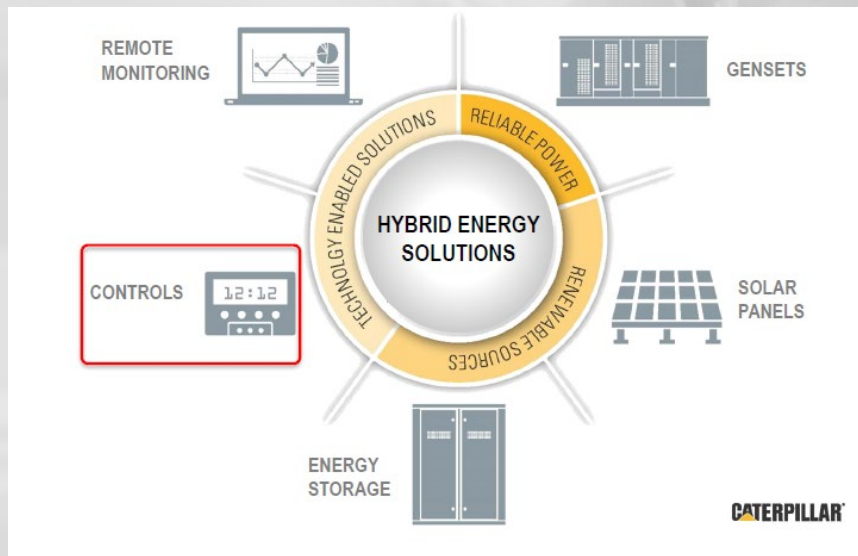


Caterpillar Micro Grid Solutions



AGENDA

Introduction

Caterpillar Toromont relationship

Cat Micro grid solutions

Solar

DC – AC Inverter

Battery Energy Storage System

Micro grid Controller

General

Sharanjit Singh

Email : ssingh@toromont.com

Cell: 416 578 1075

WE ARE TOROMONT CAT

Toromont Cat is your Cat dealer in

- Eastern Half of Canada (Manitoba to Nfld)
- Largest Gaseous Gen Set Supplier in Canada
- More than 200 Power-only Field Technicians
- Over 180 Natural Gas Projects in E.Canada
- 16 MW LNG Mining Power Plant (Stornaway)
- Caterpillar population 24.4 GW 27,700 units (as of 2013)
- Engine production in some markets expected to be predominantly gas product by 2025



42
BRANCHES

3,700+
EMPLOYEES

7
PROVINCES
& 1 TERRITORY

1,600+
TECHNICIANS

TOROMONT
Power Systems



POWER SYSTEMS

Toromont Cat Power Systems is an industry leader in the supply and integration of backup and prime power generation systems, rental generators, marine engines and industrial engines through customized engineering and packaging

PRODUCTS

Natural Gas Generators
Diesel Generators
Storage Systems
Uninterruptible Power Supply
Automatic Transfer Switches
Switchgear & Paralleling Controls
Controls and Switchgear
Power Accessories

SOLUTIONS

Global Adjustment (GA)
CHP Systems (Cogeneration)
Micro grids
Rental Power
Parts & Service
Generator Inventory
Electric Power Retrofit

TOROMONT **CAT**

TOROMONT
Power Systems

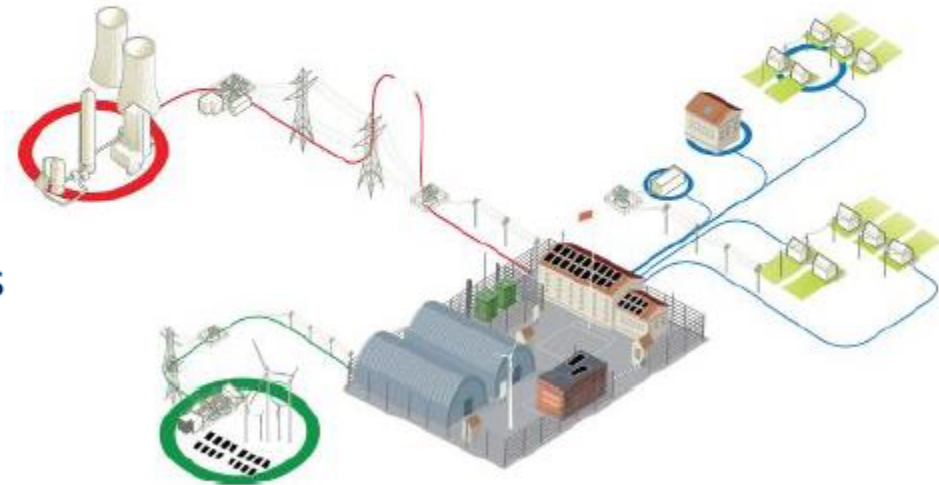


Microgrid

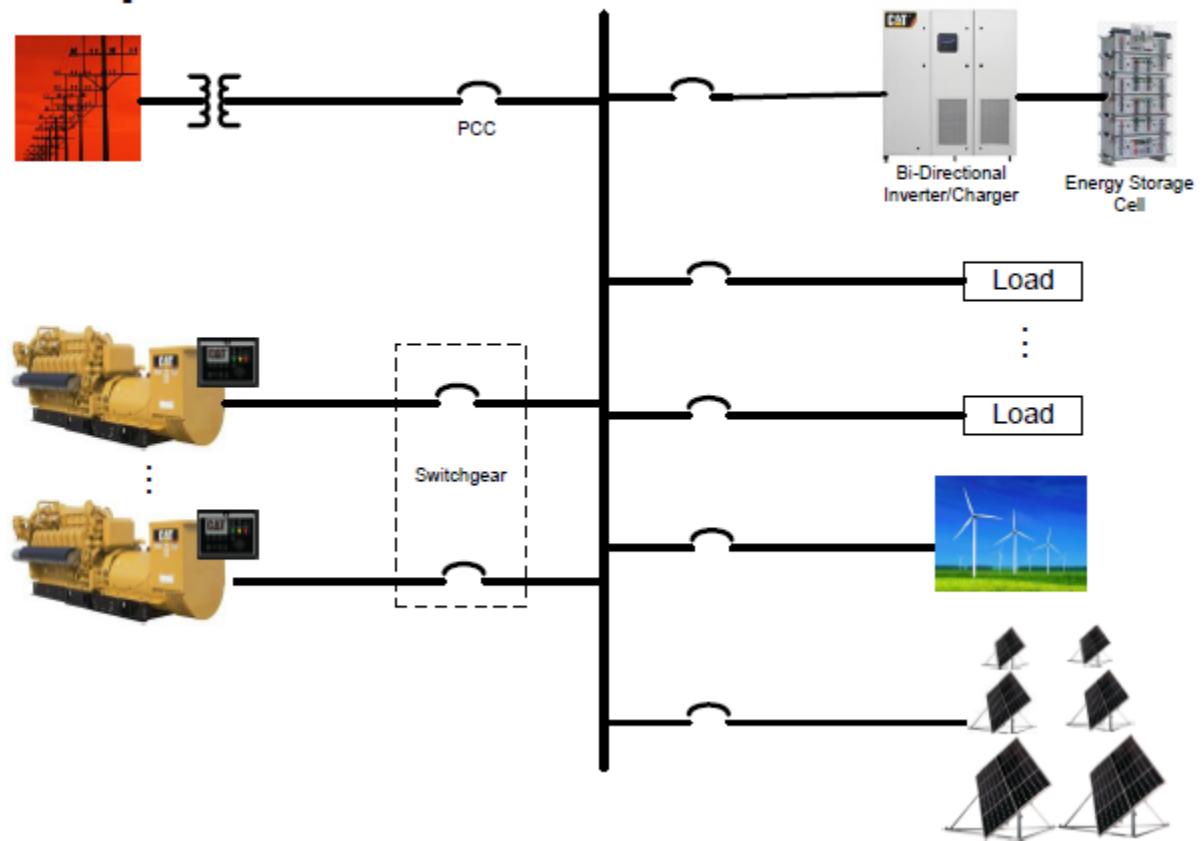
Any localized grid with its own power generation resources, loads and definable boundaries and acts as a single controllable entity qualifies as a microgrid.

A power grid that:

