Sensor Networks and Research Applications at Rural Electric Distribution Cooperatives

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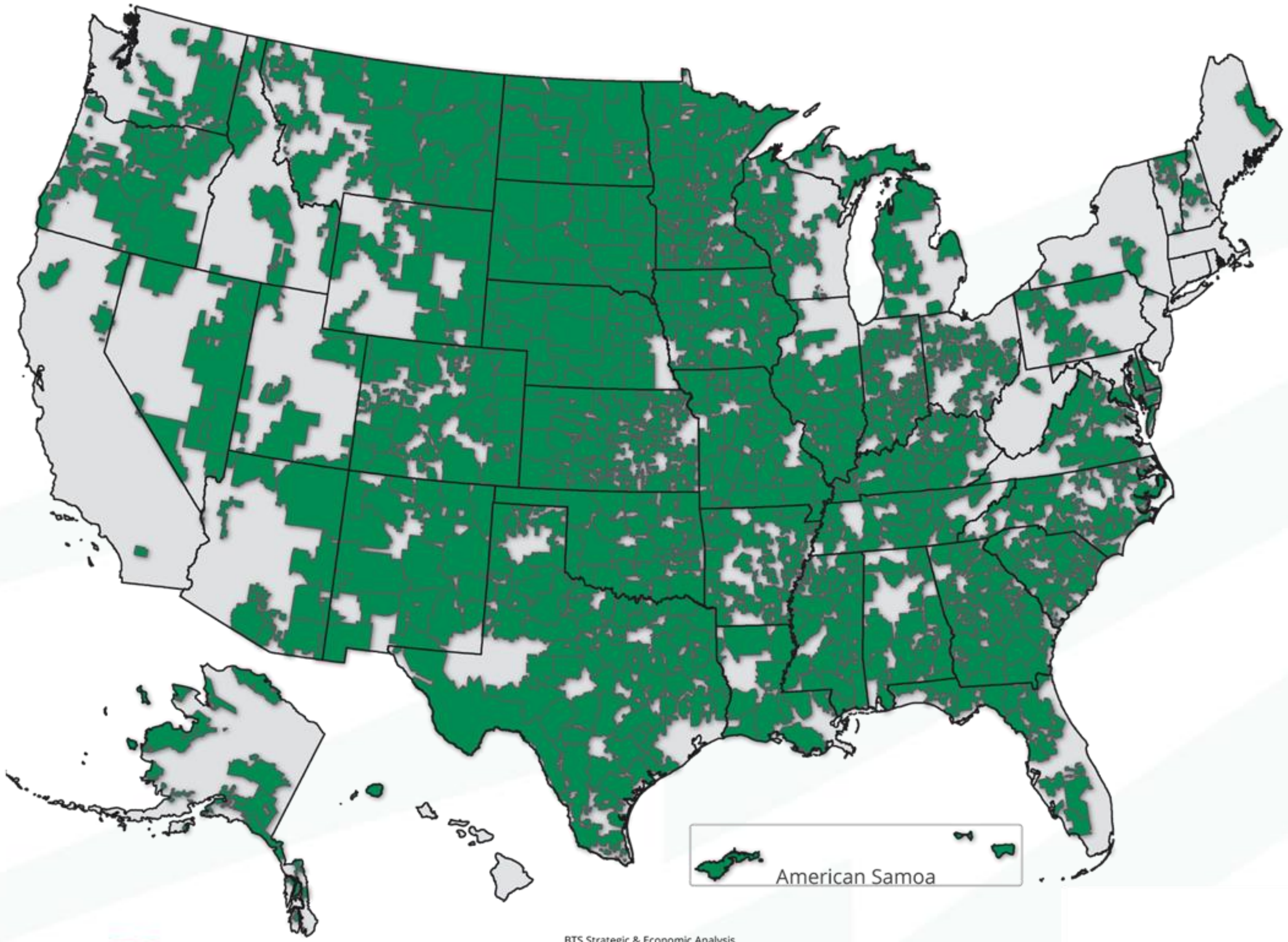

- Serve 42 million people in 47 states through 65 generation & transmission (G&T) co-ops and 840 distribution co-ops
- Own and maintain 42% of the nation's distribution lines
- Average 7.4 consumers per mile of distribution line

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NRECA Research Team

- Objective: Develop and demonstrate new technical capabilities that directly address challenges faced by electric cooperative utilities.
- Funded by cooperative member dues, U.S. Department of Energy (OE, EERE, and ARPA-E), and U.S. Department of Defense (DARPA).
- Strategic focus areas:
  - Utility data analytics
  - Grid cybersecurity
- Research projects are usually collaborative partnerships with universities, national laboratories, utility vendors, and cooperative utilities.

