Eaton’s Energy Transition Overview

Presentation for IEEE SusTech
Joe Cappeta- Director, Technical Applications
Ted Witham – Energy Transition Application Engineer
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The electrical industry’s role is expanding to become the central switchboard to power the future as we move to a net zero carbon energy system.

### Electrification
- **75M**: Projected EV chargers in 2030
- **50%**: Increase in proportion of global building energy from electricity

### Renewables
- **~50%**: Global GDP covered by government net zero pledges
- **75%**: Of global additions in power gen through 2050 from solar and wind

### Digitalization
- **~56B**: Connected devices by 2025
- **75%**: Proportion of enterprise-generated data processed at the edge by 2025

### Grid resilience
- **67%**: Increase in major US power outages over the last two decades
- **~900GW**: New storage needed for US to shift 100% renewable energy
The energy transition will require flexible energy systems.

EVERYTHING AS A GRID is our approach to reinventing the way power is distributed, stored and consumed. With advanced technologies and digital intelligence, we are unlocking a low-carbon energy future for all.
The new power landscape

Enabling customers to safely add more renewables, storage and electrical vehicle infrastructure to their energy mix.
Mining, metals, minerals commercial buildings applications
Reliability and efficiency to maximize ROI and safety

Products, solutions and services to design, build and operate for resiliency and a low-carbon energy future

- Commercial power distribution products
- Backup power, UPS, surge & IT power distribution
- Conduit, cable & wire management solutions
- Intelligent energy management software
- Indoor and outdoor lighting and control solutions
- Microgrid and DER solutions
- EV charging infrastructure
- Service – power systems engineering, turnkey project management
- Furniture for technology-intensive environments
Brightlayer Industrial suite

A new perspective on scalable software solutions.

**Optimize your operations**
- Remotely capture data and insights from power equipment in dangerous environments
- Increase power and operational reliability with proactive maintenance

**Leverage actionable insights**
- Recognize and remediate issues before failure occurs
- Extend equipment life and increase revenue-generating potential

**Improve safety and compliance**
- Dispatch personnel with the right tools, parts and protective gear
- Capture data to support environmental and sustainability goals
Buildings require a comprehensive infrastructure solution to enable sustainable, resilient and cost-effective performance

Eaton’s comprehensive EV charging infrastructure offerings include equipment, software and engineering services solutions to meet EV charging project requirements.

**EV charging**
AC Level 2 and DC level 3 fast chargers for residential, commercial, and fleet operations

**Battery storage**
Eaton xStorage Battery Energy Storage System (BESS) includes batteries, inverters and management software to shave peak demand cost for EV charging applications

**EV Charge management software**
Enables users to operate a network of charging stations, from charging point management and power management to financial rules

**Microgrids and Distributed Energy Resource (DER) integration**
Incorporate local solar photovoltaics and other renewables into new or existing infrastructure to maximize charger deployment and help meet sustainability goals

**Power distribution equipment and grid connection upgrades**
Installation and upgrades of electrical equipment, including transformers, switchgear, switchboards, and panelboards

**Electrical engineering services**
Includes feasibility analysis of planned EV deployment sites, power systems analysis of electrical infrastructure, electrical system conceptual design and configurations, system protection analysis and recommendations, automation and control solutions and turnkey electrical services

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Eaton's full EV Charging Infrastructure portfolio works together to simplify fleet electrification & enables lower TCO