1. Can operate independently and
2. Operate in conjunction with the area's main electrical grid

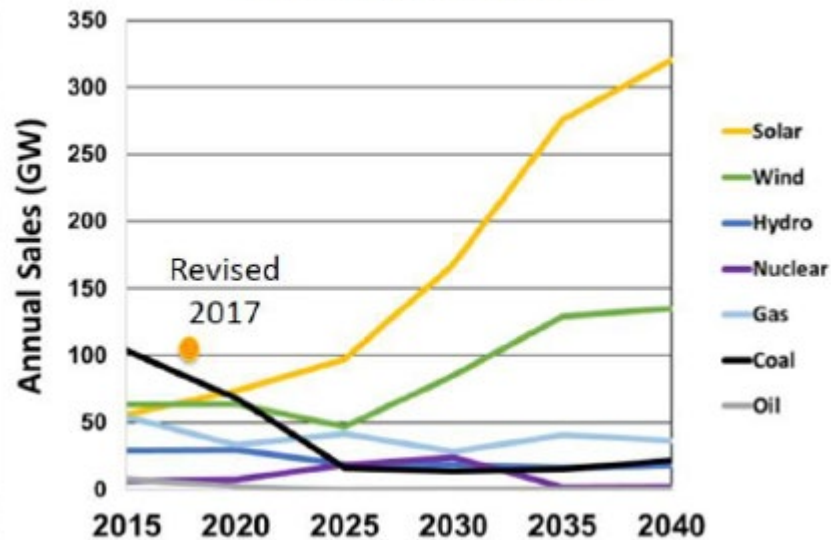


Microgrid Components

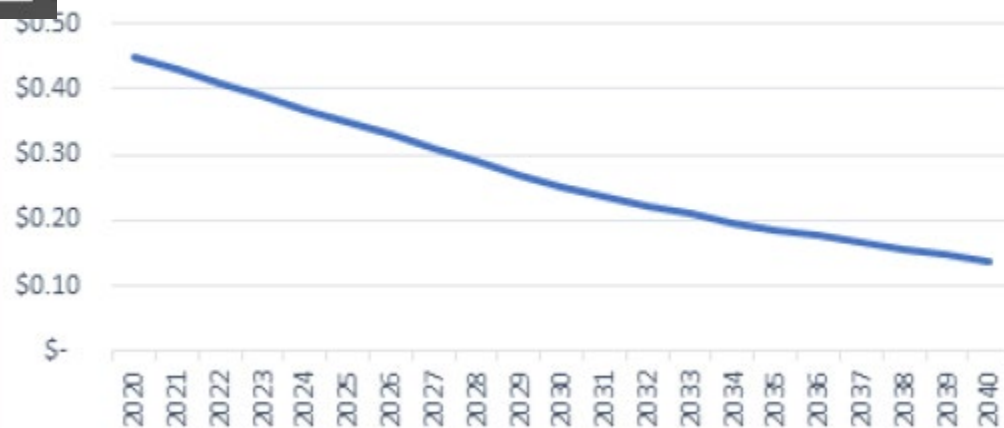


Trends

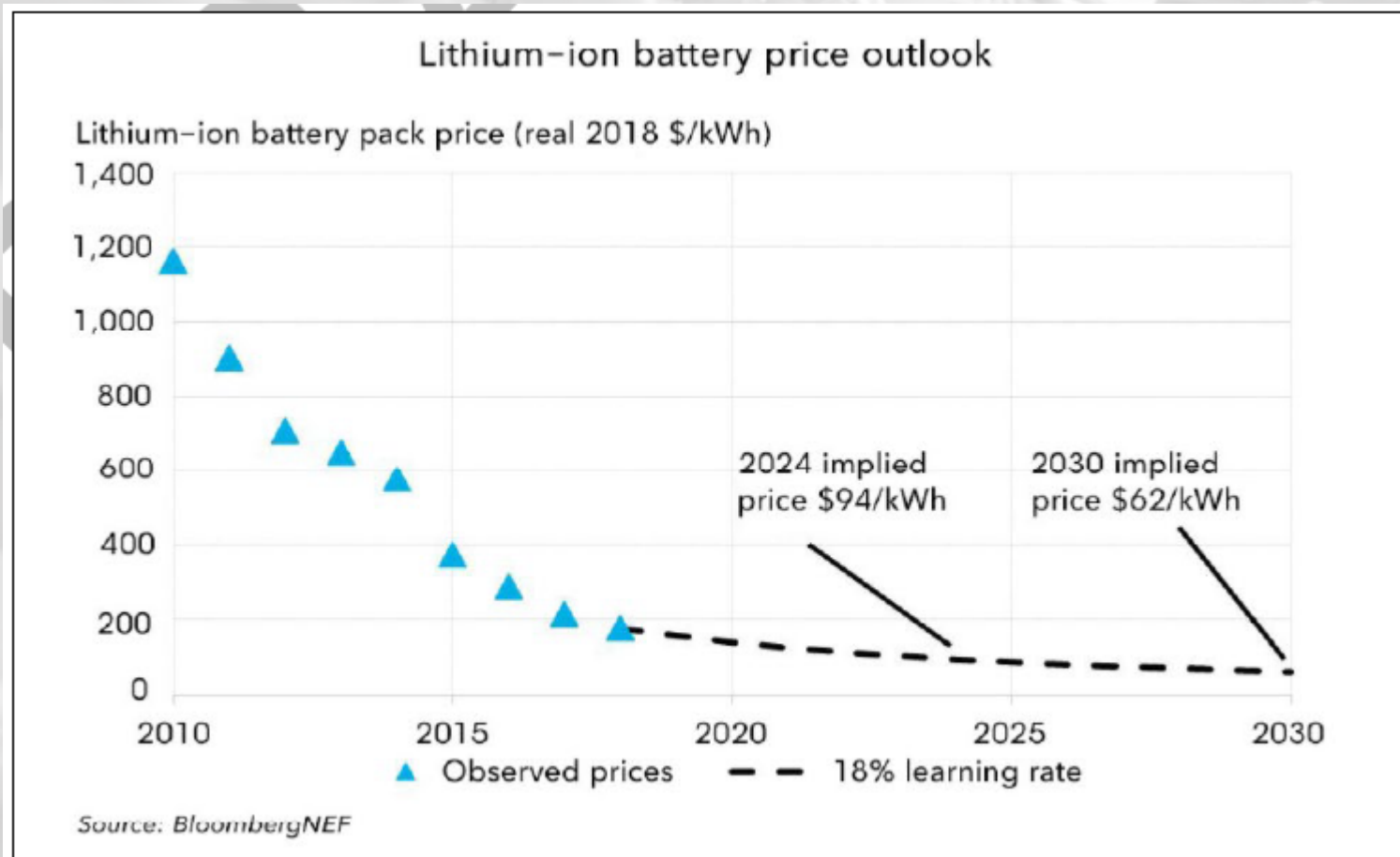
Global Electricity Capacity Additions



Solar PV Cost Trend (\$ / Watt)

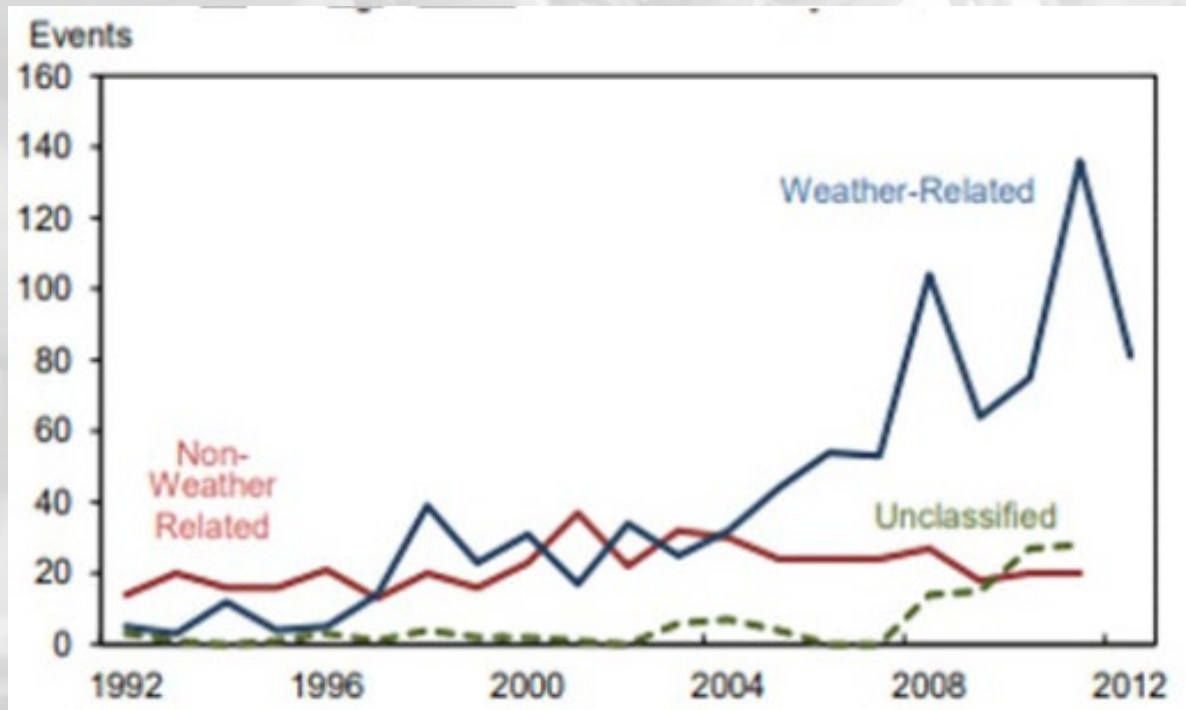


Trends



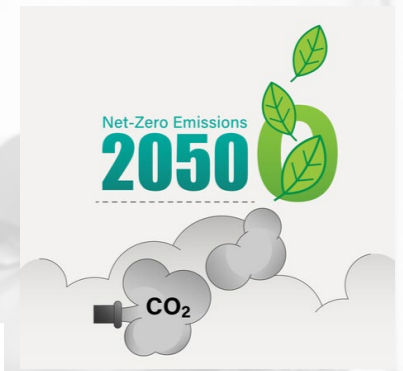
Trends

Natural Disasters

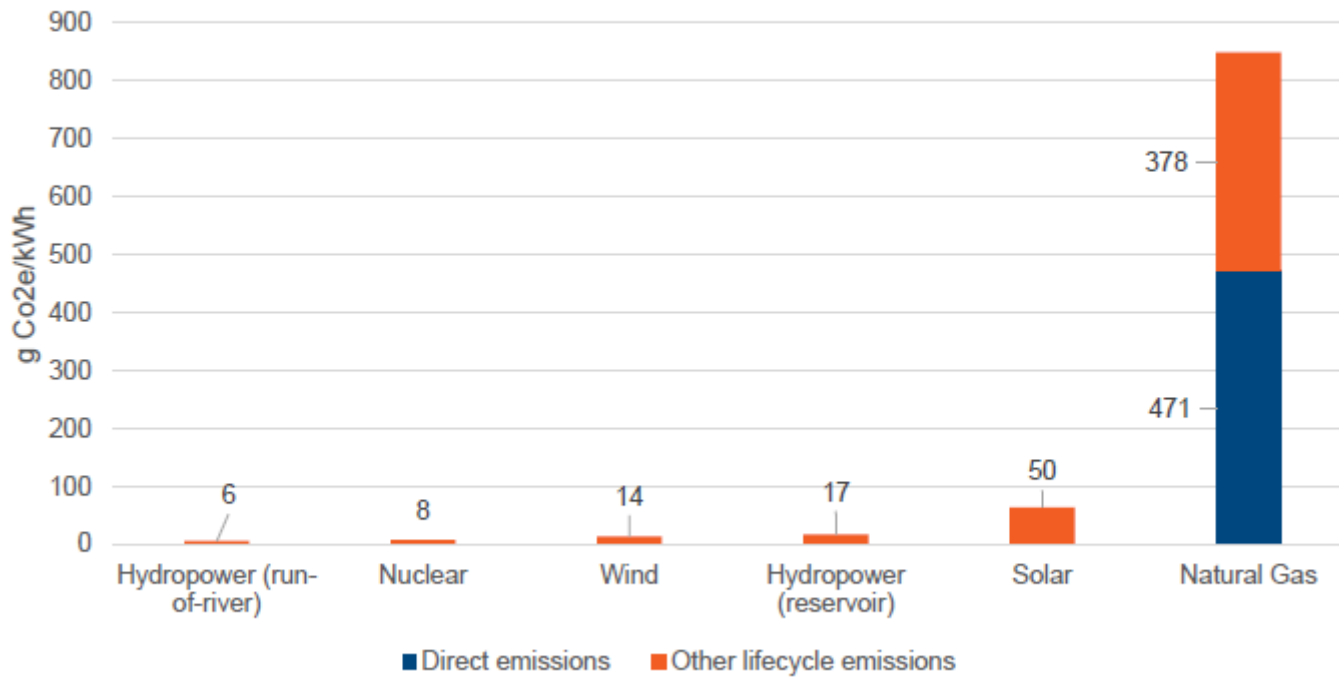


Trends

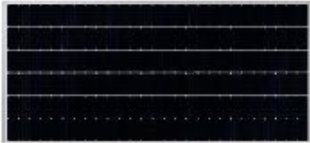
Net zero emissions



Lifecycle emissions in electricity generation



Cat Solar Photovoltaic (PV)



PVC415
Shingled-Cell Mono PERC

- High Efficiency for Space Constrained Applications



PVC445/450 - Mono PERC
PVB445/450 – Mono PERC Bifacial

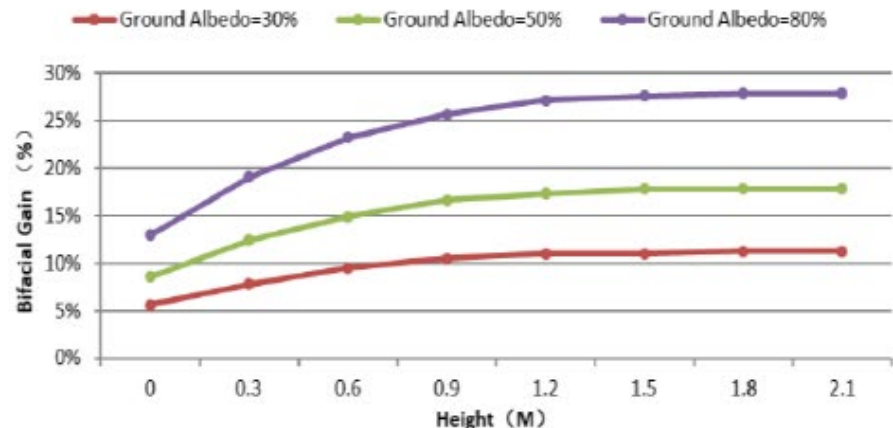
- Low Cap-Ex Product

Optimizing
the Solution



More than 100+ MW of Solar PV sold since the Launch!

