Smart Energy Now

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CUEPRA 2009 Conference

Smart Grid Components & Targeted Benefits

“Intelligent” Communication Infrastructure

Behind the Meter Applications

- ENABLE SAVE-A-WATT
- Energy Efficiency
- Peak Load Mgmt
- Time of Use Rates
- CO2 Offset from peak reduction

Smart Metering / AMI

- Remote meter reading
- Remote connect / disconnect
- Remote initiation of service
- Prepaid metering
- More billing options (weekly, bi-monthly or monthly)
- Auto On site outage reporting
- Off cycle reads
- Meter accuracy improvement
- Reduced energy theft
- Improved public safety

Distribution Line Eq.

- Improved system efficiency ((Automated Switched Bank Capacitors)
- Improved Reliability (Automated Electronic Recs)
- Self Healing capability
- Improved PQ
- Emergency load reduction
- Reduced equipment inspections
- Improved asset management
- CO2 offset due to fewer truck rolls

Substation Automation

- Improved reliability
- Remote breaker operation
- Improved Voltage Regulation (Automated Substation Voltage Regulation)
- Automated Emergency load reduction
- Improved asset management

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- Grid modernization
- EE enabler
- Enables widespread integration and dispatch of Distrbuted Energy Resources (e.g. PV)

Benefits of a Smart Grid

- Provide Benefits to Customers
  - Reduce outages and outage duration
    - Ohio average Saifi projected to move from 1.6 to 1.1
    - Indiana average Saifi projected to move from 1.23 to 1.0
    - Kentucky average Saifi projected to move from 1.15 to 1.0
      - » (Excludes major storms but includes ET outages)
  - Provide more options to customers
  - Improve customer satisfaction

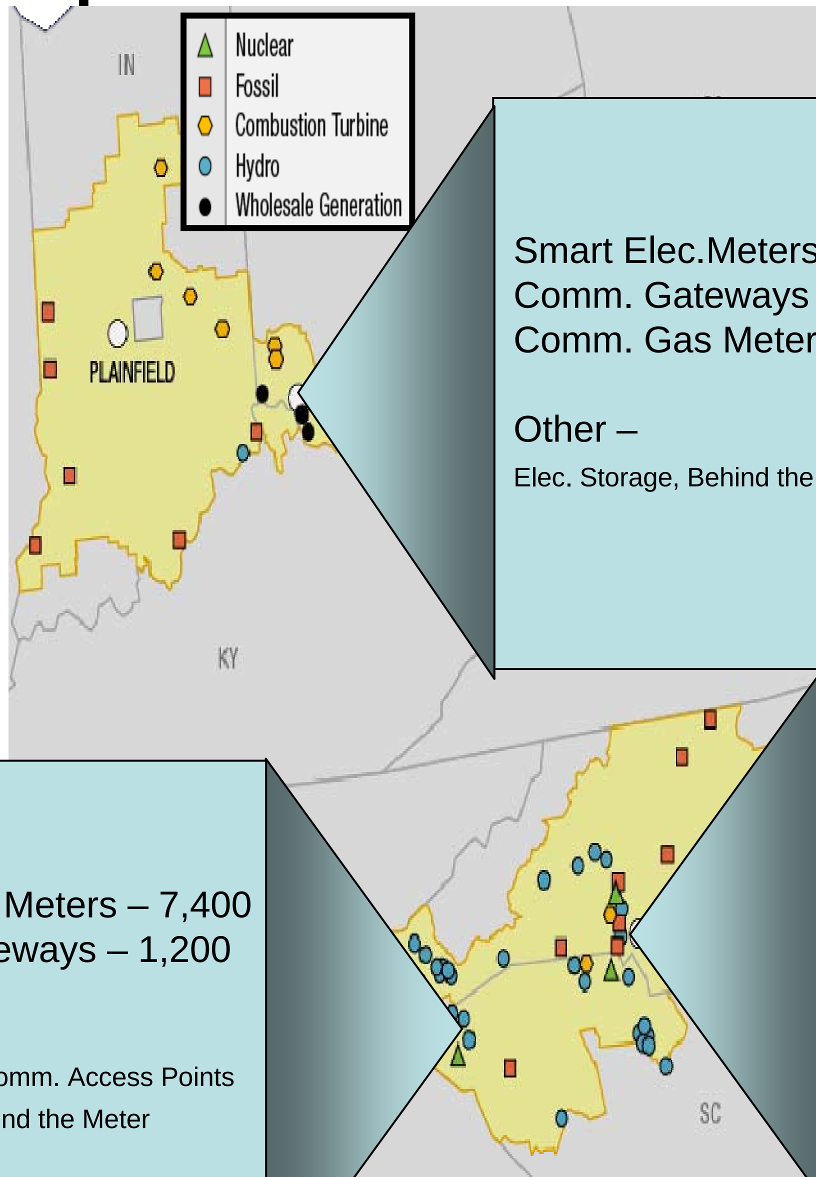
- Provide Benefits to the Company
  - Gain operational efficiencies through automation
  - Improve system performance through better, more timely information

- Provide Benefits to Our Communities
  - Provides environmental benefits such as integration of <u>renewables</u>, <u>carbon reduction</u>
  - Improves public safety and employee safety

