (100%). The Biomass output is reduced to cater

for PV+BESS hybrid plant provisions. The BESS throughput is used to mitigate the difference between supply and demand (charge during renewable generation & discharge when renewable generation output is zero overnight). As demand is lower in the winter and solar output is very high and for a longer duration due to the location in the northern hemisphere, we observe that BESS will be able to cater for most of the energy balancing throughout the day. Therefore, in this scenario ICE generators are not required to run allowing them to be on standby mode during contingencies. Refer to Exhibit 11 for graphs.

There is another analysis that compares ICE generators' usage during the day in summer with and without the hybrid BESS+PV plant. Refer to Exhibit 12 for comparison of scenarios.

Clearly the Base case runs more ICE generators than if hybrid generation were to be installed (no ICE generation requirement). The calculated power savings in this case is around 36 MWh (same as winter) during the day. Assuming 1 Liter of diesel generates 5Kwh of electricity. Therefore 1 MWh should consume about 200 Litres of diesel. Therefore, the diesel required to provide for the difference would be 7200 Liters a day. Assuming the price of diesel is $1.47 per Liter, this will amount to about $10,600 savings in fuel per day in the winter.

Controller: Design & Operation

Microgrid can be operated in 2 modes of operation as described in the augmentation model above:

1.   Electrically Connected to Utility Grid
2.   Islanded Mode

When the microgrid is electrically connected to the Utility Grid, then the static switch is in the closed position & current control is optimally utilized to provide for preset power. In case of fault or maintenance contingencies on the main Grid, then the microgrid switches to an islanding mode to prevent spreading of the fault to the microgrid.

In island mode, the static switch remains open & the control system then maintains the voltage, frequency & phase angle on its own. Critical loads are thus maintained without any power quality issues. Islanded mode could also be classified into two further modes:

1. Intentional Islanding
2. Unintentional Islanding

The micro sources for microgrids consist of small-scale turbines/engines, PV panels & battery cells. They are low cost & highly reliable with minimum emissions. Power electronics provide control & adaptability required for the Microgrid. Correctly designed power electronics & controls ensure that the Microgrid will meet most technical & commercial needs. The system design for this could be achieved with 3 important components;

● Local micro-source controllers
● System optimizer
● Distributed protection

The control method in this microgrid has two distinct modes of control operation. Refer to Exhibit 13 for the controller logic diagram.

● Current mode (IM)
● Voltage mode (VM)

These control modes correspond to the system's operating mode, grid-connected or islanding (respectively).

Current Control:

The current control loop is utilized to direct the grid current for control of the electrical grid. The active and reactive components of the current introduced into the grid are controlled using pulse width modulation (PWM) techniques. A current controller is less sensitive to voltage phase shifts and to distortion in the grid voltage. The main feature of the current controller is its inherent capacity to restrict the converter output current amid a microgrid fault subsequently providing overcurrent protection to the converter reducing the fault current contribution. Refer to Exhibit 14 for block diagram representation of current control mode.

The voltage waveform for the pulse width modulation of the voltage source inverter will be acquired from the current controlled strategy and can be synchronized with the grid frequency. For grid-connected operation, the controller is designed to produce a constant current output. A phase locked loop (PLL) is utilized to decide the frequency and angle reference at the point of interconnection. A necessary aspect to consider in grid-connected operation is synchronization with the grid voltage. It is essential that the grid current reference signal is in phase with the grid voltage for unity power factor operation. This grid synchronization can be carried out by utilizing a Phase Locked Loop algorithm where grid frequency, voltage reference & phase angle is matched.

Control – Steady State: During steady state operations under intentional islanding conditions, the main objective of the controller within the energy management system is to maintain stable voltage & frequency under the prescribed limits. The other key functions would be achieving power balance, intelligent power sharing within the power park and different generations. Some key functionalities would be to forecast demand & PV output based on historical days & allocate generation & storage to react efficiently considering the stochastic nature demand & renewables.

The primary control is achieved via droop control. The P–F droop controls active power thus controlling the frequency of the microgrid. The Q–V droop controls the reactive power thus controlling the voltage in the microgrid. The response times in this type of control are much faster. And this can be mainly achieved by local measurement without need for advanced communications. However, eliminating steady state errors could be a challenge in this type of control methodology.