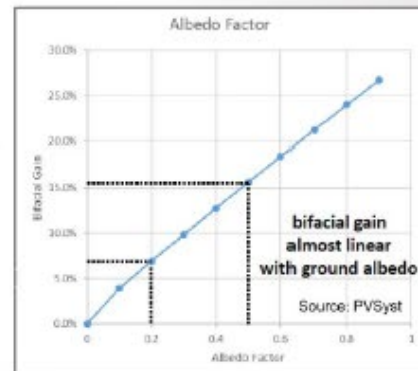
Monocrystalline Bifacial



Backside Energy Yield: **Albedo**

Bifacial gain improves with increasing ground Albedo

- Same as monocrystalline
- Utilize backside of the panel
- Improved energy capture



TEMPERATURE CHARACTERISTICS (STC)		
Module Operating Temp. Range	(°C)	-40 to +85
Temperature Coefficient of P_{MPP}	$T_K(P_{MPP})$	-0.350%/°C
Temperature Coefficient of V_{OC}	$T_K(V_{OC})$	-0.284%/°C
Temperature Coefficient of I_{SC}	$T_K(I_{SC})$	+0.050%/°C

MECHANICAL LOADS	
Front Side Max Static Load	5400 Pa
Rear Side Max Static Load	2400 Pa
Hailstone Test	25 mm hailstone at 23 m/s

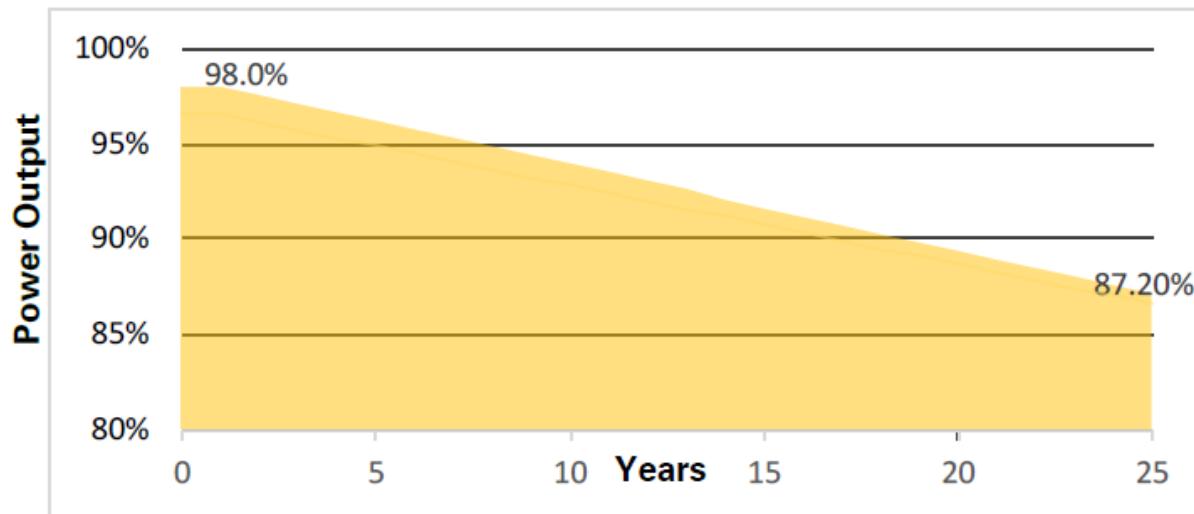
DURABILITY TEST CYCLE			
Accelerated Tests	Competitor products*	Cat Product	Cat Advantage
Damp Heat	1000 hrs.	2000 hrs.	2x testing hrs.
Thermal Cycling	200 cycles	600 cycles	3x testing cycles
PID (85°C/85RH)	96 hrs.	192 hrs.	2x testing hrs.
Mechanical load**	Static	Dynamic + Thermal Cycle + Humidity Freeze	Much less cell breakage and power loss
LID	Not required	60-100 kWh/m ²	Validation of early hour performance
LeTID	Not required	Pass proprietary test	Validation of long term PERC performance
Salt mist	Not required	Pass IEC test	Validated for use in harsh environment
Ammonia	Not required	Pass IEC test	
Dust and Sand	Not required	Pass IEC test	

Proven Energy Yield

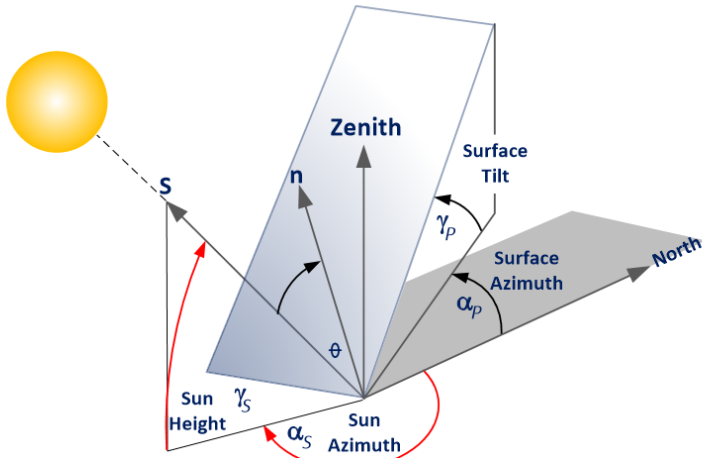
- 19.6% to 20.9% efficiency
- -0/+5W positive power tolerance

Module Warranty

- 10-year warranty for materials and processing
- 25-year warranty for linear power output. Produces more than 98% power in the first year, then declining by 0.45% per year, ending at 87.2% power after 25 years.



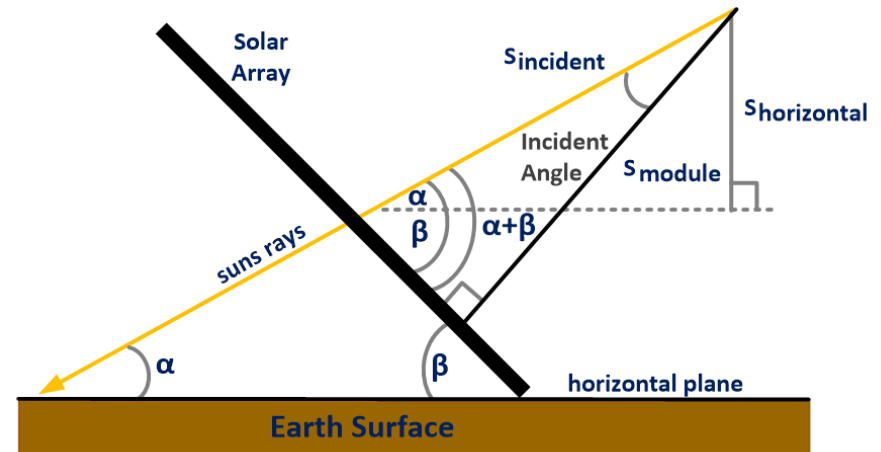
Array Orientation – Altitude & Azimuth



Azimuth: The Sun's position from east to west; it is the angle between true south and the point on the horizon directly below the Sun.



The Incident Angle



Incident Angle: The angle between the sun's rays and a line perpendicular to the array surface.