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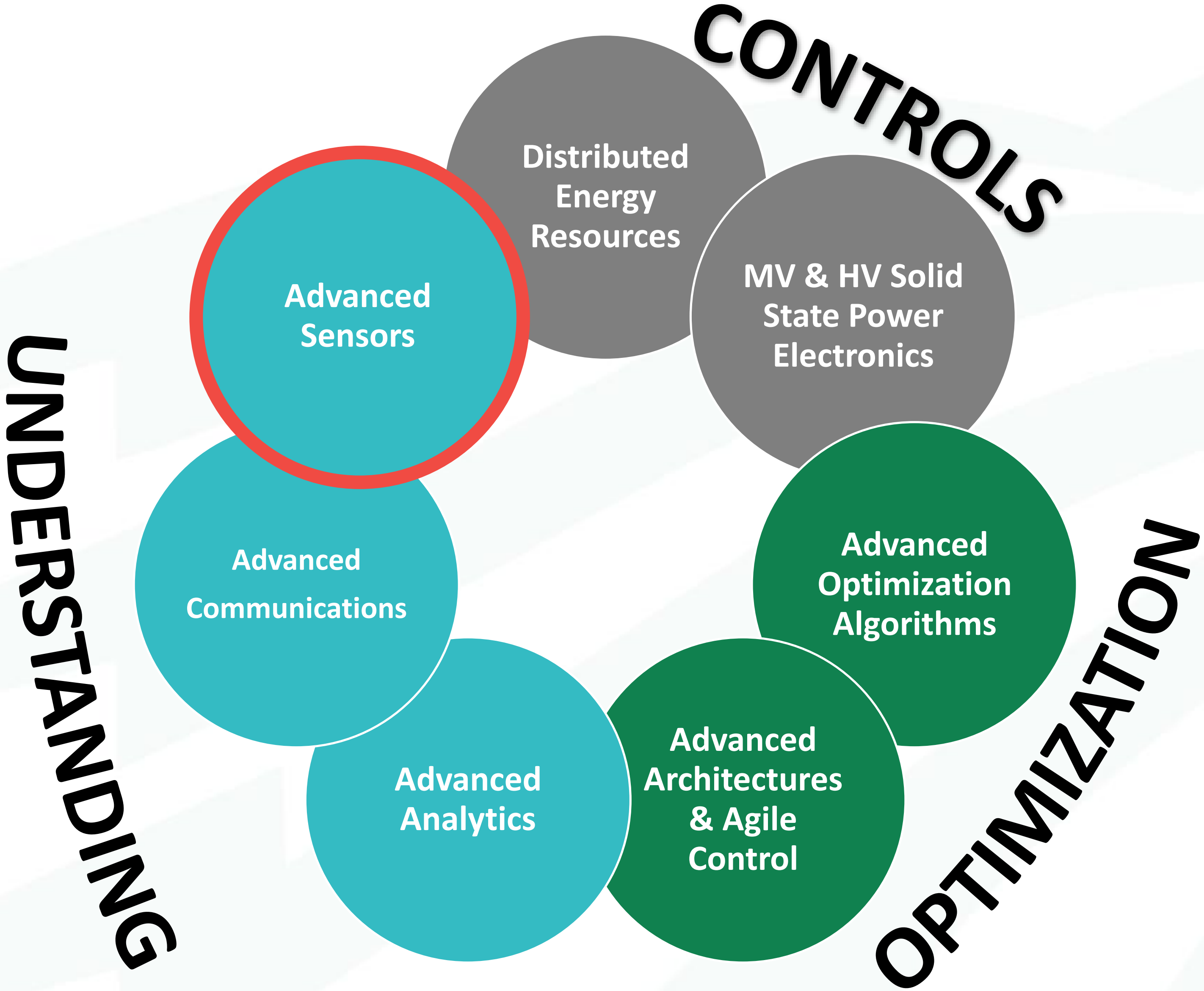
Emerging Grid Requirements

- Enabling distributed & renewable generation
- Facilitating changing consumer demands (incl. vehicles)
- Mitigating aging infrastructure impacts
- Accommodating changing central generation mix (increasing natural gas generation)
- Managing rapidly evolving cybersecurity threats
- Increasing critical infrastructure resiliency