Secondary control uses PI controller to reduce droop induced deviations mainly for restoring frequency and voltage to nominal values after primary control has stabilized the microgrid system. Here communication links are used to collect data and adjust references in the distribution grid.

Tertiary Control is utilized to perform economic dispatch in island mode or to control power flows between main grid & microgrid. Refer to Exhibit 15 for more information on detection algorithms.

Grid Connection Switch from Intentional Islanding: As we know and understand, the use case for our microgrid ecosystem is its ability to serve a remote community on its own. However, this introduces grid related issues, especially during a fault which could lead to thresholds that could sometimes be beyond the control capabilities of the inherent devices within the microgrid environment. Therefore, it is necessary to detect these abnormalities in advance using intentional islanding detection techniques so the open switch at the point of interconnection with the grid could be closed for additional Grid support. The sequence of detection is per Exhibit 16. Voltage imbalance technique is the preferred connection detection algorithm utilized here. The voltage and frequency are the parameters utilized here to check whether or not the microgrid is in grid connected or islanded mode. This detection is achieved by using a Phase Locked Loop (PLL) control system that consists of the power park transformation, a PI regulator, and an integrator. A Proportional Integral (PI) regulator can be utilized to control this variable, and the yield of this regulator is maintaining the grid frequency. In addition to the frequency, a synchronous reference frame PLL (SQ-PLL) is equipped for following the magnitude of its input signals, frequency & voltage. These two parameters are used in the connection detection algorithm to detect the grid condition & connect.

Voltage Control – Unintentional Islanding: This use case is a scenario where the distribution grid is connected to the main interconnected grid and a massive imbalance in the main grid occurs & the distribution grid must island itself unintentionally to protect the microgrid from grid induced imbalances. The microgrid profile should therefore need a few modifications to mitigate the imbalance between local load and grid generation and to diminish the disconnection transient. The current compensation is given to control the voltage regulation.

Micro Grid Control Use Cases:

Frequency Droop Regulation – adaptive active power droop controller:

In case of frequency fluctuations, the BESS will react accordingly by injecting the $\Delta P = \lambda$ (droop) ($f-f0$). Refer to Exhibit 17 for graphs.

1. Beckhoff power meter used, sending measurements to BESS EMS

2. BESS EMS commands BESS to regulate deviation in frequency

3. BESS responds by providing the ΔP(KW) (according to its droop characteristics). Refer to Exhibit 18 for graphs.

When microgrids don't have external assistance of the wider grid to support its requirement like frequency, BESS provides an improvement in frequency containment & restoration with improved droop characteristics and virtual inertia control which could potentially outperform conventional generation units due to its sheer capacity of improved ramps & droop control characteristics.

Inertia Control – BESS: GFM vs GFL:

During microgrid operations, there could be several factors that could cause electrical disturbances. One such event would be a frequency disturbance (e.g.: instantaneous loss of generation). However, the inherent ability to sustain the microgrid frequency within prescribed limits would be difficult due to insufficient synchronized generation that would otherwise assist in arresting the rate of change of frequency (ROCOF). In such circumstances, having BESS in the microgrid is helpful with its advanced droop control and ramping characteristics. Therefore, when developers plan the microgrid, it must have the right mix of grid forming & grid following BESS as they have slightly different characteristics when responding to sudden frequency deviations. Refer to the example detailed in Exhibit 19.

For a microgrid system that has been intentionally islanded with limited or no synchronous generation within it, BESS is the only defence mechanism against frequency deviation and its rate of change. Therefore, it's clearly safer to build a higher proportion of GFM, therefore this has to be considered against additional CAPEX cost for GFM, subject to further studies.

Generation Shifting:

The BESS controller must follow Automated Generation Control (AGC) signals relayed by the site controller to charge batteries to store energy and discharge energy when commanded. Refer to Exhibit 20. In case of signal generated by AGC, the site controller

will send a command (charge or discharge) to the BESS EMS, BESS will react accordingly by processing charge or discharge on the battery containers.