Application and Racking



Ground Mount
Fixed Tilt



Ground Mount
Single Axis Tracker



Ground Mount
Dual Axis Tracker



Rooftop
Ballasted

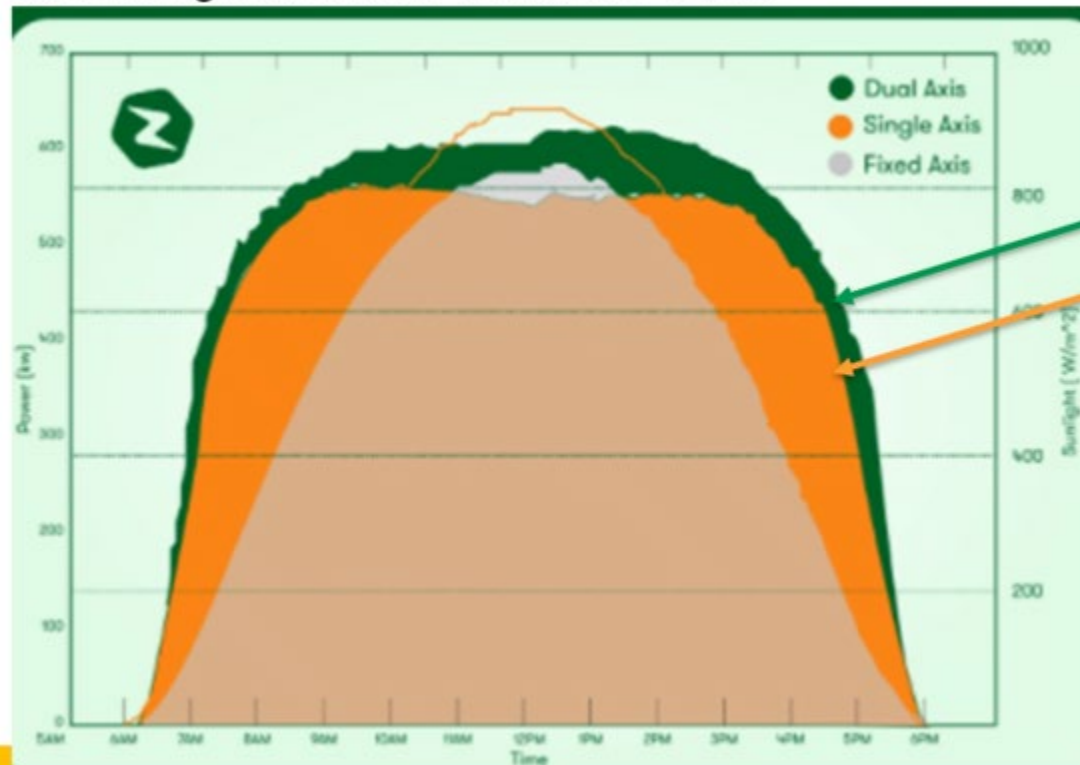


Carport
Cantilevered and Tee



Canopy

Energy Yield – Fixed vs Single Axis Tracker vs Dual Axis Tracker



20-40% Gain

15-25% Gain

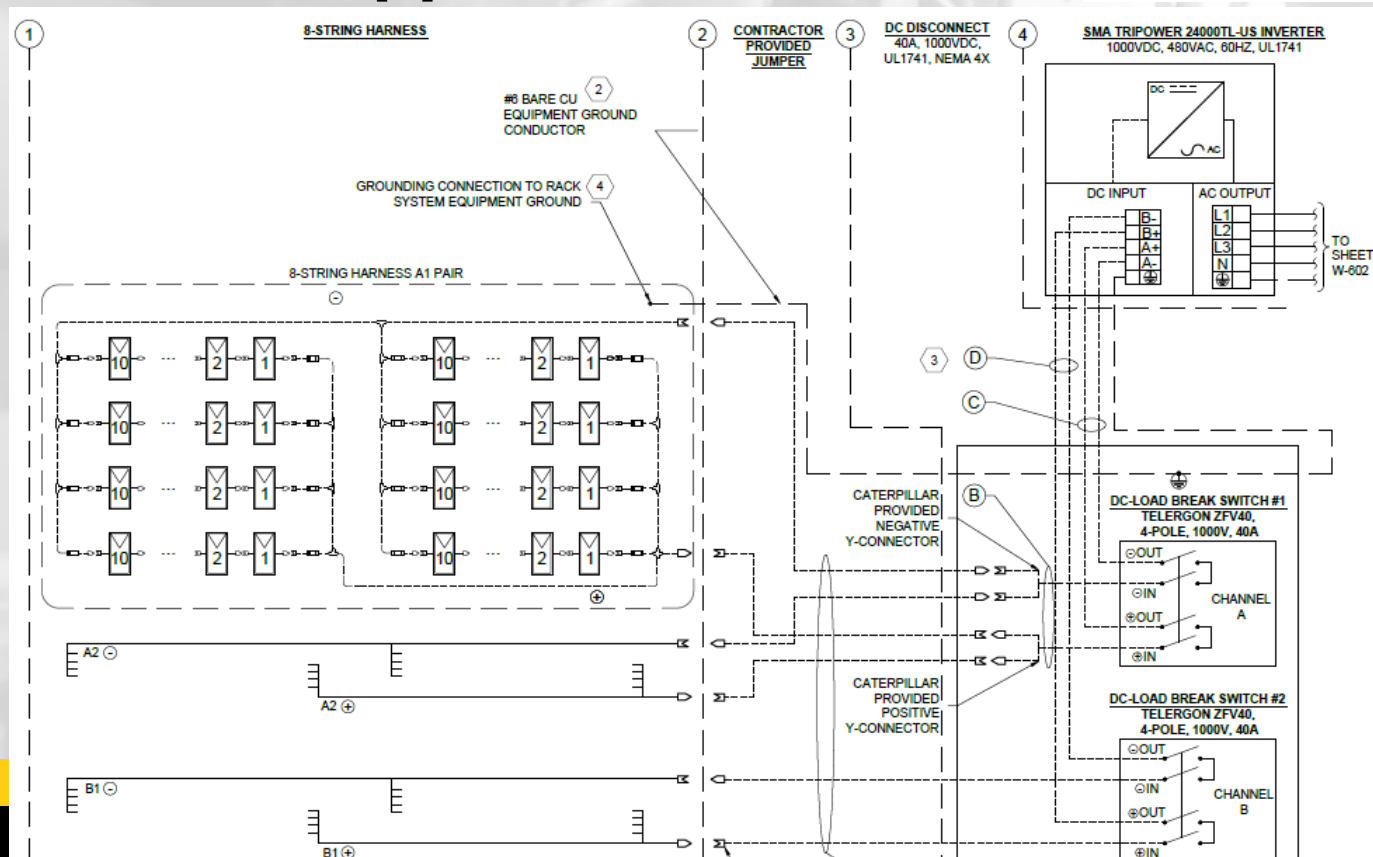
Inverters

SMA
CSA ,UL approved



UL Three Phase 33 kW – 150 kW

UL Single Phase 3 kW – 7.7 kW



Inverters



UL Three Phase 33 kW – 150 kW
UL Single Phase 3 kW – 7.7 kW

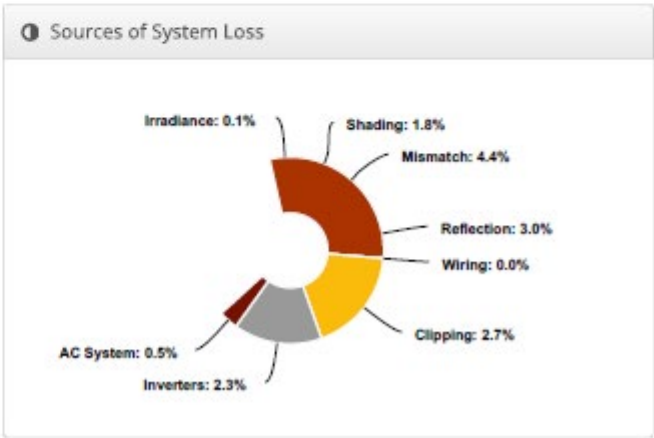
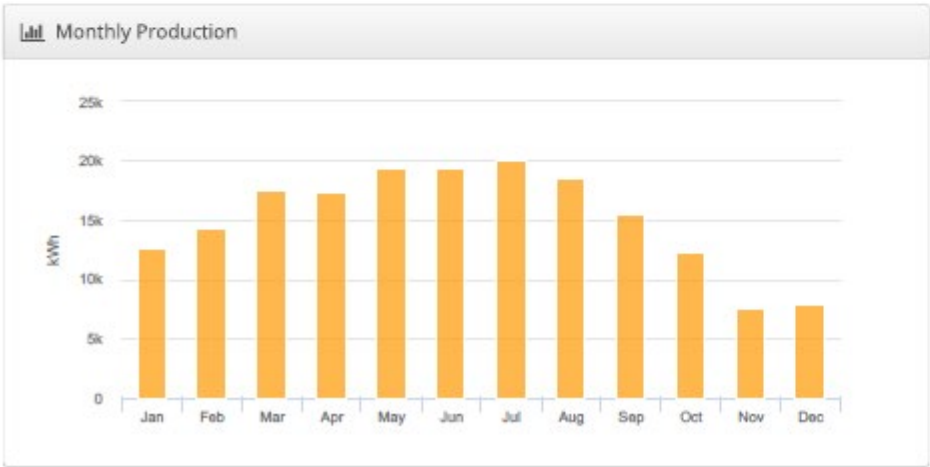
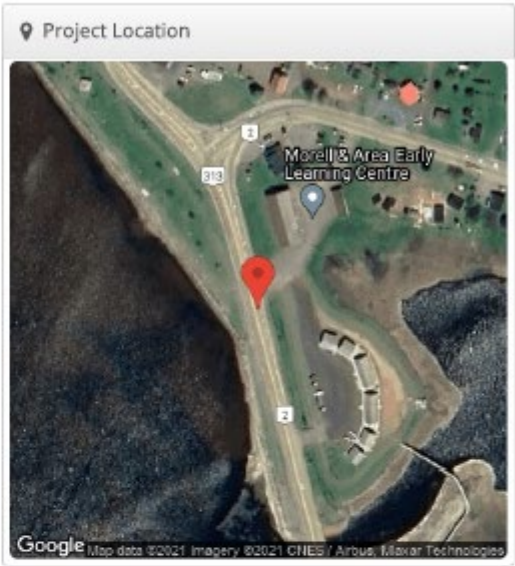
Technical data	Sunny Tripower CORE1 33-US	Sunny Tripower CORE1 50-US	Sunny Tripower CORE1 62-US
Input (DC)			
Maximum array power	50000 Wp STC	75000 Wp STC	93750 Wp STC
Maximum system voltage		1000 V	
Rated MPP voltage range	330 V ... 800 V	500 V ... 800 V	550 V ... 800 V
MPPT operating voltage range		150 V ... 1000 V	
Minimum DC voltage / start voltage		150 V / 188 V	
MPPT trackers / strings per MPPT input		6 / 2	
Maximum operating input current / per MPPT tracker		120 A / 20 A	
Maximum short circuit current per MPPT / per string input		30 A / 30 A	
Output (AC)			
AC nominal power	33300 W	50000 W	62500 W
Maximum apparent power	33300 VA	53000 VA	66000 VA
Output phases / line connections		3 / 3-(N)-PE	
Nominal AC voltage		480 V / 277 V WYE	
AC voltage range		244 V ... 305 V	
Maximum output current	40 A	64 A	80 A
Rated grid frequency		60 Hz	
Grid frequency / range		50 Hz, 60 Hz / -6 Hz ... +6 Hz	
Power factor at rated power / adjustable displacement		1 / 0.0 leading ... 0.0 lagging	
Harmonics THD		<3 %	
Efficiency			
CEC efficiency	97.5%	97.5%	97.5%
Protection and safety features			
Load rated DC disconnect		•	
Load rated AC disconnect		•	
Ground fault monitoring: Riso / Differential current		• / •	
DC AFCI arc-fault protection		•	
SunSpec PLC signal for rapid shutdown		•	
DC reverse polarity protection		•	
AC short circuit protection		•	
DC surge protection: Type 2 / Type 1+2		○ / ○	
AC surge protection: Type 2 / Type 1+2		○ / ○	
Protection class / overvoltage category (as per UL 840)		1 / IV	

Heliscope Analysis

Ground Mount Array - South Side (35deg) Revised PV.C - UPEI - CCCCA, 5524 St. Peters Road in St. Peters Bay, Kings County, Prince Edward Island

Report	
Project Name	PV.C - UPEI - CCCCA
Project Address	5524 St. Peters Road in St. Peters Bay, Kings County, Prince Edward Island
Prepared By	Colleen McWilliams celizer@solaralliance.com

System Metrics	
Design	Ground Mount Array - South Side (35deg) Revised
Module DC Nameplate	131.7 kW
Inverter AC Nameplate	100.0 kW Load Ratio: 1.32
Annual Production	182.3 MWh
Performance Ratio	91.2%
kWh/kWp	1,384.1
Weather Dataset	TMY, 10km Grid, meteonorm (meteonorm)
Simulator Version	Bab6c1dc12-d6b09898f2-d64b51de0f-2475be9f8d



Condition Set

Description	Condition Set 2-PVC4XX Bifacial											
Weather Dataset	TMY, 10km Grid, meteonorm (meteonorm)											
Solar Angle Location	Meteo Lat/Lng											
Transposition Model	Perez Model											
Temperature Model	Sandia Model											
Temperature Model Parameters	Rack Type	a		b		Temperature Delta						
	Fixed Tilt	-3.56		-0.075		3°C						
	Flush Mount	-2.81		-0.0455		0°C						
	East-West	-3.56		-0.075		3°C						
	Carport	-3.56		-0.075		3°C						
Soiling (%)	J	F	M	A	M	J	J	A	S	O	N	D
	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
Irradiation Variance	5%											
Cell Temperature Spread	4° C											
Module Binning Range	0% to 1.12359%											
AC System Derate	0.50%											
Module Characterizations	Module	Uploaded By		Characterization								
	PVC445MB03H (Caterpillar)	Caterpillar		200310.Caterpillar_PVC445MB03H.PAN, PAN								
Component Characterizations	Device					Uploaded By		Characterization				
	Sunny Tripower Core1 CEC (SMA)					Folsom Labs		Default Characterization				

Components

Component	Name	Count
Inverters	Sunny Tripower Core1 CEC (SMA)	2 (100.0 kW)
Strings	10 AWG (Copper)	18 (2,387.8 ft)
Module	Caterpillar, PVC445MB03H (445W)	296 (131.7 kW)

Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	-	4-17	Along Racking

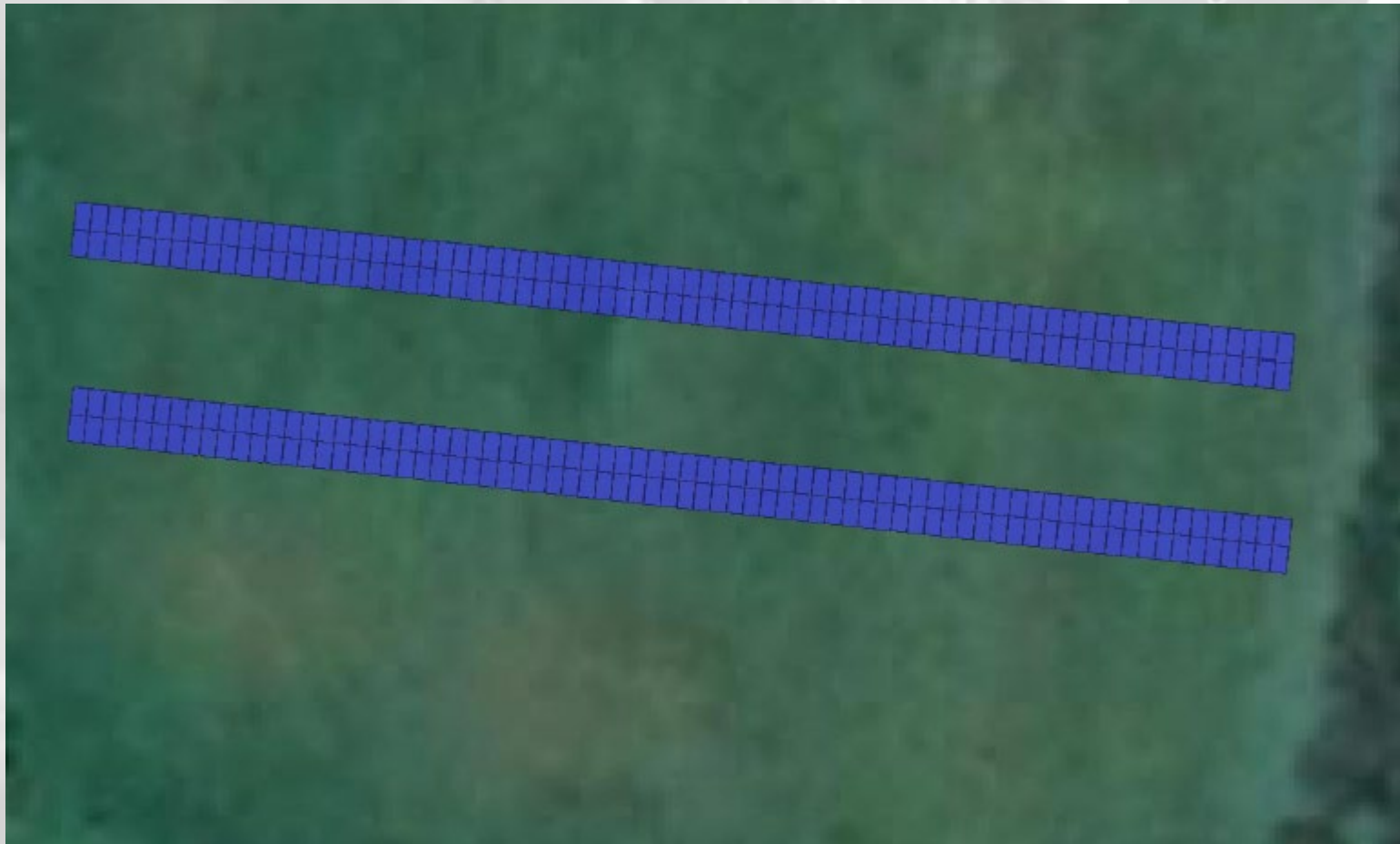
Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	Fixed Tilt	Portrait (Vertical)	35°	186.20169°	26.6 ft	2x74	2	296	131.7 kW

Annual Production

	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	1,259.0	
	POA Irradiance	1,517.2	20.5%
	Shaded Irradiance	1,490.5	-1.8%
	Irradiance after Reflection	1,445.2	-3.0%
	Irradiance after Soiling	1,517.5	5.0%
	Total Collector Irradiance	1,517.5	0.0%
Energy (kWh)	Nameplate	200,984.7	
	Output at Irradiance Levels	200,727.3	-0.1%
	Output at Cell Temperature Derate	201,632.6	0.5%
	Output After Mismatch	192,697.7	-4.4%
	Optimal DC Output	192,684.1	0.0%
	Constrained DC Output	187,482.8	-2.7%
	Inverter Output	183,226.4	-2.3%
	Energy to Grid	182,310.2	-0.5%
Temperature Metrics			
Avg. Operating Ambient Temp		8.8 °C	
Avg. Operating Cell Temp		16.3 °C	
Simulation Metrics			
		Operating Hours	4605
		Solved Hours	4605

Heliscope Analysis



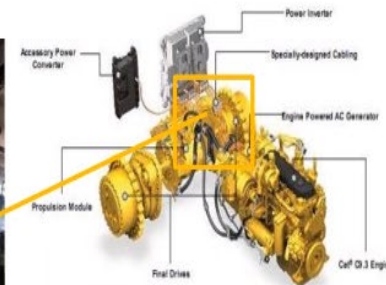
Battery Energy Storage Systems (BESS)

Bi-Directional Inverter – BDP

- Provides intelligent charging and discharging of energy storage solution
- Leverages technology developed for the electric drive machines
- 1000kva rating



D7E Electric Power Train



Battery Energy Storage Systems (BESS)



Cat® BDP1000 Energy Storage Inverter

The Cat® BDP1000 (Bi-directional Power) energy storage inverter provides reliable control of the Energy Storage System (ESS). Integrated controls provide complete management of the charge and discharge of the ESS. The BDP1000 is compatible with a range of storage solutions and can be packaged with the ESS. The patented Cat non-linear droop control system allows ultra-fast response for smooth reliable power off grid.