<table>
<thead>
<tr>
<th>AC charger range</th>
<th>DC charger range</th>
<th>Power distribution equipment</th>
<th>Energy storage</th>
<th>Digital solutions</th>
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<tr>
<td>Eaton Green Motion EV Smart Breaker Charger</td>
<td>Eaton Green Motion Building Series</td>
<td>Eaton DC Fast Charger</td>
<td>Eaton Broad Portfolio of Power Distribution Equipment</td>
<td>Eaton xStorage BESS</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Max output power rating</th>
<th>Residential private</th>
<th>Multi-tenant residential</th>
<th>Workplace and Community</th>
<th>Fleet and Highways</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.7 kW @ 240 Vac</td>
<td>![Image]</td>
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<tr>
<td>7.7-11.5 kW @ 240 Vac</td>
<td>![Image]</td>
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<tr>
<td>19.2 kW @ 240 Vac</td>
<td>![Image]</td>
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<tr>
<td>50kW to 150 kW @ 480Vac</td>
<td>![Image]</td>
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<tr>
<td>120 Vac – 38 kVac</td>
<td>![Image]</td>
<td>![Image]</td>
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<tr>
<td>250kW -1MW / 250kWh/340kWhr rating</td>
<td>![Image]</td>
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AC vs DC Charging

AC Level 1
- 120V
- Home
- Up to 2.4kW

AC Level 2
- 240V
- Home / Public / Fleet
- Up to 19.2kW

Fast DC
- 400-1000V
- Public / Fleet
- 50kW and higher

AC is limited by the lowest of the two components, the onboard charger or the AC charger (208-240V)

DC is limited by the lowest of the two components, the rate the battery can charge or the DC charger (50-1000V)

Note: All but Stellates and Volkswagen are offering NACS, it is assumed they will adopt NACS.
### Vehicle Charging Example

90 kWh battery (typically charge 20% to 80%)

Time (h) = 0.6 x 90 kWh / (rating of charger)

<table>
<thead>
<tr>
<th>Rating of charger</th>
<th>Location</th>
<th>Charger Type</th>
<th>Charger Ampacity</th>
<th>240V Charge Time</th>
<th>208V Charge Time</th>
<th>30 Miles Charge Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.7 kW</td>
<td>Home</td>
<td>Level 2</td>
<td>32A</td>
<td>7.0 hours</td>
<td>8.1 hours</td>
<td>1.3 hours</td>
</tr>
<tr>
<td>9.6 kW</td>
<td>Work / Public</td>
<td>Level 2</td>
<td>40A</td>
<td>5.5 hours</td>
<td>6.5 hours</td>
<td>1.0 hours</td>
</tr>
<tr>
<td>11.5 kW</td>
<td>Work / Public</td>
<td>Level 2</td>
<td>48A</td>
<td>4.75 hours</td>
<td>5.4 hours</td>
<td>0.9 hours</td>
</tr>
<tr>
<td>19.2 kW</td>
<td>Fleet / Public</td>
<td>Level 2</td>
<td>80A</td>
<td>2.75 hours *</td>
<td>3.2 hours</td>
<td>0.5 hours</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rating of charger</th>
<th>Location</th>
<th>Charger Type</th>
<th>400-1000VDC</th>
<th>30 Miles Charge Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 kW</td>
<td>Public</td>
<td>Fast DC</td>
<td>1.0 hours</td>
<td>12 minutes</td>
</tr>
<tr>
<td>150 kW</td>
<td>Public</td>
<td>Fast DC</td>
<td>30 minutes</td>
<td>4 minutes</td>
</tr>
</tbody>
</table>

* If onboard converter is 11.5 kW then the time will be 4.7 hours
Case study: Impact of truck electrification on the grid

**Depot Characteristics:**
- 100 Class 6 trucks
- 30 Class 8 trucks
- Site load today ~ 500 KW

**Electrified Depot:**
- Class 6 trucks: ~ 100 kWh per day
  - 10,000 kWh in 8 hours = **1250 kW** (@ 100% LF)
- Class 8 trucks: ~ 400 kWh per day
  - Overnight charging
    - 12,000 kWh in 8 hours = **1.5 MW**
  - Slip-seating (multi-shift)
    - 400 kWh in 45 min = ~550 kW per vehicle
    - Assume 4-6 vehicles charging = **2 – 3 MW**

