# Cyber-physical Architecture for Resiliency

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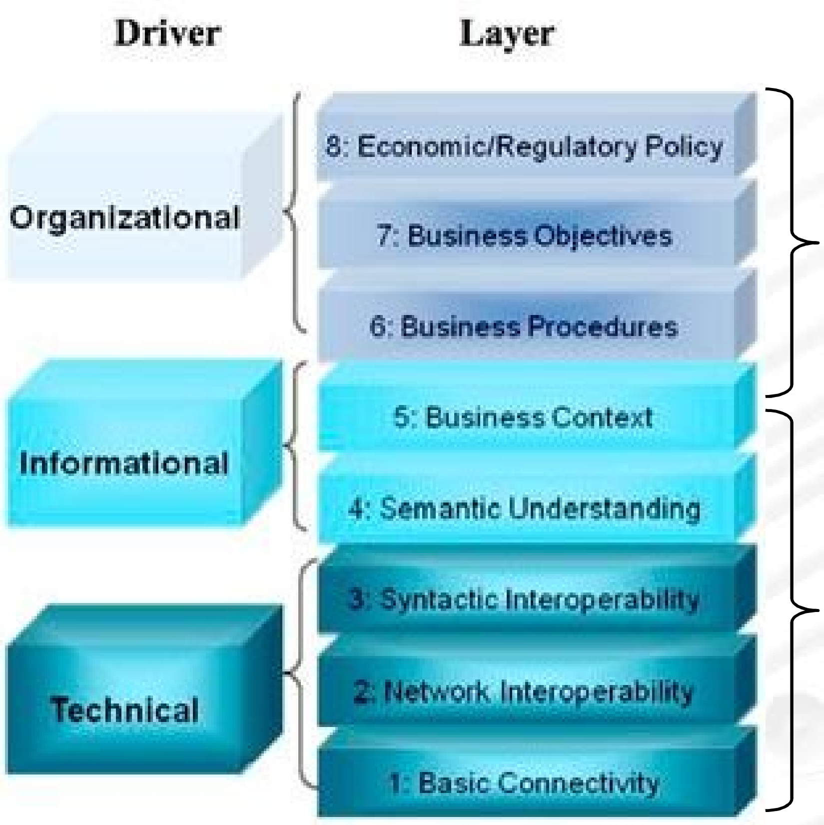
Chairman and CTO, EnerNex

# TE in Architectural Context

## GWAC Stack




## TE Panel Topics

- Market Design Considerations
- Business & Operational Value
- Transactive Control Framework
- Cyber-Physical Architecture