New Technologies for New Challenges



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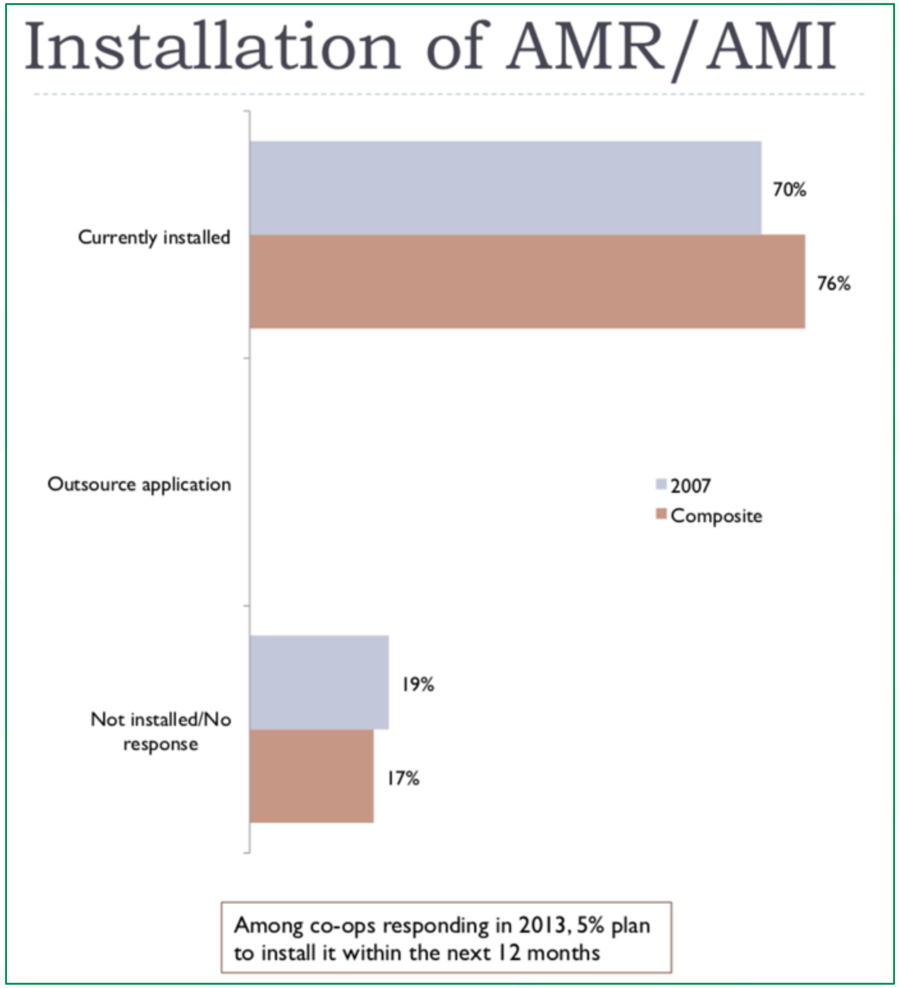
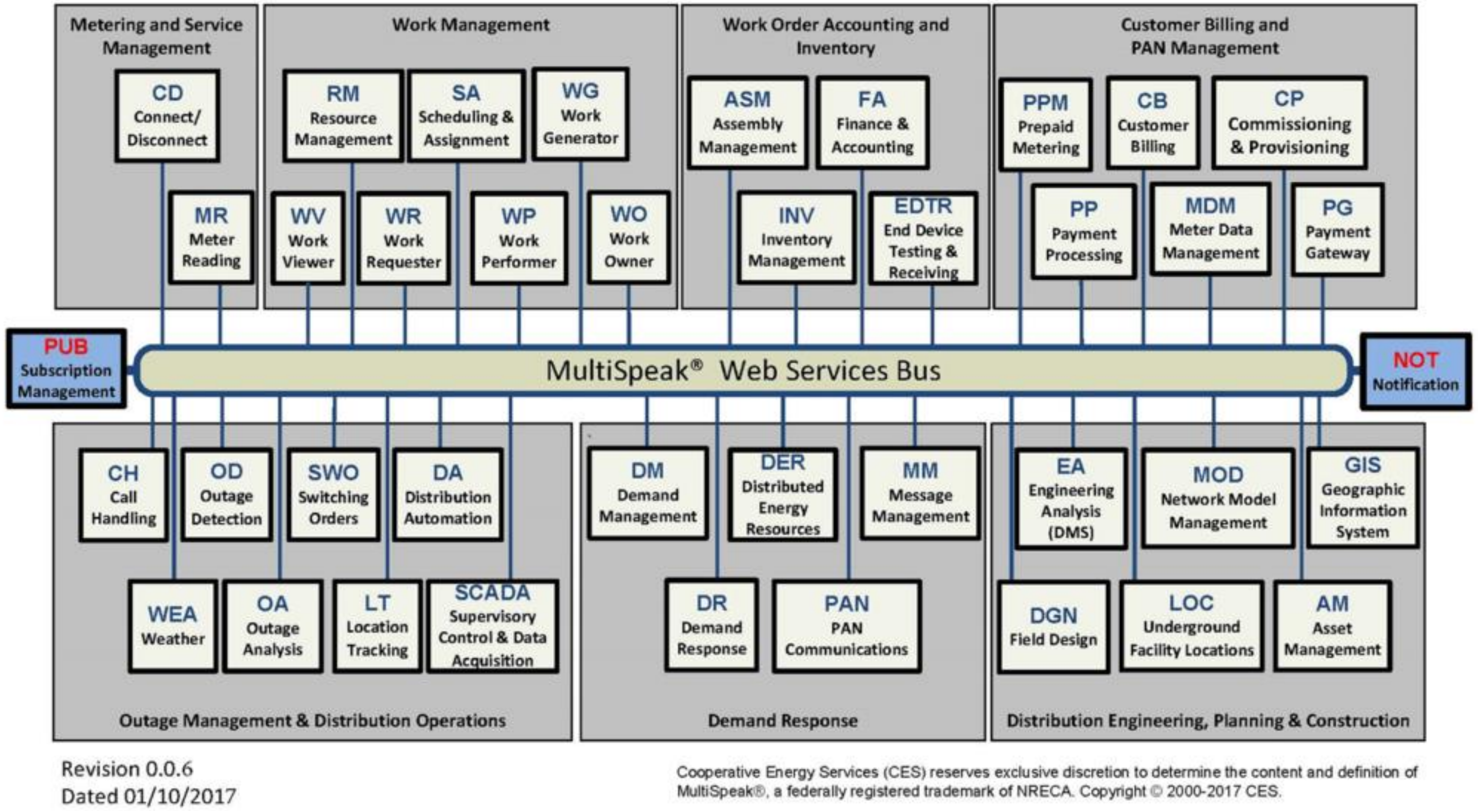
Sensors at Distribution Cooperatives

- AMI installed nearly everywhere*
- SCADA used by the majority of co-ops
- Communications support:
  - Existing deployments primarily use PLC (1-5 baud)
  - Wireless RF gaining more widespread use
  - Fiber deployments growing rapidly from demand for rural high-speed internet
- Falling DPMU costs suggest power quality monitoring opportunities.
- A lot more can be done with data from existing sensors!