Depot’s load on the grid can go from 2.5X to 6 times based on charging deployed
Hierarchy of Dealing with Power Scarcity

- Power System Design
- Load Management
- Energy Storage
- DER Integration
- Microgrids
EV Charging Infrastructure Power System Design

- Power System Design
- Load Management
- Energy Storage
- Microgrids
Green Motion EV Smart Breaker Chargers Flexible installation and integration options

- 32A (7.7kW @ 240V) AC Level 2 Charger with integral communications, control & revenue grade metering
  - 2P 40A BR & BAB styles
- Energy Star Certified
- Open approach through cloud APIs and OCPP enables integration with your preferred charging management solution.
  - OCPP = Open Charge Point Protocol
- The universal J1772™ charging connector is compatible with any EV meeting the SAE J1772™ charging standard
- UL listed and tested for electrical safety and features 20mA ground fault protection
EV charging integrated assemblies for scalable EV Charging deployments

**EV Charging integrated Panelboards**

- EV Charging Smart Breakers (EV Chargers) integrated in panelboards for cleaner, cost effective installations
- Expandable up to 10 Chargers per Panelboard for PRL3X designs and up to 18+ Chargers in IFS (Integrated Facility System) switchboard
- Better protection against vandalism, expensive components hidden inside a supply closet
- Ideal solution for depot charging where scalable EV systems are needed
- Optional 4G connectivity with external hotspot

**EV Charging integrated Busway**

- EV Charging integrated Busway designs for cost effective, scalable EV Charging deployments
- Offering for 19.2kW (80A) and 7.7kW (32A) charging
- Utilizes existing plug-in busway
- Expandable up to 25 Chargers per 2500A run.
- New designs improve moisture resistance for plug-in busway
- Ideal solution for depot charging where scalable EV systems are needed
- Optional 4G connectivity with external hotspot
Green Motion Fast DC

Positioning
❖ Fleet and public parking where high output high speed charging is required

Specification
❖ 50-150kW dual and single nozzle design
❖ 480V three phase power input
❖ CCS1 nozzle
❖ Support current and future EVs with 400-1,000 Vdc charging
❖ Small footprint at 150 kW when compared to other solutions
❖ Support OCPP 1.6J (Open Charge Point Protocol)
❖ Various payment methods available through CNM

Warranty
❖ 2 years parts
EV Charging Infrastructure – Load Management

- Power System Design
- Load Management
- Energy Storage
- Microgrids
Power Management

- Creates a virtual twin electrical panel with both EVSE and uncontrolled loads
- Allows site hosts to install more chargers on a limited electrical service
- Output amperage is automatically adjusted based on the number of vehicles plugged in to a group of chargers
CNM Features Delivered

- **Power Management**
  - Proportional sharing across a group of EVSE
  - Single phase and 3 phase
  - Load leasing model to protect in event of network outage
  - Accommodation for reserved loads
  - Requires assisted setup process
Energy Storage

Power System Design

Load Management

Energy Storage

Microgrids
# xStorage 250-1000 BESS

## Product overview

### Applications
- EV fast charging
- Community buildings
- Commercial buildings
- Industrial facilities
- Microgrids

### Energy functions
- Peak shaving
- Load shifting
- Backup power
- Solar self-consumption
- Demand response

### Environment
- Enclosures: IP54/NEMA 3R
- Temperature: -25°C to 55°C
- Humidity: 5% to 100% non-condensing
- Elevation: 1000m without derating

### Listings
- System: UL 9540
- PCS: UL 1741 SA, SB
- IEEE1547
- Batteries: UL 1973, 9540A
xStorage
Storage / Operation Optimization / Financial Optimization