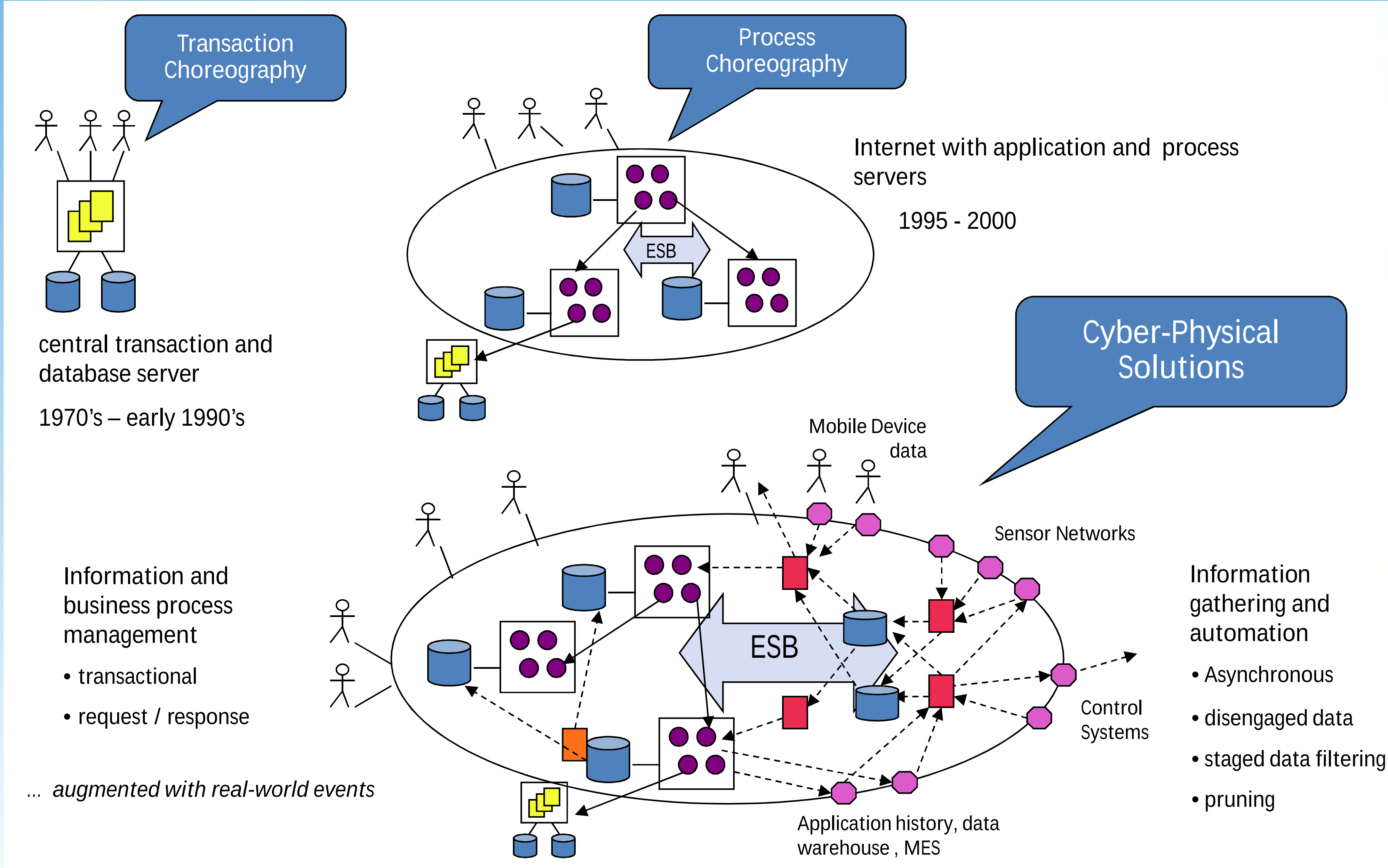
**Paul De Martini**

**Ron Ambrosio**

**Erich Gunther**

# A Cyber-Physical System

Driving to Grid 2020



# Corporate Campus Microgrid: Business Values

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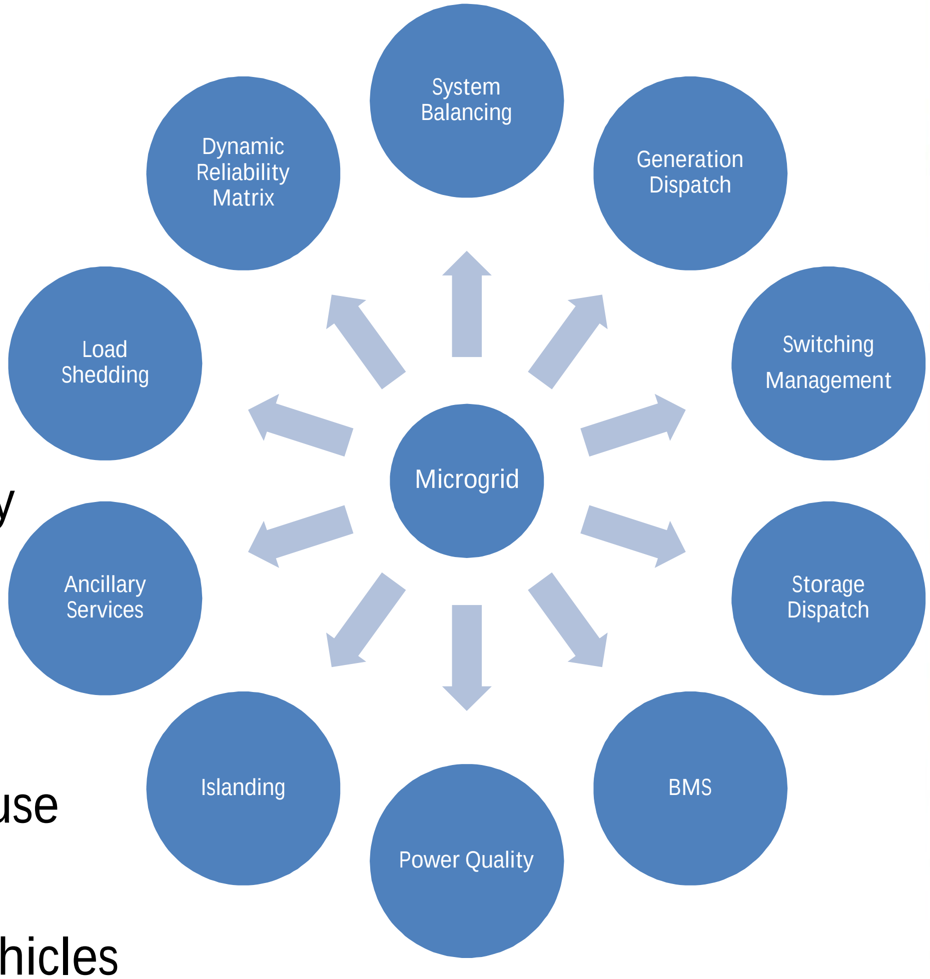
- Summary Objective:
  "Achieve business continuity with a system that pays for itself and supports environmental stewardship"

- Order of energy use / load order is:
  1. Energy efficiency/energy conservation
  2. Renewable energy
  3. Direct access energy

- Campus will be Net Zero Energy (NZE) facility
  - California AB900 Net Zero Facility
  - Efficiency and conservation top priority
  - Minimum 30% reduction in energy use
  - Minimum 30%-35% reduction in water use
  - Reduce employee automobile trips
    - Electric charging stations for 300 vehicles



# Corporate Campus Microgrid: Business Values

- 100% renewable energy from on-site generation preferred
  - On-site solar and on-site fuel cells fueled with biogas
  - Remaining power supplied by off-site renewable energy
  - Microgrid/storage/off-site Renewables used to balance load
- Direct Access is preferred method of purchasing renewable
- Design for all revenue opportunities (e.g. peak shaving, ancillary services, demand charge management, renewable energy supply on weekends)
- Extremely high energy supply reliability required
  - High hourly employee productivity/revenue generation
  - Self generation needed in event of utility outage
- High power quality required – including during islanded operation
  - Computer equipment sensitive to momentary conditions
  - Critical Labs & Loads have specific concerns

