XENDEE

Cummins

Maximizing Microgrid Controller Efficiency, with Cummins and Xendee

Microgrid Controller Integration

August 8, 2024

Agenda

- **Speakers' Introduction**
- **Xendee Comprehensive Platform:** Intro to Xendee and software overview
- **The Power of Cummins:** Intro to Cummins and our Power Systems business
- **Cummins in the Microgrid Space:** Cummins background, products, and capabilities in Microgrids
- **Testing OPERATE in the Power Integration Center (PIC):** How Cummins and Xendee combined resources for testing this capability with real hardware and real power
- **Introducing OPERATE by Xendee:** Learn how Xendee's integrated planning and control platform utilizes the same optimization algorithm throughout the entire microgrid engineering process.
- **Q&A**

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Speakers' Introduction

Michael Stadler, Ph.D, M.S.

Co-Founder and Chief Technology Officer
Xendee Corporation

Michael has more than 25 years of experience in microgrid design and modeling. He was a Staff Scientist and led the Grid Integration Group at Lawrence Berkeley National Laboratory, won the PECASE Award of the White House, and acted as Key Scientist of the Microgrid and Smartgrid Department at BEST (Bioenergy and Sustainable Technologies Corporation) where they developed the first microgrid testbed in Austria in 2017. At Xendee leads the technology, marketing and customer success teams.

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Enrico Della Corna

Systems Engineering Technical Specialist
Cummins

Enrico has 9 years of experience at Cummins in a variety of engineering roles, mainly in the Power Systems business. His past 5 years have been spent in systems simulation, with specific focus on microgrids and analyzing both the technical and economic factors of system design. He holds a Bachelors in Mechanical Engineering from Penn State University, and is currently pursing a Masters in Systems Engineering from Cornell University

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Xendee Company Snapshot

Founded:

Xendee was founded in 2018 in San Diego, California by our Executive Team with the express purpose of streamlining the microgrid design process. Since then, we've developed a variety of products to meet the needs of customers handling projects from the proposal stage all the way to live operation.

Leadership Team:

Adib Nasle - *Chief Executive Officer*

Michael Stadler - *Chief Technology Officer*

Scott Mitchell – *Chief Software Officer*

Awards and Recognition:

- 2021 Edison Gold Award
- US White House Presidential Science Award
- US Dept of Defense Standard Platform

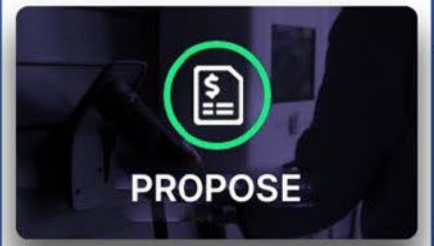
Some of our Partners:

XENDEE

Xendee is a software company that helps with design optimization, modeling services, and holds a current catalog of industry leading technologies to accelerate the design process.

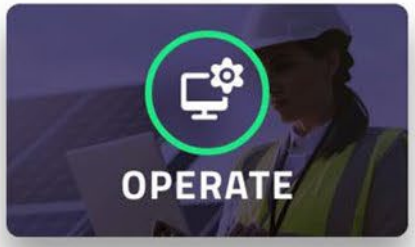
Xendee Design Process

Multi-Site Analysis:
Evaluate thousands of sites in minutes to identify opportunities matching investor priorities.



Single-Site Analysis:
A catalog driven proposal tool designed to win deals fast and pass projects to engineers efficiently.

Detailed Engineering:
Model power, energy flow, and financial constraints to ensure risk-free deployment.



Operation Suite:
Control and optimize runtime to reduce energy cost by up to 80% and maximize resilience and profit.

Feedback to Improve Modeling

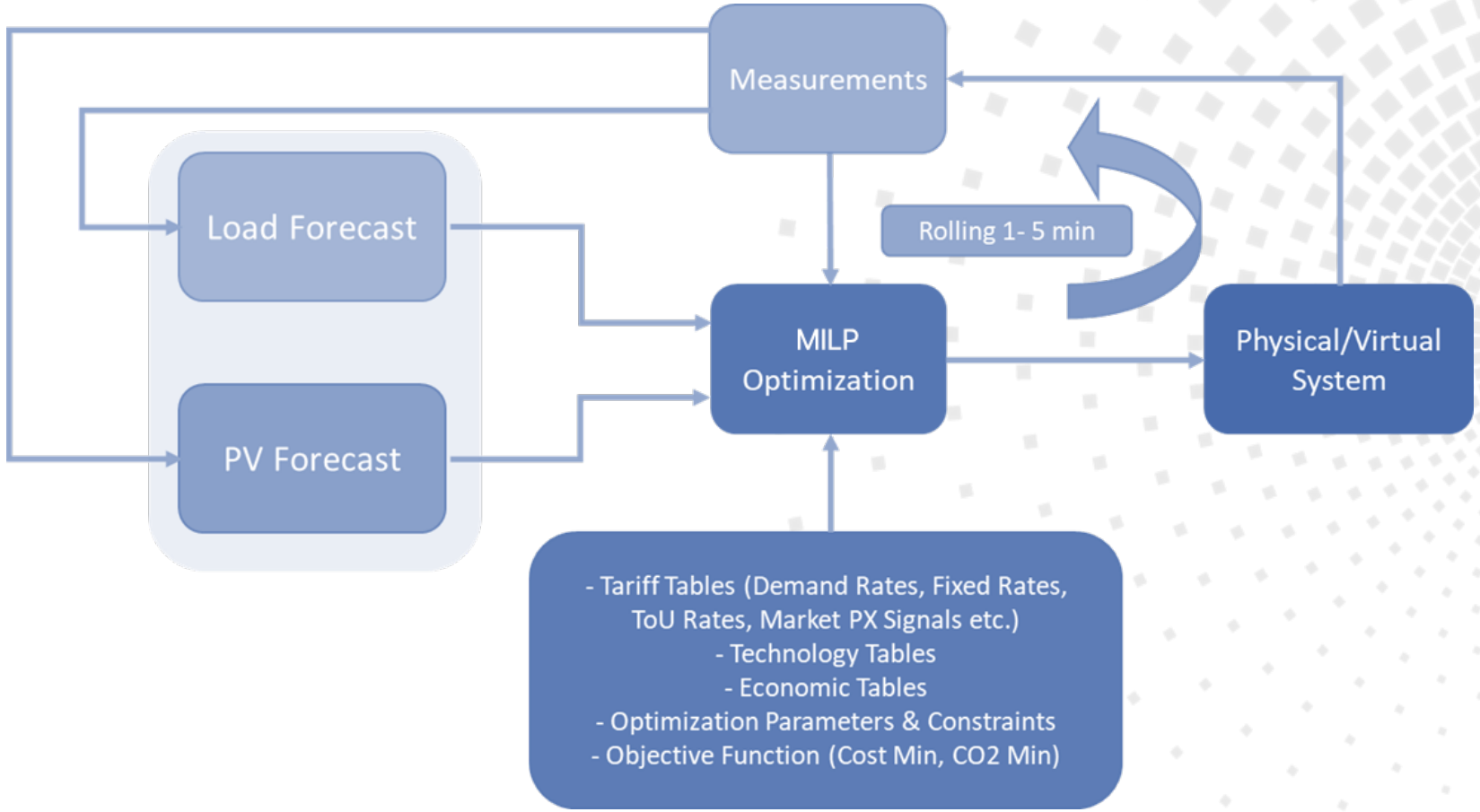
Modeling Services are also available to customers to expand the capabilities of your team.

The OPERATE DER and Microgrid Controller

Adaptive Behavior: Model Predictive Control (MPC)

Model Predictive Control (MPC) establishes an adaptive behavior by repeating forecasting and dispatch optimization every 1 to 5 mins for a forecasting horizon of 48 hours.

MPC picks the most accurate forecasting model based on evaluation logic and scoring system and provides 48-hour short/mid-term forecasts.