**xStorage features:**
- FFR, grid code compliance
- DR
- Peak shaving
- Arbitrage
- Islanding
- PV integration

**xStorage w/ Aggregation features:**
- FFR
- DR Peak shaving, arbitrage

<table>
<thead>
<tr>
<th>Base Storage</th>
<th>Optimization</th>
</tr>
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<tbody>
<tr>
<td>xStorage BESS + Power Xpert microgrid controller</td>
<td>xStorage BESS + Enel X DER.OS</td>
</tr>
<tr>
<td>Inverter</td>
<td>Inverter</td>
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<tr>
<td>Energy battery</td>
<td>Energy battery</td>
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<td>Service contract</td>
<td>Service contract</td>
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<tr>
<td>Monitoring software</td>
<td>Monitoring software</td>
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<tr>
<td>GSEC</td>
<td>GSEC</td>
</tr>
<tr>
<td>Higher level controller</td>
<td>Higher level controller</td>
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</tbody>
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BESS simple one-line
Microgrids

- Power System Design
- Load Management
- Energy Storage
- Microgrids
Eaton’s broad microgrid capabilities
Make us your easy button

Feasibility studies
- Feasibility study to evaluate the economic and resilience impact of your microgrid project

Design, build & construct
- Leading turnkey services and power systems engineering capability for technical microgrid project development

Hardware deployment
- Expansive electrical portfolio and robust supply chain to procure solar PV and battery energy storage

Microgrid software
- Intelligent microgrid controls paired with economic optimization software to deliver energy savings

Market services
- Unlock additional value from your DER assets by enrolling in flexibility programs such as demand response

Operations & maintenance
- Ongoing system maintenance from Eaton’s highly trained team of dedicated field services personnel

Eaton offers customers the ability to fund projects as an operational expense by seamlessly structuring deals with trusted financing partners
Eaton’s Power Xpert Microgrid Controller (PXMC)

PXMC system features

✓ Intelligent system-level controller that interfaces with device-level local controllers
✓ Web-based user interface for monitoring & control (optional HMI screen)
✓ Automated system sequence of operations based on user-defined parameters
✓ Control strategies such as renewable firming, peak shaving, and islanding
✓ Self-consumption – maximize energy consumption from on-site and renewable sources
✓ Manage transition functions including load shedding and grid reconnect – black start
✓ Modular system architecture that can be scaled to the application
✓ Software suite for system configuration and commissioning
✓ Alarm and event management
✓ Historian data logging of system events (optional)

Industrial-grade Gateway platform
Programmable logic (Soft PLC) IEEE 2030.7 / 1547 and IEC 61850 / 61313.3 compliant
Over 80 communication protocols supported including Modbus and DNP3 Client/Server

Built-in Cybersecurity
Meets all IEEE and IEC requirements for substation-grade equipment (IEEE 1686 and IEC 62351)
Embedded cybersecurity • Built-in firewall • TLS encryption • AES 128/256 • X.509 malware protection
Compliant with UL-2900-1 • NERC CIP • NIST Smart Grid security guidelines
Pow-R-Line Xpert microgrid switchboard (or switchgear)

A fully integrated intelligent, scalable, and efficient solution for your microgrid infrastructure

Intelligent
Eaton’s family of Power Xpert Microgrid Controllers provide a right-sized control solution for any microgrid application.

Optional external monetization interface give a facility the ability to unlock additional revenue streams from their flexible generation assets.

Scalable
The microgrid control components are contained in a single panel structure to future-proof the design and easily add new DERs and loads.

A wide range of switchboard integrated metering, protection and control options offer a solution customized to any application.

Efficient
Cost and lead time are always a factor, Eaton supports a configurable built-to-order approach reducing microgrid control design and manufacturing time.

All control and protection aspects of the integrated solution are factory assembled, integrated, and tested to ensure smooth field installation and commissioning.

