Co-optimizing Energy and Process in the Microgrid

Microgrids are about energy supply and demand management at any scale

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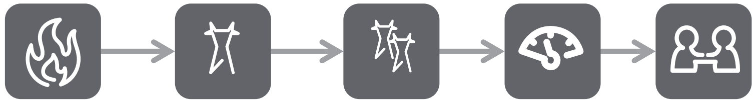
Energy Megatrends – 3D+E is setting the stage for Microgrids

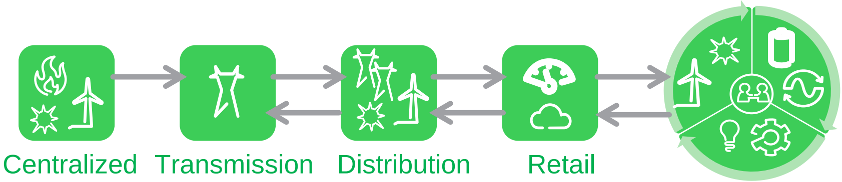
Decarbonization | **Digitization** | **Decentralization** | **+ More Energy**

Historical Energy Value Chain



- Consumers responsible for their own MV/LV Traditional Power Distribution Assets and Operations "behind the meter", Many implement EE Measures
- Consumers have some partial base-load and traditional backup power generation of many varied capabilities, but few significant islanding systems.
- Beyond EE, Increasing Local, Efficient Self-Generation + Microgrid Islanding is the road ahead.

The New Energy Landscape



- Utilities house significant Grid-Connected 3rd party owned Solar PV plants with complementing BESSs. In some cases the developer is the utility, but in others it is a 3rd party or a new "Prosumer".
- Larger Prosumers and Municipalities use PPA and ESCO/IPP PPA/Lease models to leverage existing and build new DERs, including significant Combined Heat and Power (CHP)
- Reduction in costs for DER technologies, increase in reliable delivery + new business models for Energy Services result in the new Energy Landscape

What new energy “Prosumers” are looking for

- Reduce energy consumption
- Improve and monetize flexibility
- Energy / Fuel source arbitrage
- Efficient Operations

Efficiency

kWh

Supply Flexibility

$

- Innovative Product and Hedge Structures
- Global Program
- Real-time-price forecasting
- Portfolio Risk Management

- Reduce Greenhouse Gasses
- Minimize carbon footprint
- Improve LEED
- Corporate Perception/Image

Sustainability

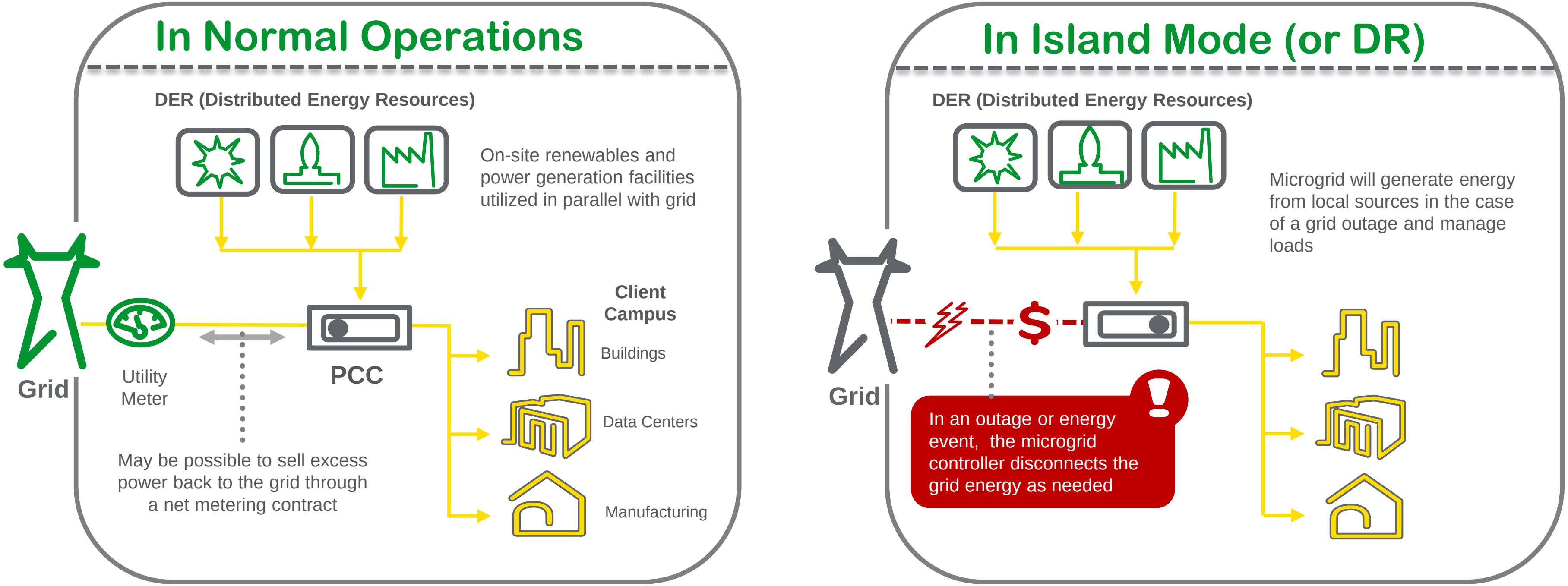
Resiliency

- Service site loads during times of grid instability
- Protect assets against harmful effects of poor power quality
- May have 0 Risk Tolerance

+ solution able to **scale** to the entire enterprise *and* be **delivered simply**.

What is a Microgrid?

"An integrated energy system consisting of interconnected loads and distributed energy resources which, as a single entity, can be controlled and operated in parallel with the grid or in an *islanded* mode."



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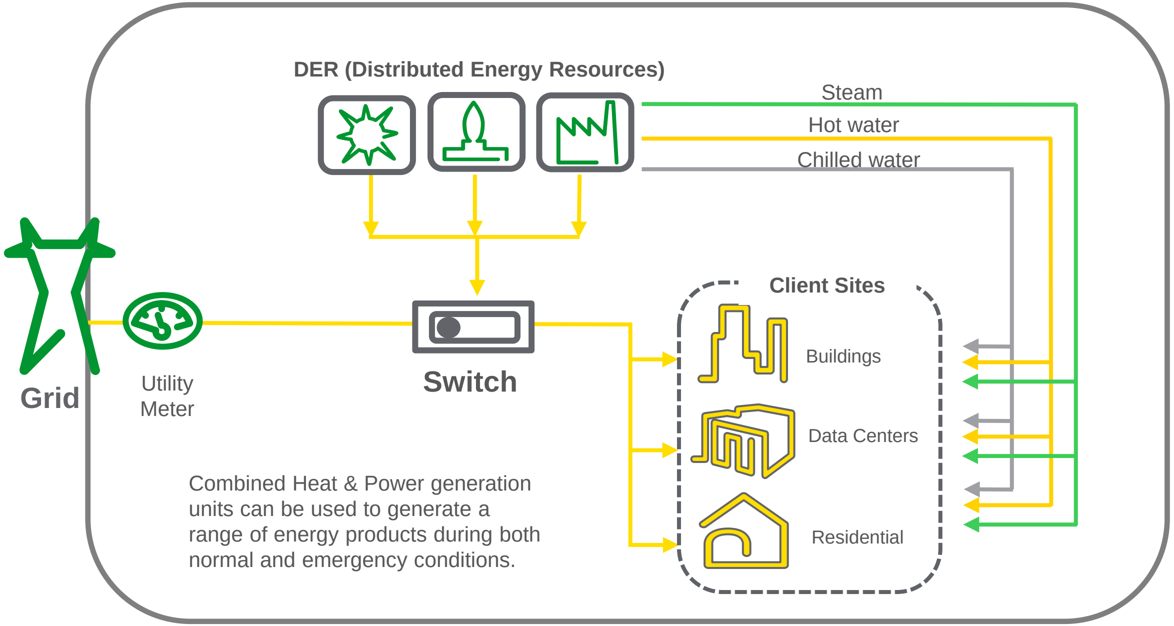
Combined Heat and Power Microgrid & District/Campus Energy