Grid Support

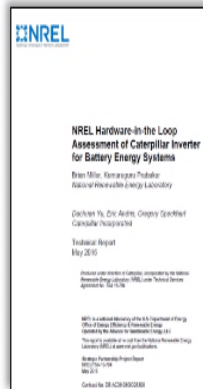
- UL1741 (pending)
- IEEE1547:2018
- Grid following
- Provide Reactive Power
- Voltage and Frequency Ride Through
- Open Phase Detection and Anti-islanding
- High Rate of Change of Frequency Ride Through (ROCOF) ($> 100\text{Hz/s}$)
- Voltage Regulation by Power

Parallel Ready

Plug-and-play paralleling with other power sources.

Cat Energy Storage Solution

- CAT BDP Features
 - Line-interactive
 - Seamless transition between charge and discharge
 - Grid-Following or Grid-Forming or Grid-Firming
 - NREL test “exceeded expectations”
 - Fault Clearing Capability
 - VAR PF Conditioning
 - Overload
 - Speed



Source: Rocky Mountain Institute



Li-ion

- Minutes to hours of energy
- Scalable capacity to enable time shifting
- 1,000's of cycles



Ultra-Capacitors

- Seconds of duration of energy
- Used alone or in conjunction with Li-ion
- 1,000,000's of cycles.

Cat Energy Storage Packaged Solutions



Factory Built and Tested (Plug-n-play)

- Includes fire suppression equipment
- Options for Environmental Control (HVAC)



Storage



Cat Bi-Directional
Inverter (BDP)

Energy Storage System – Battery System

- Power and energy battery type
 - 2C and 0.4C
 - 1000V DC
- Air cooled, NMC chemistry
 - Leading Power Density
- World class quality supplier
 - Industry Leader
- Factory installed and tested
- Rugged rack design where needed
- Continued technology development to meet cost, quality, and performance



Energy Storage System – Safety

- Multiple risk mitigation options for fire management
 - StatX Fire suppression system
 - Smoke and heat detection
 - Aerosol fire retardant
 - External fire alarm and manual pull station
 - Optional Li-Ion Tamer Off gas detection
 - Integration with power conversion system
 - Optional Dry water pipe
 - Integrated distribution with heat activated sprinkler heads



Fire Control Panel



Fire Department Connection

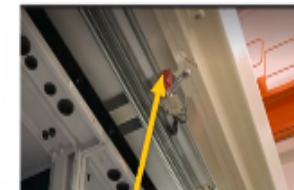


Aerosol Fire Suppression Generator

- Electrical Safety Provisions
 - Door Interlocks
 - Container AC circuit breaker and interlock circuit with inverter
 - Integrated battery/inverter DC interlock circuit
 - Active system temperature monitoring (Transformer, Inverter, Battery)



AC Breaker



Door Switch

Caterpillar Energy Storage Standard Product Options



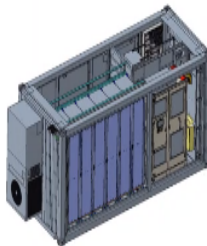
PGS1260 HD
672kWhr w/ 1MW Inverter



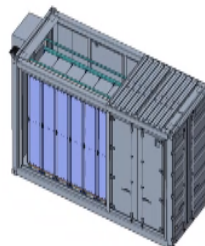
PGS1260
672kWhr w/ 1MW Inverter

PGS1260 Design

- Mobile or Stationary
- 1MW Bi Directional Inverter
- 672kWhr high discharge battery
- Isolation Transformer
- Trailer Mounted Option
- Seamless Genset Integration
- Rugged Connections
- Integrated Controls
- Transient Assist/Grid Stabilize
- Fire suppression
- HVAC, Inverter Cooling
- Communications



ES1.5H0.5-1MW
1.5MWh w/ 1MW Inverter



ES1.5H0MW
ES2.5H0MW

1.5/2.5MWh battery only

ES1.5H0.6MW Design

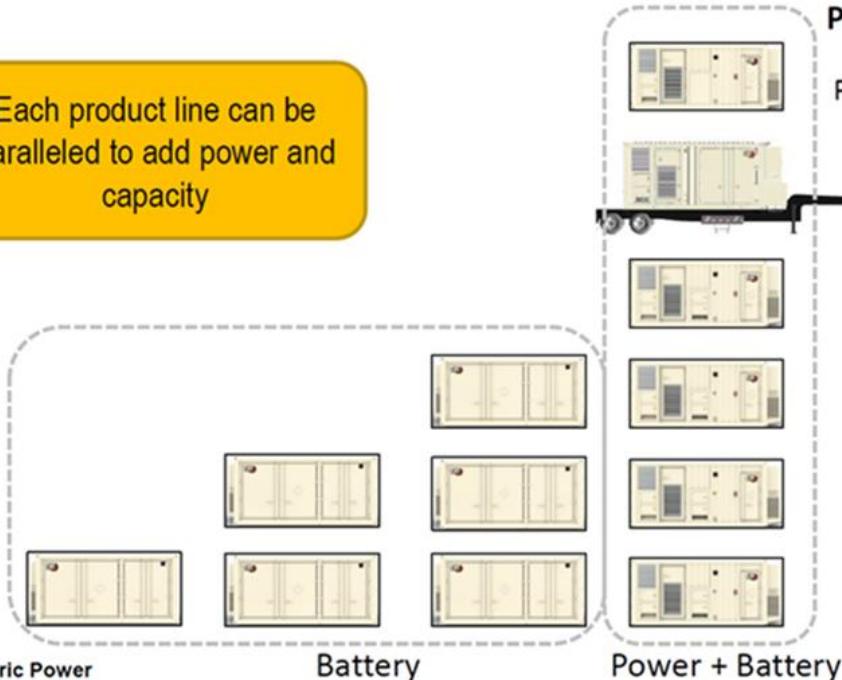
- Stationary
- 1MW Bi Directional Inverter
- 1.5MWhr slow discharge battery
- Fire suppression
- HVAC, Inverter Cooling
- Communications
- Seamless Genset Integration

ES2.5H0MW

- Stationary
- 2.5MWhr slow discharge battery
- Fire suppression
- HVAC
- 4MWhr / 1MW as a set
- Transformer to 480-690V
- Scalable from 1.5 to 9MWhr

Product Line Options and Scalability

Each product line can be paralleled to add power and capacity



Cat® Electric Power
Caterpillar: Confidential Yellow

Battery

Power + Battery

6

Performance Description Product Type, Power, Energy

PGS, 840kW/1.26MW, 448/672kWh

PGS-HD, 1.26MW, 672kWh

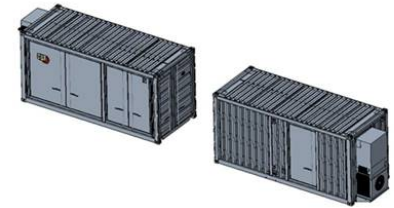
ES, 0.6MW, 1.5 MWh

ES, 1MW, 3/3.5/4 MWh

ES, 1MW, 5.5/6/6.5 MWh

ES, 1MW, 8/8.5/9 MWh

CATERPILLAR®



TIME SHIFT

- Slow Discharge / Slow Recharge
- Low Cycle Frequency
- Peak Shaving / Demand Charge Mitigation / CHP/ Time Shift Applications
- Usage More than 1 hour

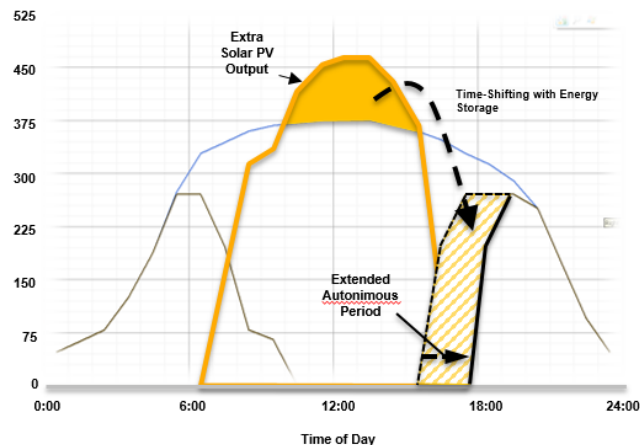
CATERPILLAR®

TOROMONT
Power Systems

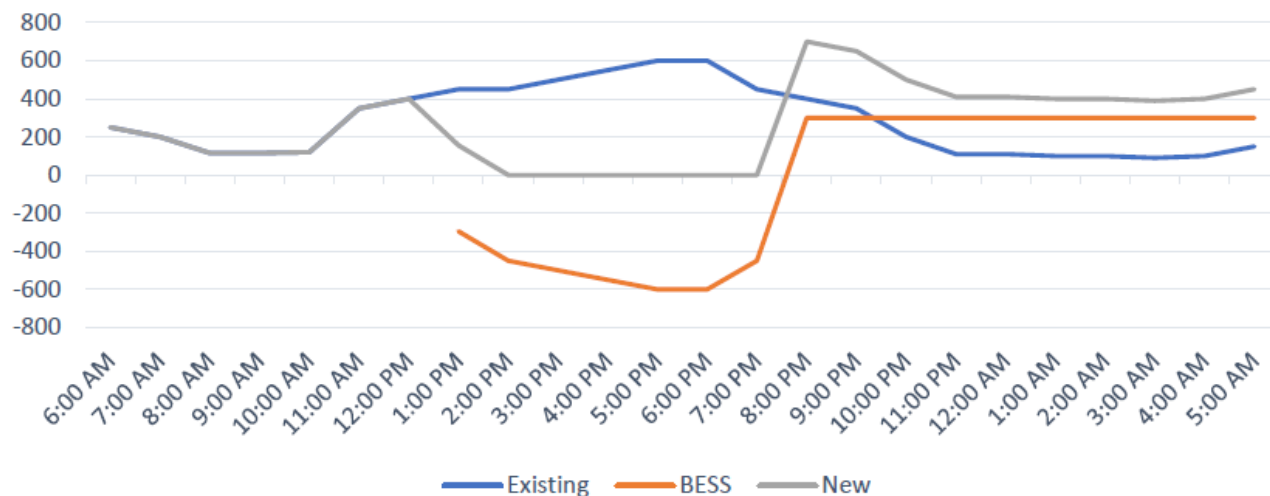


Time Shift

- Charge batteries when PV is available (day)
- Discharge batteries when PV is unavailable (night)
- Long duration events
 - Multiple hours
- Energy (duration) is most important



Effect of BESS on Load Profile for Peak Demand Reduction (kW)