Overview of 2008 Activities

- Smart Grid Deployments
- Results and Findings from Deployments

Equipment Installed 2008



Smart Elec.Meters – 44,900
Comm. Gateways – 2,900
Comm. Gas Meters – 25,229

Other –

Elec. Storage, Behind the Meter

Smart Elec. Meters – 7,400
Comm. Gateways – 1,200

Other –

Elec. Storage, Comm. Access Points and Relays, Behind the Meter

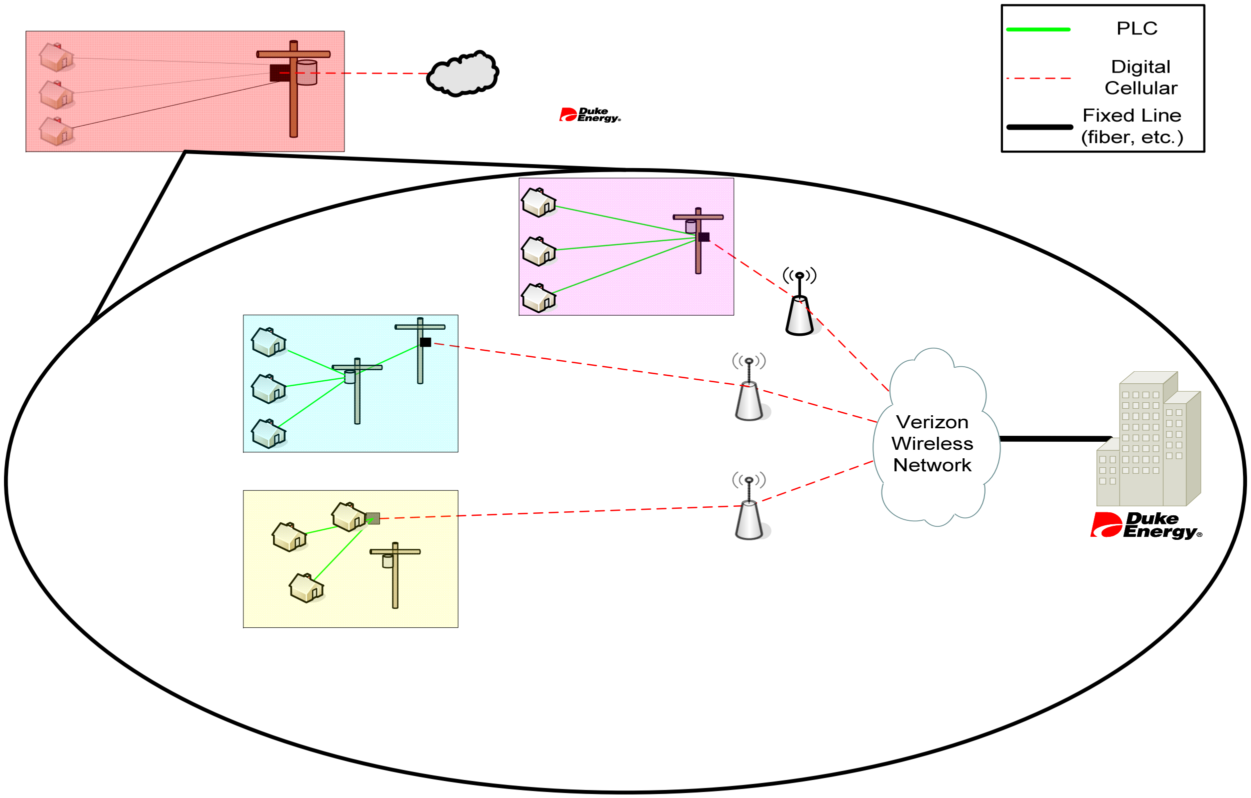
Smart Elec.Meters – 4,700
Comm. Gateways – 900

Other –

Smart Street Lights, Elec. Storage, Comm. Access Points and Relays, Smart Sensors, Behind the Meter

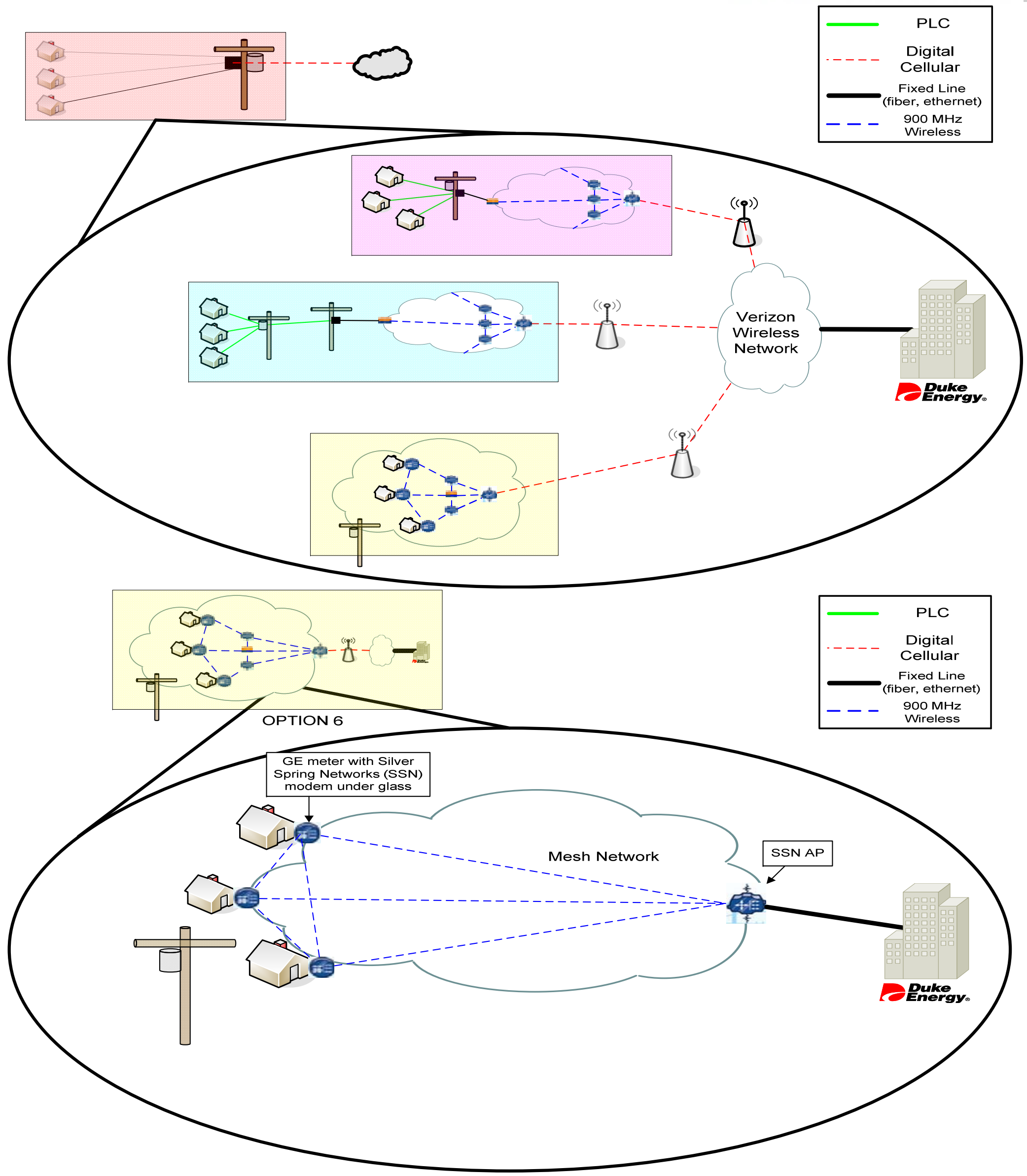
Charlotte NC

- **Smart Meters – Mass Market Residential**
  - Utilizes PLC Meter to Transformer on the Low Voltage
- **Communications Gateway**
  - Communications Box
    - Data Collector,
    - EVDO modems
  - X-2000 and x-3000 Communication Nodes
    - Optional equipped with various components EVDO Modem,
    - Data Collector's,
    - WiFi,
- **Digital Cellular WAN**
- **Energy Storage Device**
- **Behind the Meter**
  - Home energy Gateway, smart home devices
- **MV Line Sensors**
- **Smart Street Lighting**
  - Smart Server, EVDO modems, and intelligent ballasts