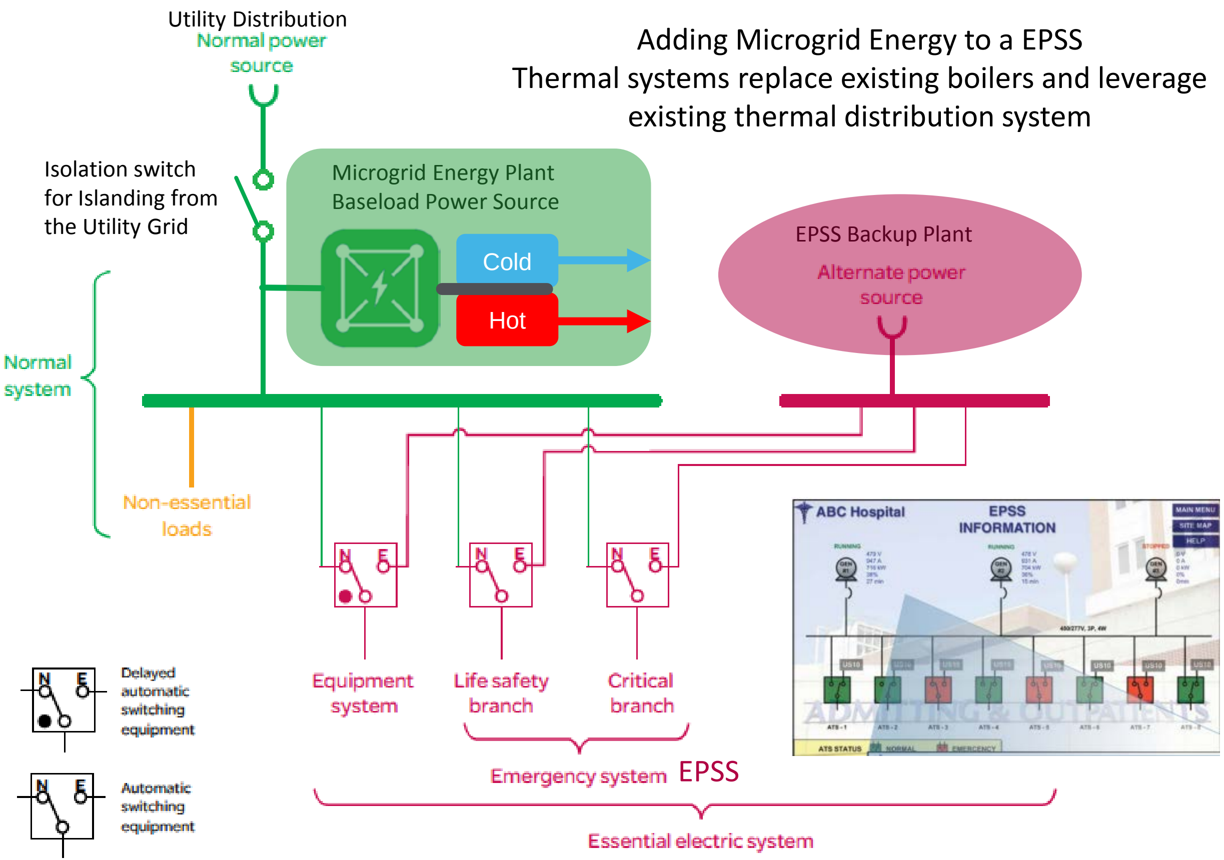
CHP provides superior efficiency and reliability, meeting the prosumer's thermal and electrical needs, around-the-clock, including during grid outages



- Steam, hot water and chilled water is produced at District Energy Centers or Central Utility Plant's
- Environmentally Sound and Energy/Fuel Efficient
- Individual buildings do not need their own chillers/ boilers
- Provides Architectural Flexibility

Microgrid: Complements what a facility has today

- A Microgrid Energy Plant may be composed of CHP, Storage, Solar or other Distributed Energy Resource
- Complements and extends the capabilities of existing Emergency Power Supply Systems (EPSS = Backup Generation + UPS)
- A baseload Microgrid provides baseload power generation and all thermal generation required.
- Remainder of electric power supplied by solar, storage, or other in combination with utility.
- In Emergency Operations, Microgrid islands from Utility and powers more loads than Backup power system alone.
- In Normal Operations, Microgrid assets dispatch economically providing daily value to the owner, not just during emergency



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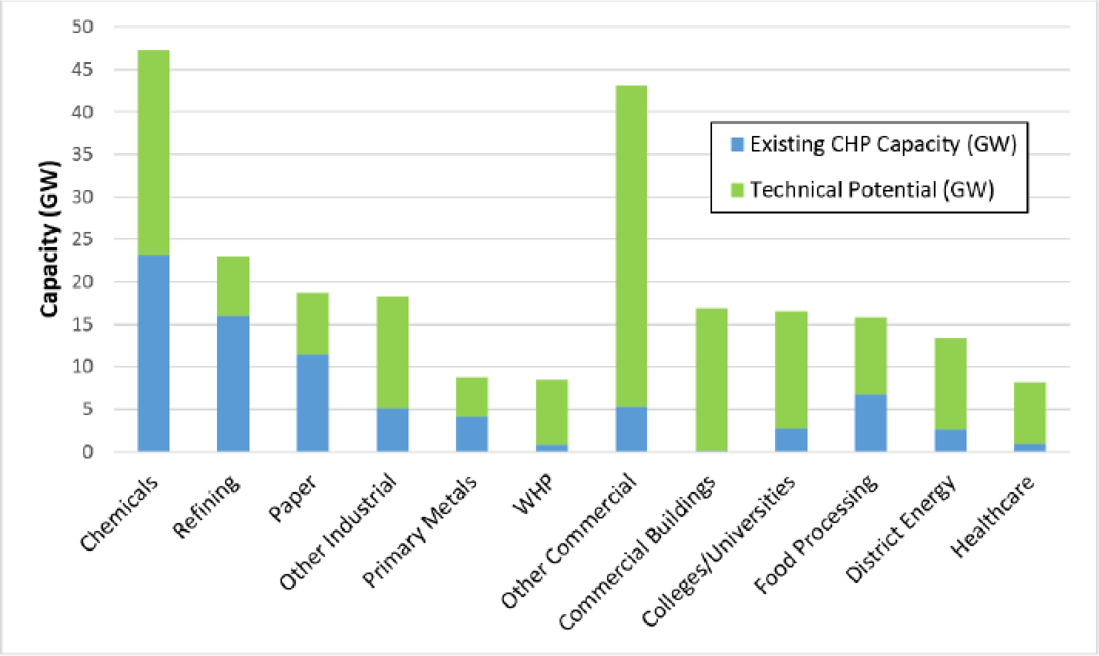
Combined Heat & Power (CHP) Potential in the U.S.

Today the vast majority of installed CHP is not capable to island

Different customer processes demand different levels of optimization

Figure 1: Existing CHP Compared to On-Site Technical Potential by Sector[2]



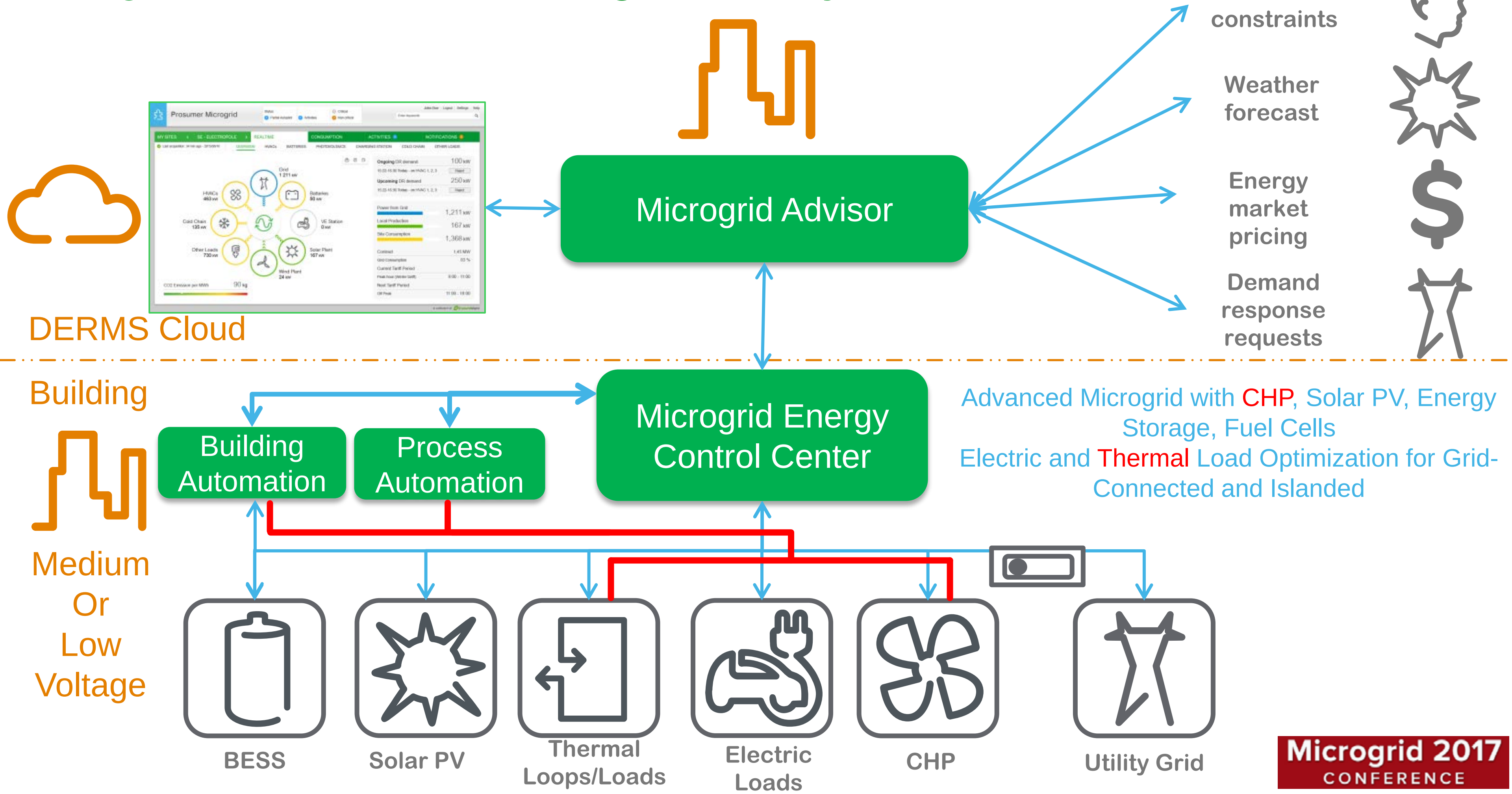
U.S. DOE CHP Deployment Program, 2016.