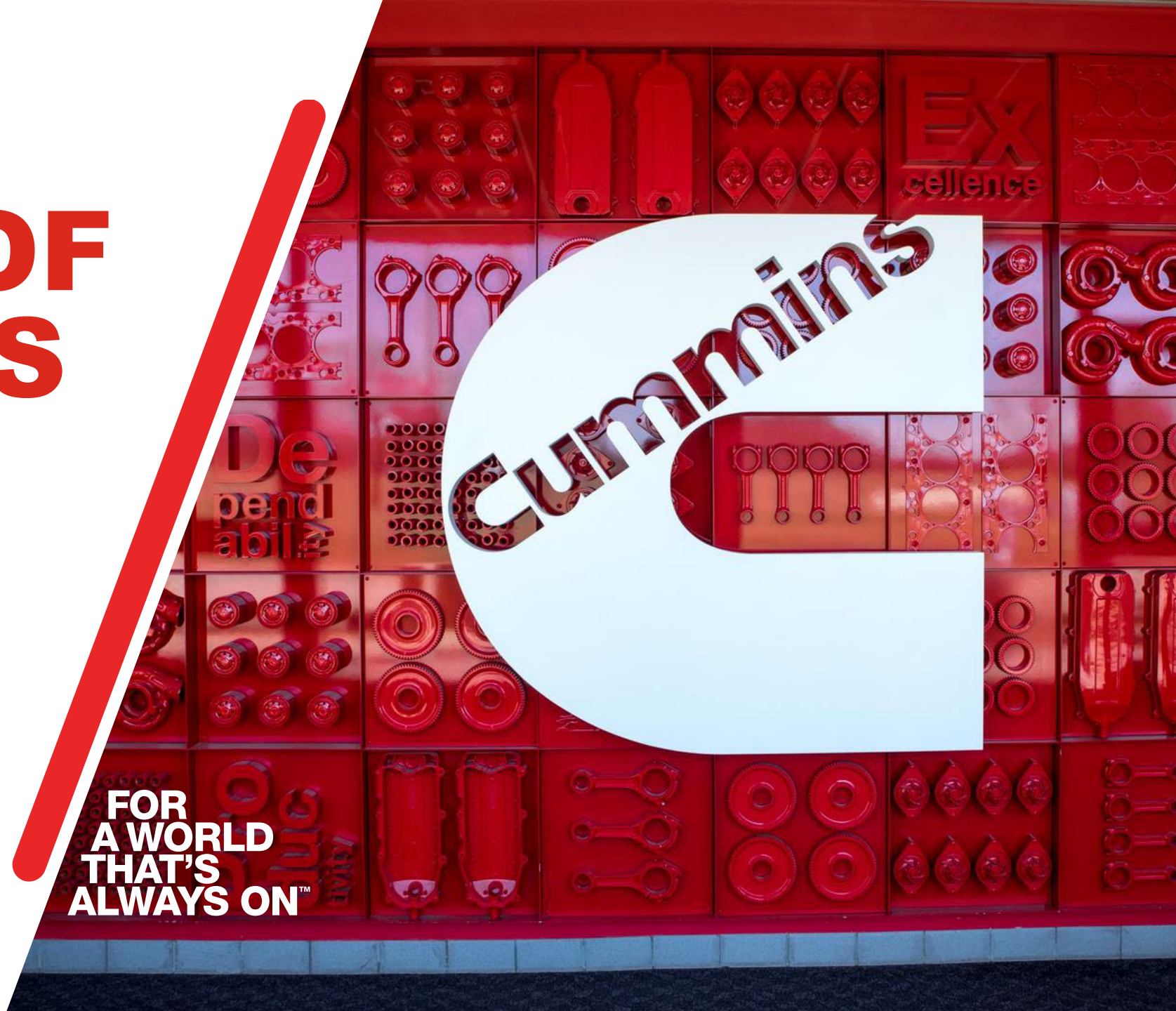


THIS IS THE

POWER OF CUMMINS

August 8, 2024

Public



Powering a more prosperous world

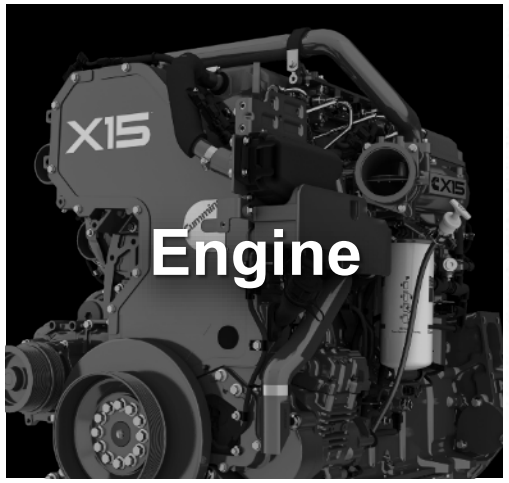
190	Countries and territories*
75,500	Global employees
105	Years of industry leadership
19,000	Cummins certified dealer locations
$1.4B	Invested in research and development in 2023

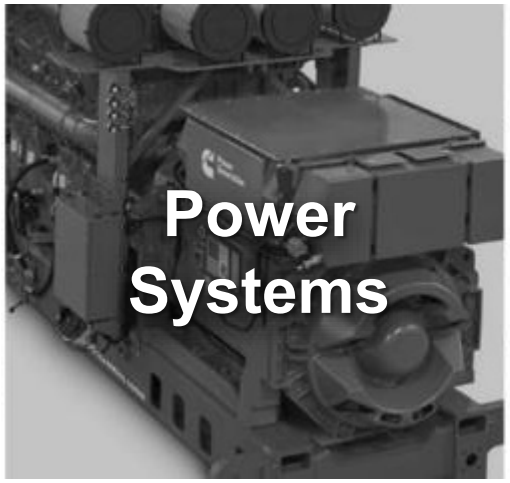
** Approximation of countries and territories with Cummins service*

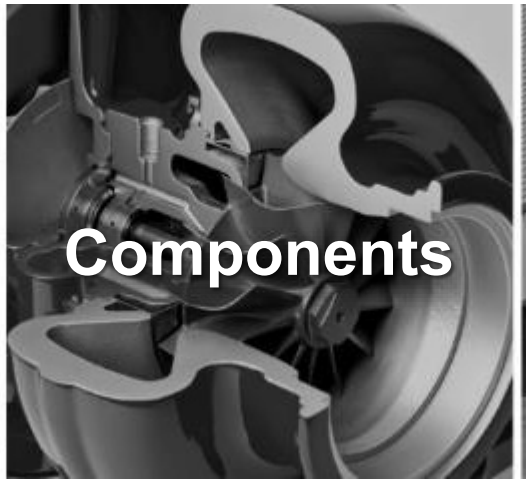
As published in the 2023 10K found on cummins.com.

Five operating segments

Cummins has a long track record of delivering leading power solutions.
As we look ahead, we know our industries and regions will continue to change,
and we are committed to bringing our customers the right technology at the right time.







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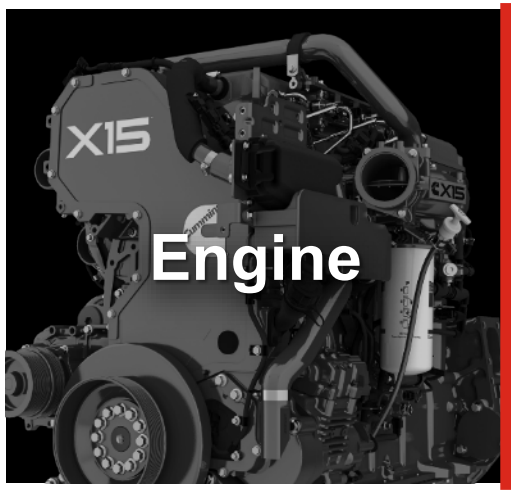
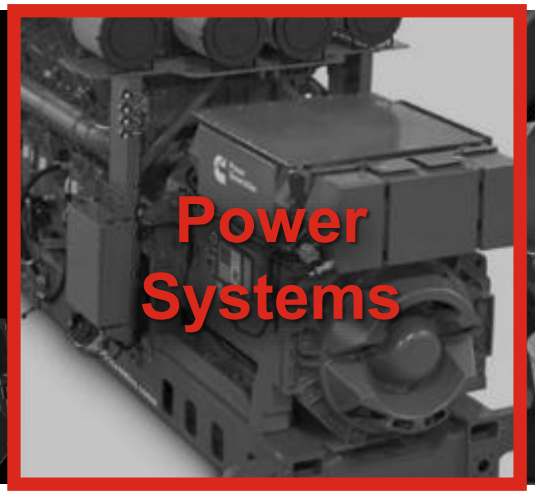
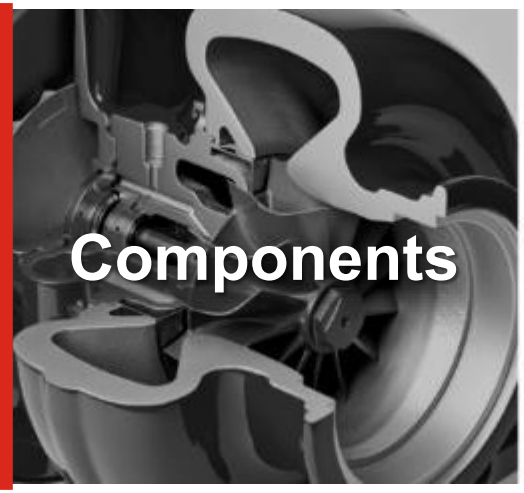