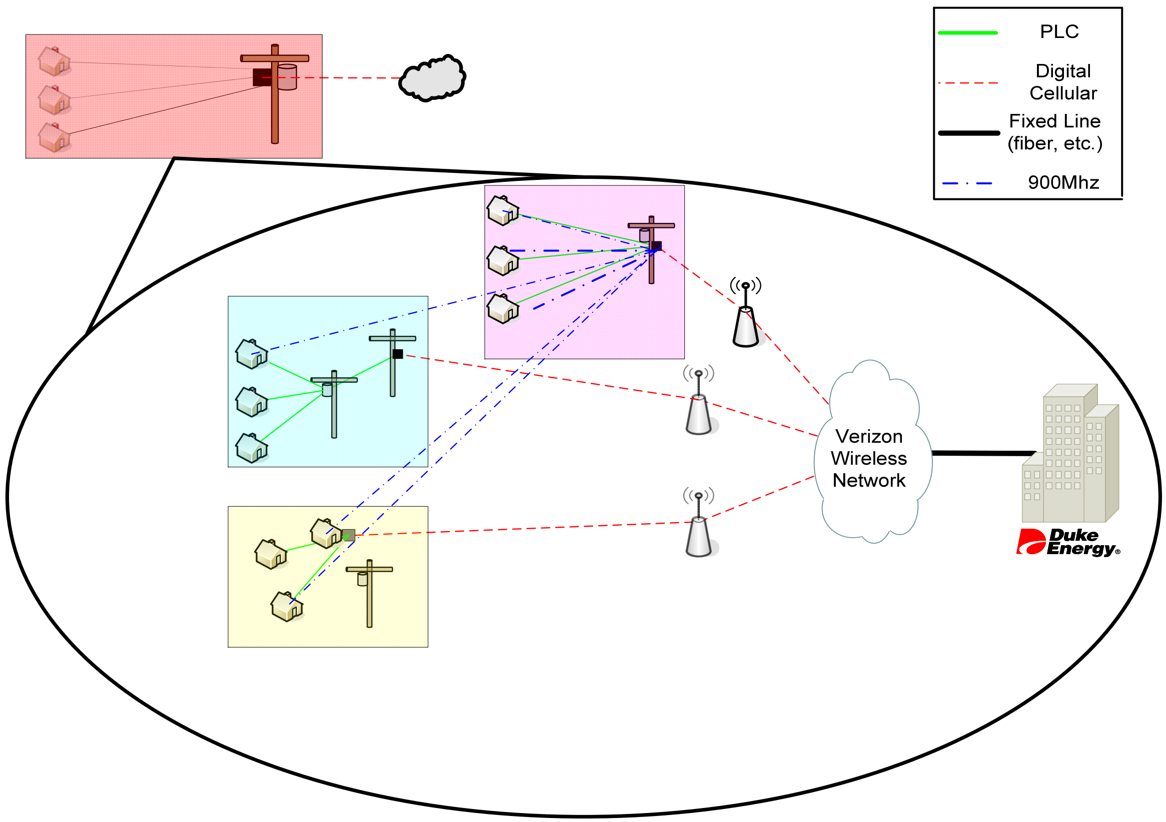
Greenville SC

- Smart Meters – Mass Market Residential
  - Utilizes PLC Communications Meter to Transformer on the Low Voltage
- Communications Gateway
  - Communications Box
    - PLC Data Collector,
    - RF E-bridge modems
- Digital Cellular WAN
- RF Meshed wireless
  - AccessPoints, Relays, Batt. b/u
- Smart Meters – Form2s 240v
  - Equipped with RF module
- Energy Storage Device



Cincinnati OH

- Smart Meters – Mass Market Residential
  - Utilizes PLC Communications Meter to Transformer on the Low Voltage
- Gas Meters equipped with wireless modules
- Communications Gateway
  - X-2000
    - Optional can be equipped with various components EVDO Modem, PLC Collector's, ERT receiver, WiFi, voltage and current sense, Battery b/u
- Digital Cellular WAN
- Energy Storage Device



Results!

- **Meter Reading**
  - Reading 4700 meters daily with 15 minute interval information
  - Monthly revenue billing based upon remote meter readings
  - Capturing 4 to 8 channels of load profile information daily
- **Outage Notification**
  - 5 occurrences in the Charlotte deployment in the month of December 2008 of meter notifications for outages on the low voltage line between the transformer and the meter 3 repaired prior to customer being aware of outage
- **Meter Tamper detection**
  - Remote detection of meter tamper utilizing the forward and reverse power information from the meter and the power outage information from the meter.
- **Asset Management Accuracy**
  - Improvements in accuracy of data for the meter to transformer relationship due to utilizing the PLC signal between the transformers and the meters
  - Improvements in accuracy of GIS information utilizing the Lat/Long information in the communications gateway.

Outage Detection

- XXX Carmel Rd Apt #A – The meter went down on 1/04 at 10:12 AM. Today I went to the house and confirmed there was no power at the meter. The customer was not home so I had a crew stop by to see what the problem was. The crew determined that one of the hot legs blew taking off the rain guard and causing the loss of power. The cable was replaced and power was restored at 2:59PM today.
- XXX McAlpine Farm Rd – The meter went down on 12/21 at 2:06 AM. Today I went to the house and confirmed there was no power at the meter. The customer was not home so I had a crew stop by to see what the problem was. The crew detected that one leg had 120V and the other had 14V and therefore the cable was bad. The cable was replaced and power was restored at 4:21PM today.
- XXX Trimmings Ct – The meter went down on 12/22 at 6:15 PM. This meter feeds a hot water heater and the customer was unaware of the outage. Confirmed there was no power at the meter. The customer was not home, a crew to resolve the problem.

Meter Tamper

- Forward and Reverse power flow was detected on a meter that should only have forward power on the service
- Upon investigating the data the number of outages detected for the meter was higher than adjacent meters
- A Service technician was dispatched and found that the meter was plugged in upside down.

Predicative Maintenance

- Utilizing the signal strength of the PLC signal between the meter and transformer, we are analyzing the data to determine deterioration in the low voltage cable prior to an actual failure.
- In one instance the signal level between the meter and transformer had been recorded at a -46db before the failure of a cable and after the failure and restoration the signal level was at a -12db.
- The -12 db to -24db level is what we are typically seeing. If monitoring of the signal level is conducted and alarmed on it may be possible to identify cable deterioration over time and schedule the replacement prior to having an unscheduled outage.