Delivering Maximum Value From Sensor Data



Challenges:

- Backhaul and data storage.
- Security.
- G&T–D interfaces.
- System integration.
- Developing end-use applications:
  - Planning
  - Operations

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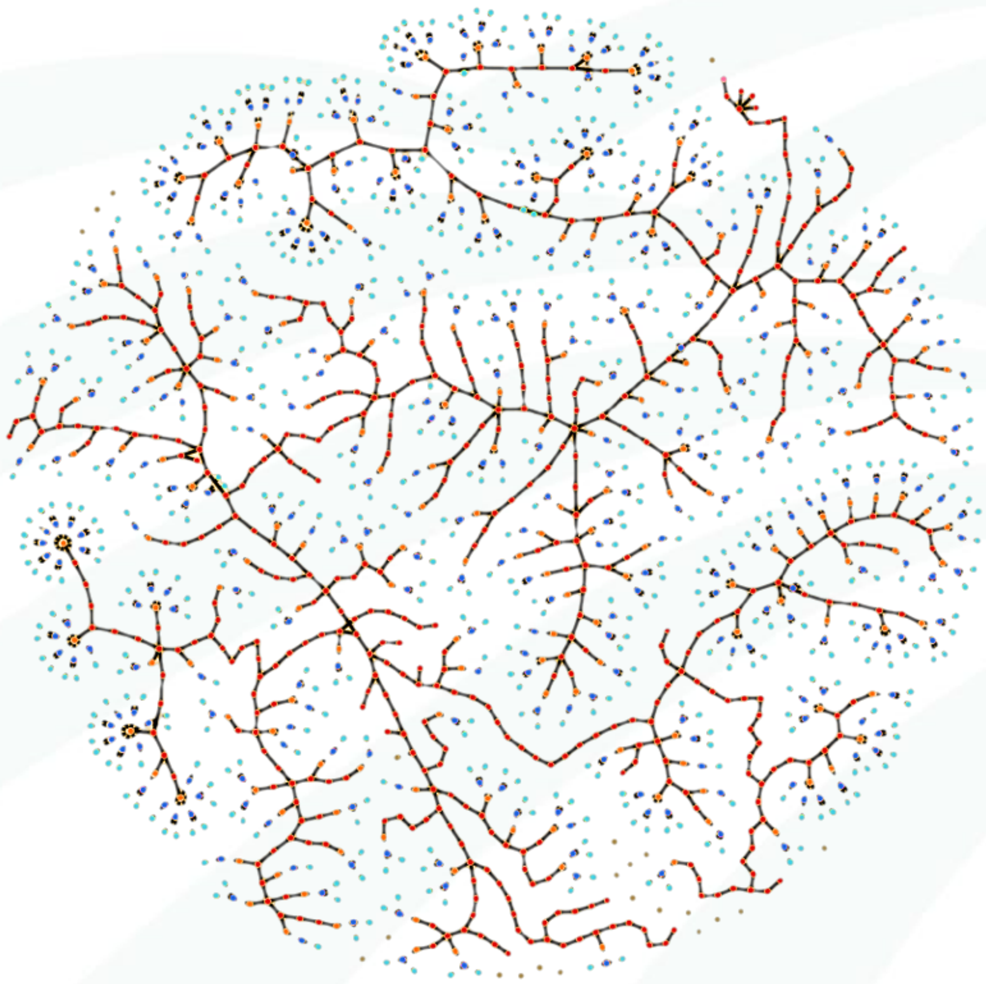
Planning Research – Open Modeling Framework

- Sensor data key input to planning models
- Software results put in to free and open source electric utility modeling software, Open Modeling Framework (OMF, https://www.omf.coop)
- Built by the co-ops and the US Department of Energy
- Offers models to determine:
  - Cost-benefit and engineering analysis models for multiple DERs (solar, energy storage, etc.)
  - Full distribution and transmission dynamic powerflow simulation
  - Supporting tools in Python for data import, conversion, simulation and visualization
- Users from 176 organizations (utilities, vendors, universities, national labs) as of June 2017.