POWER SYSTEMS

DIVERSE MARKETS

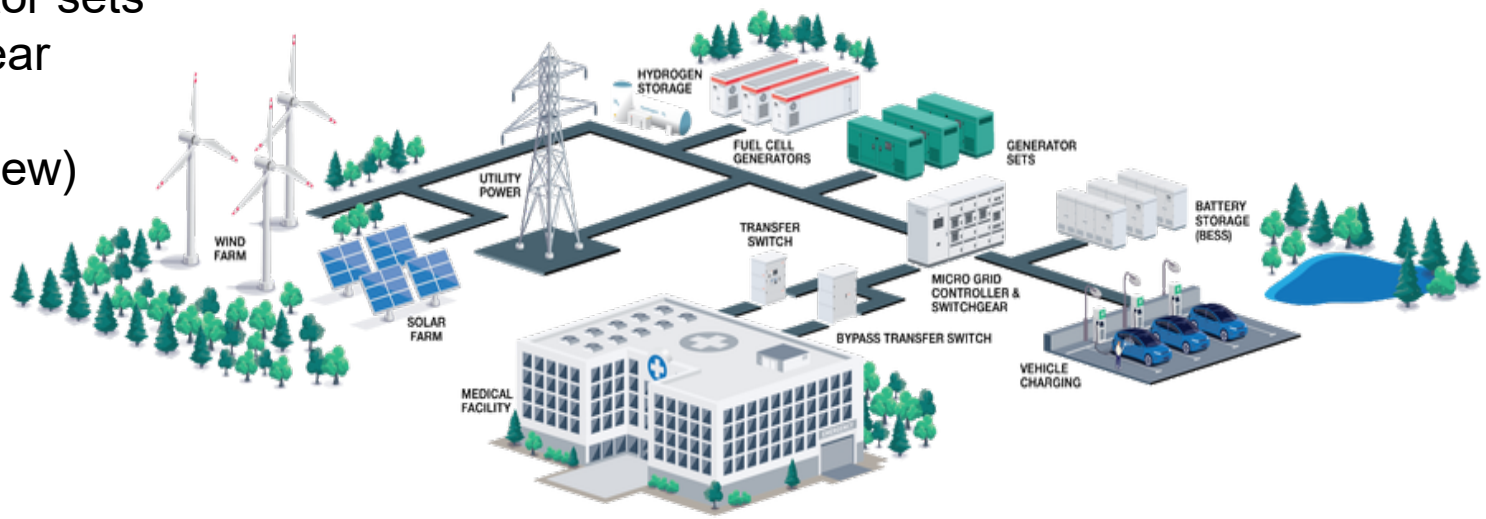
WE WORK WITH CUSTOMERS IN ALMOST EVERY INDUSTRY IMAGINABLE

Cummins in the Microgrid space

Cummins Power Systems Business brings an extensive background in emergency standby power, prime power applications, genset paralleling, and power system controls. The expansion into Microgrids is built on this foundation.

Cummins is actively growing our Microgrid-relevant product portfolio, with products including:

- Diesel and Natural Gas Generator sets
- Microgrid Controls and Switchgear
- Battery Storage (New)
- AC and DC Vehicle Charging (New)
- Fuel Cell Generators (New)
- Electrolyzers (New)



For more information, go to:
https://www.cummins.com/generators/microgrids

PowerCommand® MGC300 & MGC900

Small Scale ~ 3MW → **Large Scale & Complex Systems**

MGC300 & MGC900

Customized to Project Needs

Features	MGC 300	MGC 900
Product Application	Simple Microgrid Systems	Complex Microgrid Systems
Energy Resource Optimization	Available	Available
Colored Touchscreen User Interface	19"	19"
Generator Support Capability	Up to 2	Unlimited
Renewable Support (PV, Storage, etc.)	Available	Available
Load Support Capability	Up to 6	Unlimited
Weather Data Interface	Available	Available
Communication Protocol	Modbus TCP/IP	Modbus TCP/IP

For more information, go to: https://www.cummins.com/generators/microgrid-control

Cummins Power Integration Center (PIC) – Fridley MN, USA

Site Background

- 20,000 sq ft facility adjacent to Fridley manufacturing plant
- Fully operational microgrid power system with 2MW electrical bus capacity, independent from Fridley plant loads
- Configurable electrical connections to allow multiple asset types, topologies, and use cases to be tested without additional capital expense

Application Opportunities

- Microgrid use case validation
- DER (Distributed Energy Resource) Asset integration testing
  - Fuel Cells
  - Electrolyzers
  - Gensets
- Mobile Hybrid Applications
- New Component and System Control validation

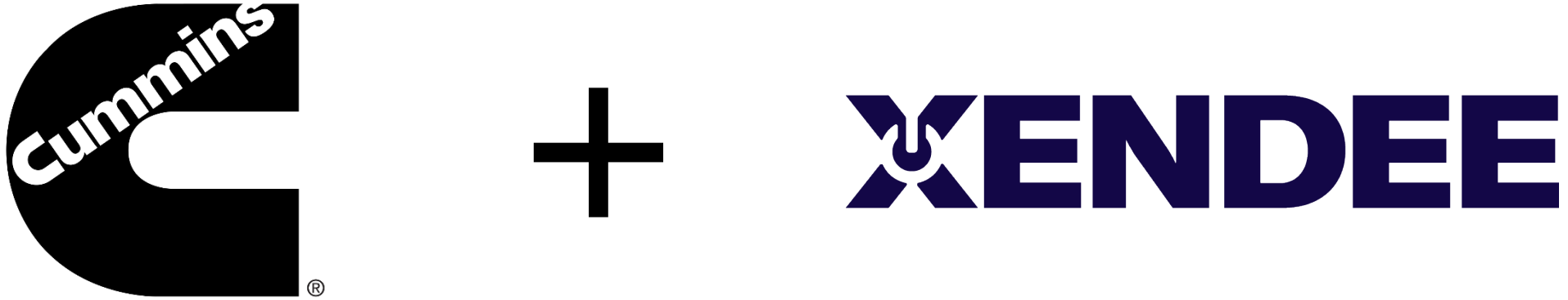
Outdoor Testing Area

Control Room & Office Space

Microgrid Switchgear Area

Mezzanine Testing Area

What brought Cummins & Xendee together?