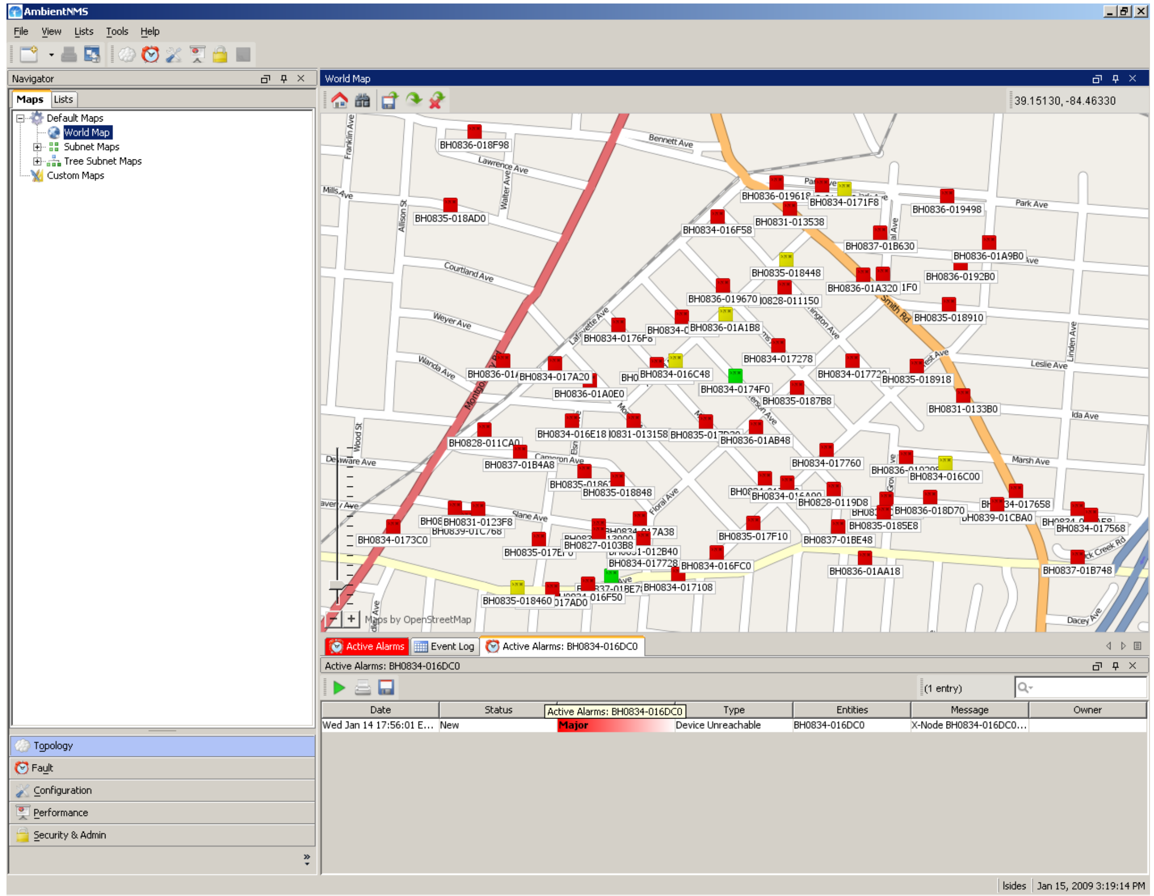
Asset Management

The Picture to the left shows the relationship of the meters to the transformers as depicted in Atlas and CIS.

The picture to the right shows the meter to transformer relationship as determined using the PLC network.

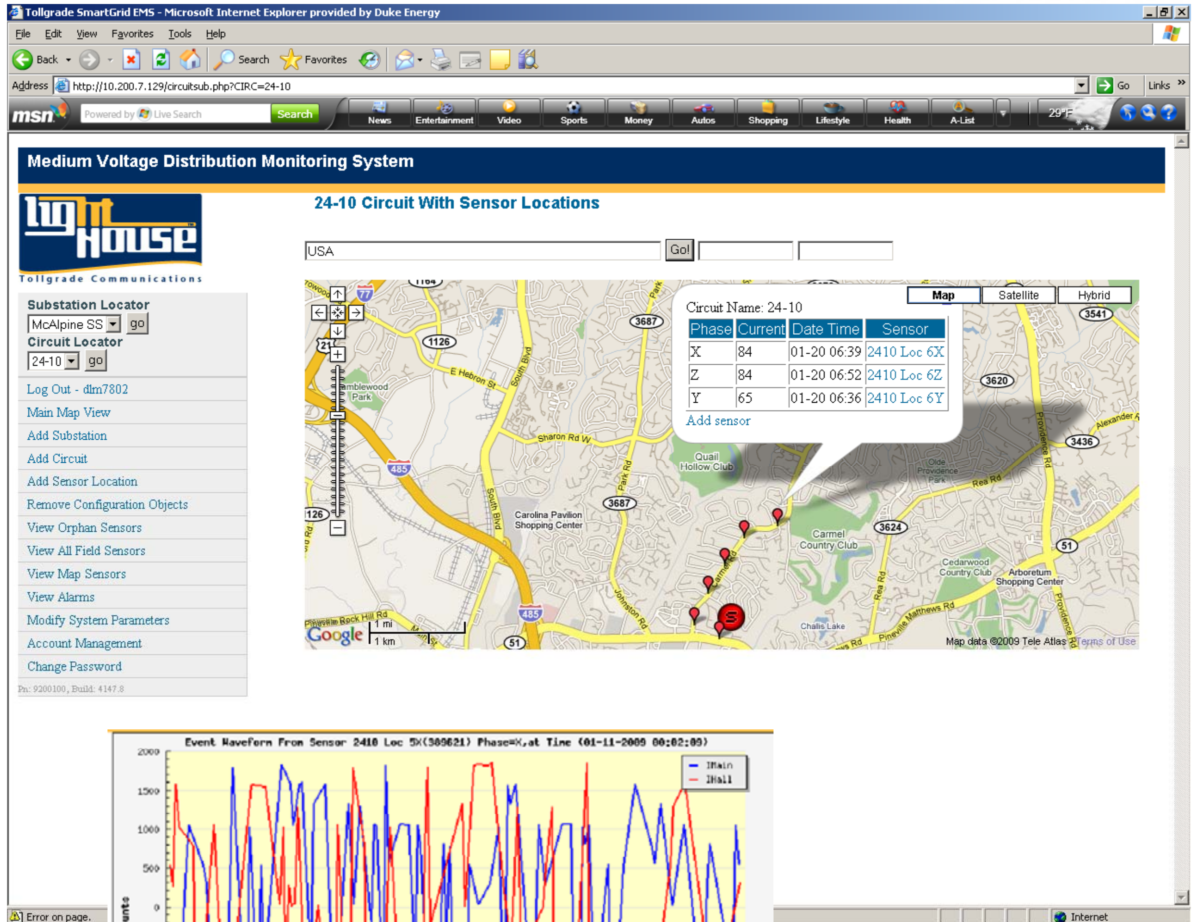
GIS Accuracy

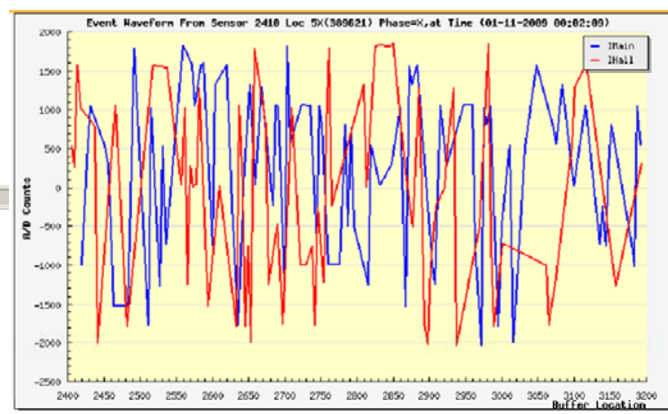
Improvements in accuracy of GIS information utilizing the Lat/Long information in the gateway.