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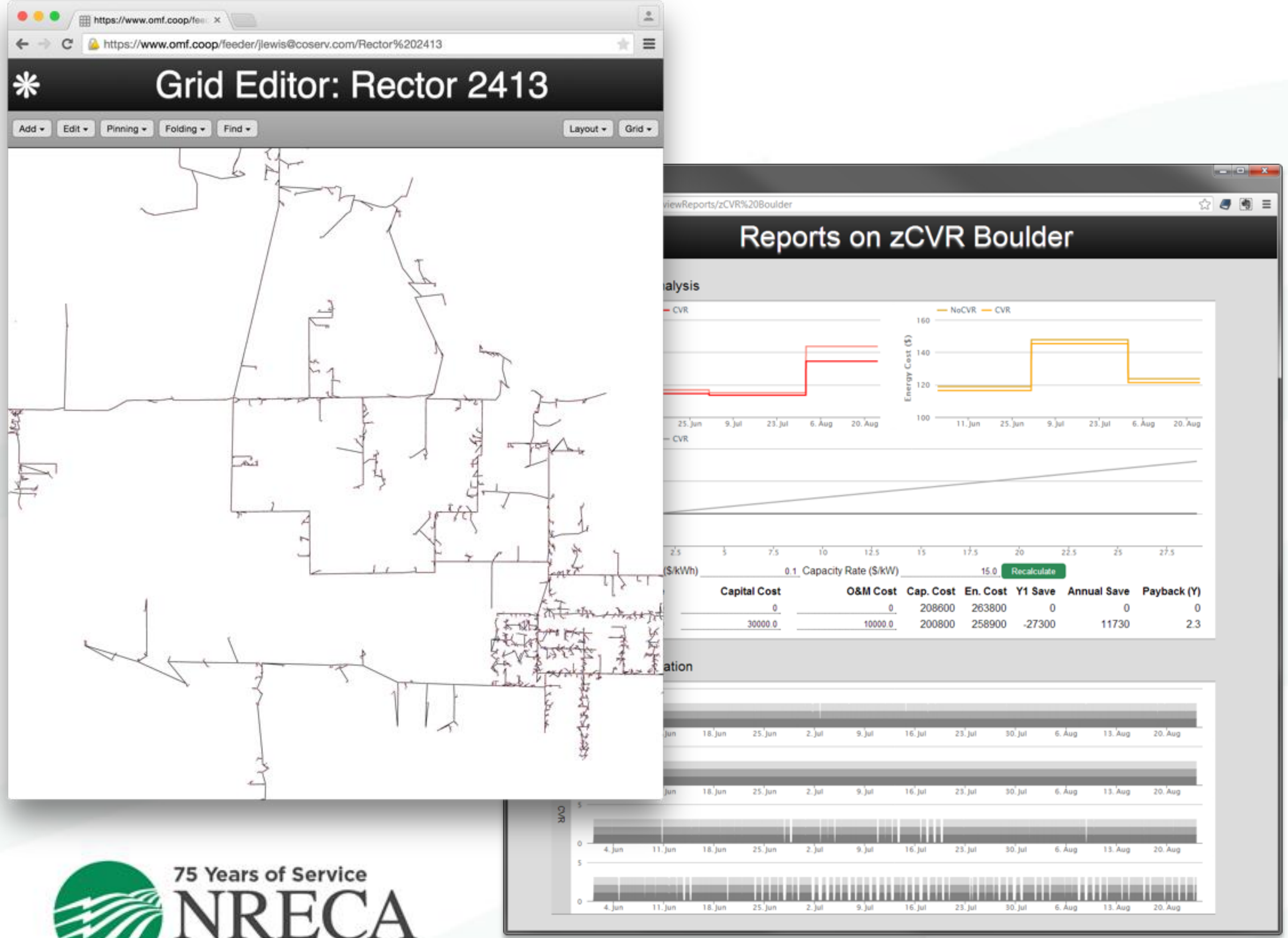
Planning Application: Volt-VAR Optimization



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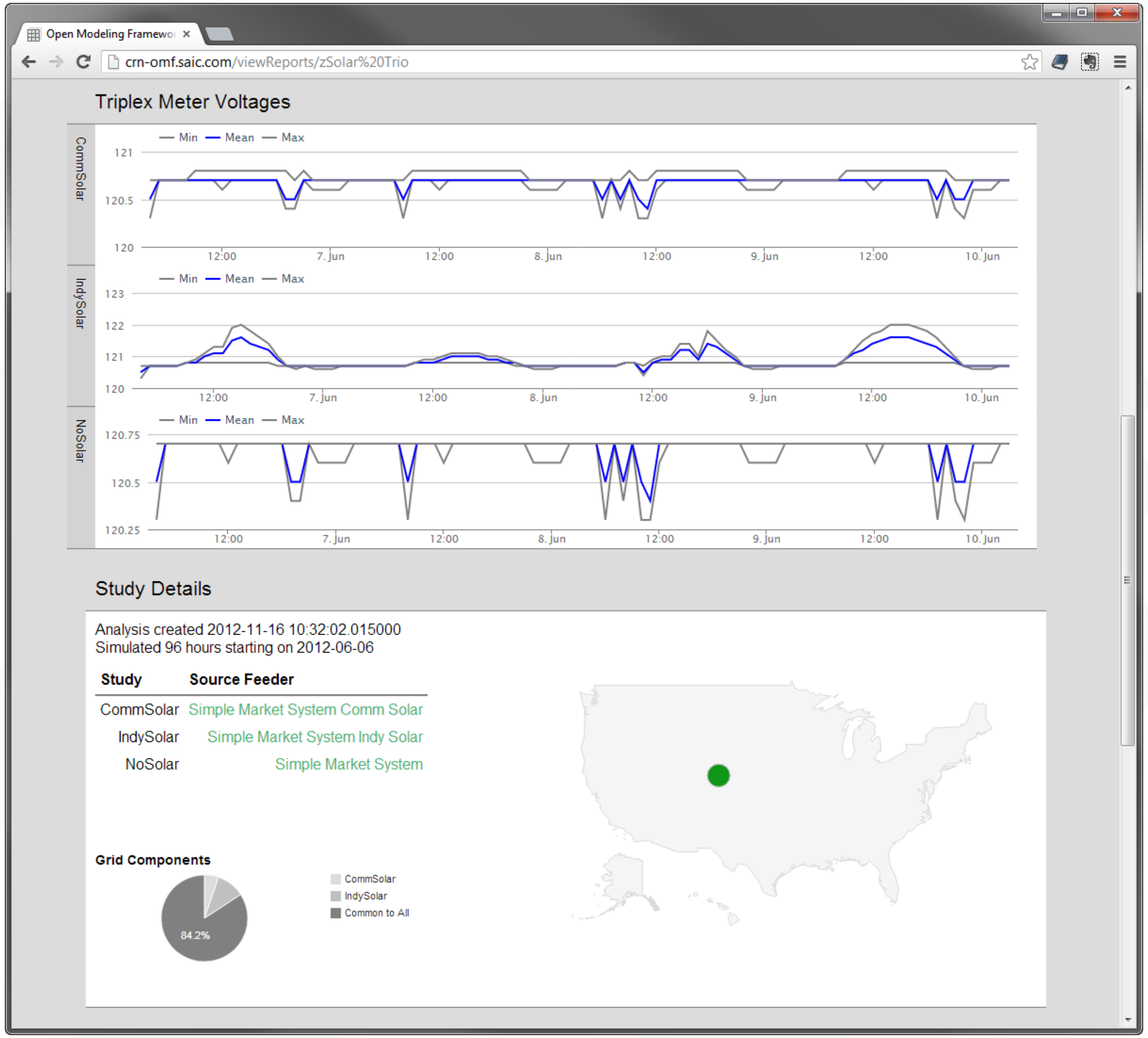
- Inputs:
  - AMI or SCADA data (used to calibrate load models)
  - CYMDIST or Windmil models (converted automatically to open format)
- Key results:
  - Quasi-static time series (QSTS) simulation run via GridLAB-D
  - VVO control scheme evaluated over multiple seasons
  - Control algorithm comparison to verify reasonable number of control actions of voltage regulators and capacitor banks
  - Peak demand and energy reductions converted to cost impacts
- More information:
  - https://www.cooperative.com/public/bts/smart-grid/Documents/NRECA_DOE_Costs_Benefits_of_CVR.pdf