# Microgrid Use Cases

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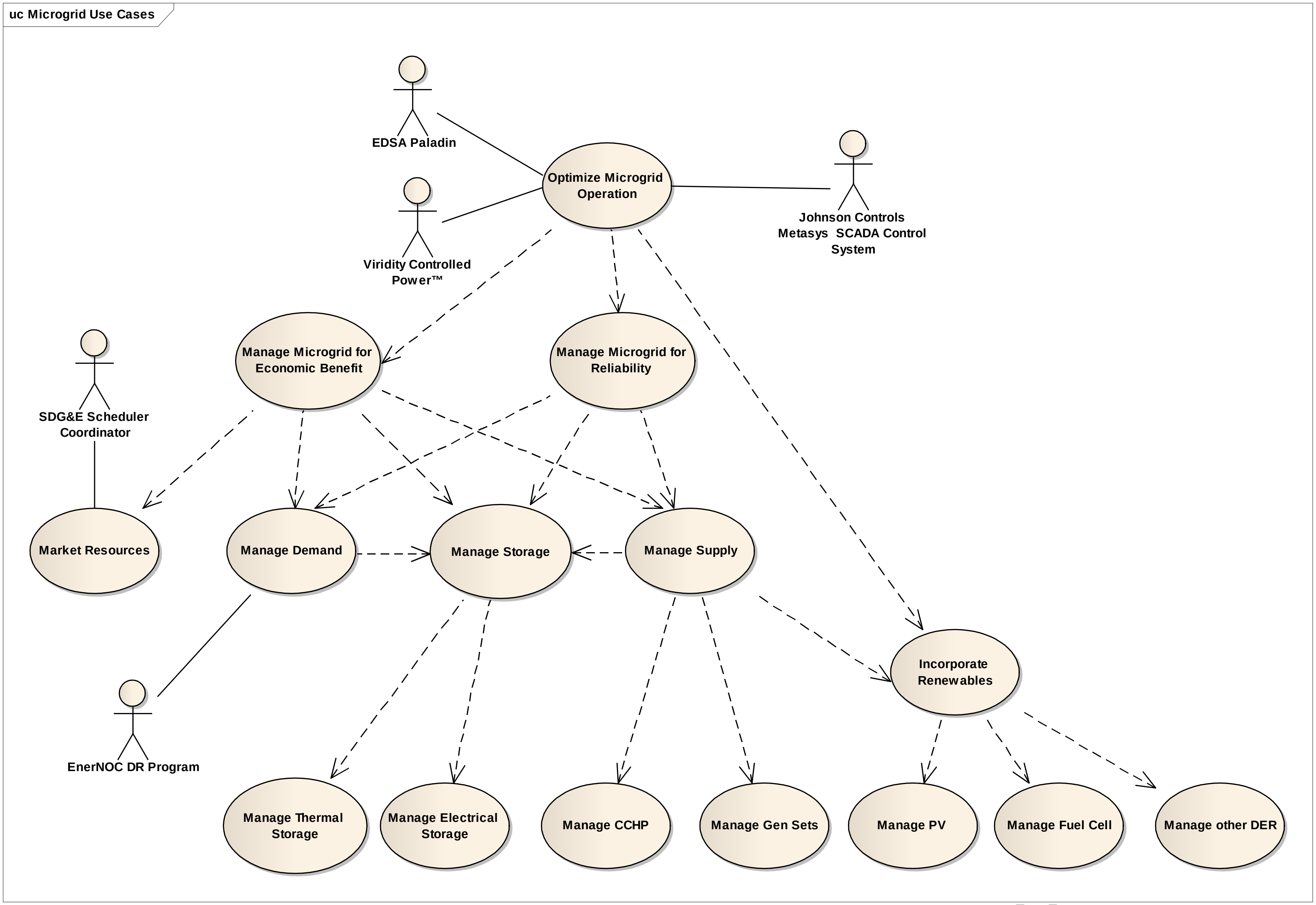