1. Site controller sending request to the BESS EMS to start charge or discharge mode
2. BESS in charging or discharging mode

SOC Management: SOC estimation is inherently uncertain due to multiple sources of error—measurement inaccuracies, sensor drift, model imperfections, and battery degradation, to name a few. Some of these uncertainties are unavoidable, but the degree of uncertainty can be quantified through a probabilistic approach to enable optimal decision-making BESS SOC% must be considered before triggering the command to the BESS. Refer to Exhibit 21 for a logic diagram.

The EMS system continuously monitors the operational data applying cloud-based algorithms that integrate fundamental battery signals with probabilistic analysis delivering accurate SOC probability distributions. This provides operators with actionable insights for confident decision-making.

Voltage Regulation: The microgrid plant controller measures voltage continuously across various points of the microgrid network & inputs its recommendations into the controller. This controller can automatically instruct various modes of voltage control to a variety of voltage control devices, some of the devices being:

- Capacitor Banks (static)
- Reactor Banks (static)
- Static Compensator (Static)
- Synchronous condenser (Static)
- Line de-energization/energization (static)
- Synchronous compensation (Spinning or synchronized reserve)
- BESS PCS (dynamic)

In our microgrid case, we have 3 sources of dynamic voltage regulation as per the list above.

1. Biogas: assuming it's a 4MW internal combustion engine complemented by an AC alternator. The Biogas generator is expected to remain synchronized to the microgrid

all the time based on the inflexible nature of biogas operations. By adjusting the field current of the alternator, we can either overexcite – supply leading reactive power or under excite – supply lagging reactive power. Refer to Exhibit 22 for diagrams.

2. Diesel Engines: For reactive compensation support, the internal combustion engines running on diesel (coupled with an AC alternator) must remain synchronized to the microgrid electrically. Also, reactive power compensation would only be provided at Stable Operating Level (Baseload) of the generator, typically 30–50% of the generator output, unless the alternator is in a Synchro Self Shifting (Clutch) configuration that enables seamless decoupling from its diesel-powered ICE prime mover and running in the Synchronous Compensation load at no load powered by the Microgrid electrically. Just like the biogas generator, even the diesel-powered generator's reactive compensation capabilities are controlled by adjusting the field current of the alternator, we can either overexcite – supply leading reactive power or under excite – supply lagging reactive power. Refer to Exhibit 23 for example of leading vs lagging power supply curve.

3. BESS PCS: The power converter systems (PCS) in Battery Energy Storage systems can provide voltage regulation capabilities in the microgrid. The advantage of BESS here is that the reactive capability range in BESS can be achieved in both charging and discharging direction. The power controller of BESS manipulates the direct quadrature axis where the p axis is aligned with the voltage vector which is the real power component, and the q axis is the reactive power component which is 90 degrees ahead of the d axis. Refer to Exhibit 24 for the PQ curvature in the BESS.

Stability under Fault Conditions:

Due to limited amount of fault compensation resources in an intentionally island microgrid, a fault that occurs in the microgrid could be devastating unless fault contribution measures are in place to ride through the fault until the fault is isolated. Synchronous machines like the biogas generator or the diesel-powered ICE engines provide a relatively higher fault contribution (up to 500%) of its capacity; however, they'll have to be continually operated to provide for fault contribution. Inverter based resources including PV & BESS have a lower capacity (typically 120 to 150%) based on the ambient temperatures by either creating their own voltage waveform (GFM mode) as

a voltage source or tracking grid voltage via PLL (GFL Mode) as a current source to ride through microgrid faults. Fault currents have a much faster decaying envelope because the IBR devices lack the predominantly inductive characteristics that are associated with rotating machines. Inverter-based resource (IBR) control loops can have different time constants. This will impact the fault current characteristics of the inverters. Inverter behavior is largely software/firmware defined; the filter determines the sub transient response, and the type of control implementation determines the steady-state response. With GFM based resources, the Short Circuit Ratio (SCR) can go as low as 1.2 compared to a level of 3 in traditional systems.

In a microgrid with a proportional mix of IBR based resources and traditional synchronous machines, sudden disturbances manifest into out of phase oscillations, leading to the loss of synchronous generators to maintain the rotational ability of the generator's prime movers in synchronism with the grid frequency and relative phase angle leading to oscillations. Should the amplitude of these oscillations be too high or if the oscillations don't damp down in time, it could lead to the generator protection systems disconnecting the generator from the interconnected microgrid. The effect is higher with fewer generation sources. Under this circumstance BESS under Grid Forming Mode (GFM) have control systems that monitor the microgrid & rapidly inject or absorb power proportionally in response to disturbances providing significant electrical synchronizing torque (virtual) damping the disturbance in the system as displayed in the simulation shown in Exhibit 25.