Scalable Grid Stability



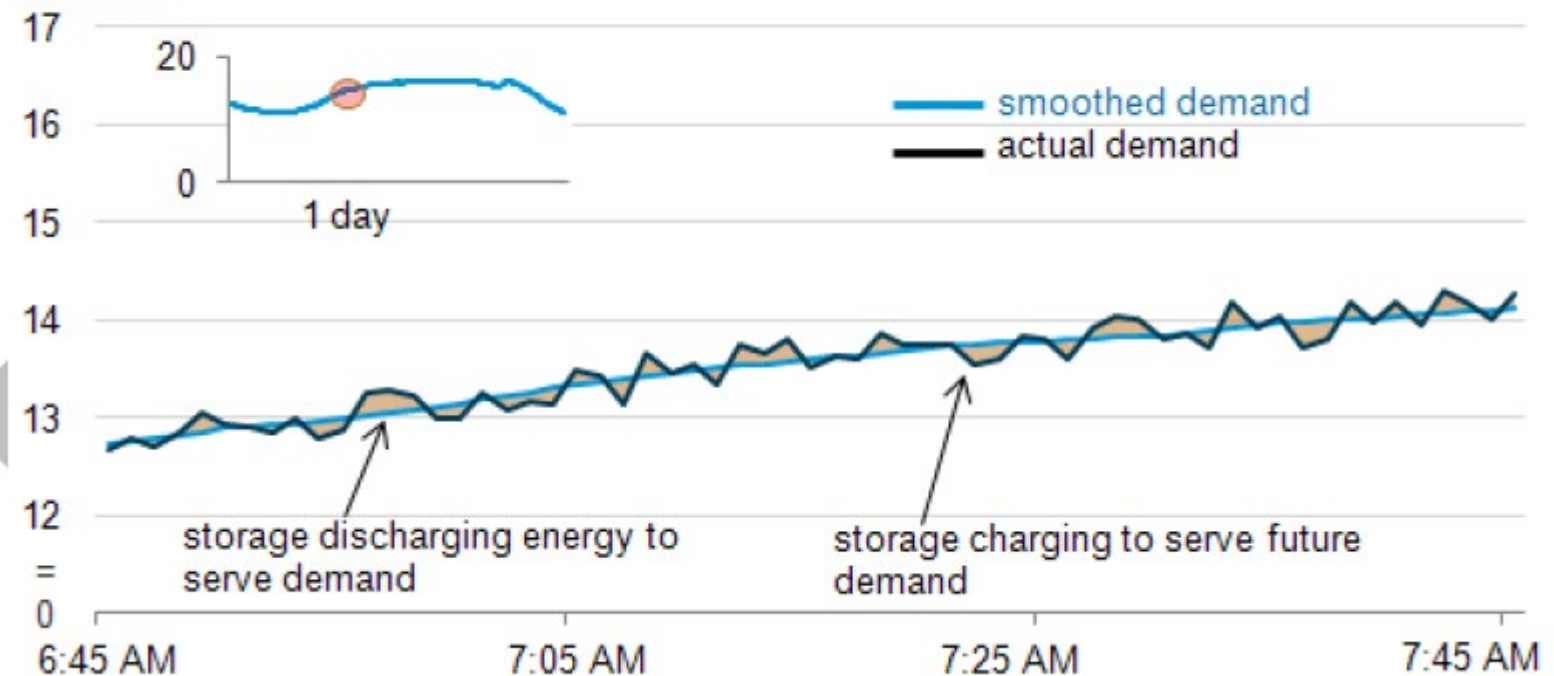
Nameplate Energy	Power	New Scalable Design	
672 kWh	1 MW	20' POWER BAY w/ 6 RACKS	
1344 kWh	2 MW	20' POWER BAY w/ 6 RACKS	20' POWER BAY w/ 6 RACKS

GRID STABILITY

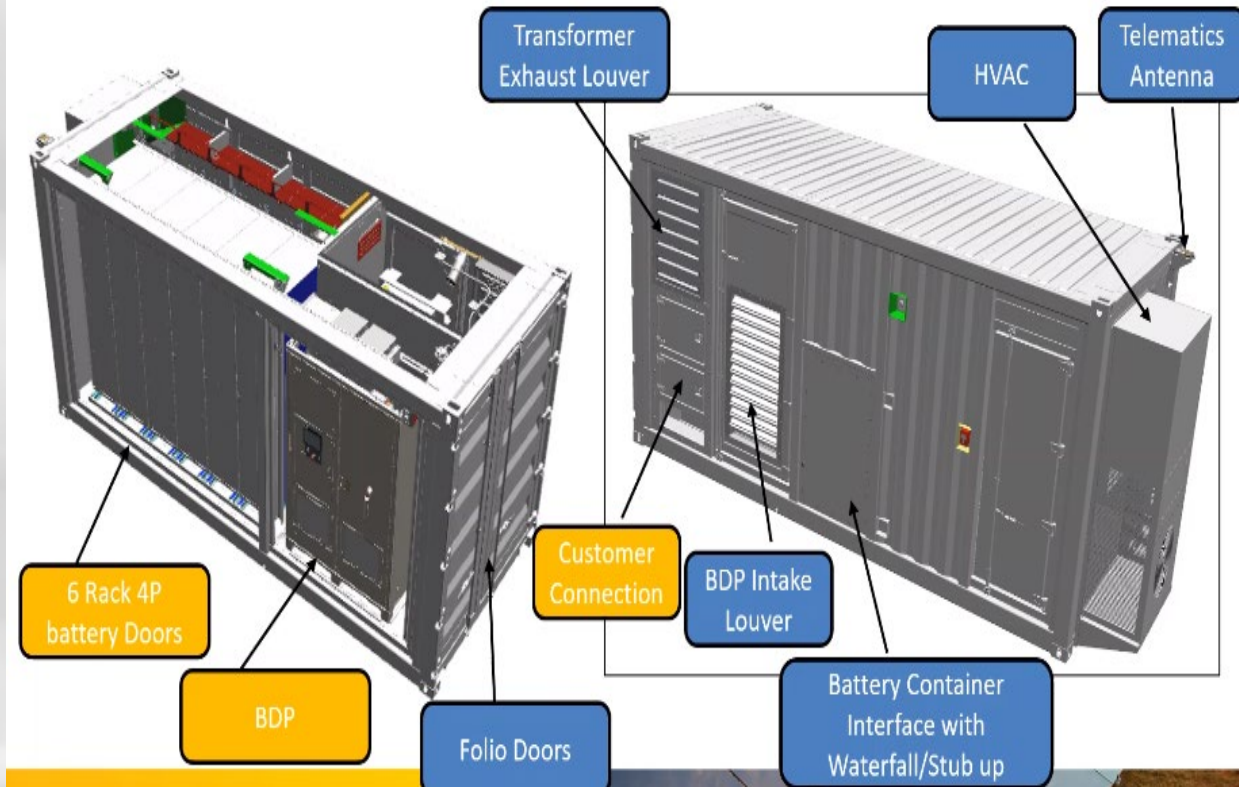
- Fast Discharge / Fast Recharge
- High Cycle Rate
- Flexible Application
- Usage less than 1 hour

Electric power demand, 60-minute period illustration

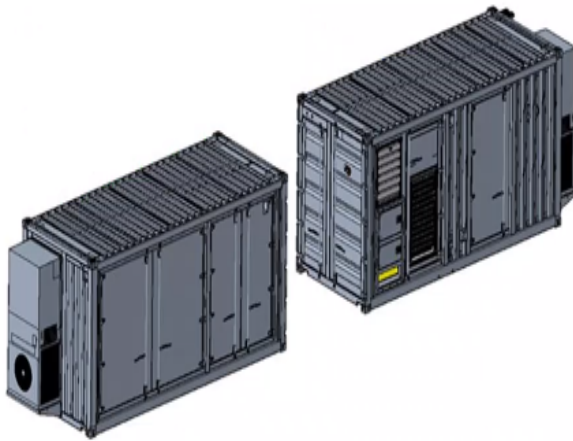
gigawatts



Power Unit – PGS1260 or ES1.5H1MW (ES037)

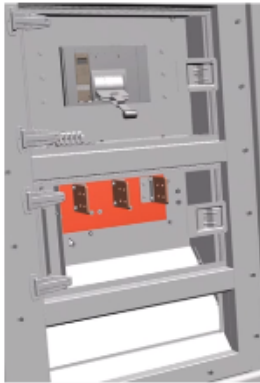


Customer Connections

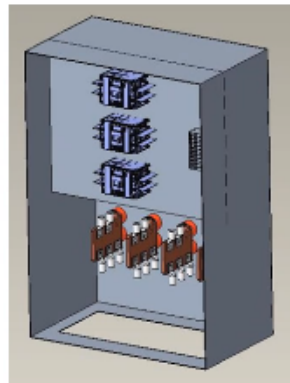


- Power Container
 - AC Power 480/600V
 - Optional AC Shore power
 - Communications
- Interconnect to Energy Container
 - DC Power
 - AC Shore power
 - Communications

Power Unit - ES1.5H1MW

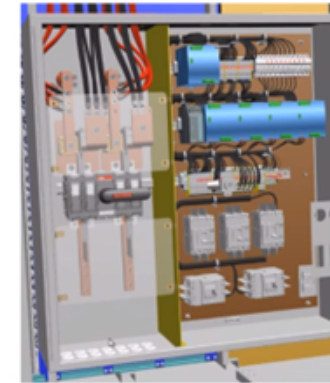


- 3-phase 480/600V 1000kva (+50%)
- 200A 3-phase 480V shore power
- SCADA/Ethernet Comms
- I/O



- 50A 3-phase 480V shore power
- 500kva/1000V DC interconnect
- Ethernet Comms
- I/O