Intelligent Sensors

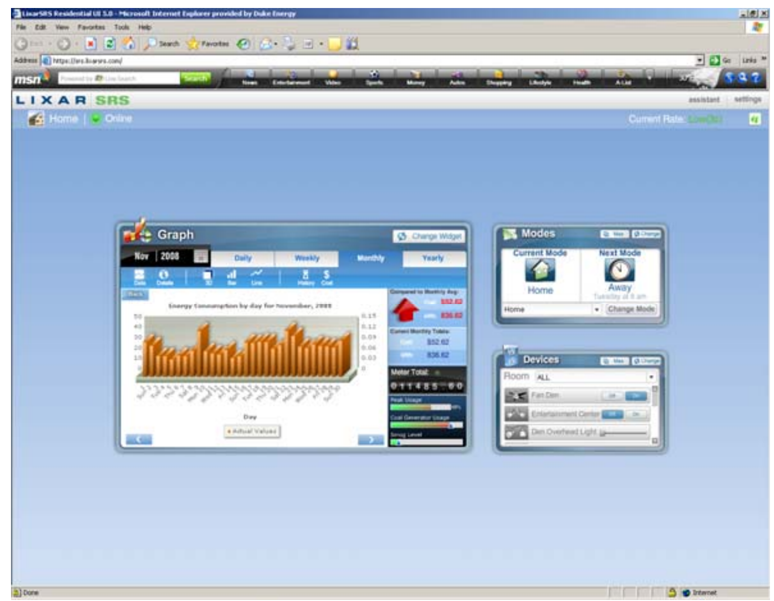
- MV Line Sensors
  - MV Current
  - Event Waveforms
  - Alarm Management





Behind the Meter

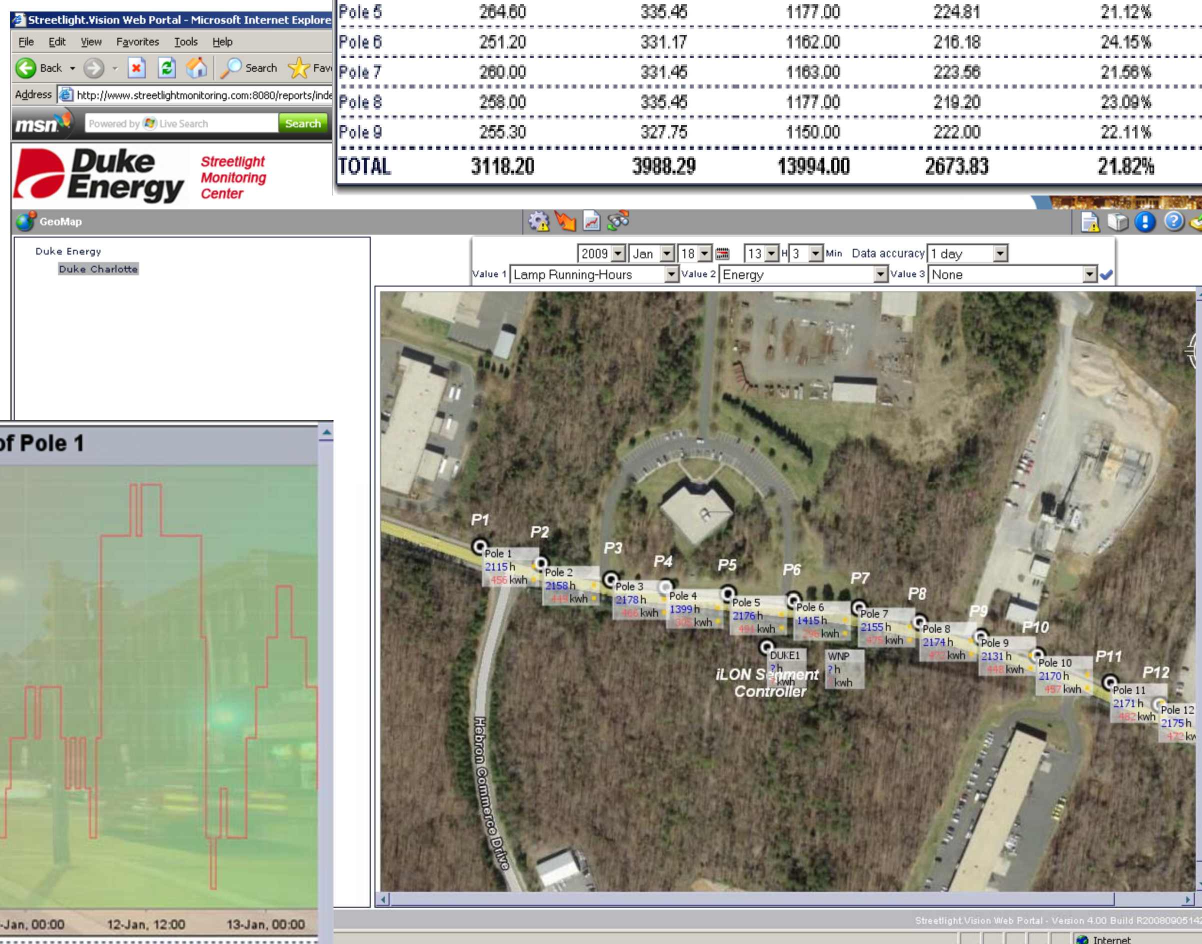
- Usage Data from the Smart Meters displayed on Customer Portal monthly, daily, hourly and 15 minute interval