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Hospitals Discover Advantages to Using CHP Systems

Combined heat and power systems—also known as cogeneration systems—use a heat engine or power station to simultaneously generate both electricity and heat. They convert waste heat from electrical generation into energy that can be used for heating and cooling. More than 200 hospitals nationwide operate CHP systems.[1]

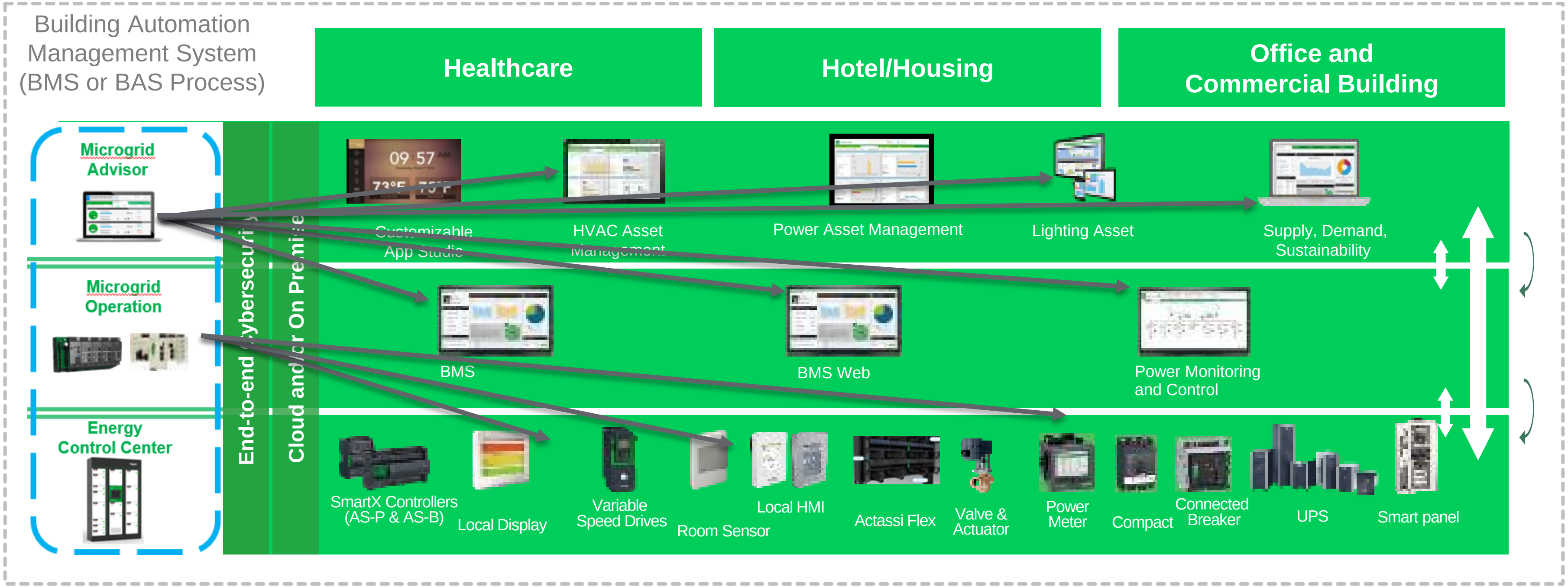
Microgrid Architecture – **Building or Facility**



Building Automation Systems

Represent Smart Load Management Options to reduce loads, a good alternative to load dispatch

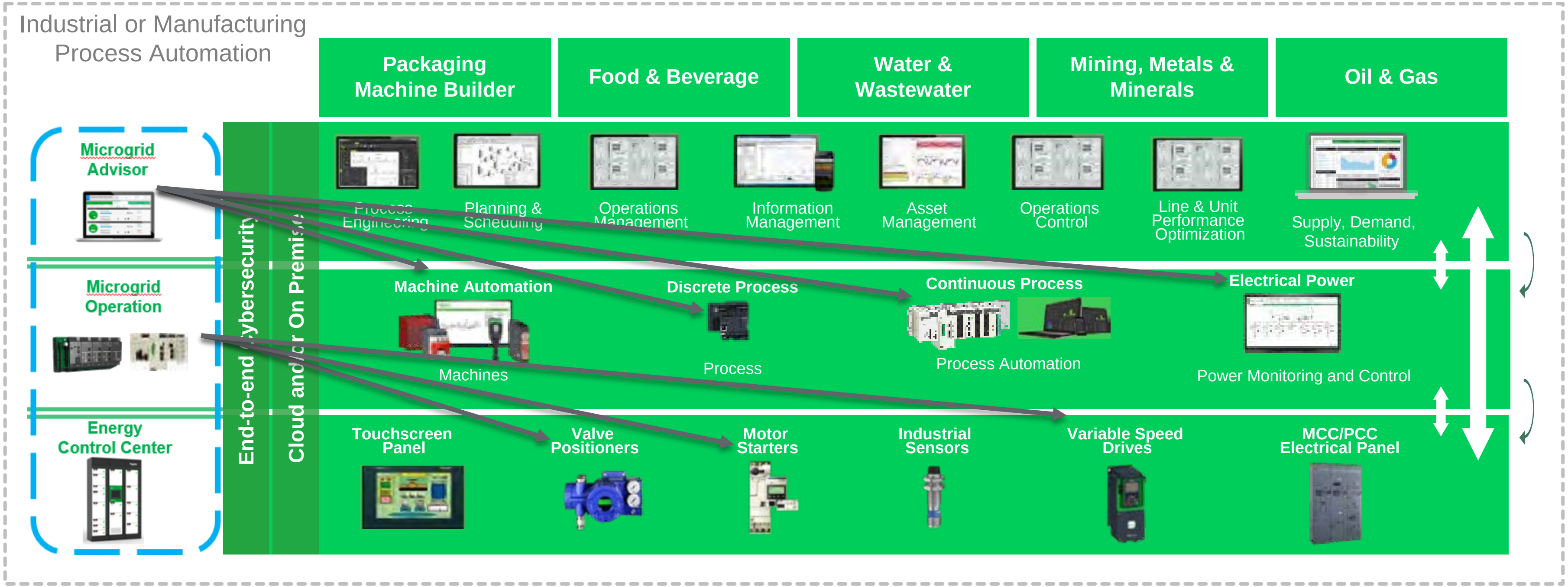
Microgrid Automation connected to Building Automation