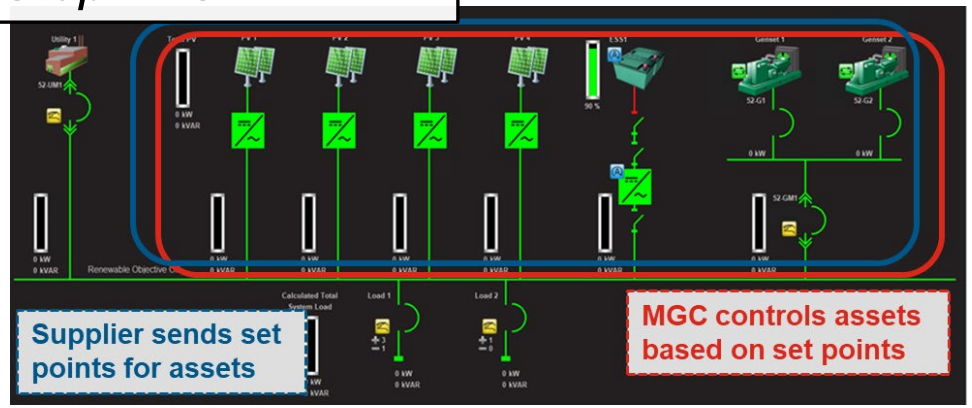
Testing optimization-based controls in a lab setting

This testing was born from a curiosity of how the optimization in Xendee's DESIGN software would translate to a real microgrid system.

The team created a Xendee DESIGN model of a scaled-down version of the Fridley plant. Then, the optimization-based algorithm was applied in the PIC lab by setting up the Cummins Microgrid Controller (MGC) to receive commands from Xendee's servers via their OPERATE system.

Step 1: DESIGN

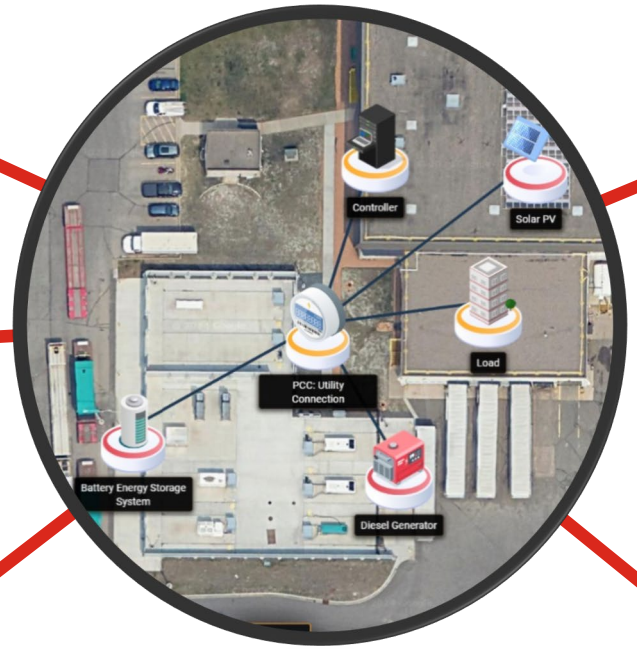
Step 2: OPERATE



‘Mini-Fridley’ test setup

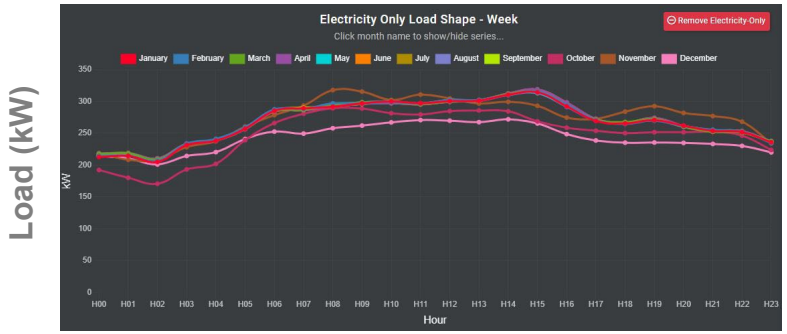
Location:
Cummins PIC Lab
Fridley, MN USA

Customer Goal:
Optimize for Levelized Cost Of Energy



Site Load Profile:
Measured 90-day load from Fridley plant, scaled down to 500 kW Peak

Full Day Load Profile



Time of Day (hours)

DERs Considered:

- Diesel gensets
  - (2) 250 kW units, total 500 kW capacity
- Li-Ion battery energy storage
  - 250kW / 500 kWh
- Solar arrays
  - (2) 200 kW arrays, total 400 kW peak output

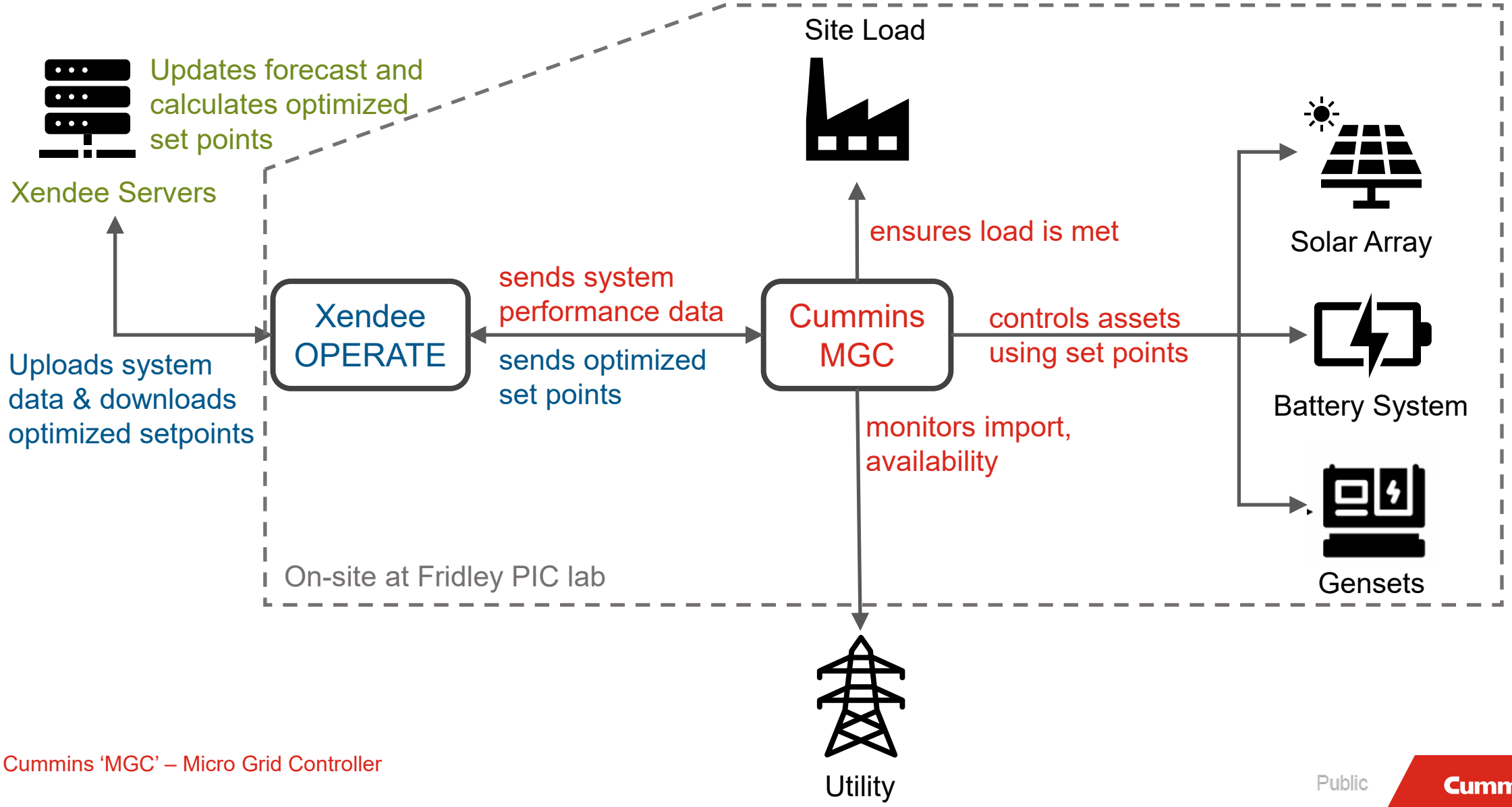
Utility Information:
Clean Power SF tariff: B-19-NEM1
Selected this tariff to demonstrate more active microgrid behavior

B-19, Medium General Service

Summer – June 1 through September 30	Secondary
Peak	$0.12847
Part-Peak	$0.09738
Off-Peak	$0.07540
Winter – October 1 through May 31	
Peak	$0.10872
Off-Peak	$0.07531
Super Off-Peak	$0.03048
Demand Charges (per kW)	
Summer Max Peak Demand	$21.22
Summer Max Part-Peak Demand	$3.08
Winter Max Peak Demand	$2.52