Planning Application: Solar Integration

OMF

- Inputs:
  - Load and circuit model as before
  - Utility location (used to automatically import historical weather data from NOAA)
- Key outputs:
  - Overvoltage detection for centralized versus distributed solar deployment options
  - Reverse powerflow prediction based on climate and demand
  - Changes to voltage regulation and protective device operation calculated
- More information:
  - Research report: https://goo.gl/41hwXp
  - Try the model: https://www.omf.coop/newModel/solarEngineering/EAC



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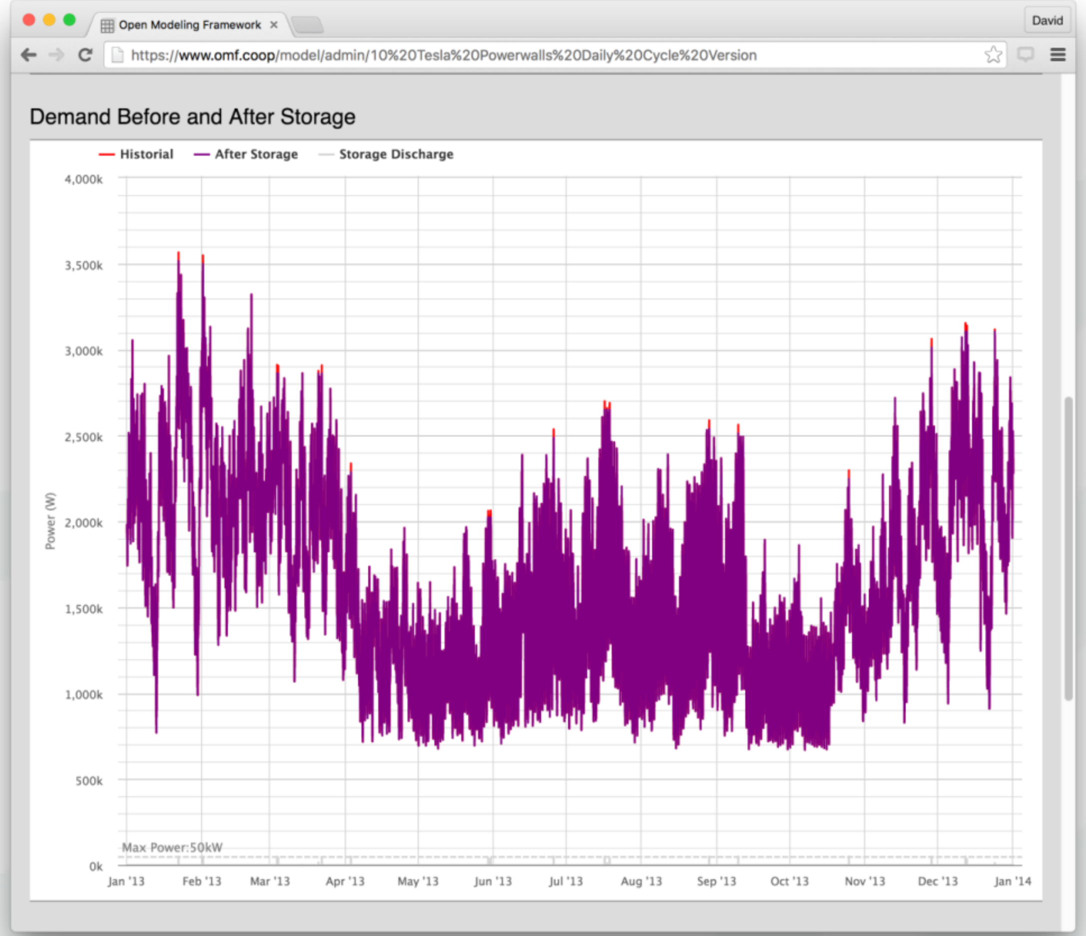
Planning Application: Energy Storage Valuation



- Inputs:
  - Load, circuit, location data as before
- Key outputs:
  - Calculation of realistic storage dispatch (via forecasting algorithms on top of scikit-learn)
  - Impact of net load on cash flow for the utility based on arbitrage, peak demand reduction or asset capacity deferral approaches
  - Integrated in to full QSTS circuit simulation to calculate interaction with solar, electric vehicles and load control
- More information:
  - Try the storage capacity deferral model: https://www.omf.coop/newModel/storageDeferral/EAC2