Industrial and Energy Plant Automation Systems

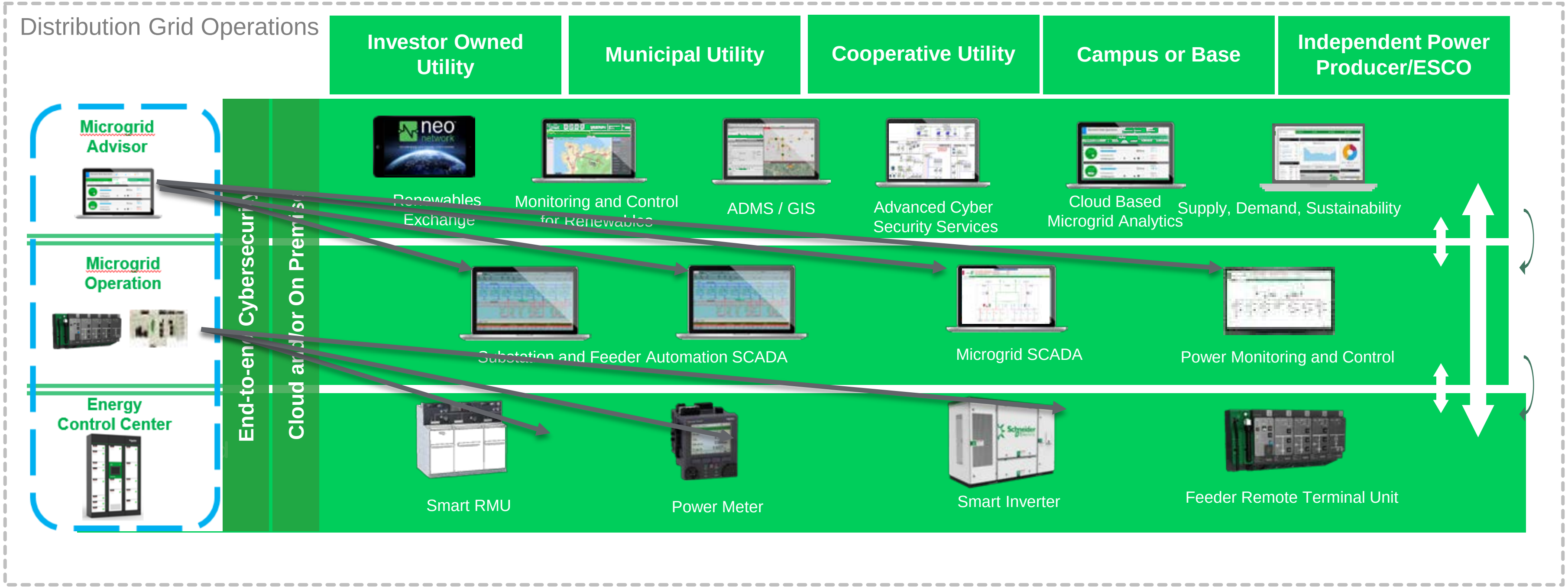
A dynamic process of load prioritization, system operation and economic efficiency

Microgrid Automation connected to Discrete and Continuous process automation



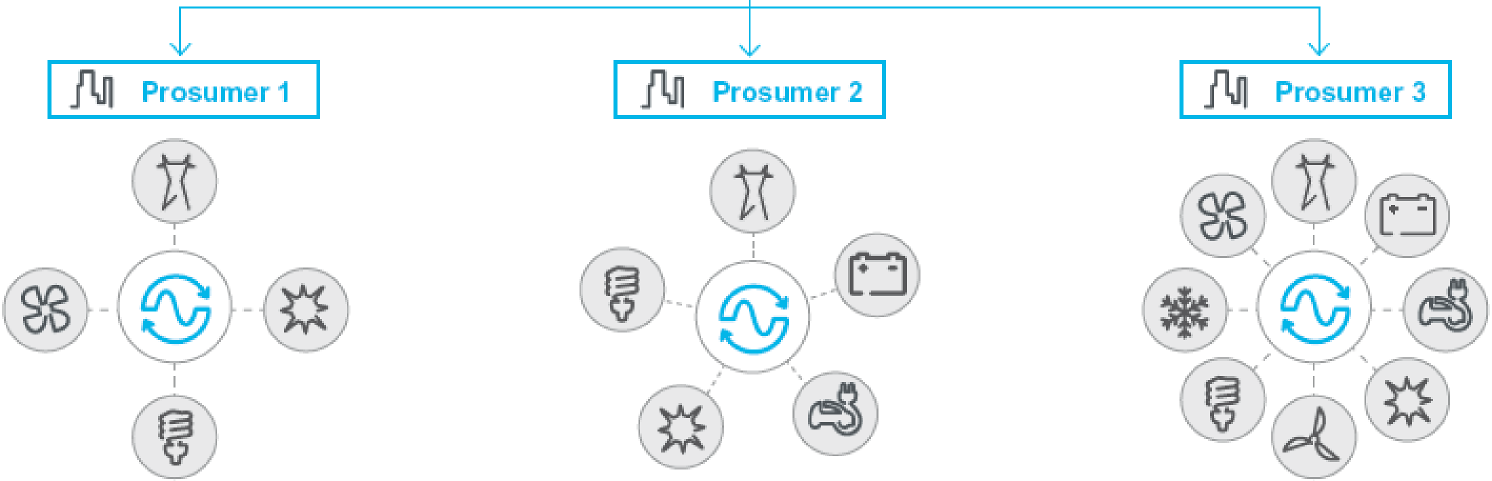
Grid Automation Systems

Utility Scale, Medium Voltage Distribution systems may form Microgrid islands across a campus, city or other district. Substation Area, Feeder or Multi-Feeder level