Black Star Functionality:

Should a fault in the microgrid system trigger a complete microgrid blackout, then the generation and flexibility sources within the microgrid must be capable of restoring power during a complete power outage and energizing the facility/microgrid network without the use of external power resources. The BESS must be capable of supplying auxiliary power to the BMS, BESS Controller, Site Controller, HVAC, and any other essential controls and loads. The system shall at a minimum be capable of 3 sequential starts, energize on-site BESS and PV auxiliary loads, and allow the BESS to charge from the PV System.

Sequence 1 – Black Start Detection: First, the site controller must detect the loss of grid power, this will be indicated by the voltage & frequency readings on the microgrid elements.

Sequence 2 - GFM Activation: The DC system (Block) of BESS energises the PCS; the PCS now would act in a grid forming mode establishing independent and stable voltage & frequency waveforms.

Sequence 3 – Dead-line Charge: The GFM BESS will now energise its local busbar and subsequently energise lines that connect other sources of generation or load. However, this entails absorption of leading or lagging reactive power due to the length of the lines or inherent reactive gain in cables. This will require BESS to possess the sufficient reactive capability to enable deadline charging.

Sequence 4 – Restart Other Generators: Black start capable generators or Grid following (GFL) BESS would now use the PLL methodology to pick the reference voltage and frequency generated by the GFM BESS and synchronize accordingly.

Sequence 5 – Energize Loads: The microgrid master controller enables automatic switching coordination to energize critical loads such as hospitals first and then residential blocks

Sequence 6 – Normal Operations: Once the grid is stabilized, then normal operations will resume as usual. Refer to Exhibit 26 for the sequence diagram.

Microgrids with conventional black start capable generation systems are harder to synchronize & sustain without further breakdown & restart sequences because loads are connected in blocks & the ramp of the generator makes it difficult to catch up both in terms of active and reactive power. However, having BESS in the microgrid restart mechanism helps smoothen load ramps due to its bidirectional capability and versatility to adjust to varying loads with faster ramps rather than block loading, smoothening the synchronizing sequences resulting in redundancy and success of a single start. Refer to Exhibit 27 for illustration of this sequence.

Stacking of BESS Services:

All the use cases can be stacked on top of each other; however, this will then require an effective margin & therefore will reduce the capability of BESS to provide active power. The microgrid control system must efficiently and seamlessly be able to balance this

among the generators and BESS for enabling these use cases on top of energy balancing. Refer to Exhibit 28 for a diagram of energy balancing.

Appendix 6. LCOE Calculation

- Total CAPEX: CAD 3,700,000

- OPEX: Not separately included — assumed minimal or bundled

- System Capacity: 8MW / 8MWh

- Lifetime: 10 years

- Discount rate: 0% (for clear comparisons)

- Annual Energy Output:

    o Assuming **1** full cycle per day:

        ▪ Annual Output = 8MWh × 365 = **2,920 MWh/year**

        ▪ Over 10 years = 2,920 × 10 = **29,200 MWh total**

Formula:

LCOE = Total Lifetime Cost / Total Lifetime Energy Output

    Results:

        LCOE = CAD 3,700,000 / 29,200 MWh

        LCOE = CAD 0.1267/kWh

Utilization Scenarios below, shows that the more the battery is utilized, the lower the LCOE gets, making the system more cost-efficient, however, further consideration should be taken due to asset degradation that may shorten battery life.

Appendix 7. ROI Calculation

This section presents a financial analysis of the integration of a Battery Energy Storage System (BESS) within a microgrid architecture that also includes other Distributed Energy Resources (DERs), such as photovoltaic (PV) solar panels and biomass generation. The objective is to evaluate the economic contribution of the BESS under varying seasonal conditions and system configurations. The analysis is structured around two primary operational scenarios: one representing summer conditions with high solar availability, and the other reflecting winter conditions with reduced PV output. A third, blended scenario combines both seasonal profiles to provide a comprehensive year-round assessment of system performance and return on investment (ROI).