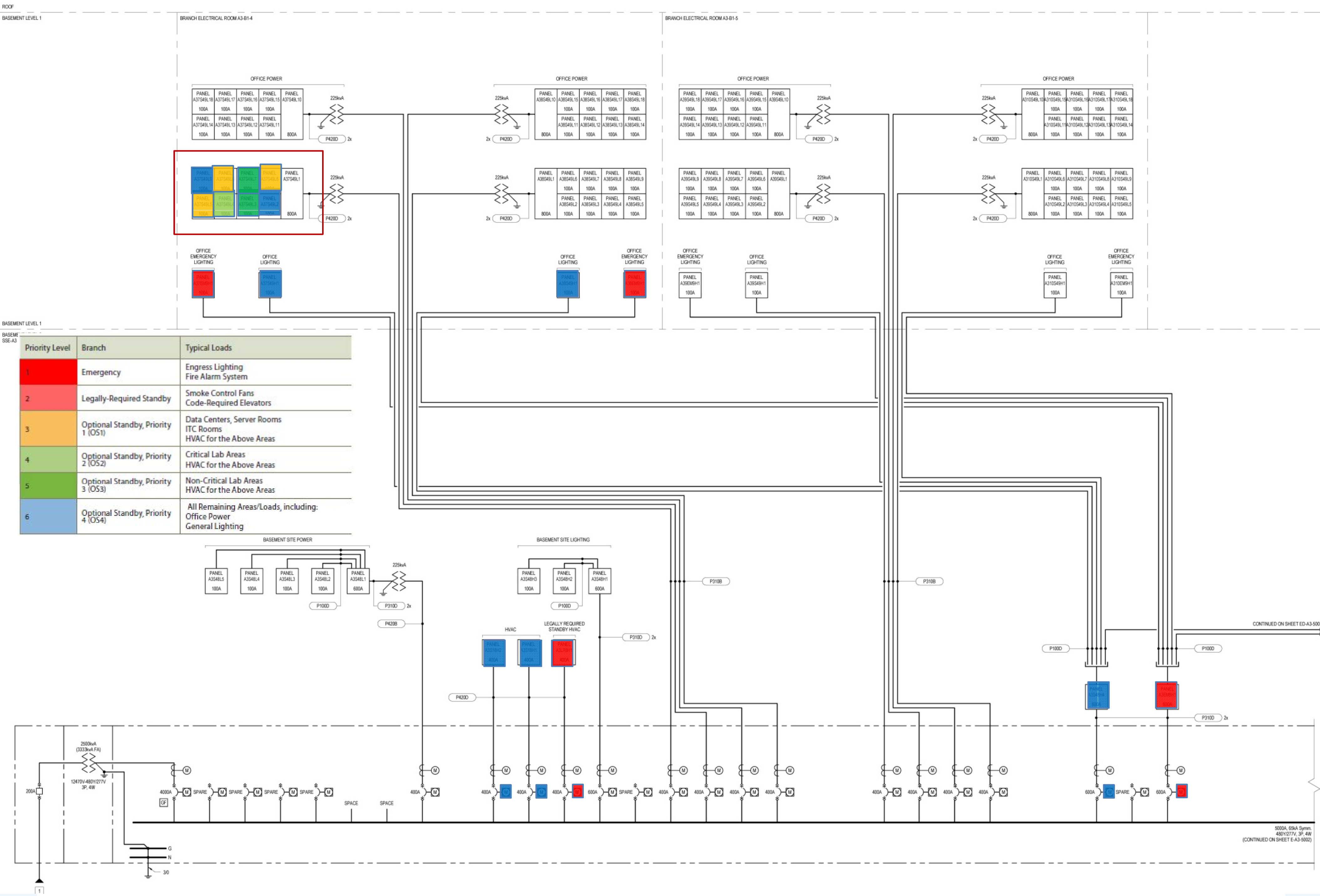


| Priority Level | Branch | Typical Loads |
|---|---|---|
| 1 | Emergency | Engress Lighting<br>Fire Alarm System |
| 2 | Legally-Required Standby | Smoke Control Fans<br>Code-Required Elevators |
| 3 | Optional Standby, Priority 1 (OS1) | Data Centers, Server Rooms<br>ITC Rooms<br>HVAC for the Above Areas |
| 4 | Optional Standby, Priority 2 (OS2) | Critical Lab Areas<br>HVAC for the Above Areas |
| 5 | Optional Standby, Priority 3 (OS3) | Non-Critical Lab Areas<br>HVAC for the Above Areas |
| 6 | Optional Standby, Priority 4 (OS4) | All Remaining Areas/Loads, including:<br>Office Power<br>General Lighting |

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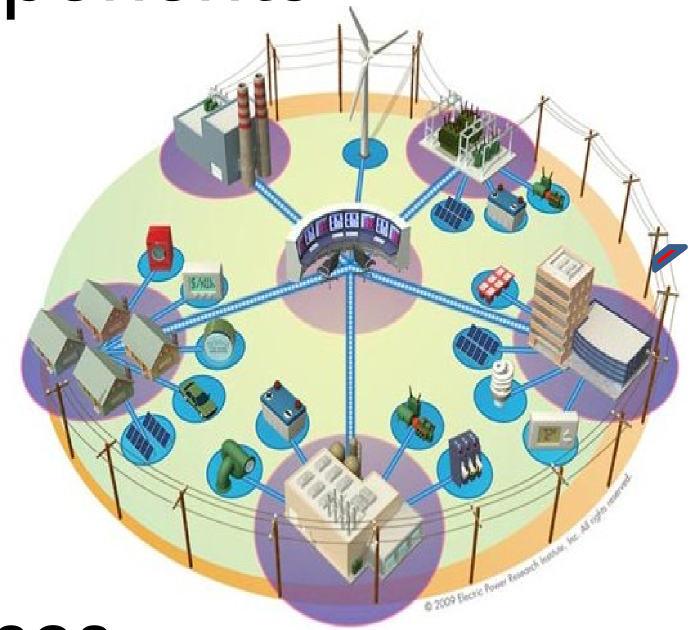
# Infrastructure Elements

- Electrical system communicating devices – switches, sensors, inverters
- Communications network components
- Generation sources
- Power conversion devices
- Building automation system
- Human interface devices
- Loggers, historians and databases
- Centralized and distributed controllers



# Infrastructure Concerns

- Many managed devices
- Many physical networks – proprietary, boutique, and TCP/IP
- Many logical networks – operations/control, measurement, building automation, corporate
- Many protocols – DNP3, MODBUS, BACNet, OpenADR, etc.
- Many gateways
- Many interoperability points
- Many points of security vulnerability