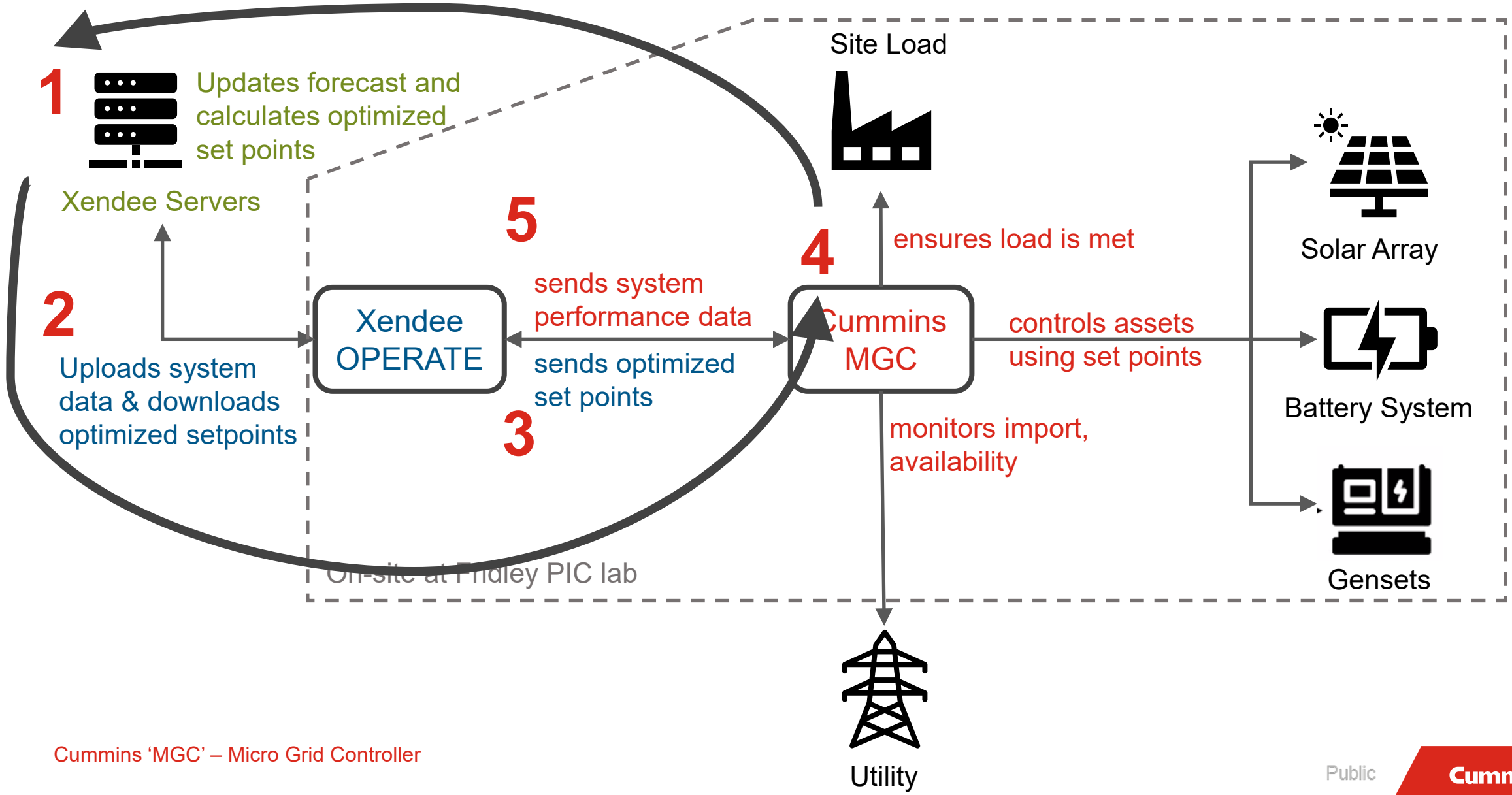
Xendee model for PIC lab testing

Integrating OPERATE with MGC



Cummins 'MGC' – Micro Grid Controller

Integrating OPERATE with MGC



Cummins 'MGC' – Micro Grid Controller

PIC Lab Test Overview

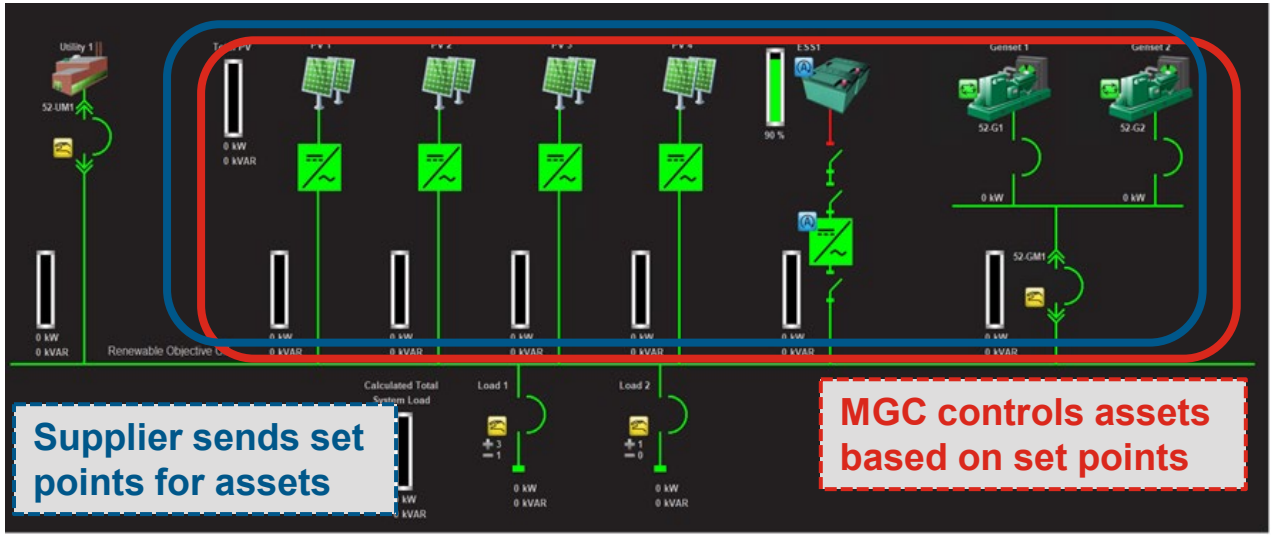
Test Details

Goals: Observe optimization, compare with DESIGN modeling

- 15 min set point update from OPERATE
- 24/7 testing for multiple weeks
- **OPERATE provides all set points: Utility, PV, Batt, and Gens (fully available)**
- **Load profile: non-sequential week of measured data, ~10 second load change intervals**
  - Based on Fridley 90-day measured data file (repeated to create a 1-yr profile)
- No simulated outage events
- Pricing based on Clean Power SF tariff

Key Learning Goals:

- Can the MGC interface with the OPERATE system to receive setpoints for multiple assets?
- Observe cost savings from fully optimized system during the test
- Compare behavior predicted by DESIGN model with PIC test system with OPERATE



PIC Lab test results and learnings

Key Learning Goals:

- ✓ Can the MGC interface with the OPERATE system to receive setpoints for multiple assets?
  - Confirmed - Updates to the MGC software enabled this capability with relatively low effort.
- ✓ Observe cost savings from fully optimized system during the test
  - Test demonstrated savings, despite minimal impact from PV
- ✓ Compare behavior predicted by DESIGN model with PIC test system with OPERATE
  - The specific week selected for testing did not match the DESIGN model hour for hour
    - Snow covering the PV arrays created a significant difference in the test reality from the solar forecast
    - The site load forecast was still accurate, and results still showed strong savings for Demand Charges

Challenges/Takeaways:

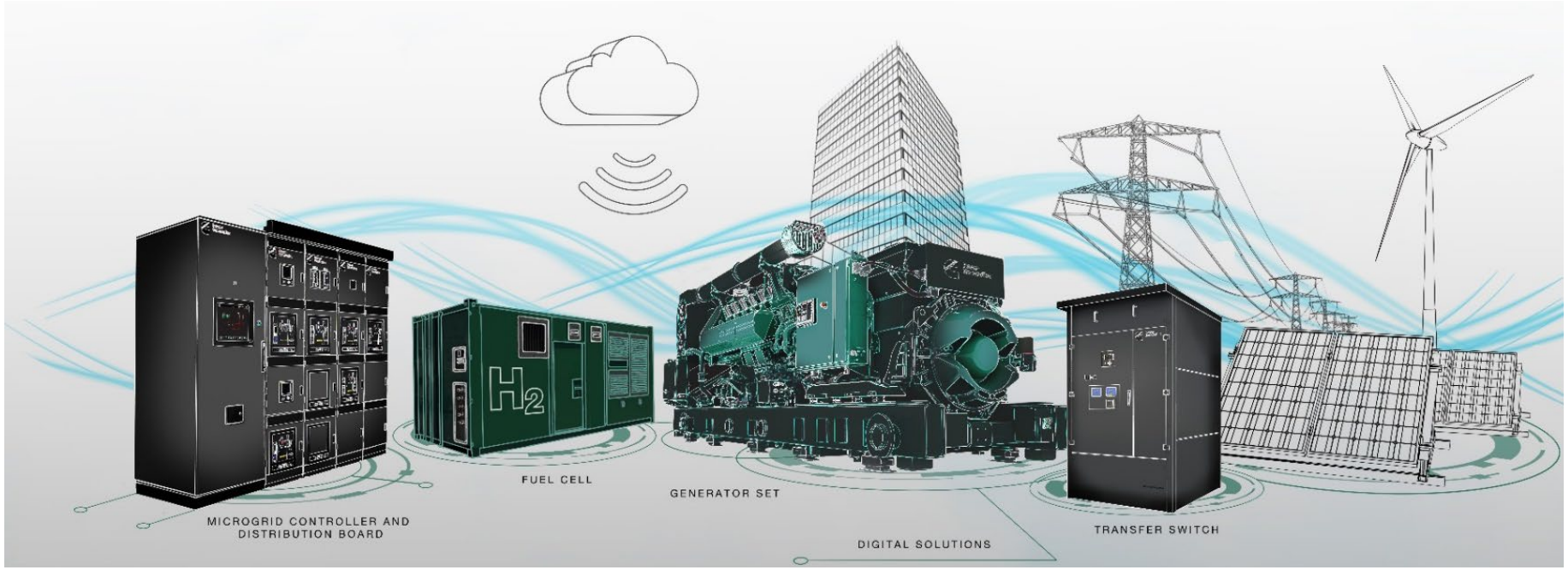
- Gaining network access for the OPERATE gateway was more challenging than expected (due IT protections)
- Communication issues between OPERATE and the MGC early in the testing were improved through troubleshooting
- The OPERATE – MGC control interface recovered well from unexpected events (utility outage in Fridley, crash of load bank)
- Forecasting is key to savings – and forecast quality relies on input data quality

What's Next?

Cummins is actively modeling, designing, and selling microgrid projects.

Have interest in adding Xendee's OPERATE on top of a Cummins microgrid solution?

➡ **Cummins can work with Xendee to provide this integrated solution.**



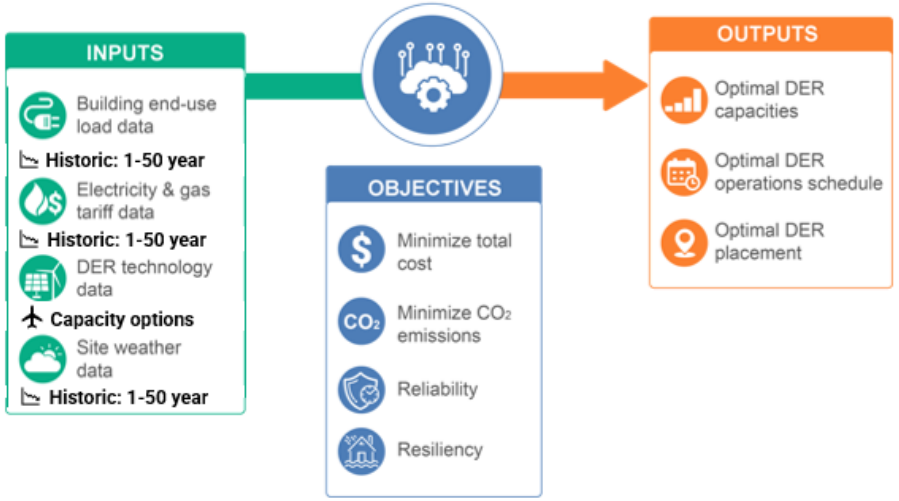
And stay tuned as we continue to add to our portfolio of microgrid offerings!

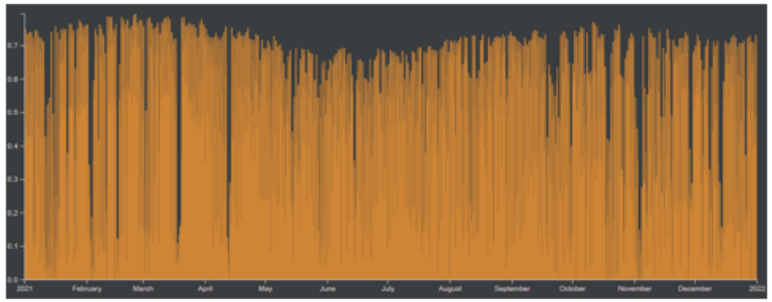
https://www.cummins.com/generators/microgrids

One Platform for Design and Control

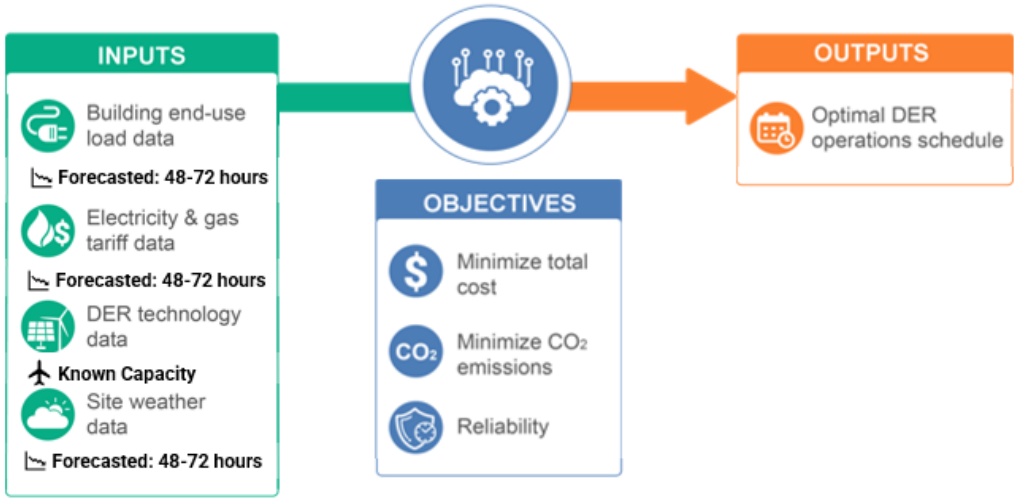
Consistent Bankable Results

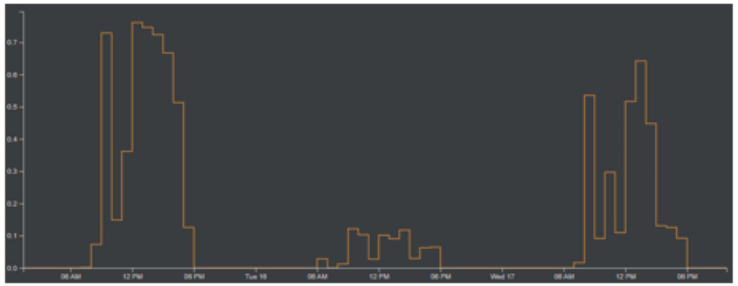
XENDEE DESIGN





XENDEE OPERATE





MPC Follows IEEE 2030.7

Block 4	**Grid Interactive Control Functions** (Area EPS control, Spot Market, DMS, TSCADA, Connection to adj. Microgrid)
Block 3	**Supervisory Control Functions** (Forecasting, Data management and Visualization, Optimization [e.g. Volt/ VAR, Economic dispatch], Dispatch, State Estimation, Emergency Handling, Generation Smoothing, Spinning Reserve, Topology Change Management, Black Start, Protection Coordination)
Block 2	**Local Area Control Functions** (Sequence Logic/Status control, Load Management, Building Energy Management, Plant Controller, AGC, Fast Load Shedding, Resynchronization, Disturbance Recording)
Block 1	**Device Level Control Functions** (Voltage/Frequency Control, Reactive power Control, Electric Vehicle Control, Energy Storage Control, Load Control, Generation Control, Islanding Detection, Fault Protection)