Prosumers have varying degrees of supply and demand flexibility

The more flexibility the better the optimization



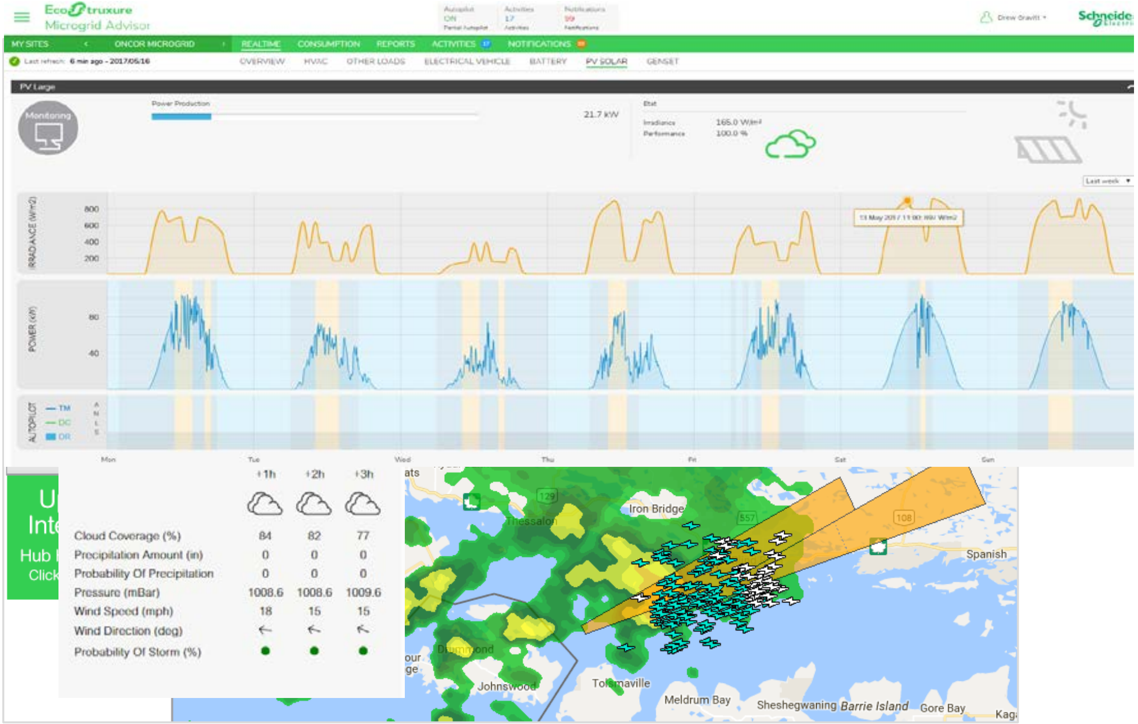
Lights and Motors
Grid and Solar

Lights and EV Charging
Grid, Solar and Storage

Lights and EV Charging, HVAC and Cold Storage
Grid, CHP, Solar and Storage

Weather and Load Forecasting drives system behavior

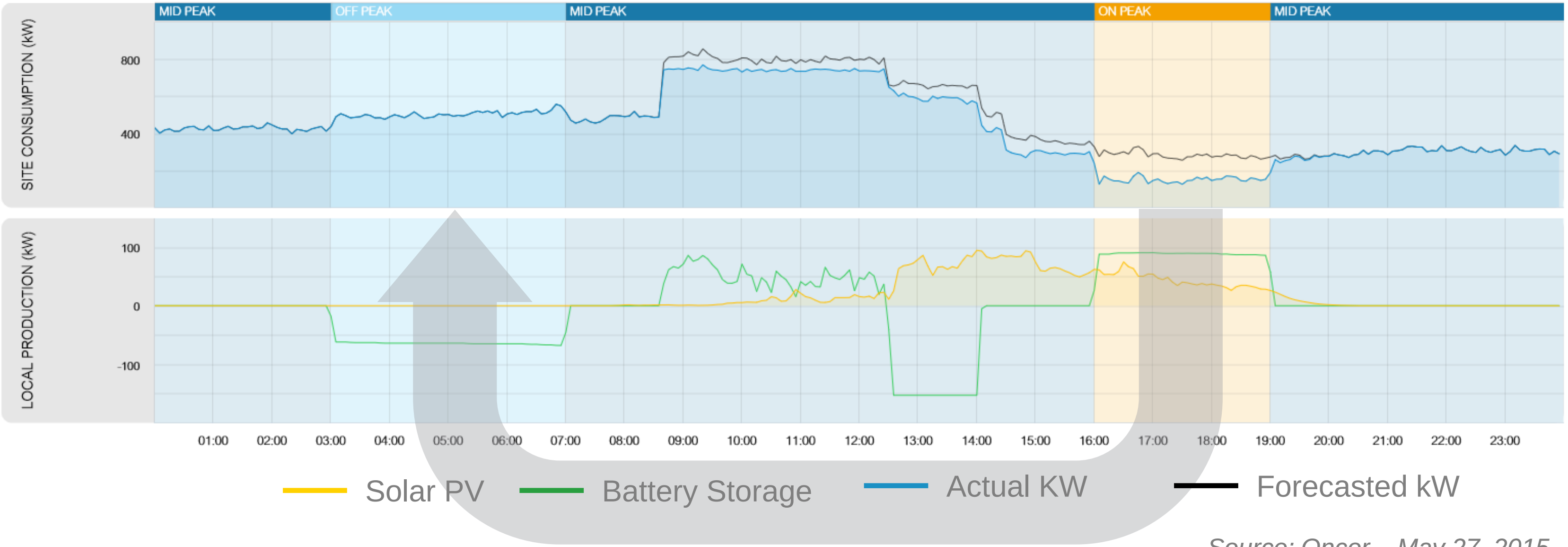
Impacts Heating/Cooling and other industrial or manufacturing process operations. Pre-warns of possible electrical supply disruption



Microgrid Energy Management System integrates weather forecast information

- Pre-heat or cool HVAC Control
- Supply PV irradiance forecast
- Forecast Electrical and Thermal Loads
- Adjust Circuit Load Shed/Add schedule based on emergency operation or islanded mode

Case Study: Oncor Microgrid, Lancaster Texas – May 27, 2015
Peak Electric or Gas Pricing – Tariff Optimization



Source: Oncor – May 27, 2015

- ***Tariff Optimization and Demand Limiting, happening every day***
  - *Prosumer optimization of battery charge, discharge, tariff Management and peak shaving*
  - *Demand Limiting begins at 9:00AM, set at 700kW*
  - *Algorithm completes demand limiting, and then recharges to prepare for Peak Tariff event*
  - *Algorithm evaluates additional demand limiting value compared to tariff management case, and decides to charge and prepare the BESS for next period based on optimizing economic performance.*

Case Study: Pre Heating Building Zone – Feb 17, 2015
Heating applied at 4-6AM Off-Peak, HVAC Curtailed 8-11AM

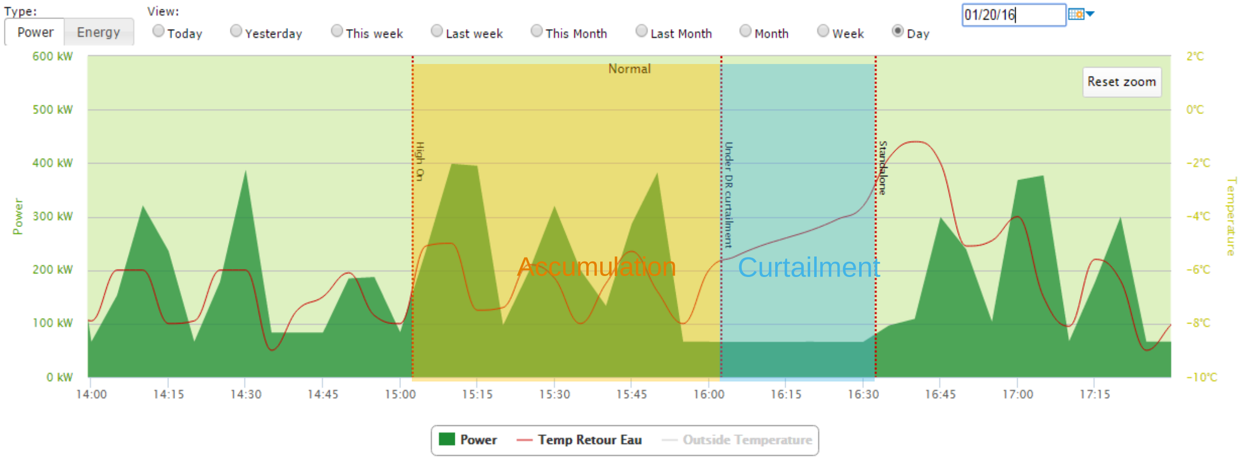
Inside Temperature Maintained between 20 and 22.5 degrees Celsius

Duration of pre-heating optimized based on weather forecast of Outside Temperature

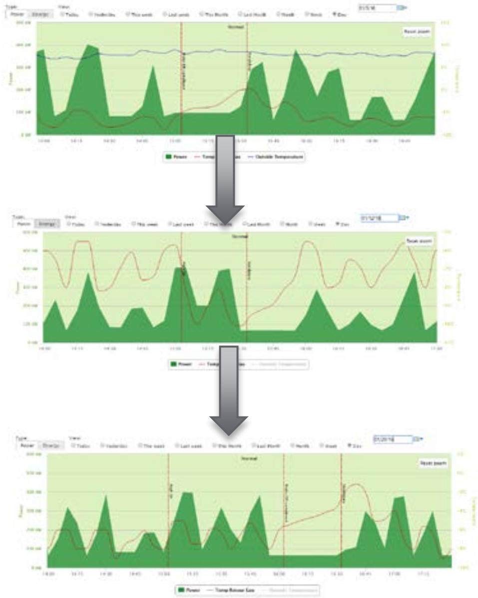
Integrating the power management system with the building automation system

Case Study: Cold Storage System Energy Optimization
January 2016 – Thermal Accumulation/Curtailment

- Scenarios Analyzed in January 2016 with the following use cases
  - Remote monitoring of Cold Storage Load and Thermal Performance
  - Historical Scenario Analysis and Adjustment Trials
  - Optimizing energy consumption based on thermal inertia potential
  - Maintain -2c to -8c range

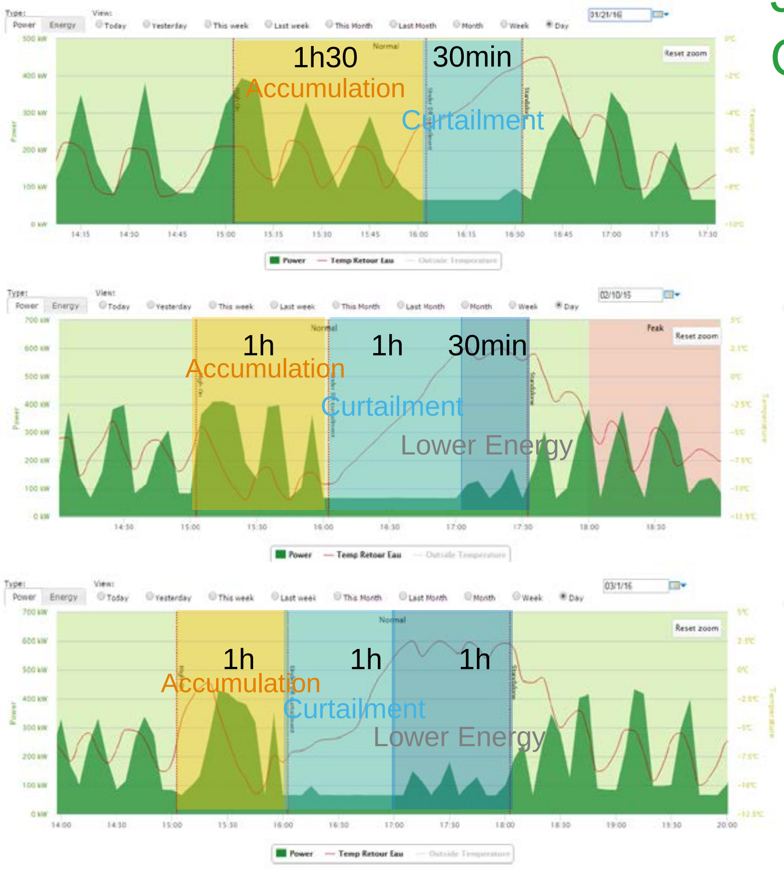


January 20th – Typical day
60 minutes accumulation + 30 minutes curtailment



Case Study: Cold Storage System Energy January 2016 – Thermal Accumulation Curtailment, followed by low energy period