# Utility Microgrid for Resiliency

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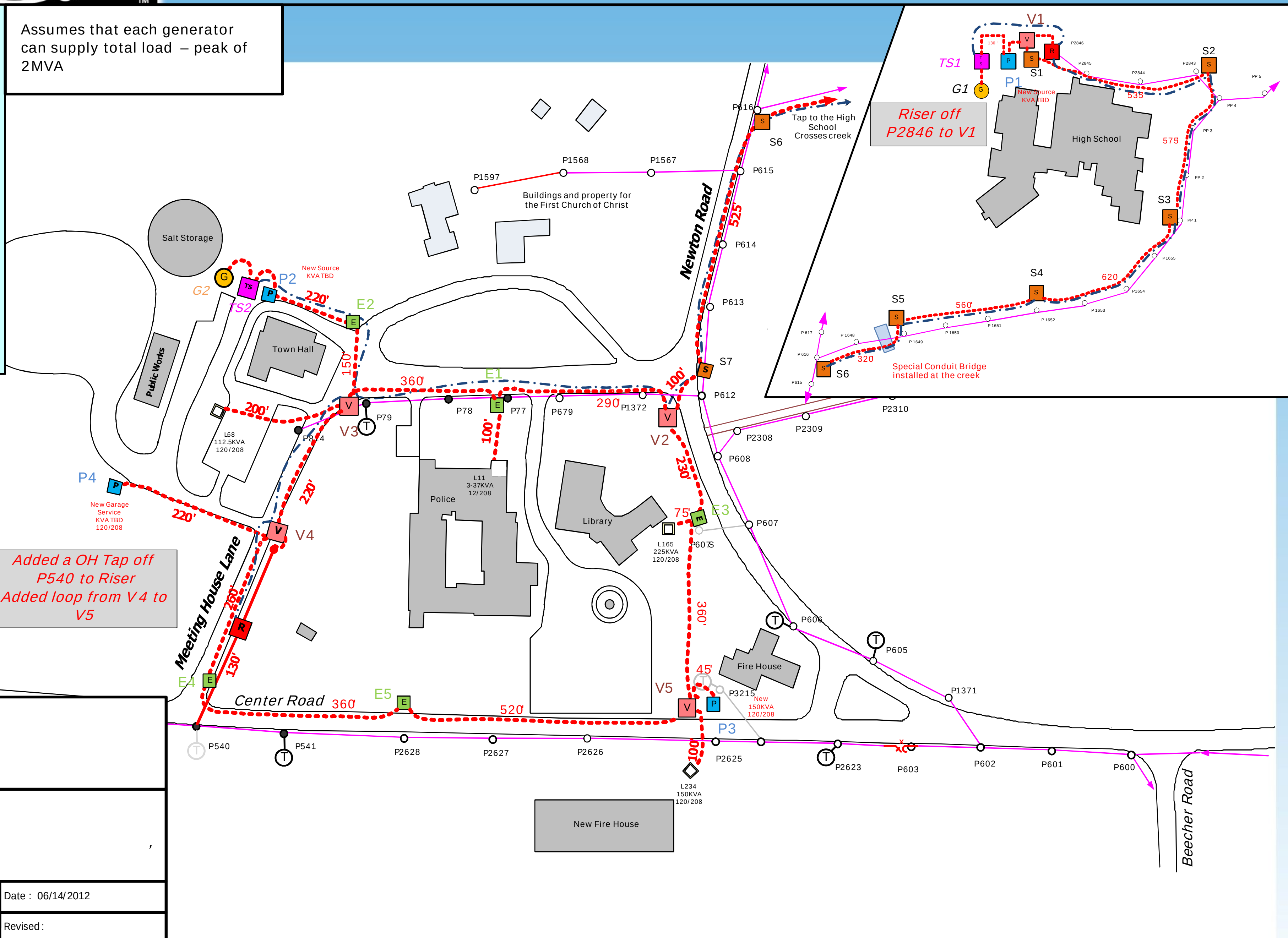
**Equipment Legend**

- GENERATOR
- VISTA SWITCH
- LCB CABINET
- NEW PAD XFRMR
- LV TRANSFER SWITCH
- CONCRETE SPLICE BOX
- OH SUPPLY LINE
- UG SUPPLY LINE
- NEW UG SUPPLY LINE
- NEW OH SUPPLY LINE
- COMMUNICATION LINE
- OH TRANSFORMER
- 3PH PAD TRANSFORMER
- RECLOSER SWITCH

Assumes that each generator can supply total load – peak of 2MVA

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Grid-Interop 2012

# Utility Microgrid: Additional Infrastructure Issues

- Even more networks – substation, field area wireless and wired, critical customer networks including building automation
- Increased cyber-physical security vulnerability
- Even more devices - critical customer UPS and generators, building automation devices and systems

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# Summary

- Microgrids are a hot topic and can/should include transactive energy concepts to meet business objectives
- The large number of components in electrical, communications, and control infrastructure require maximal application of systems of systems engineering discipline
- Even green field implementations must deal with the reality of multiple standards and technology systems integration

# GridWise® Architecture Council

## *2013 Meetings & Workshops*

GWAC Web Meeting
January 23, 2013
10:00 AM to 12:00 PM PST

GWAC Meeting and Transactive Energy Workshop
February 5-6, 2013
General Electric's Grid IQ Experience Ctr
Atlanta, Georgia

GWAC Web Meeting
March 20, 2013
10:00 AM to 12:00 PM PST

GWAC Web Meeting
April 24, 2013
10:00 AM to 12:00 PM PST

GWAC Meeting and Transactive Energy Workshop
May 21-22, 2013
World Trade Center
Portland, OR

Transactive Energy Conference
May 23-24, 2013
World Trade Center
Portland, OR

GWAC Web Meeting
June 26, 2013
10:00 AM to 12:00 PM PST

# GWAC Transactional Energy Conference

- First International Conference and Workshop Transactive Energy: Implementing the Future of the Electric System
- May 23-24, 2013, World Trade Center, Portland, OR