Battery Unit ES1.5H0MW

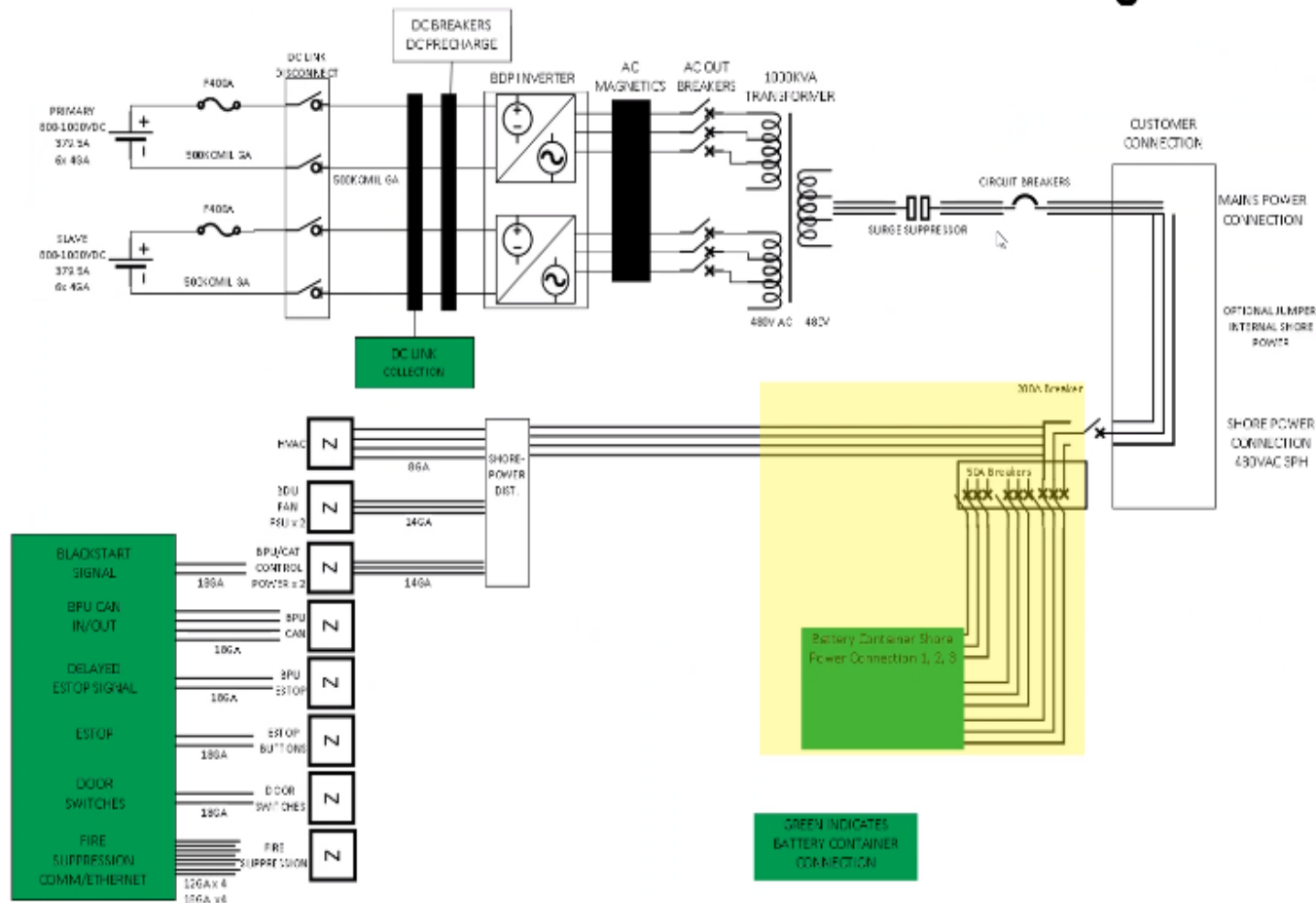


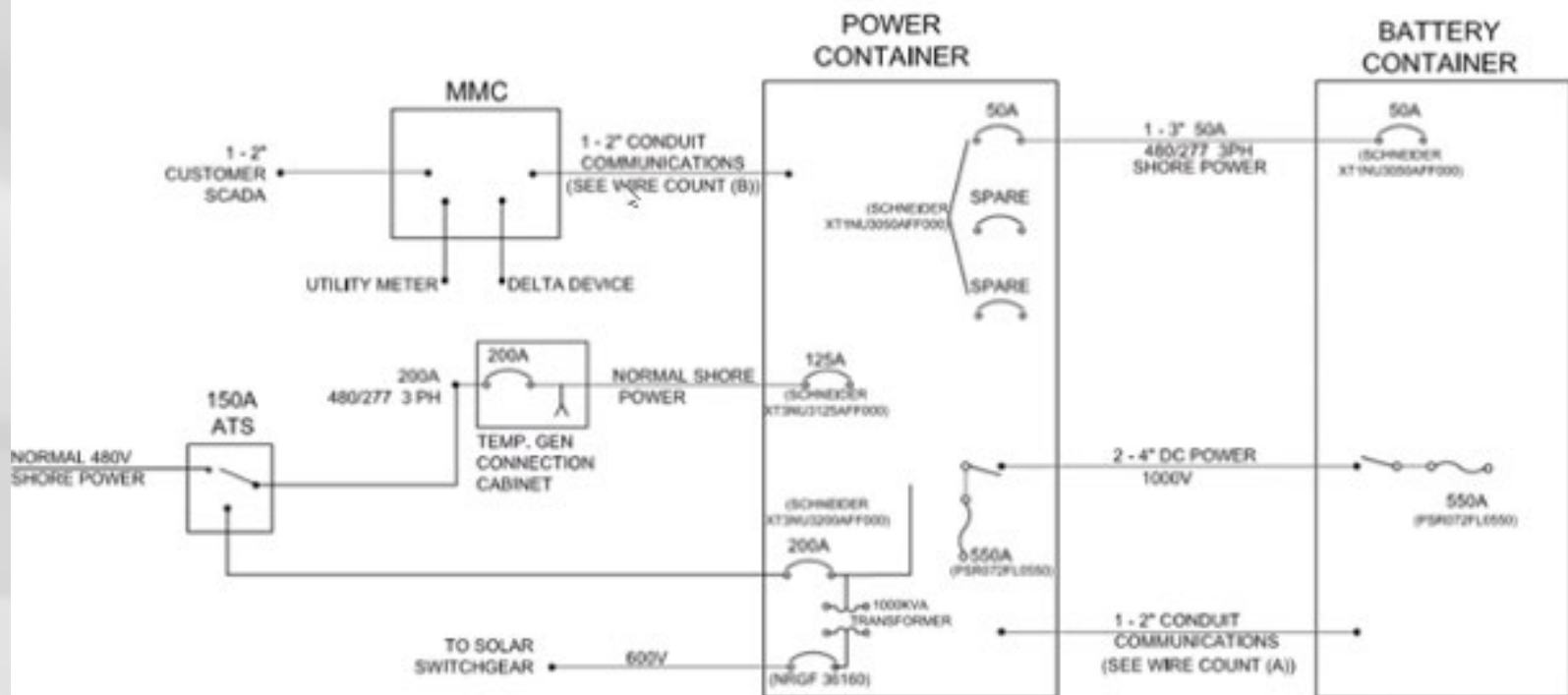
- 50A 3-phase 480V shore power
- 500kva/1000V DC interconnect
- Ethernet Comms
- I/O

Warranty Period

- For Cat Microgrid Energy Storage Systems associated with the Energy Storage System, the warranty period is 60 months, whichever comes first, starting from date of sale to the first user.
- For Master Microgrid Controller, the warranty period is 24 months.

Power Unit – PGS1260/ES1.5H1MW 480V One Line Diagram – N America





Regular Maintenance

Procedure	Interval	Personnel
Air Filter Replacement	6 months* (depending on environment)	Mechanical Technician
Inspection and cleaning	6 months	Mechanical Technician
Fire Suppression System inspection and maintenance	6 months	Certified fire suppression technician
Coolant Level Check and Top Off	6 months	Mechanical Technician
Coolant Flush and Fill	6 years	Electrical Technician
Replace Batteries	10-15 years* (depending on project design and use)	Electrical Technician trained for working on live systems up to 1000V

Cat Microgrid Master Controller (MMC)

CAT MMC



- Scalable master controller for any size microgrids
- Integrates all energy sources (genset, renewable, utility)
- Optimizes production of energy (lowest cost of electricity)
- Ensures reliable operation
- Open protocol can communicate to almost any source

**Controller Options
for Every Situation**

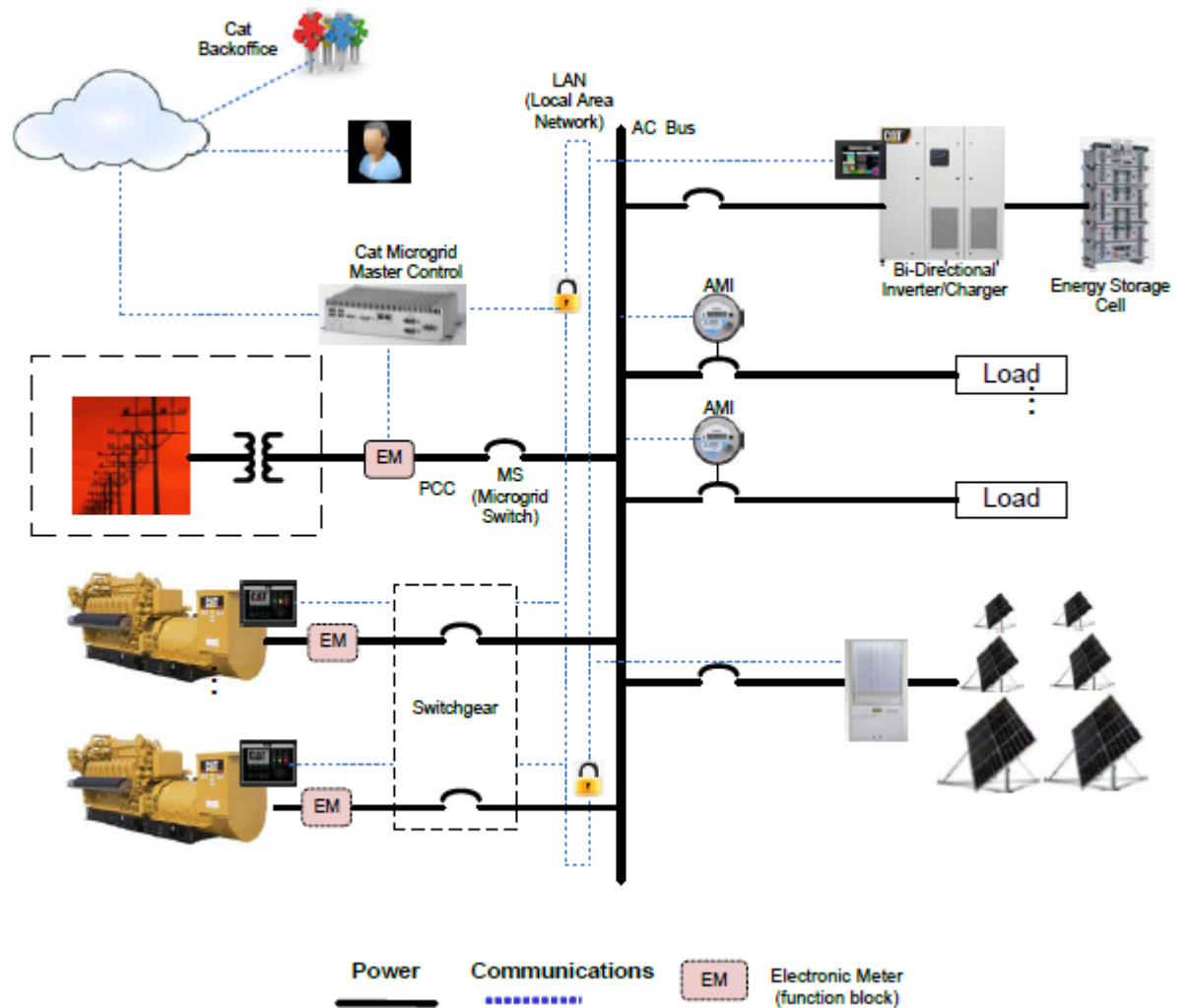
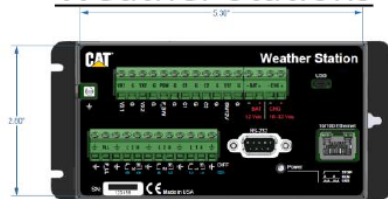
Power Metering



Comms Solutions



Weather Stations



TPG Microgrid System Diagram

PV Fixed Array 250kW



 x 10

PV Tracking Array 250kW

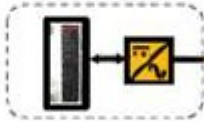


 x 10

Energy Storage
Lithium Ion Battery
250kW / 10 min



Energy Storage
Ultra-capacitor
250kW / 30 sec



3 x
410ekW Prime



System Controller

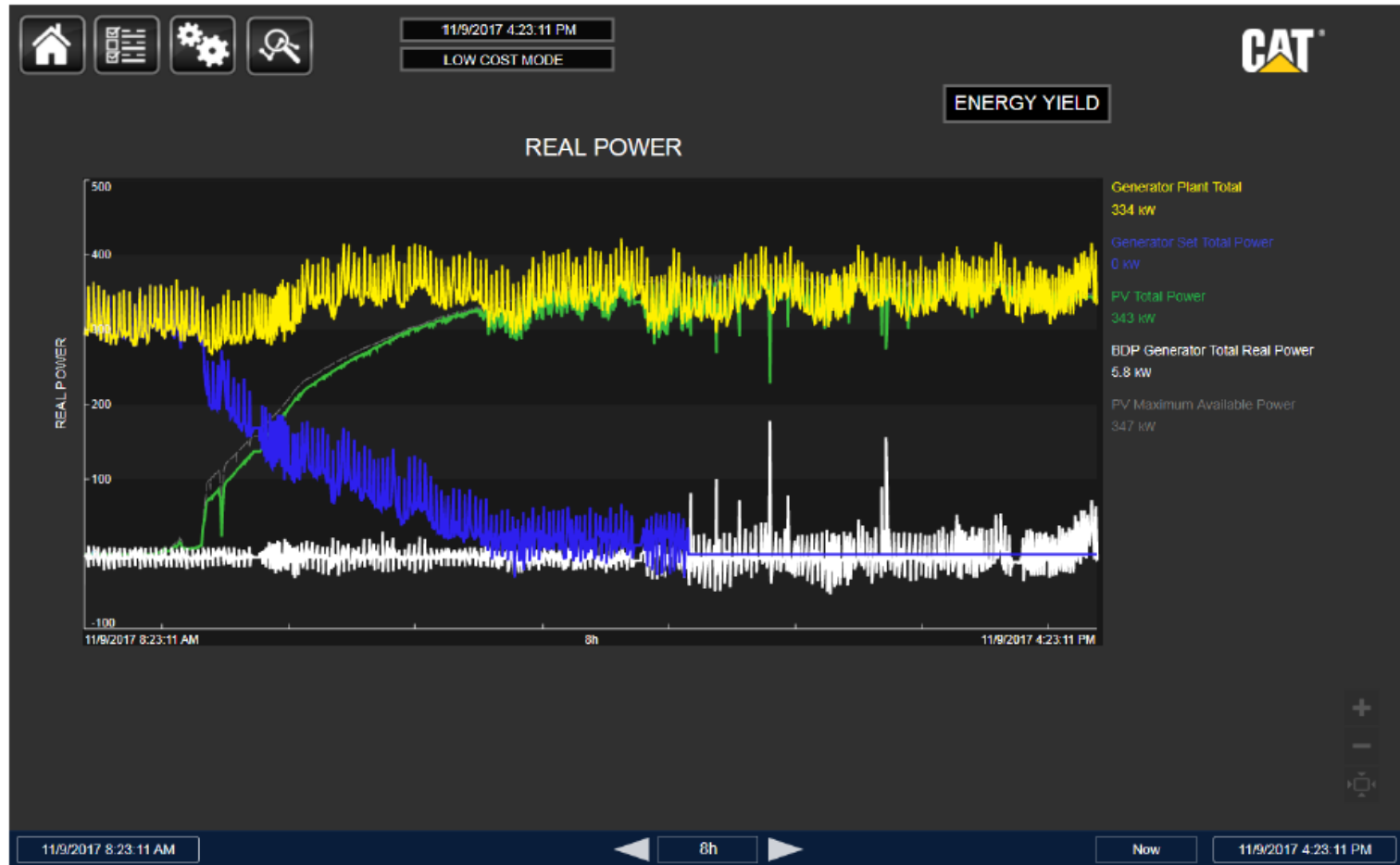
- "Fuel Save" Controller – 1H2016
- MMC – 2X fuel savings -- 2H2016