Regulation by the BMS at 2C



- Results
  - Without accumulation: about **100kW** improvement during curtailment
  - With accumulation: about **200kW** of flexibility during a curtailment
  - 1h of accumulation allows to curtail the load for 1h
  - After 1h of curtailment, BMS is regulating the temperature at 2C. This results in a smaller energy consumption period than the usual regulation at -8C)

With curtailment	No curtailment
- Water temperature regulated at -8°C - Accumulation at -10C during 30 minutes - Curtailment during 1h30 with a temperature regulation set point at +2Ck - Temperature goes back to -8C after 1h30	Water temperature is regulated at -8C during 3h30

Islanding and Islanded Operations: Fast Load Shed/Add

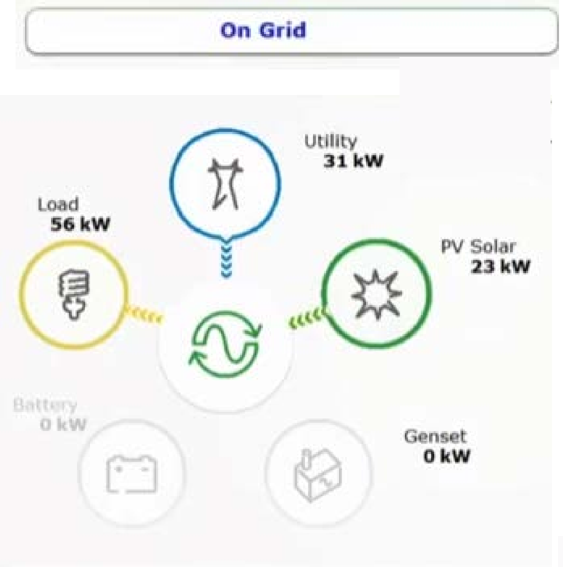
Intelligent Fast Load Shed (iFLS) or can be an economic decision

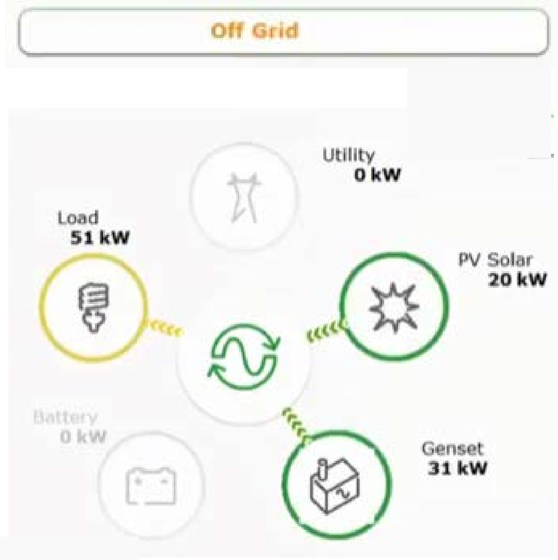
Islanding Operation may be required at any time, any day or night, at any point in your building, manufacturing or industrial process operations

iFLS/A – Intelligent Fast Load Shed/Add must rapidly eliminate the right circuits/loads, at that time, to keep CHP engines and other local energy resources from tripping offline. This varies by process and by time.

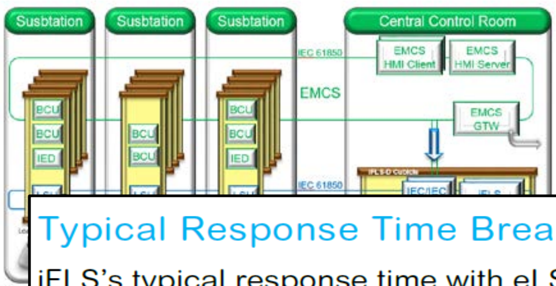
Microgrid and HVAC BMS integrated controls lower lighting or alter temperature set points

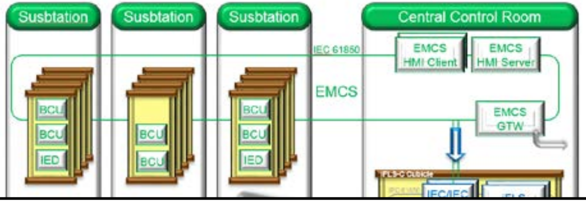
Microgrid and Process Automation System integrated to define circuits and dynamic iFLS schedule for islanding





iFLS – Intelligent Fast Load Shed Architecture





Typical Response Time Breakdown

iFLS's typical response time with eLSU is less than 30 ms from the contingency trigger detection up to the load shedding contact closure.

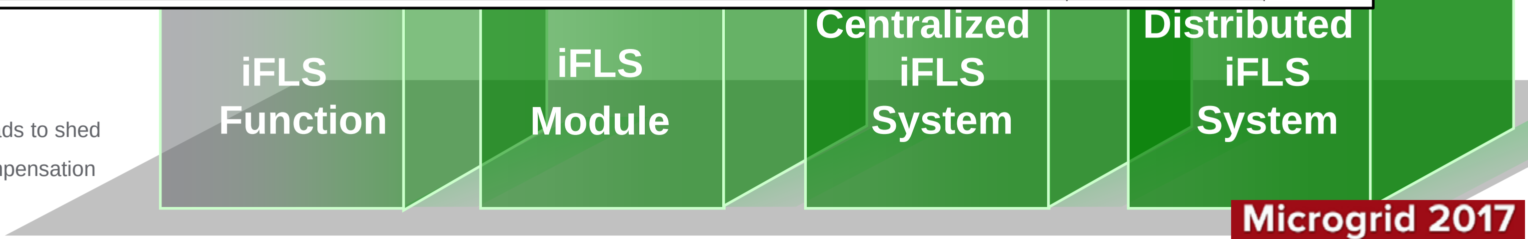
T0	IED detects contingency trigger / condition	0 ms
T1	IED confirms the detection (to protect against spurious triggering)	1 ms
T2	IED publish contingency trigger through Goose	3 ms
T3	Goose frame is propagated through the ethernet network	3,250 ms
T4	iFLS decodes the trigger, creates and published load shedding frame	13,250 ms
T5	Load Shedding frame is propagated through the ethernet network	13,5 ms
T6	Load Shedding frame is received and executed by the eLSU	19,5 ms
T7	eLSU shed contact is closed	26,5 ms

Proactive evaluation

- Contingency B
- Complete Syst
- Embedded Top
- Analyze existin
- Predict system
- Determines ho

Optimal loads to she

- High Selectivity
- Load Priorities
- Groups & Dynamic Groups
- Hardware Reaction Capability
- Selects best combination of loads to shed
- Breaker Failure Automatic Compensation
- High Response Performance



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Utility Distribution Control Center