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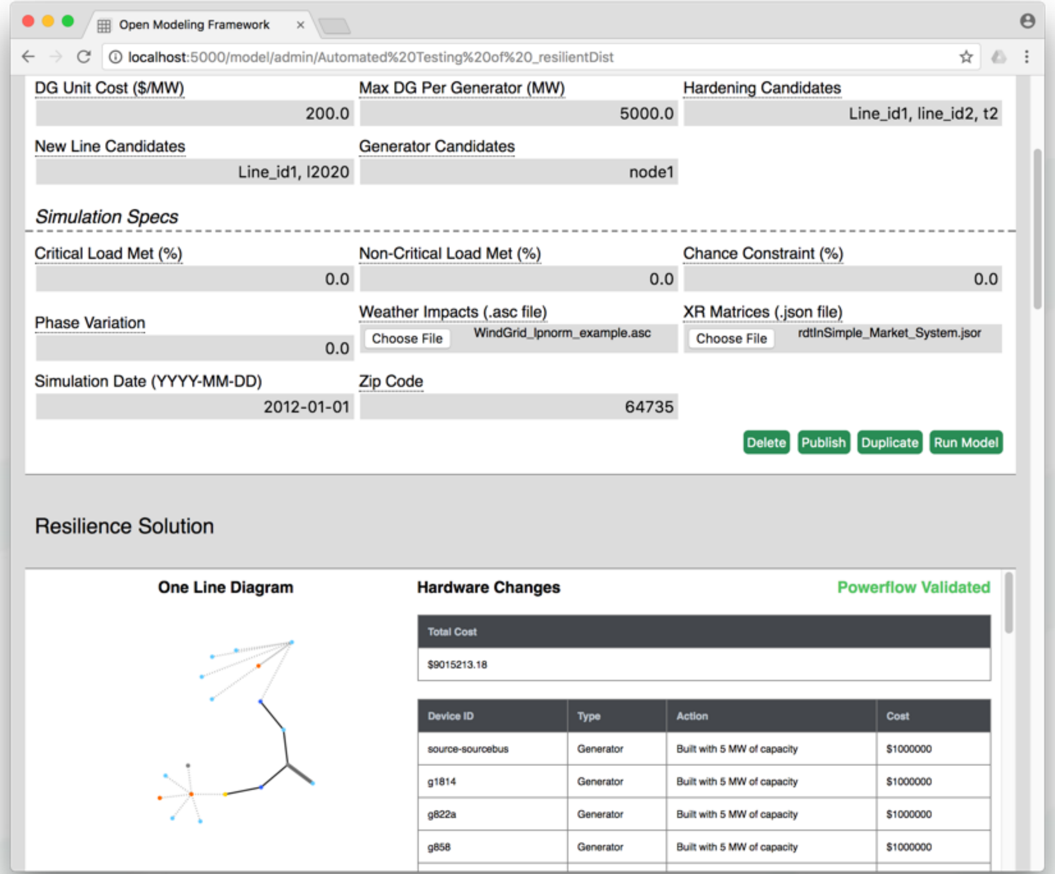
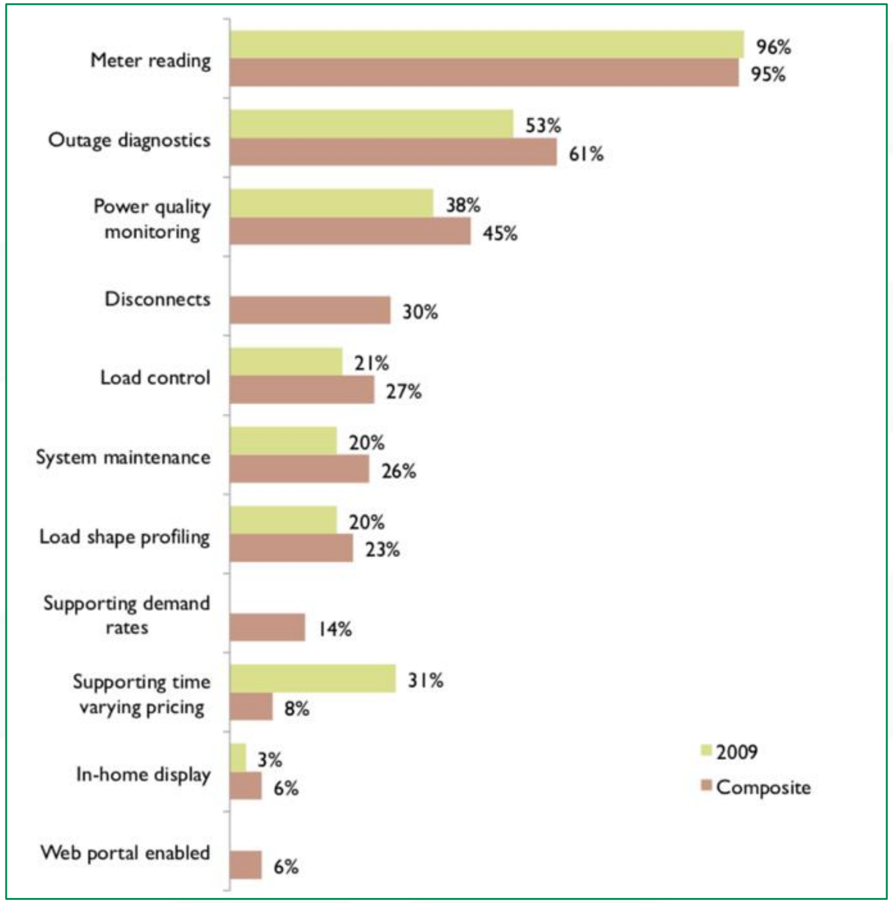
Planning Application: Optimal Resilience Investment