Interaction with higher block if desired

OPERATE's MPC

Interaction with lower blocks via different communication protocols

Technical Steps Needed for Successful OPERATE Deployment

First historic data and later, the current (real-time) measurements of:

- End-user load/demand
- PV generation
- Battery inverters
- EV charging and discharging
- other DERs

Communication protocols for measurement data points.

- **The forecasting algorithms** (solar PV and end-user load/demand) are calibrated and then tested to validate the algorithms.
- The missing historic data needs to be identified and replaced with similar data, or by interpolation, and extrapolation.

Model Predictive Control (MPC) based framework is designed to optimize the real-time operation of DERs.

This includes the higher-level supporting modules (communication, data manipulation) and the main **Optimization Engine** of XENDEE Operate.

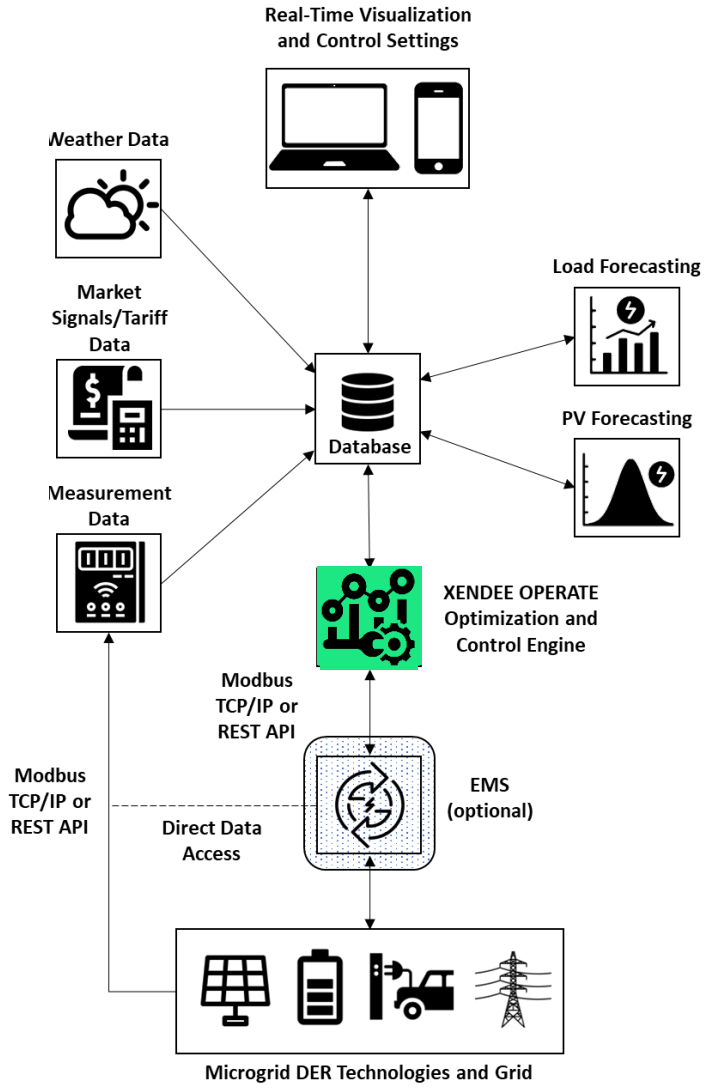
Open loop test requires **tested forecasting algorithms and the optimization engine** to virtually generate the system set-points for a rolling time horizon in real-time (no communication feedback)

Closed Loop testing requires the actual **system to follow the optimal set-points generated.**

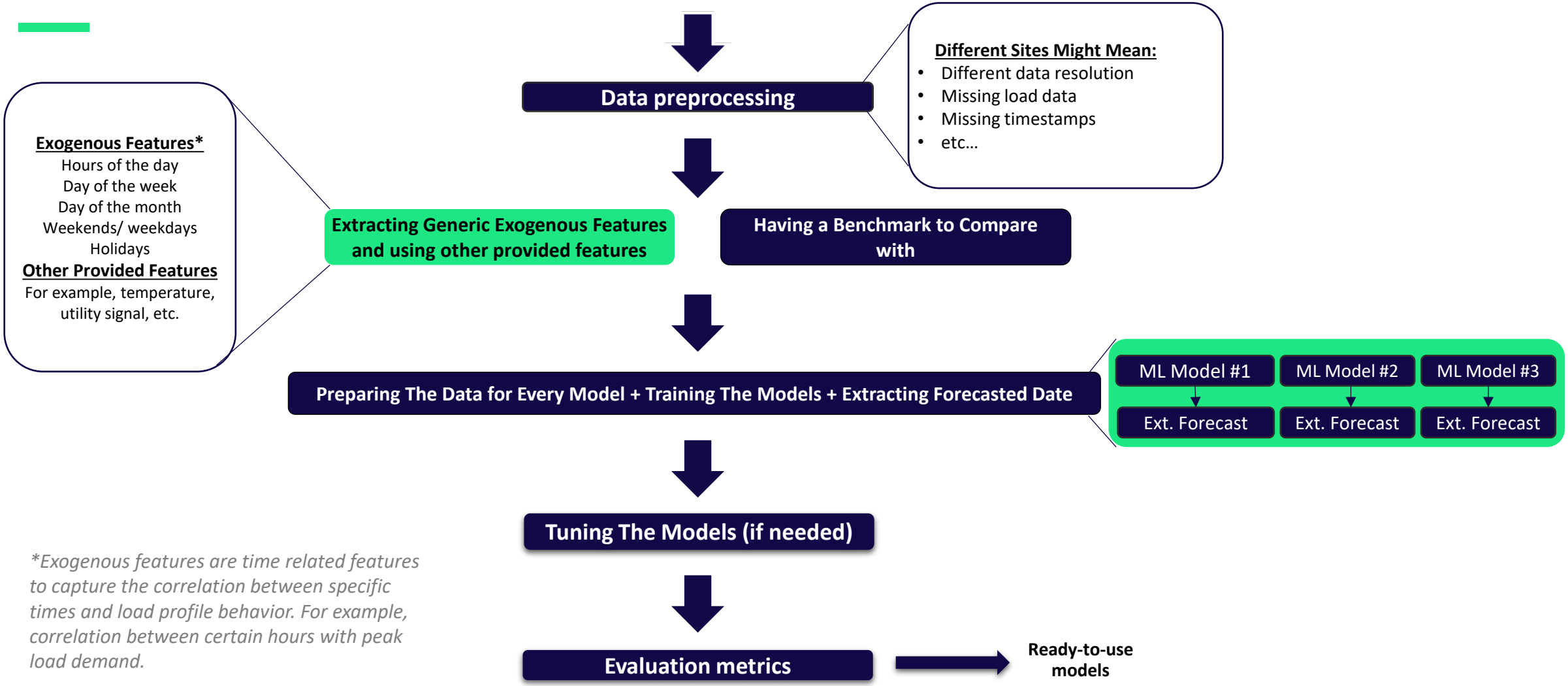
The actual system follows the set-points of Xendee Operate and the current measurements are updated for the next iteration of the optimization.