- Who: organizations…researching, developing and deploying Transactive Energy techniques and business models
- Goal: facilitate accelerated development of Transactive Energy to
  - Enable scalable adoption of intermittent and distributed resources
  - Implement vision of two-way, participatory electric grid
- Continuing work of the GridWise® Architecture Council in developing a Transactive Energy framework

# Questions

# Use Case: A Disaster: Business Continuity Following Severe Earthquake (Island Mode)

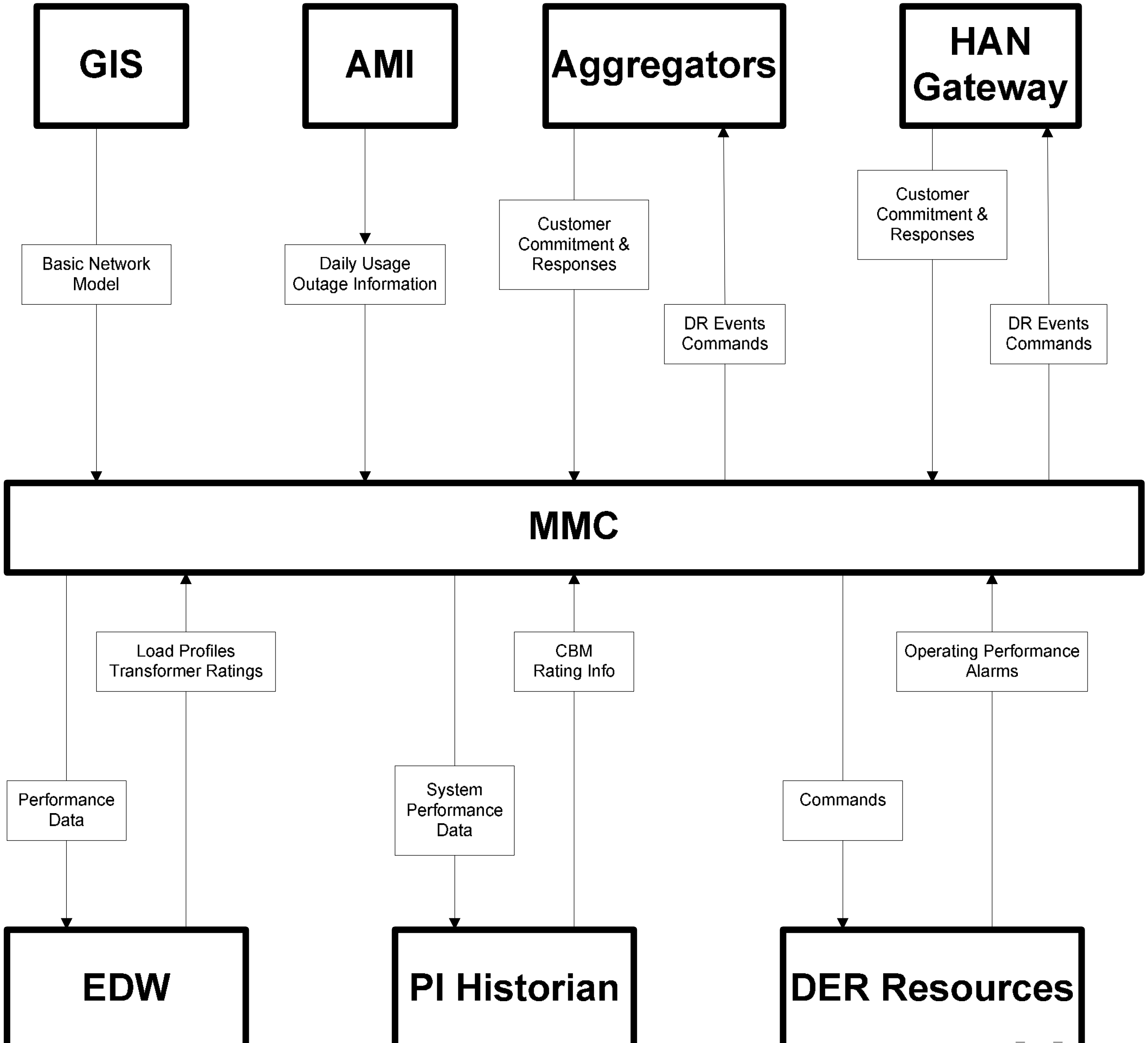
- Goal: Examine campus energy storage and generation following local earthquake
  - Assume electric, gas, water and communications infrastructure degradation
  - Review operation under generation options
    - (e.g. Fuel cells, Solar, Gen sets, & Off site)
  - Review operation under various storage options
    - (e.g. Compressed air, and other feasible options)
- Examine islanded campus operation , if one or both of utilities two 12kV feeder(s) fail
- Examine campus operation, if utility gas line fails
- Plan for extended outages
- Consider potential effects on major product release
- Consider possible assistance to local community/local grid support
- Examine mitigation costs versus disaster likelihood
  - Balance costs and benefits
  - For example  mitigation for 7.0+ quake must consider costs
  - Energy system mitigations should be aligned with disaster planning/mitigation
- Review of Business Continuity valuation methods
- Capture of significant intangibles