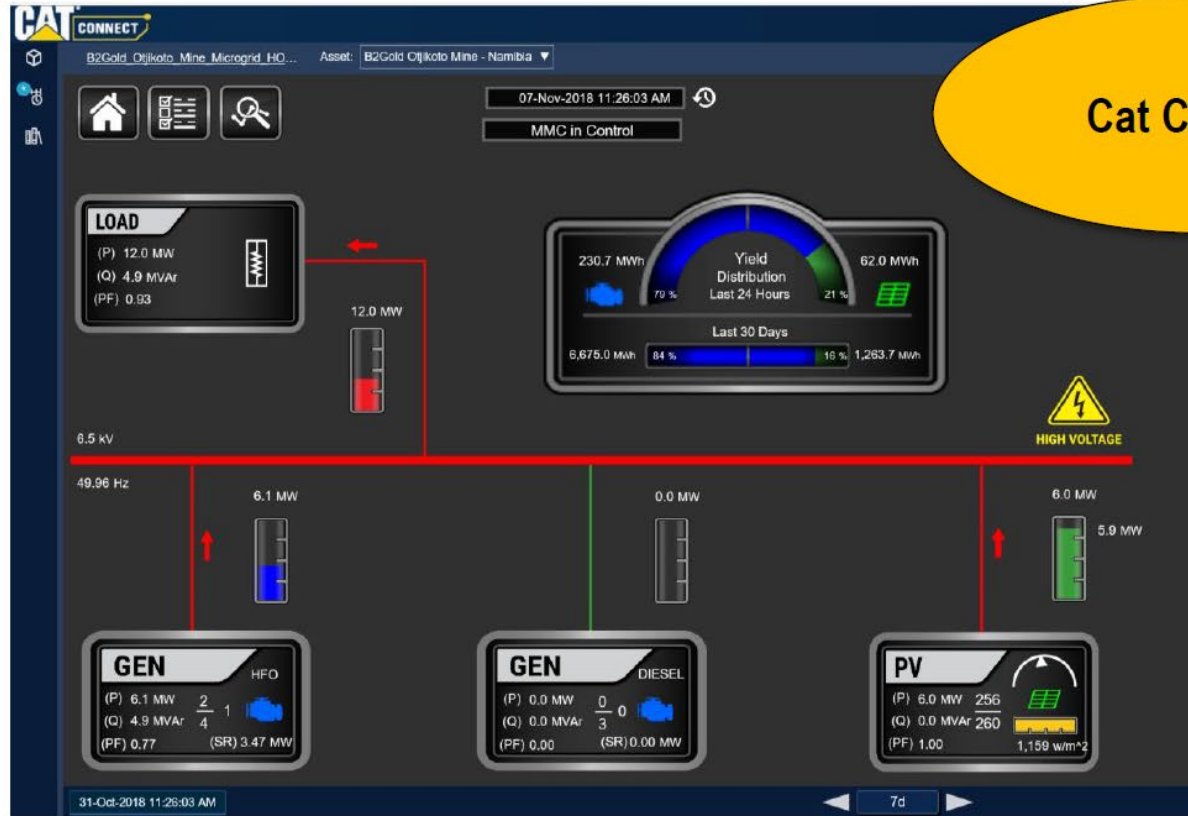
Switchgear

Site
Prime
Power
Loads

Remote Monitoring – Reports & Trending

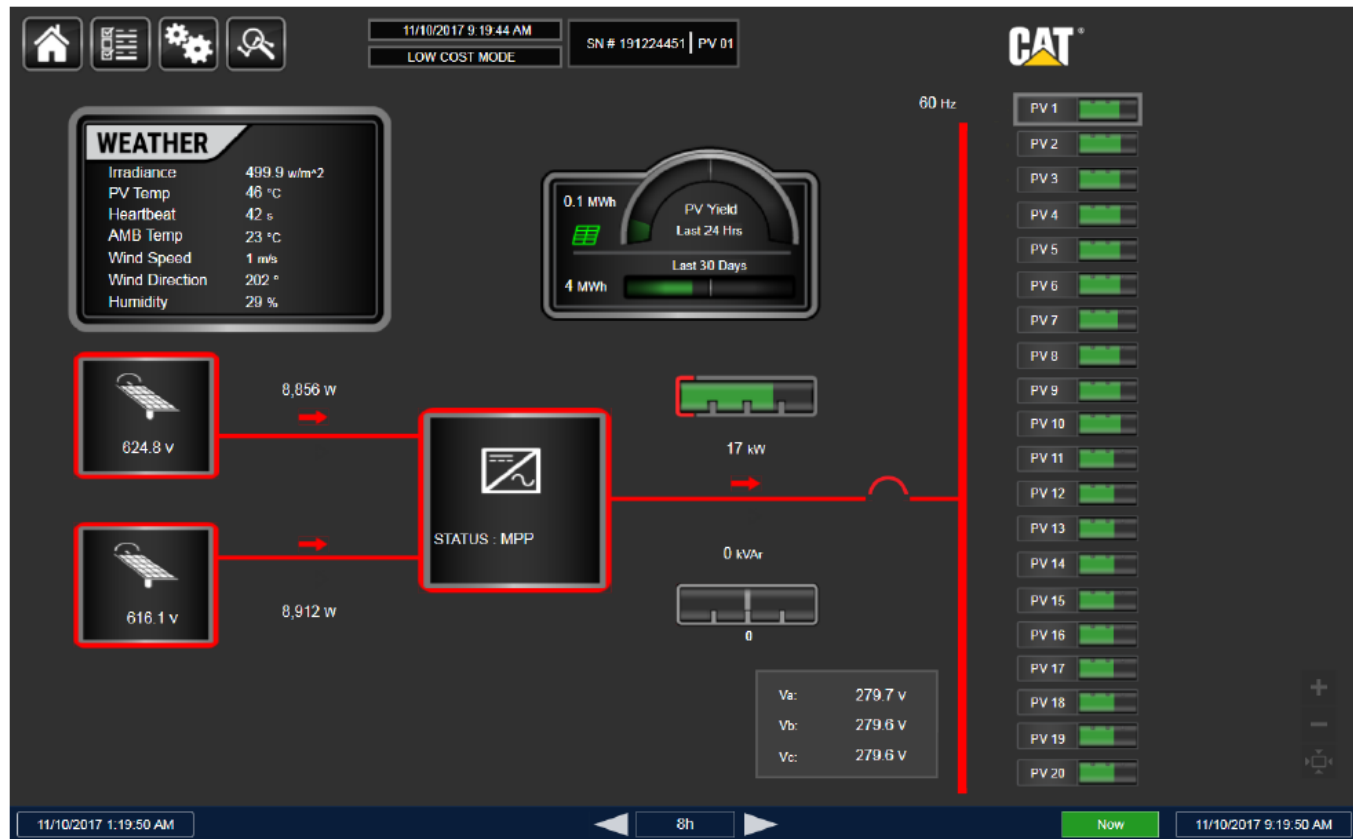


Cat Master Microgrid Controller (MMC) User Interface

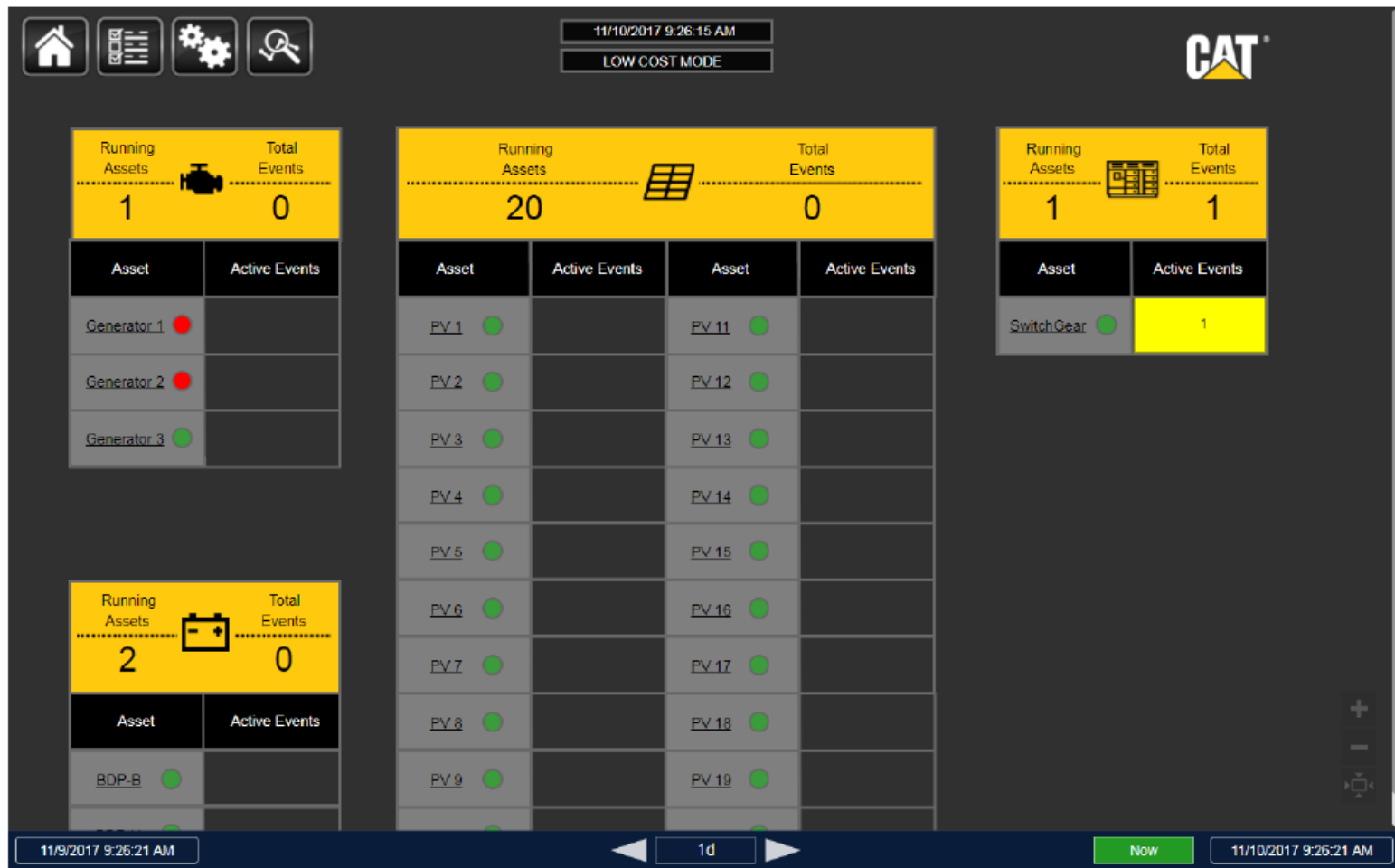


Cat Connect

Remote Monitoring – Detailed Status



Remote Monitoring – System Health



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