Finally, a sensitivity analysis is conducted to explore optimization strategies. This includes evaluating the impact of resizing key components—such as the PV array, the BESS, or other DERs—on the overall financial performance of the microgrid. The goal is to identify configurations that maximize ROI while maintaining system reliability and sustainability.

First, we will present the formulas used in the various calculations:

1. Diesel Saved per Day

   Diesel Saved (L)=Energy Saved (MWh)×200 L/MWh

2. Fuel Savings per Day

   Fuel Savings (CAD)=Diesel Saved (L)×1.47 CAD/L

3. Annual Fuel Savings

   Annual Fuel Savings=(Winter Savings+Summer Savings)

4. Annual Maintenance Cost

   Maintenance=0.02×BESS Cost Maintenance=0.02×BESS Cost

5. Net Annual Savings

   Net Savings=Annual Fuel Savings–Maintenance

6. Payback Period

   Payback Period=BESS CostNet Annual Savings

7. Annual ROI

   ROI=(Net Annual SavingsBESS Cost)×100

8. Carbon Savings

CO2 Saved (kg)=Total Diesel Saved (L)×2.68 kg/L

Below a Comparison of the two seasonal scenarios for our microgrid project, along with a payback curve visualization:

A. Summer Scenario (Full PV Output) :

Annual Savings: $1,905,120 CAD

Net Annual Savings: $1,831,120 CAD

ROI: 49.49%

Payback Period: 2.02 years

B. Winter Scenario (50% PV Output) :

Annual Savings: $979,020 CAD

Net Annual Savings: $905,020 CAD

ROI: 24.46%

Payback Period: 4.09 years

Payback Curve Over 10 Years:

See Exhibit 31 for a graph showing how quickly the investment in the BESS is recovered under each scenario. The **summer scenario** reaches full payback in just over **2 years**. The **winter scenario** takes just over **4 years** to break even.

C. Mixed Seasonal Results (Exhibit 40)

Payback Curve Over 10 Years:

See Exhibit 32 for graph on 10-year ROI.

D. Sensitivity Analysis (Exhibit 41)

Year-round blended ROI analysis comparing four configurations of our microgrid project.

See Exhibit 33 for ROI by scenario of change or adjustment of the DERs

Conclusion:

- **A larger PV** offers the **highest ROI** and fastest payback.

- **Smaller BESS** is also efficient, with reduced cost and solid returns.

- **Hybrid diesel–biomass** is more sustainable but has a slightly longer payback.

Appendix 8. Long Term Service Agreement (LTSA) Plan

A well-established LTSA should consist of the following to assure continued service and performance of the BESS microgrid:

1. Scope of Services

- Preventive Maintenance: Tiered inspections and system testing based on OEM requirements and site accessibility. Monthly, quarterly, and annual physical inspections and performance checks.

- Corrective Maintenance: SLA-based resolution of faults related to BMS, inverters, EMS, and communication systems. On-call fault resolution (inverter failures, BMS anomalies, SCADA issues).

- Remote Monitoring & Diagnostics: Continuous SCADA or dashboard visibility, with offline data logging and predictive diagnostic. Real-time visibility of microgrid energy flows and state of charge (SoC).

- System Optimization Support: Tuning of battery dispatch logic, load prioritization, and black start recovery

- Software/Firmware Management: Regular software patches and seasonal dispatch optimization

- Regular updates across inverter: EMS, and BMS platforms maintain software support

- Cybersecurity Protocols: Secure access controls, remote lockout capability, physical tamper-proofing

- Spare Parts Inventory: Local critical spares and regional stocking of long-lead equipment

- Local cache for fast movers: Vendor-held inventory for lead-time items.

- Emergency Response: Black start protocols and grid-independence testing. 24/7 support for high- priority issues impacting critical loads or islanding capability.