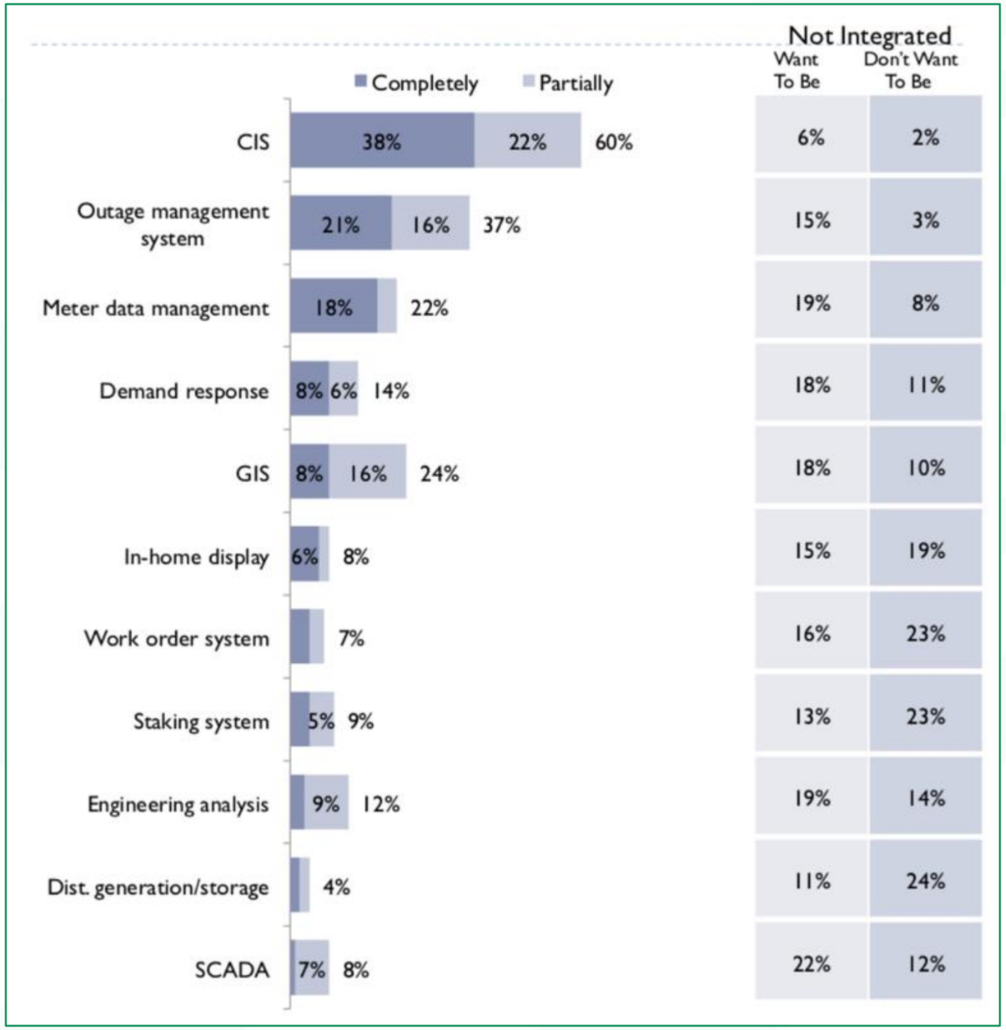


- Inputs:
  - Load, circuit, location data as before
  - Extreme weather event spatial impacts (wind speeds, water levels, etc. examples provided)
- Key outputs:
  - Estimated damage to the distribution system calculated via an asset fragility model
  - Given a fixed budget, calculates an optimal set of hardening upgrades (undergrounding, back-feeding, etc.) based on damage models
  - Calculates new switching and control actions for hardened system
- More information:
  - Model overview: https://goo.gl/VauxGd

Operations Needs

- Meter reading efficiencies typically provide the cost savings needed to deploy new systems.
- "Long tail" of additional applications added over time.
- Integration costs largest barrier to additional applications.





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Source: 2013 Co-op Technology Survey, NRECA Market Research Services

Operations Research: GridState

- A system for passively monitoring and analyzing a comprehensive range of data from and about utility electrical and control system operations
- Initial development funded by U.S. Department of Energy and DARPA for cybersecurity anomaly detection
- Objective is to provide utilities and other stakeholders total operational situational awareness
- Passively collects and organizes all communications traffic within utility industrial control system networks
- Distribution PMUs can provide more detailed and timely state awareness

Future Research: Unification of Grid Planning and Operations Software

Grid Configurations
Network Models
Future Scenarios
Utility ICS Topology

Grid Telemetry:
AMI/AMR
SCADA
Distribution PMUs

Configuration
And Analysis

OMF

GridState

Calibration Data
Physics Problems

Planning &
Engineering Analysis

Distribution System
Operations

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Conclusions

- Sensor networks widely deployed at rural electric cooperatives.
- Data integrated in to multiple planning applications.
- As backhaul bandwidth increases, operational and control opportunities emerge.

Feedback?
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