SCADA

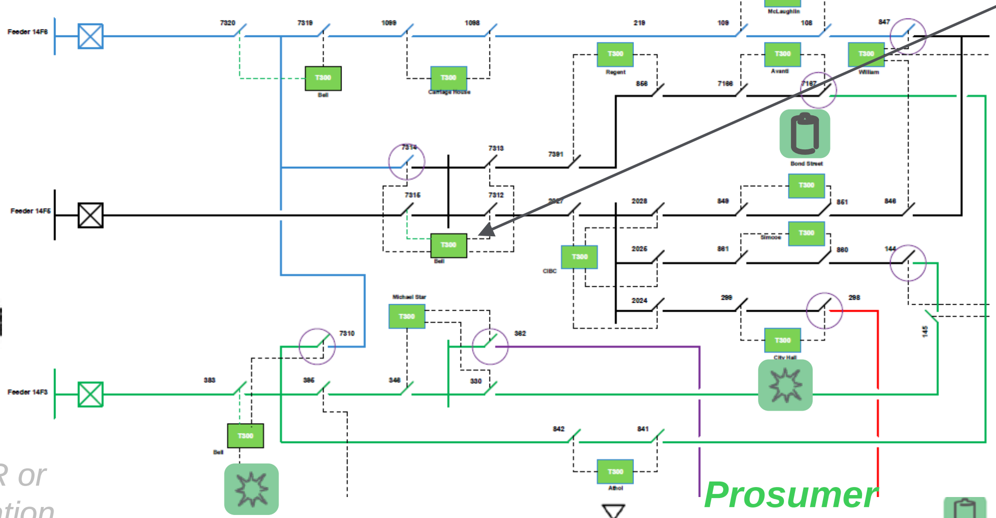
DERMS

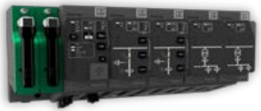
DMS/OMS

Switching

Large Area FLISR/VVO

Feeder Distribution



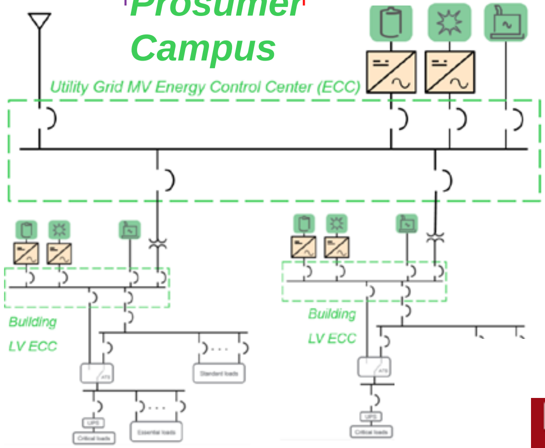


Feeder/DER Automation Self-Healing Network, Load Shed Unit or Local Generation Unit DER/Microgrid PCC

Substation

Substation, DER or Microgrid Automation, Load Shed/Add

Prosumer Campus



Prosumer Building

Economic Optimization

Microgrid Control Hierarchy for Grid, Campus and Building

Centralized and Distributed Logic Operating at different levels of the Network

Building/Plant Automation Microgrid Automation

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Case Study: Refinery CHP Load Preservation Microgrid

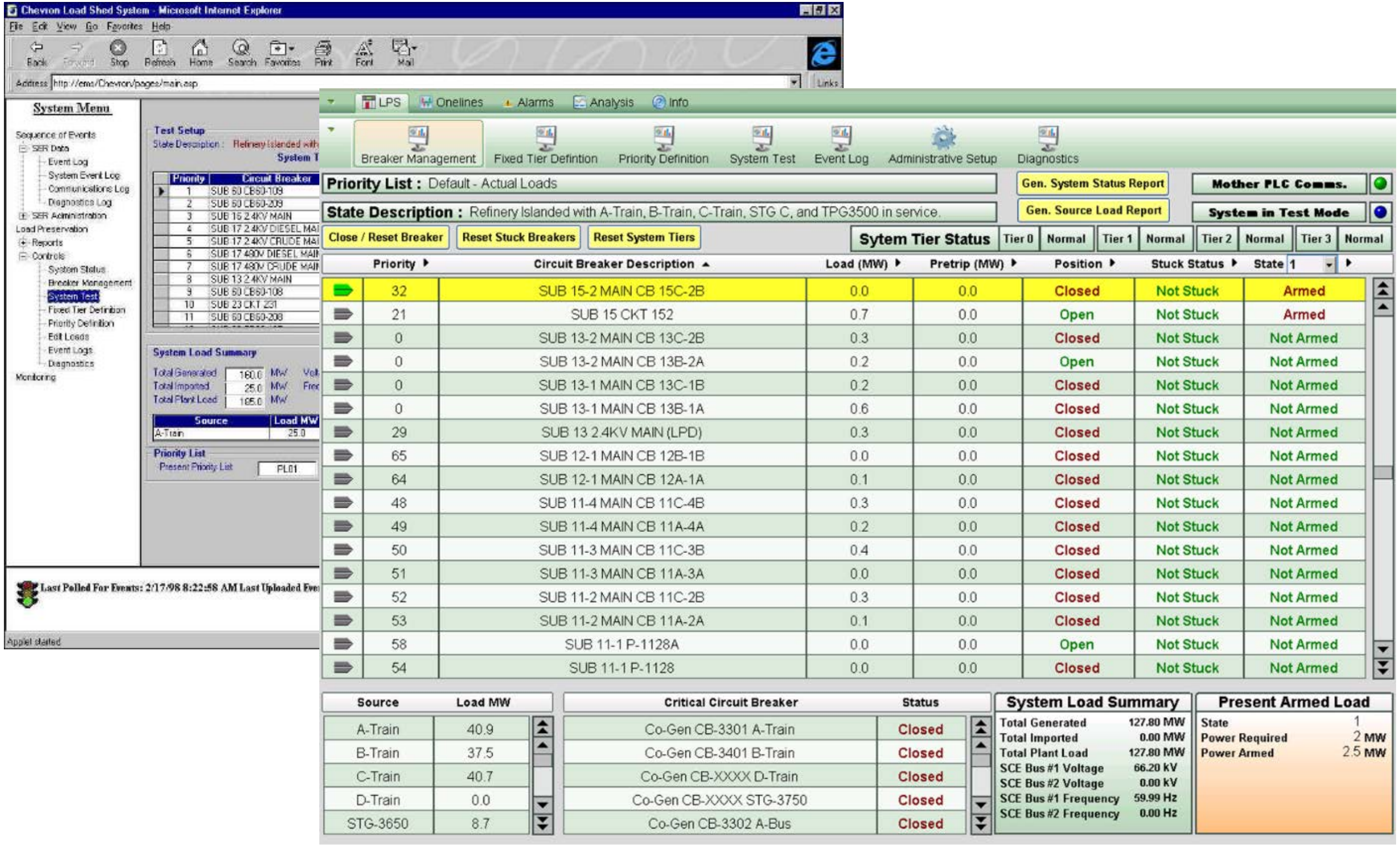
Project at a Glance

- Multiple locations (including CA, USA)
- Designed, engineered, and constructed a load preservation system microgrid for 165 MW co-generation systems serving 185 MV of load in the initial phase.
- 90% net-zero (gas-fired CHP)
- 7 cycle islanding to preserve steam system from tripping offline
- 100 breakers shed at high, medium, and low voltage, closed transition
- Export of power to utility (SCE)
- Integration of sequence of events recording
- Typical of 15 similar projects in chemicals, refining, and paper. Existing CHP retrofits

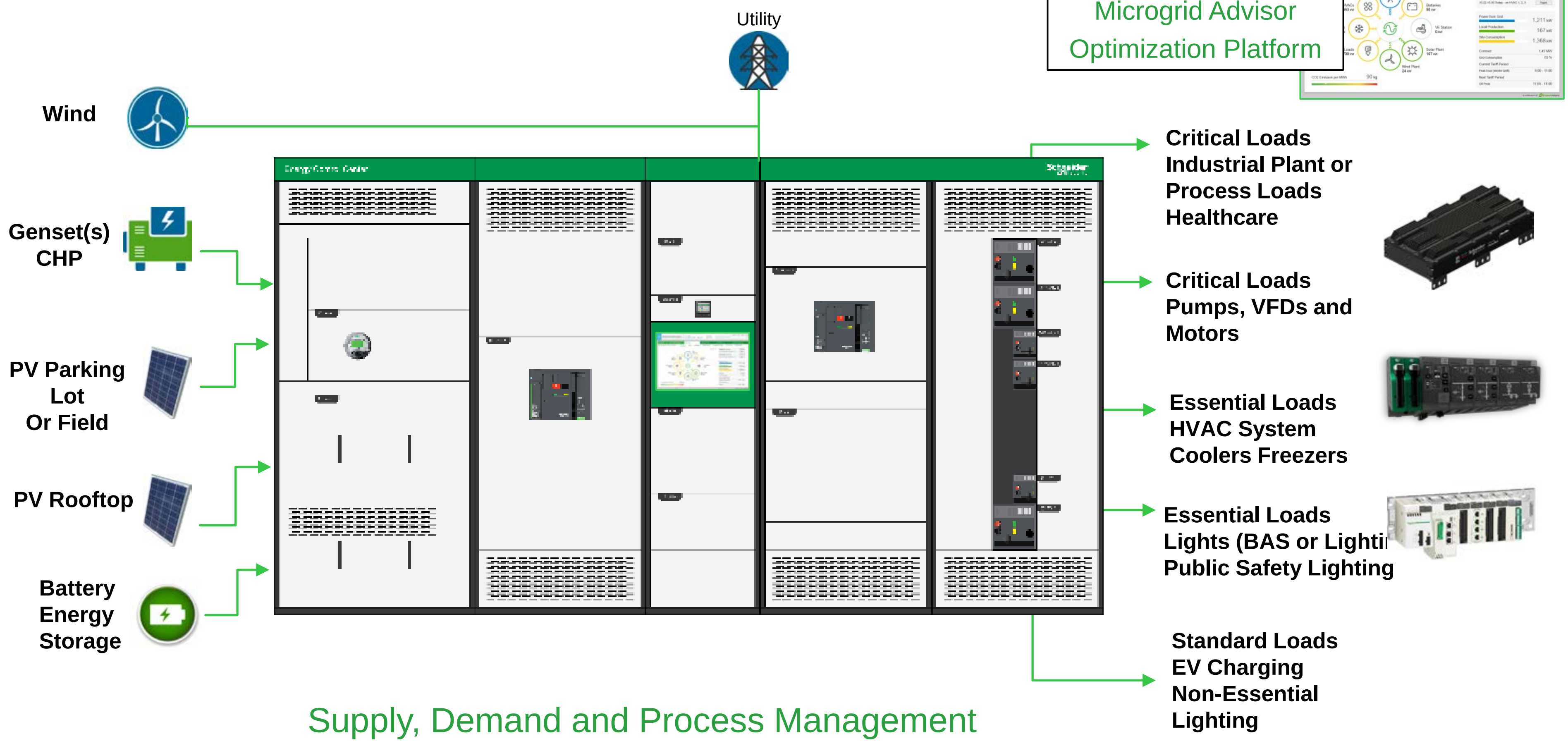
Keeping 160MW+ of CHP up when the grid is down