# Use Case: Storage, Operations & Technical Constraints

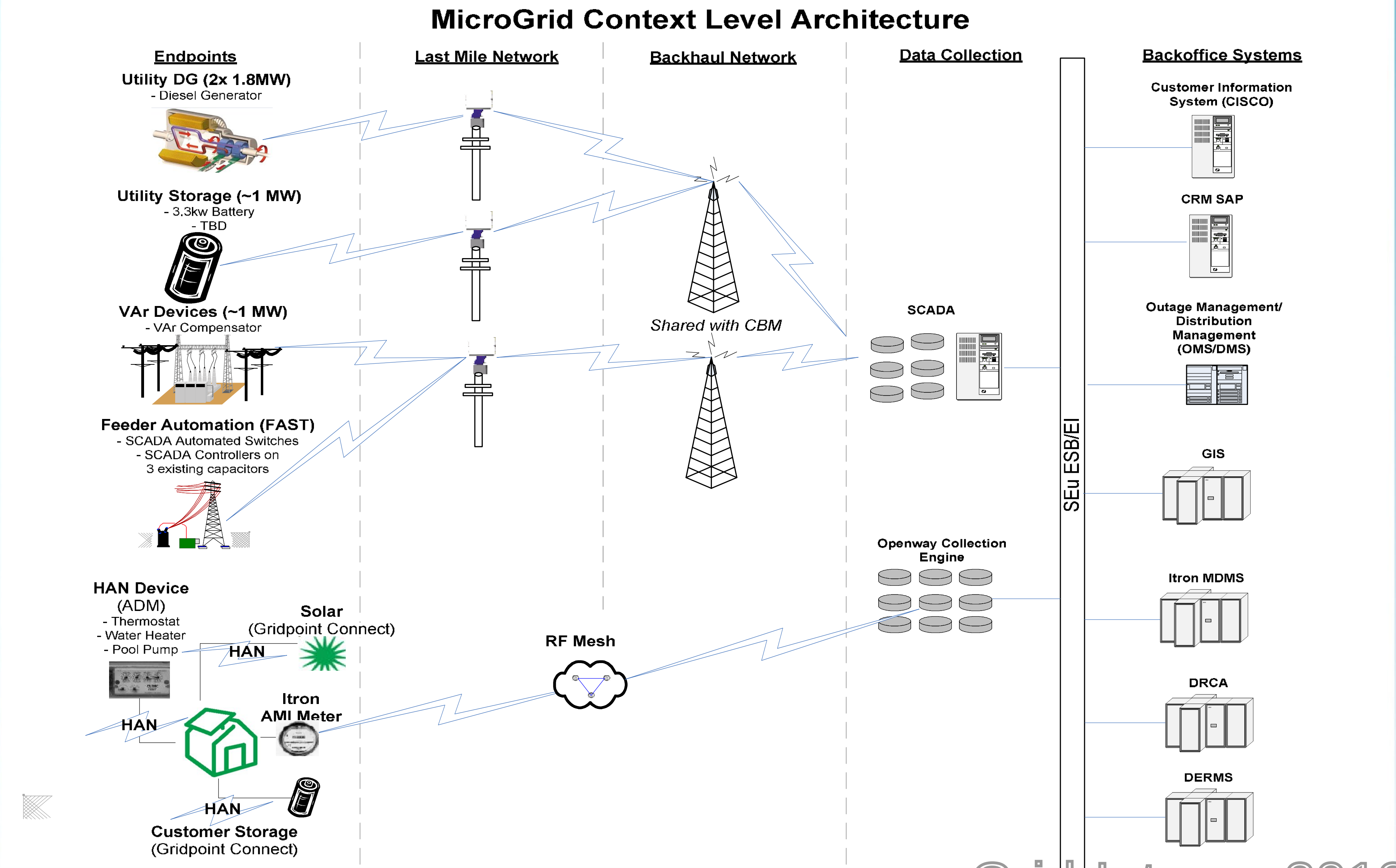
- Goal: Review tradeoff issues and mix from conventional and innovative alternatives
  - Generation options include fuel cells, solar, off-site renewables, gen sets
  - Storage options include batteries & compressed air (CAES)
  - Review current modeling and economic analyses
  - Review facility resiliency matrix and associated tradeoffs