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Meet customers where they are on their energy transition journey:
Option to “future proof” their power system design to add DERs at a later phase

**FROM: Baseline reference**

**Commercial Switchboard/Switchgear**

- Busway with single utility connection
- Main feeder circuit breaker (2000A)
- Branch air or molded case circuit breakers are not networked or communicating

**“Microgrid Ready” Switchgear**

- Kitted out switchboard section with sensing and metrology
- Add switchboard section for the microgrid and DER controls
- Set aside space for DER circuit breakers, e.g. generator, solar, BESS
- Upsize the bus to add DERs
- Main breaker electrically operated for remote operation
- Communicating breakers & trip units
- Auxiliary contacts for breakers
- Line and load PTs & load CTs at main breaker (wired to terminal blocks)
- Control power transformer

**TO: Fully integrated control solution**

**Pow-R-Line Xpert™ Microgrid Switchboard**

- Fully integrated Microgrid & DER controls with meters and relays
- Install microgrid / DER controller
- Additional device DER controllers connected and wired into the system
- Power supply and UPS backup for microgrid control system
- Point-to-point wiring engineered and installed throughout switchboard
- Network switches and gateways
- Utility relay (anti-islanding)
- Local HMI screen (optional)
Battery storage basic use cases

**Energy arbitrage**
Store energy in off-peak hours when utility rates are lowest, use stored energy when utility rates are highest.

**Peak shaving**
Dispatch battery to lower peak loads to reduce utility demand charges – highest 15 min power usage per month.
Actual microgrid performance – 24 hour period

Sunny winter day: solar and battery support the load 100% with excess solar capacity charging battery then sold back to grid

- Strong solar production during daylight hours
- Battery reaches desired SOC (80%)
- Utility ramps down as solar ramps up
- Selling power back to the grid
- Peak facility load, no Utility power used
- Support full facility load until battery SOC drops to 35%
- Cheaper off-peak Utility power used to recharge batteries
- Excess solar used to charge batteries
- Battery discharges to offset reduced solar production
- Utility power used to support minimal facility load; system ready to respond for next day

SOC = state of charge
Microgrid peak shaving functions

Cloudy to partly cloudy summer day: Scheduled operation to limit utility power throughout the day - avoid demand charges

Utility charges the battery

Utility Power Limit = 12 kW (07:00 – 20:00)

Utility Power Limit = 20 kW (20:00 – 7:00)

Battery supplements solar

Solar charges the battery
Case Study:
Microgrid at Eaton’s circuit breaker factory in Arecibo, Puerto Rico

Solution:
Eaton and Enel X partnered to develop and finance a microgrid at the site by leveraging our respective intelligent power management capabilities.

The microgrid solution contributes to local sustainability and resiliency efforts while delivering cost savings and additional revenue streams with DER monetization.

Result:
Balance business goals by fully integrating the microgrid and on-site power generation with more renewables enabling two-way power flow with decentralized generation.

- Integrated 5MW solar + 1.1MWh battery energy storage into the power infrastructure
- Transformed Eaton’s operations to become more sustainable and resilient...
- ...all while reducing energy costs by >12%
- Microgrid designed to withstand hurricanes

Watch the video:
Eaton.com/MicrogridProjects

"A postcard from the future for islands and other centralized grid systems transitioning toward more distributed resources."
— Wood MacKenzie analyst Isaac Maze-Rothstein, commenting on the microgrid project in Greentech Media
Eaton’s Arecibo Puerto Rico microgrid

Solar panels in adjacent fields secured with in-ground racking

Batteries provide ride-thru power when clouds pass over the solar panels

Two solar inverters convert DC to AC power from >19,000 solar panels

MV switch sends power from inverters to each building to tie them together

Link to NEW Arecibo microgrid video
Arecibo microgrid
Power Distribution Equipment and controls

- Installed new conduits to route power sources to the centralized switchgear and controls
- Economic optimization software paired with intelligent microgrid controls to manage DERs and utility power
- Replaced Eaton’s aging switchgear with intelligent power distribution equipment that has paralleling capability

Microgrid complements utility power from LUMA

- **Net metering** – credit for exporting excess clean power generated to the local power grid
- **Reduces strain on the power grid** during peak demand periods on the island