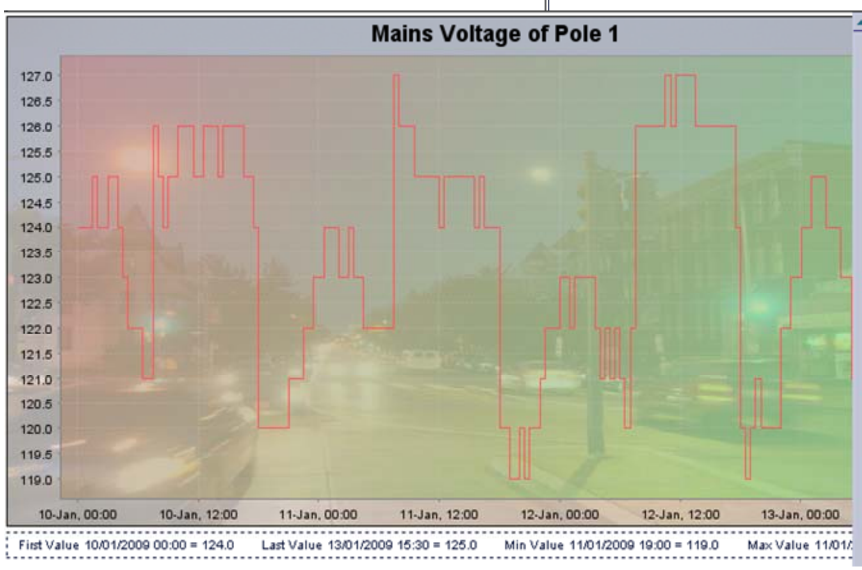


Intelligent Street Lights

- Monitor & Control Street Lights
  - Bulb Life
  - Dimming
  - Power Consumption
  - Alarming
  - Voltage Monitoring

Name	Measured (kwh)	Before (kwh)	Burning hours	Average (W)	Energy Savings (%)
Pole 1	254.70	326.33	1145.00	222.45	21.95%
Pole 10	259.00	334.59	1174.00	220.61	22.59%
Pole 11	279.00	334.59	1174.00	237.65	16.61%
Pole 12	263.00	335.45	1177.00	223.45	21.60%
Pole 2	251.40	332.31	1166.00	215.61	24.35%
Pole 3	261.90	336.30	1180.00	221.95	22.12%
Pole 4	260.10	327.46	1149.00	226.37	20.57%
Pole 5	264.60	335.45	1177.00	224.81	21.12%
Pole 6	251.20	331.17	1162.00	216.18	24.15%
Pole 7	260.00	331.45	1163.00	223.56	21.56%
Pole 8	258.00	335.45	1177.00	219.20	23.09%
Pole 9	255.30	327.75	1150.00	222.00	22.11%
TOTAL	3118.20	3988.29	13994.00	2673.83	21.82%





2009 R&D Activities

- EPRI Green Circuit Project
- McAlpine Microgrid Project
- Residential Program Offerings
- Solar Panels
- Distributed Storage
- Premise Energy Management Systems
- Demonstration Labs

McAlpine Microgrid Project Design Objectives

- Understand the technical feasibility and economic value of creating “virtual power plants” by aggregating and optimizing across distributed resources in real-time using residential locational marginal prices

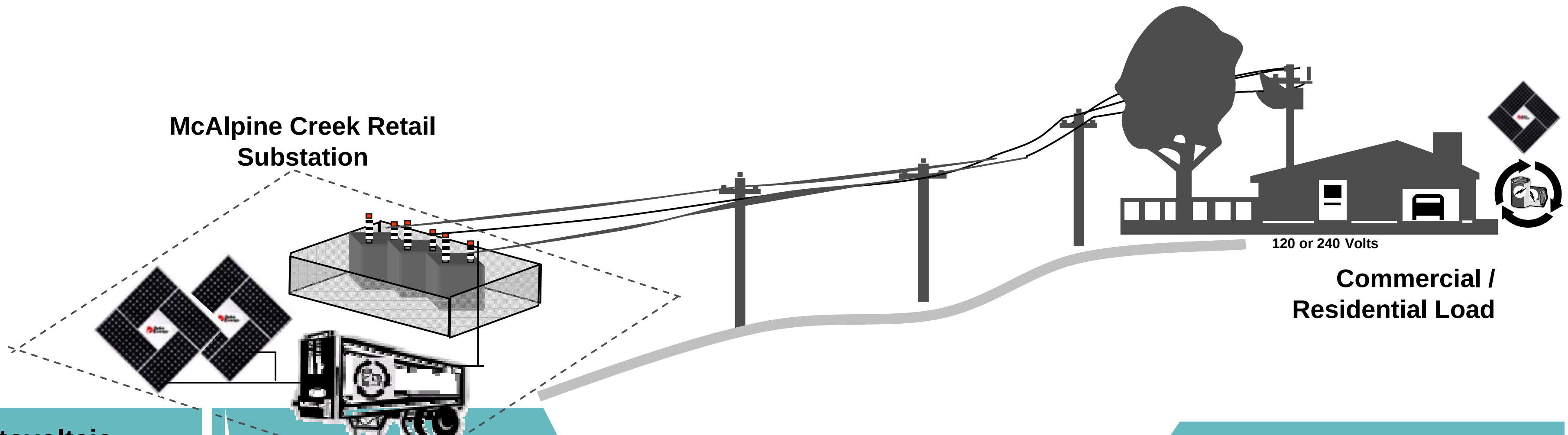
- Explore technical capabilities and operational benefits of various distributed resources

- Explore technical capability and value of islanding / ability to operate independent of the bulk power system

- Project will integrate:
  - Smart grid
  - Substation scale battery storage
  - Distributed solar generation
  - Behind the meter technology
  - Optimization engine

- Installation of equipment is planned for Q1 2009

Micro-Grid Configuration



Photovoltaic Evaluation Criteria:
- Annual Production
- Efficiency
- Lifetime cost
- Footprint
- Site preparation
- Warranty
- Post installation support and training