2. Service Schedule (Exhibit 43)

3. Performance Guarantees:

- Availability: ≥98% system availability (BESS + microgrid controller)

- Response Time:
- <4 hours (critical load service disruption)
- <96 hours field dispatch where remote access is limited
- Battery Retention: ≥80% usable capacity after 10 years
- Island Mode Assurance: At least 1 successful unplanned islanding test annually

4. Spare Parts Strategy:

- On-site: Inverter fuses, BMS boards, breakers, HMI interfaces
- Vendor-Managed: Battery modules, control boards, isolation transformers
- Procurement Protocol: Warranty/RMA workflow and predictive restocking
- Winterization Materials: Insulation kits, thermal skirts, anti-icing coatings

5. Training & Knowledge Transfer:

- On-site microgrid familiarization and black start drills
- Safety training (arc flash, thermal events, isolation procedures)
- Digital access to user manuals, troubleshooting flowcharts, and update bulletins

6. Training & Local Capacity Building:

- Resident Operator Training: Bootcamps for system restart, fault identification, and reporting
- Emergency Simulation Drills: Black start, battery isolation, islanding response
- Documentation Access: Manuals, schematics, and SOPs in digital and printed formats
- Multilingual Support: Translation available in English, French, and Indigenous languages when relevant

7. Reporting and KPIs:

- Monthly Reports: System performance, uptime, alert summary
- Quarterly Reviews: Communications failures, firmware status, integration trends
- Annual Health Report: Battery degradation, diesel offset, predictive maintenance insights
- Key KPIs:

- Availability (%)

- Mean Time to Repair (MTTR)

- Black start test success rate

- Energy throughput

- Remote intervention success rate

8. Remote Deployment Provisions (Exhibit 44)

9. Contract Terms:

- Duration: 5–15 years with renewal and tech refresh options

- System Availability:

  o Minimum Guaranteed Availability: ≥98%

  o Applies to the BESS and microgrid controller combined

  o Measured annually, excluding scheduled maintenance

- Response Time Commitments :

  o Critical Load Disruption: Remote response within <4 hours

  o Field Dispatch: On–site technician within <96 hours

  (when remote access is unavailable or ineffective)

- Battery Performance Guarantee:

  o Retention of Usable Capacity: ≥80% after 10 years

  o Covers degradation and performance under normal operating conditions

  o May include periodic performance testing and reporting

Appendix 9. Details on financing

Power Purchase Agreement (PPA) Structure for Off-Grid Microgrid Deployment:

In remote communities without access to the national grid, conventional PPA frameworks must be adapted to prioritize reliability, affordability, and community control. The following structure is proposed for the hybrid battery and microgrid project:

Operational Context:

The microgrid operates as a fully islanded system, disconnected from any centralized transmission network. Electricity is generated locally using solar photovoltaic (PV) sources and stored in a battery energy storage system (BESS) with black-start and Arctic-rated capabilities. Power is distributed directly to residential, commercial, and essential community infrastructure.

Contractual Relationship:

The energy delivery agreement will be established between the system operator (which may be the utility, a community-led entity, or a public-private partnership) and the local energy users, including households and public facilities. Rather than selling energy into an open market, the PPA formalizes the cost of service and sets long-term pricing terms based on the avoided cost of diesel generation.

Pricing Model:
- Reference Price: CAD $0.56–$1.12 per kWh — based on historic diesel electricity generation costs.
- PPA Rate: A flat or tiered rate structure can be adopted, ensuring affordability while recovering system costs.
- Escalation Clause: Optional annual adjustment based on inflation or maintenance benchmarks.
- Term: 10 years, aligned with expected BESS lifespan and long-term service agreements.

Service Guarantees:

While market-linked services such as frequency regulation or capacity payments are not applicable in this off-grid context, the system provides embedded reliability features

essential to local resilience, including: (i) Fast frequency response within the microgrid; (ii) Black-start functionality during outages; (iii) Uptime performance and availability targets. These guarantees can be documented as service provisions within the PPA and supported by performance monitoring tools.

Community Benefits:

Benefits include (i) Predictable energy costs lower than diesel generation; (ii) Reduced environmental impact and noise pollution; (iii) Opportunities for local training and ownership; and (iv) Strengthened energy security in all seasons.

Utility & Community Collaboration:

- Stakeholders: Local utility, Indigenous leadership, provincial regulators.
- Governance: Joint steering committee overseeing deployment and operation.
- Energy Sovereignty: Capacity-building and training programs included to empower community operation and maintenance.

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