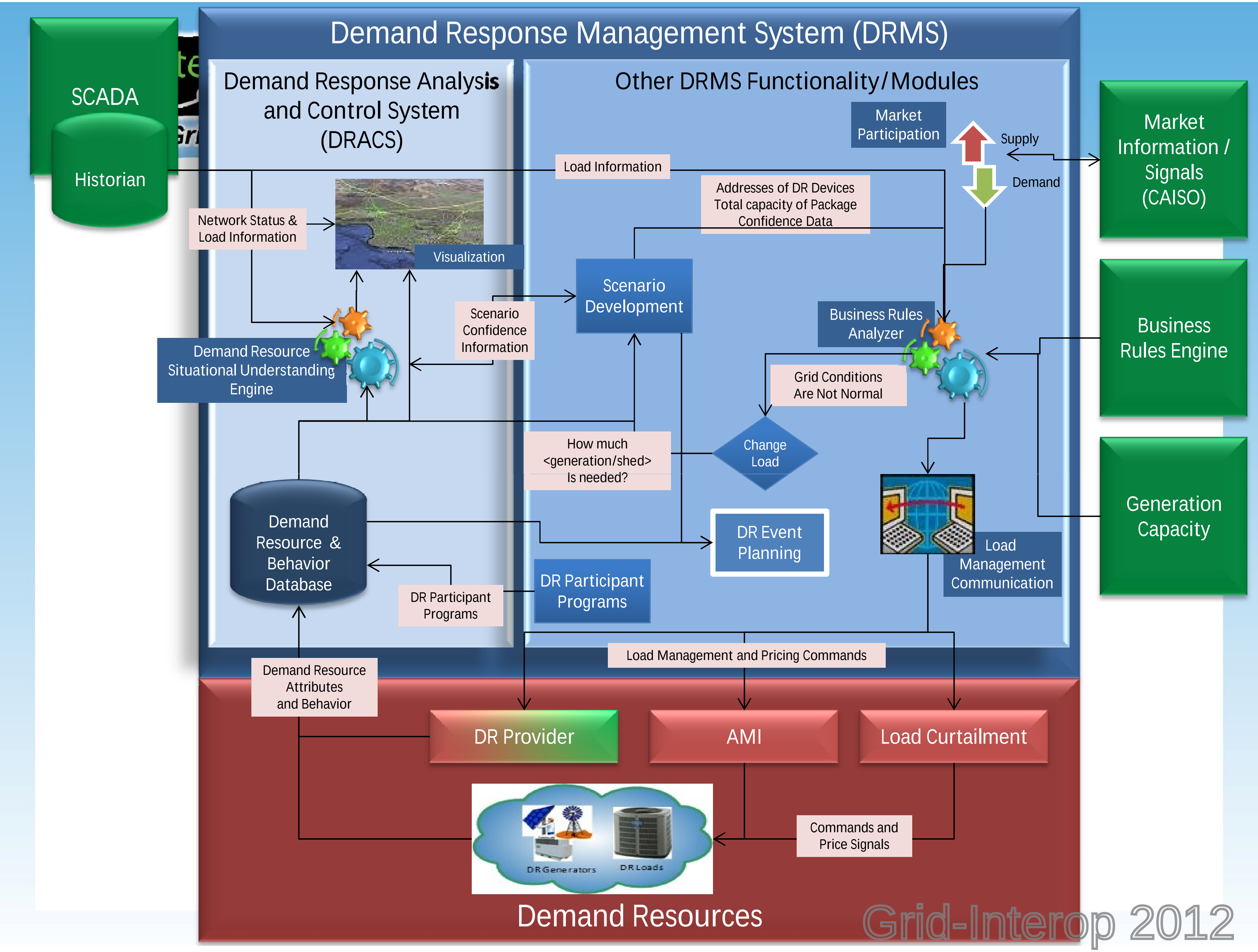
- Value Proposition: Ideal mix maximizes resiliency at lowest cost while meeting environmental goals
  - Meet possibly conflicting stakeholder resiliency, cost and renewable goals
  - Use energy storage to seamlessly integrate variable renewable energy
  - Minimize energy storage cost while meeting resiliency goals
  - Use of renewable energy for transportation needs
  - Consider carbon usage, AQMD air quality standards
  - Capture other wise spilled energy e.g. waste heat from fuel cells and weekend PV
  - Market participation
  - Ancillary services

# MicroGrid Interfaces



# High Level Architecture





Demand Response Management System (DRMS)
SCADA
Historian
Demand Response Analysis and Control System (DRACS)
Other DRMS Functionality/Modules
Market Participation
Supply
Demand
Market Information / Signals (CAISO)
Load Information
Addresses of DR Devices
Total capacity of Package
Confidence Data
Network Status & Load Information
Visualization
Scenario Development
Scenario Confidence Information
Business Rules Analyzer
Business Rules Engine
Demand Resource Situational Understanding Engine
Grid Conditions Are Not Normal
Change Load
How much <generation/shed> Is needed?
Demand Resource & Behavior Database
DR Event Planning
Load Management Communication
Generation Capacity
DR Participant Programs
DR Participant Programs
Load Management and Pricing Commands
Demand Resource Attributes and Behavior
DR Provider
AMI
Load Curtailment
DR Generators
DR Loads
Commands and Price Signals
Demand Resources
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# Infrastructure Issues

- Historical utility source quality, current data monitoring, and future high resolution monitoring/analytics
- Measure campus power quality with data analytics
- Load Flow
  - Load requirements of the area or local EPS that will be islanded
  - Reserve margins, load shedding, and demand response
- Generation Control
  - Impact of changing generation levels: second time frame (clouds), minute/hour time frame (sun cycle) on voltage/frequency
  - Voltage/frequency during emergency operation
  - Increased voltage regulator operation (tab changes, cap switching) resulting in increased equipment wear
  - Dynamic interaction of transients with conventional and non-conventional control devices
  - Reverse current flow “confuses” voltage regulators -> voltage on DG side too high or too low
- Islanding and Grounding
  - Utility system reclosing into live island may damage switchgear and loads.
  - Safety concern if PV keeps islanded system unintentionally energized

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# Infrastructure Issues

- Interactions between electrical energy sources
  - Dynamic interaction between Utility, fuel cells and PV inverters
  - Response of PV inverters to transients and harmonics
- Protection and Safety
  - What changes for protection coordination (fuse blowing/saving, reduction of reach)?
  - Effect of reverse current flow on protection
  - Magnitude and duration of steady-state fault current from PV
  - Fault current is a function of inverter controller design and setting, thermal protection of IGBT, and depth of voltage sag at inverter terminal.
  - Transient response of PV during/after disturbances
  - Cold-load Pickup
- Power Quality
  - Voltage fluctuations (flicker, sacks, swells) due to cloud shading.
  - Imbalance caused by uneven distribution of PV causing Neutral-to-Earth Voltages (NEVs) and overloaded neutrals
  - Harmonics injected by PV inverter