Timeline in Non-Standardized Manual Fashion: Multiple Months to a Year
Current Standardized and Streamlined Approach: Less than One Week
Future: Less than One Day

OPERATE Architecture



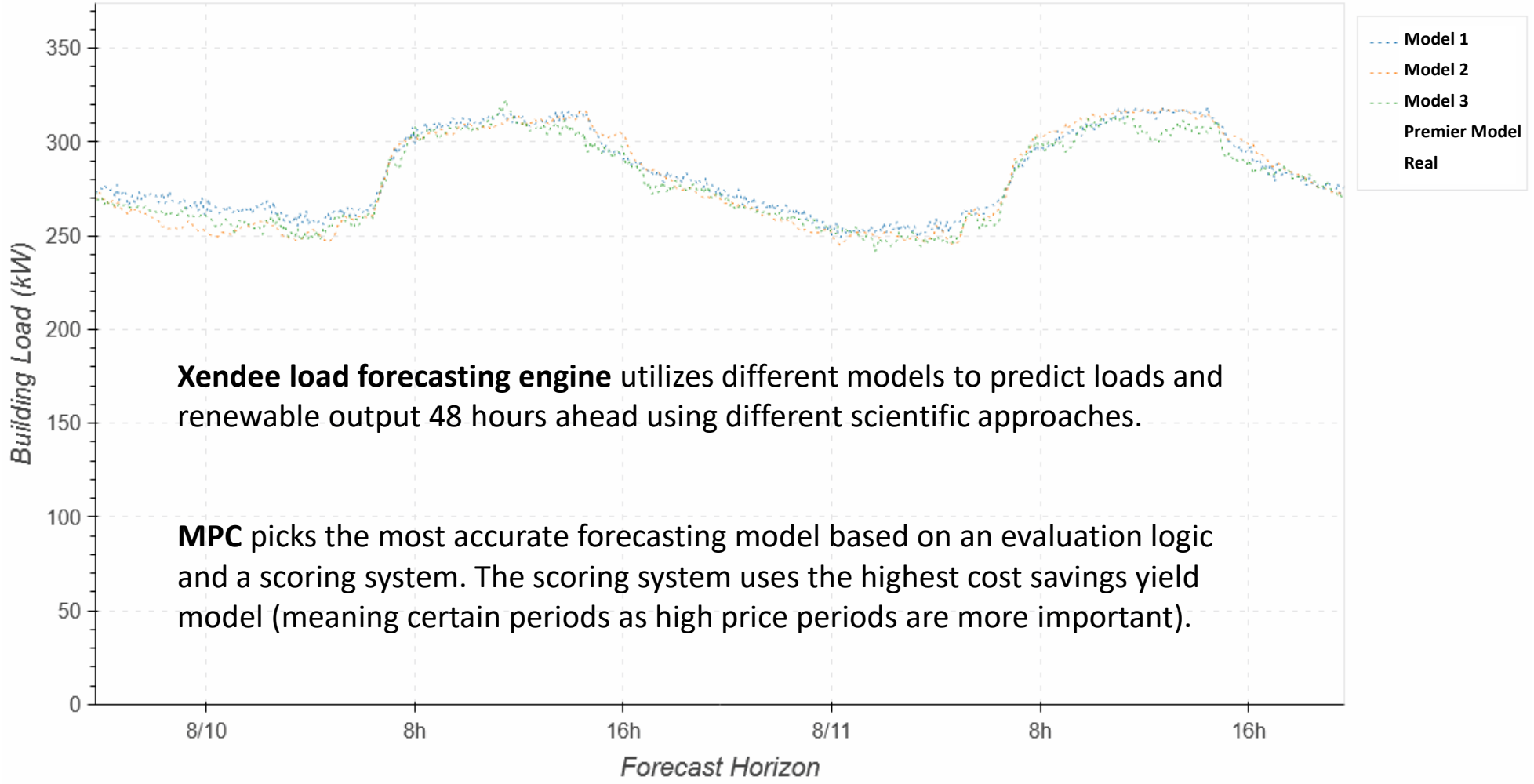
Xendee Forecasting Framework



**Exogenous features are time related features to capture the correlation between specific times and load profile behavior. For example, correlation between certain hours with peak load demand.*

Forecasting

The AI Forecasting in combination with the MPC delivers up to 65% demand charge reduction

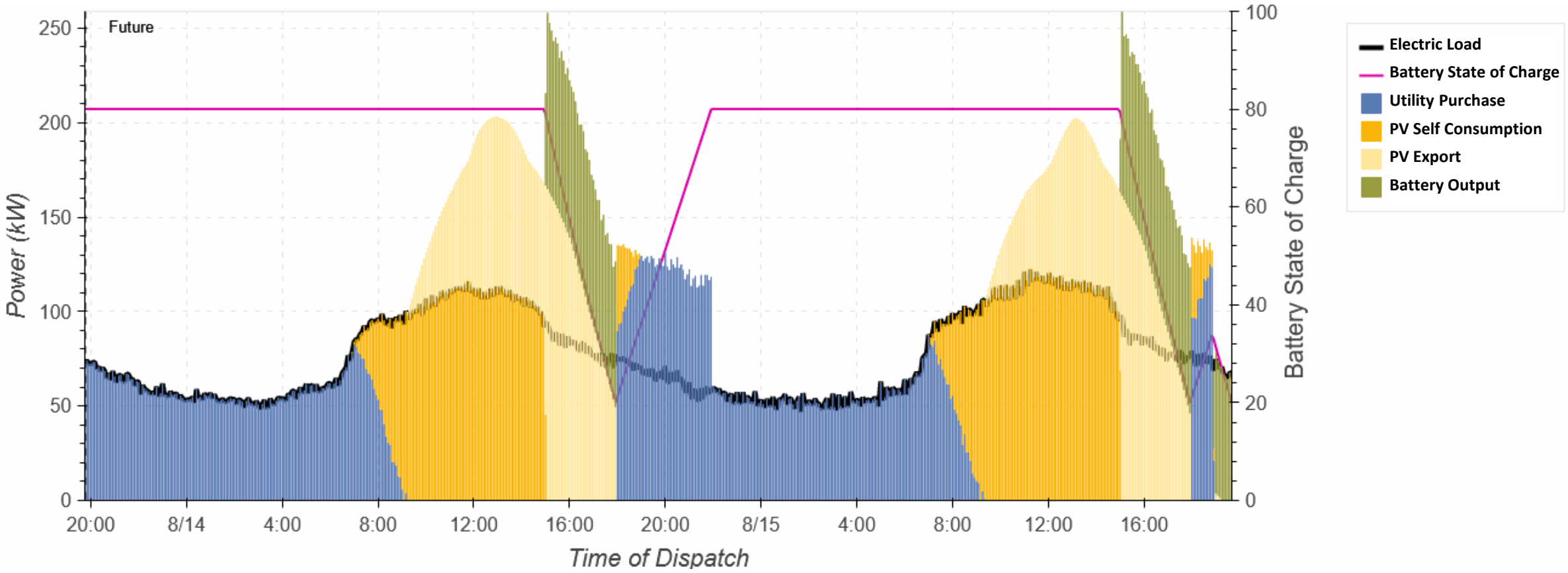


Xendee load forecasting engine utilizes different models to predict loads and renewable output 48 hours ahead using different scientific approaches.

MPC picks the most accurate forecasting model based on an evaluation logic and a scoring system. The scoring system uses the highest cost savings yield model (meaning certain periods as high price periods are more important).

Rolling Dispatch (for a Different Site)

Due to deviations between forecasts and reality and other uncertainties, Xendee OPERATE repeats the controller loop every 5 minutes, and this creates an adaptive behavior which minimizes the error.



Question & Answer Section

Please leave questions in the Q&A tab of the Zoom user panel. Any unanswered questions will be addressed by email following the event.

Enrico Della Corna
Systems Engineering Technical Specialist
Cummins

Michael Stadler
Co-Founder and Chief Technology Officer
Xendee Corporation

Thank You

If you'd like a demo of Xendee or a quote from Cummins, please use the following links:

Xendee.com/demo
cummins.com

Enrico Della Corna
Systems Engineering Technical Specialist
Cummins

Michael Stadler
Co-Founder and Chief Technology Officer
Xendee Corporation