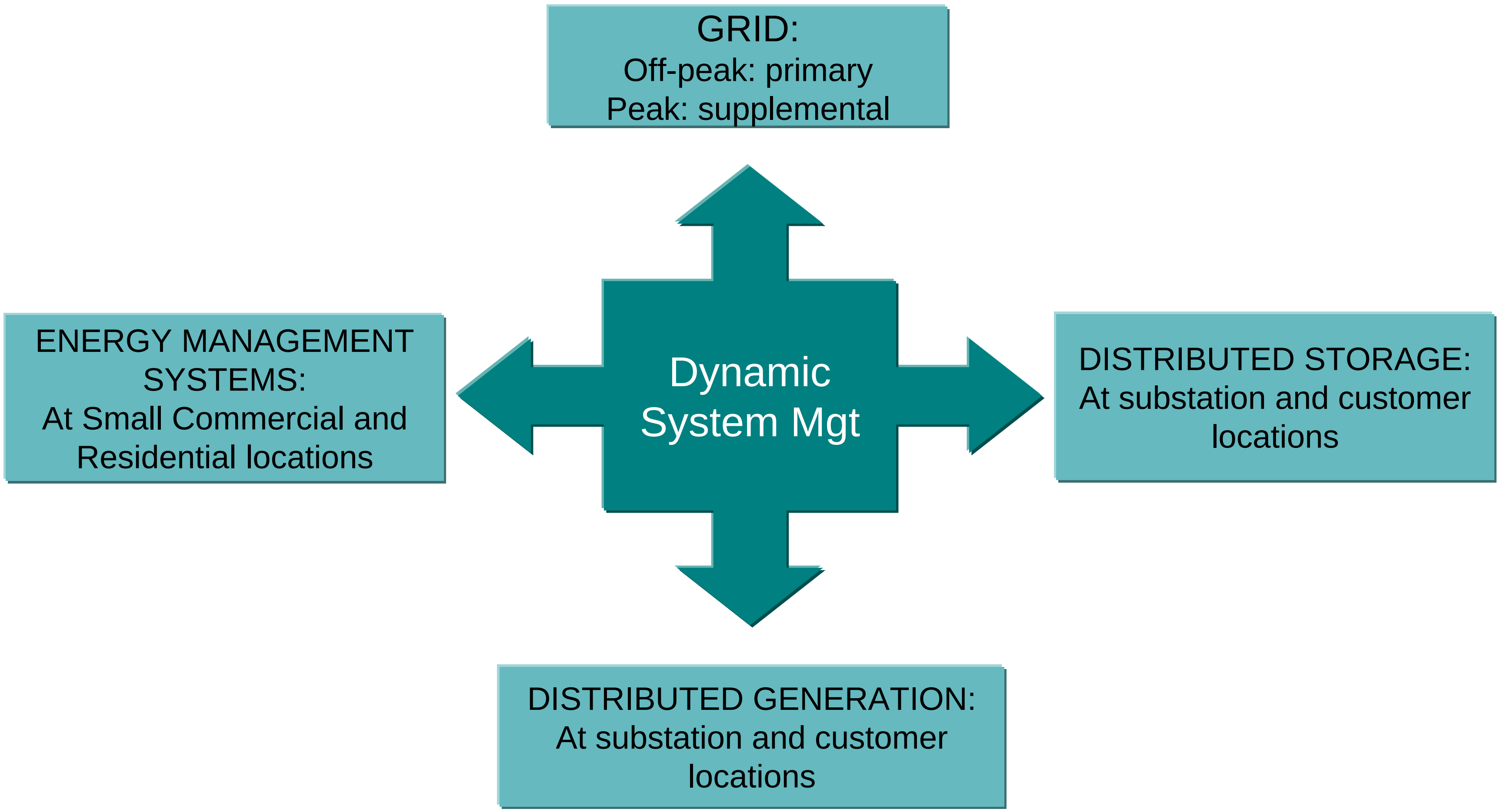
Energy Storage Evaluation Criteria:
- Real-time information & control
- Charge from multiple sources
- Power quality
- System efficiency
- Lifetime Cost
- Warranty

Data Integration & Optimization

EMS Evaluation Criteria:
- Telecommunication and network security
- Customer experience and usability
- Technical capability
- Financial competitiveness
- Sourcing

Retail Energy Desk
- Real-time dispatch using locational avoided cost valuation
- Real-time customer load forecast

Project Components



2009 Offers - Residential

Purpose: Test the hypothesis that each of the following scenarios will produce a positive business case.

Test Name	Customer Managed (Test 1)	Customer Managed + Pricing (Test 2)	Customer & Duke Shared Management + Pricing (Test 3)	Duke Only Managed (Cycling across homes with no impact on customer)
Description	Provide Customers with the ability to conveniently manage loads via a portal and other technology and feedback on load and bill reductions.	Provide Customers with the ability to conveniently manage loads via a portal and other technology and feedback on load and bill reductions. **Also, provide the ability for customers to react to price signals either manually or automatically.**	Provide Customers with the ability to conveniently manage loads via a portal and other technology and feedback on load and bill reductions. Provide the ability for customers to react to price signals either manually or automatically. **Also, customers can elect for Duke to manage their loads.**	Duke cycles equipment across houses to reduce load impacts at peak times. Customer agrees to this based on their being no discernable impacts on comfort or convenience. **This is not a stand alone test but part of other three tests.**
Hypothesized Value	Conservation off 4%-8%	Conservation of 6%-10% and peak reduction of 8% -12%.	Conservation of 6%-10% and peak reduction of 10%-15%.	Peak reduction of 5%-15% and conservation 0%
Customer Acquisition	Simplest ⟶ Complicated			

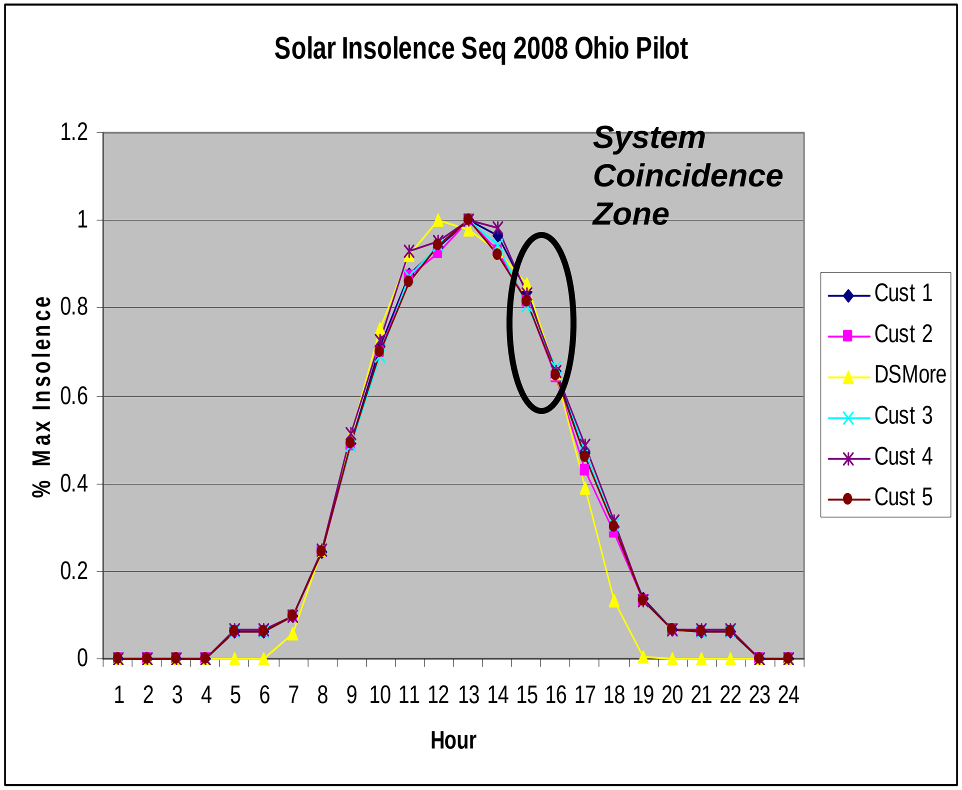
Distributed Generation: Solar

- Medium scale solar
  - Substation solar:
    - 45-50kW, Mono Crystalline Silicon,
    - Fixed or Adjustable Tilt Ground Mount,
    - DC tied to storage system,
    - Monitoring system to track/evaluate performance,
    - energy will be consumed as produced
  - Commercial solar: *still being defined*
- Residential scale solar: *still being defined*

Solar Insolence Data and Value

Placed on 5 Homes
Solar Insolence Tracked
Average Impacts here are Aug/ Sept
Mirrors DSMore results.
Confirms key problem with solar.
Lack of direct sun at 4p to 5pm, or
time of coincident system peak.

