CESA Webinar

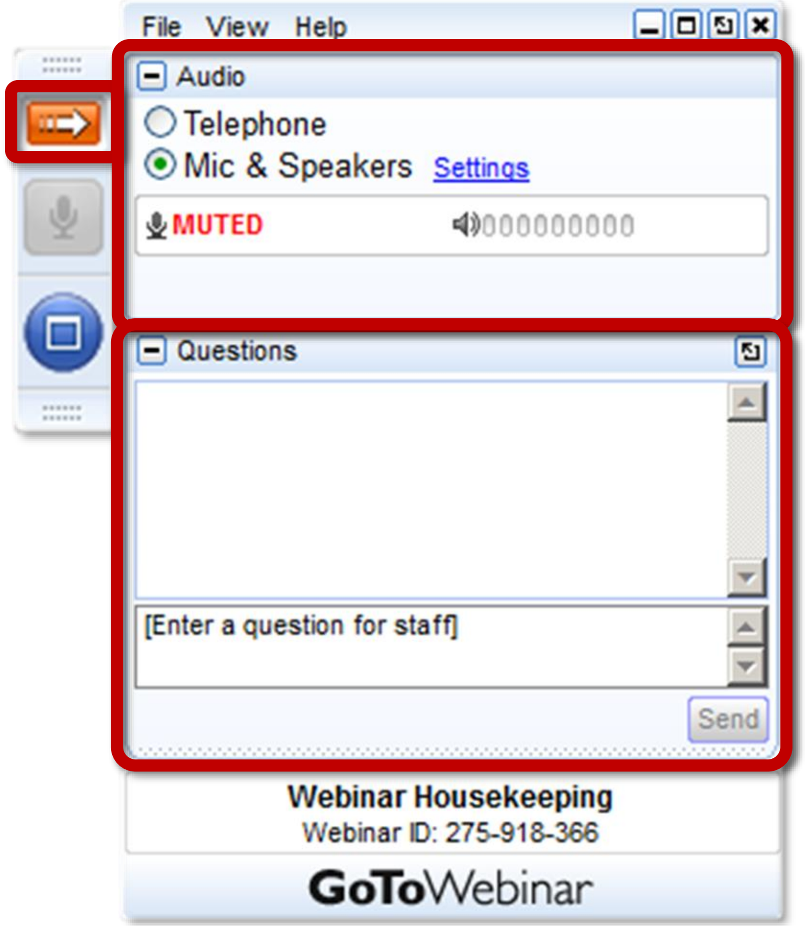
Evaluating Technology Impacts on the Distribution System: PNNL's GridLAB-D Simulation Tool

Hosted by
Nate Hausman, Project Director, CESA

March 19, 2019

Clean Energy States Alliance

Housekeeping



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Clean Energy States Alliance

Alaska Energy Authority
State of California Energy Commission
Department of Energy & Environment
Energy Trust of Oregon
Iowa Economic Development
Massachusetts Clean Energy Center
IPA Illinois Power Agency
New Mexico EMNRD Energy, Minerals and Natural Resources Department
OEI Wisconsin Office of Energy Innovation
New York State of Opportunity. NYSERDA
BPU New Jersey's Clean Energy Program™ njcleanenergy.com
Connecticut Green Bank
New Hampshire Public Utilities Commission
Maryland Energy Administration
Department of Commerce, State of Washington — Innovation is in our nature.
Vermont Clean Energy Development Fund, Public Service Department
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Office of the People's Counsel, District of Columbia — Advocating, Protecting and Educating DC Consumers
New Hampshire Department of Environmental Services
Smart Electric Power Alliance
ACEP Alaska Center for Energy and Power

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Multistate Initiative to Develop Solar in Locations that Provide Benefits to the Grid