Investment: **~$4.5 million**
Result: **Multiple outages avoided**

Case Study: Refinery Load Preservation Microgrid



Microgrid Energy Control Center



Supply, Demand and Process Management

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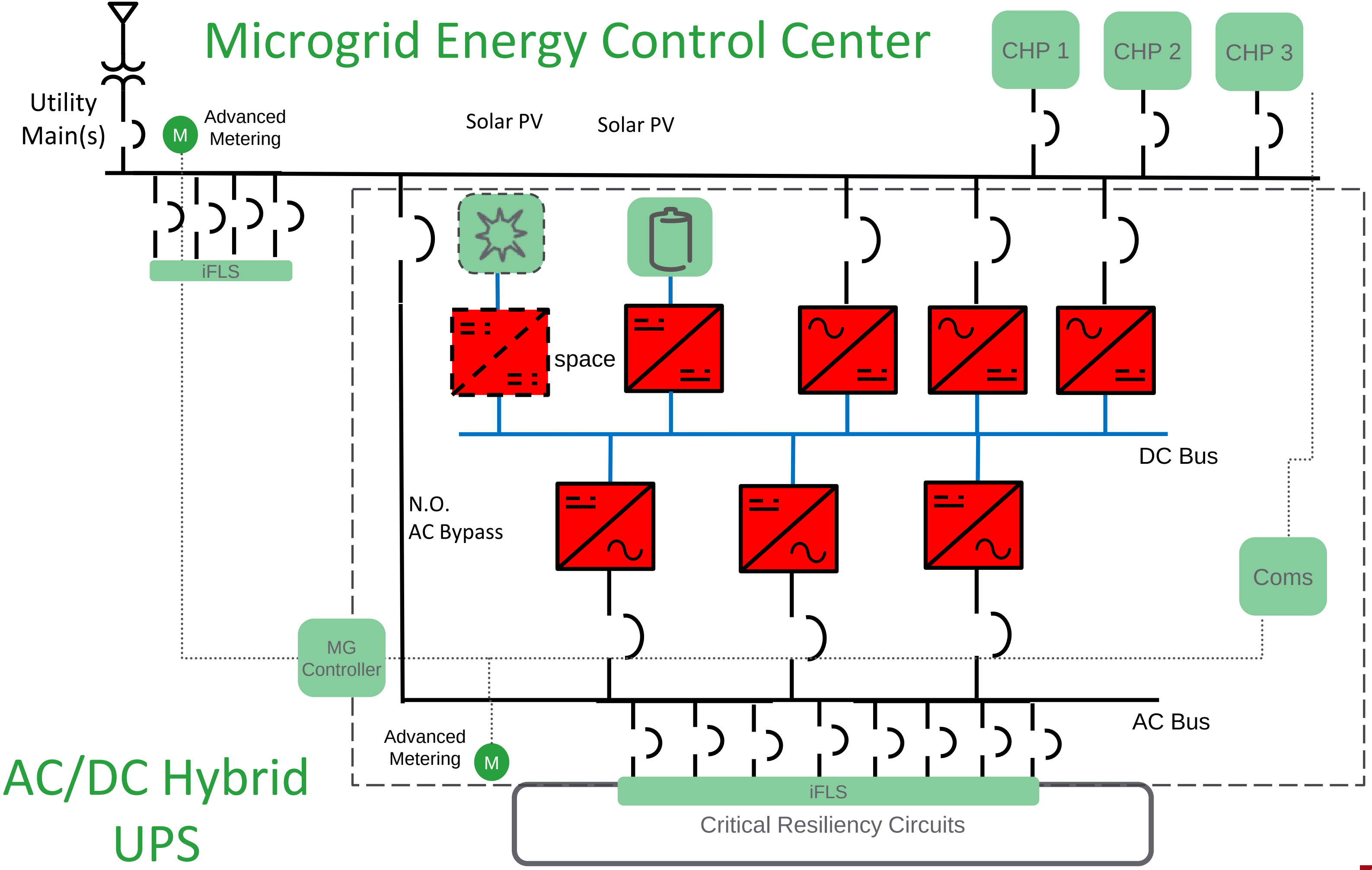

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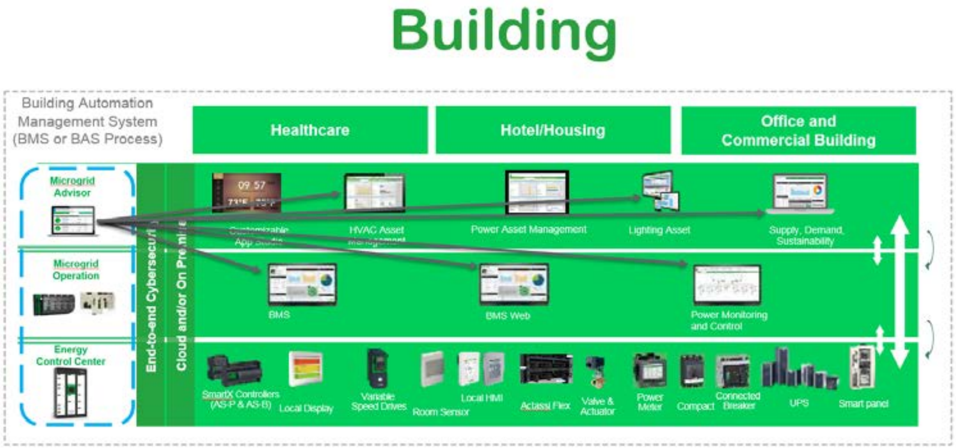
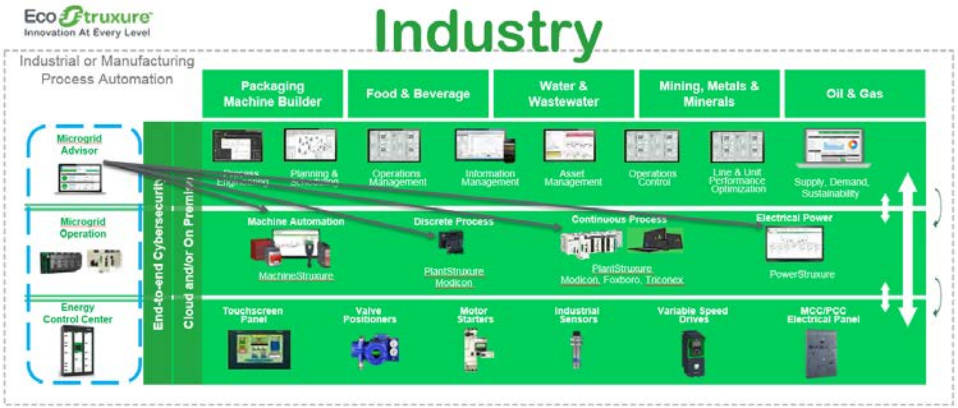
Closing Thoughts





Integration of Microgrid/Power Automation with Process/Energy Plant Automation for buildings and industrial processes can additional benefits that cannot be derived when managed separately

- Energy Economic optimization can treat the entire energy system (thermal and electrical) rather than treat each as siloed process

- Microgrid Control, PA Control along with iFLS/A enable islanding of CHP and other Distributed Energy Resource Plants

- Economic optimization of microgrid islanding operation manages which loads can and should be shed to preserve key loads at the time balanced with local supply

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