Note that rotating panels mitigates loss,
or target westward sloping roofs via
our LiDar enabled solar gain data.



Distributed Storage

Substation scale storage:

- 500kW Zinc Bromide flow battery unit mounted on a truck bed to be installed in 1Q 2009. The overall system is comprised of four main subsystems:
  - Energy Storage subsystem
    - includes the energy storage blocks, electrolyte tanks, and circulation system
  - Power Conditioning subsystem
    - includes four 125 kW grid-tied inverter/rectifiers and grid interconnections
  - System Controller
    - provides real-time monitoring, control, management and communication for the system
    - includes an energy management application that manages the charging and discharging based on user settable parameters
  - Thermal Management subsystem
    - provides active thermal management to maintain optimum temperature for all system components
    - thermal management makes use of a chiller mounted at one end of the trailer
    - electrolyte reservoir contains a liquid-to-liquid heat exchanger used to remove heat during charge
- Substation solar will be DC tied to storage unit and utilize a single inverter and control system
- Storage unit will be charged and discharged leveraging real-time optimization algorithms
- Evaluation criteria:
  - System cost – equipment, installation, interconnection, maintenance, efficiency, disposal, warranty
  - Charging capabilities – ability to charge from multiple sources as directed by an external signal
  - Monitoring – ability to monitor storage unit performance criteria and solar unit performance criteria
  - Remote Discharge – ability to discharge in response to optimization signal
  - Power quality – ability to offer PQ correction responses

Residential/Commercial scale storage

- Still being scoped
  - Primary function is to provide back up capacity during islanding to maintain 100% reliability
  - Secondary use as a distributed resource for optimization

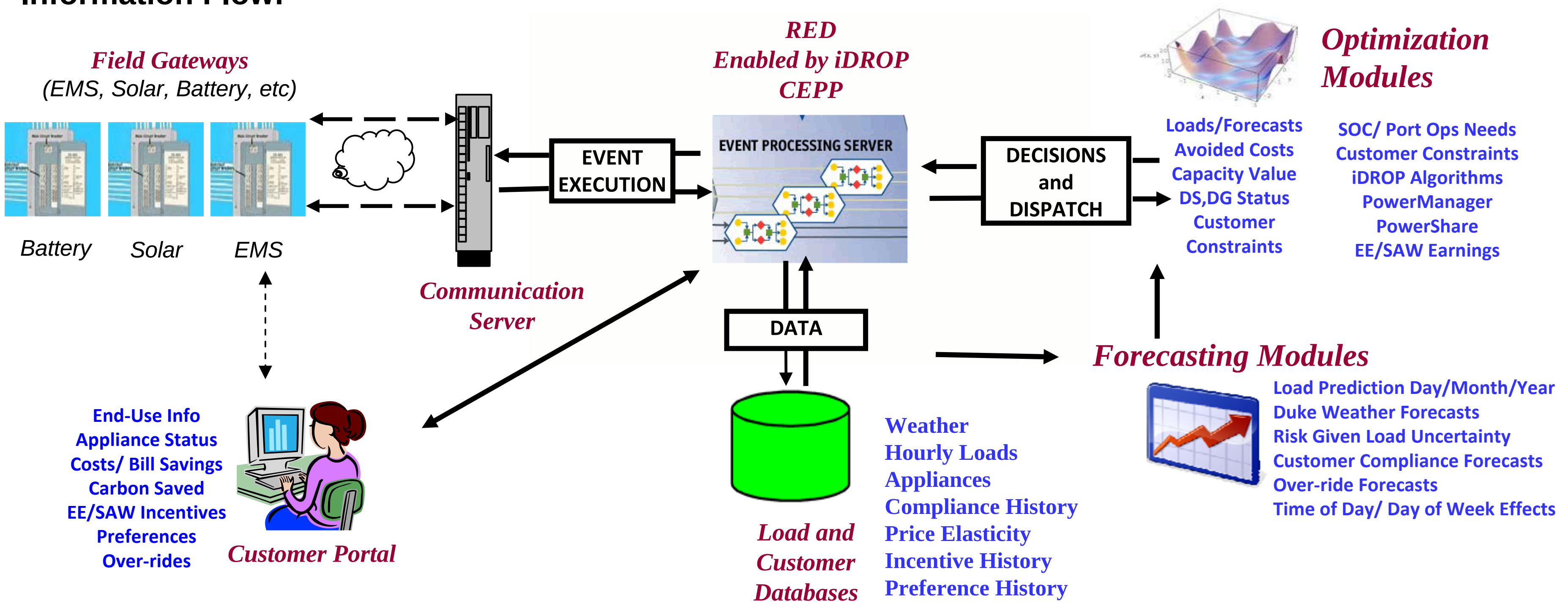
Premise Energy Management Systems

- These are technologies that enable monitoring and optimization of energy usage at appliance level with near real-time communication capabilities
  - Future state of EMS is expected to be smart appliances – communication, monitoring and optimization integrated to appliance
- Target EMS functionality includes optimization capability for 7 types of appliances and monitoring capability for 4 types of devices .
- Both monitoring and optimization of appliances can be scheduled by the customer as well as utility
- Utility tested optimization algorithms will use customer preferences, utility constraints, as well as meteorological data inputs.
- Evaluation designed to be in 2 phases:
  - **Phase I:** will evaluate communication and installation related aspects of in-home energy management systems in controlled environments such as a lab and employee homes
  - **Phase II:** deploy to approximately 200+ residential and small commercial customers on four feeders from the McAlpine substation. 2 feeders were eliminated due to a competing project need. Phase 2 will include development and testing of customer offers to conserve as well as respond to demand events

Dynamic Optimization: Engine

- Engine: **I**ntegrated **D**emand **R**esponse **O**ptimization **P**ortfolio (IDROP)
- IDROP is designed specifically to:
  - **optimize** the **micro-dispatch** of various distributed resources
  - such that the Retail Energy Desk is able to **extract the maximum amount of avoided cost and capacity value**,
  - given **customer-established constraints, compliance histories, expected future load**, and locally available **distributed generation or storage**,
  - to **achieve pre-set and/or real time needs**

Information Flow:



Demonstration Labs Will Provide a "Hands On" Experience of How a Smart Grid Will Work

- Duke Energy's Smart Energy Center, Cincinnati, OH
Physical Center, 7-10,000 sq ft
- Smart Energy Center, Raleigh, NC
Advanced Energy Company partnership
Physical center 4-5,000 sq ft
- Duke Energy Village Furman University, Greenville, SC Cliffs Cottage, physical home