CleanEnergy States Alliance
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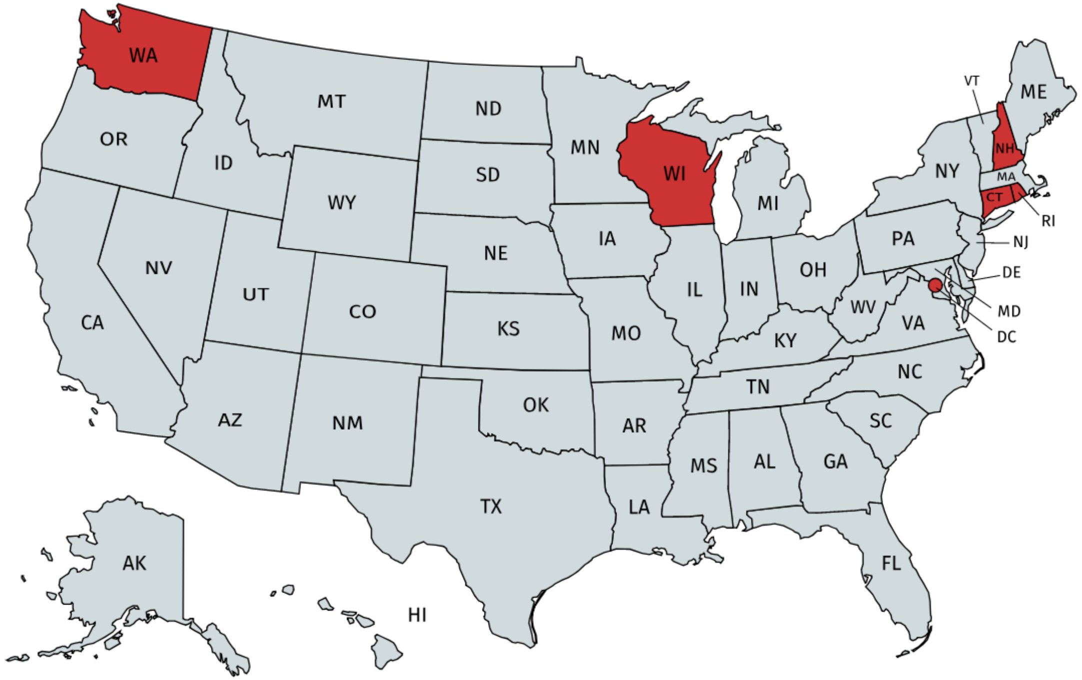
The Clean Energy States Alliance (CESA) is working with five states and the District of Columbia to identify locations where solar and other DERs could increase the reliability and resilience of the electric grid.



CONNECTICUT GREEN BANK SM

Office of the People's Counsel
District of Columbia
Advocating, Protecting and Educating DC Consumers

New Hampshire Public Utilities Commission

State of Rhode Island Office of Energy Resources

OEI
Wisconsin Office of Energy Innovation

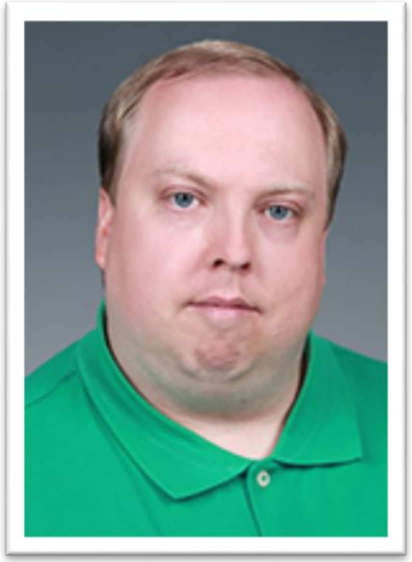
Department of Commerce
Innovation is in our nature.

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

SOLAR ENERGY TECHNOLOGIES OFFICE
U.S. Department Of Energy

Learn more at: www.cesa.org/projects/locational-value-of-distributed-energy-resources

Webinar Speakers



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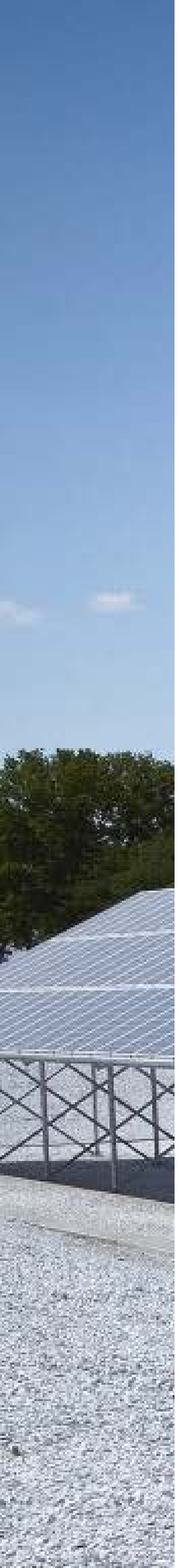
CleanEnergy
States Alliance



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Evaluating Technology Impacts on the Distribution System: PNNL's GridLAB-D Simulation Tool

March 19, 2019

Frank Tuffner
Staff Research Engineer

CESA Webinar

U.S. DEPARTMENT OF ENERGY BATTELLE

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PNNL-SA-141993

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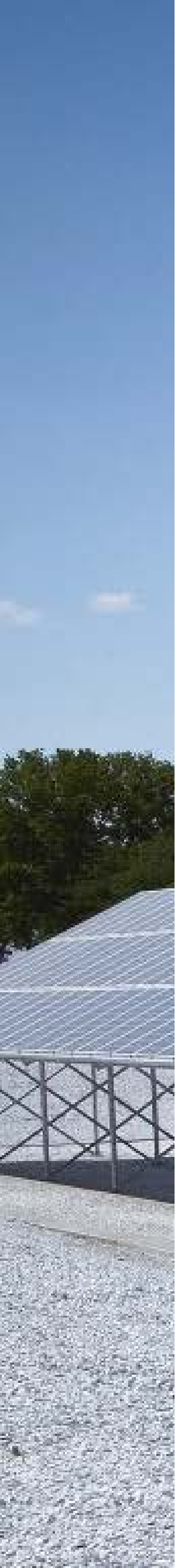
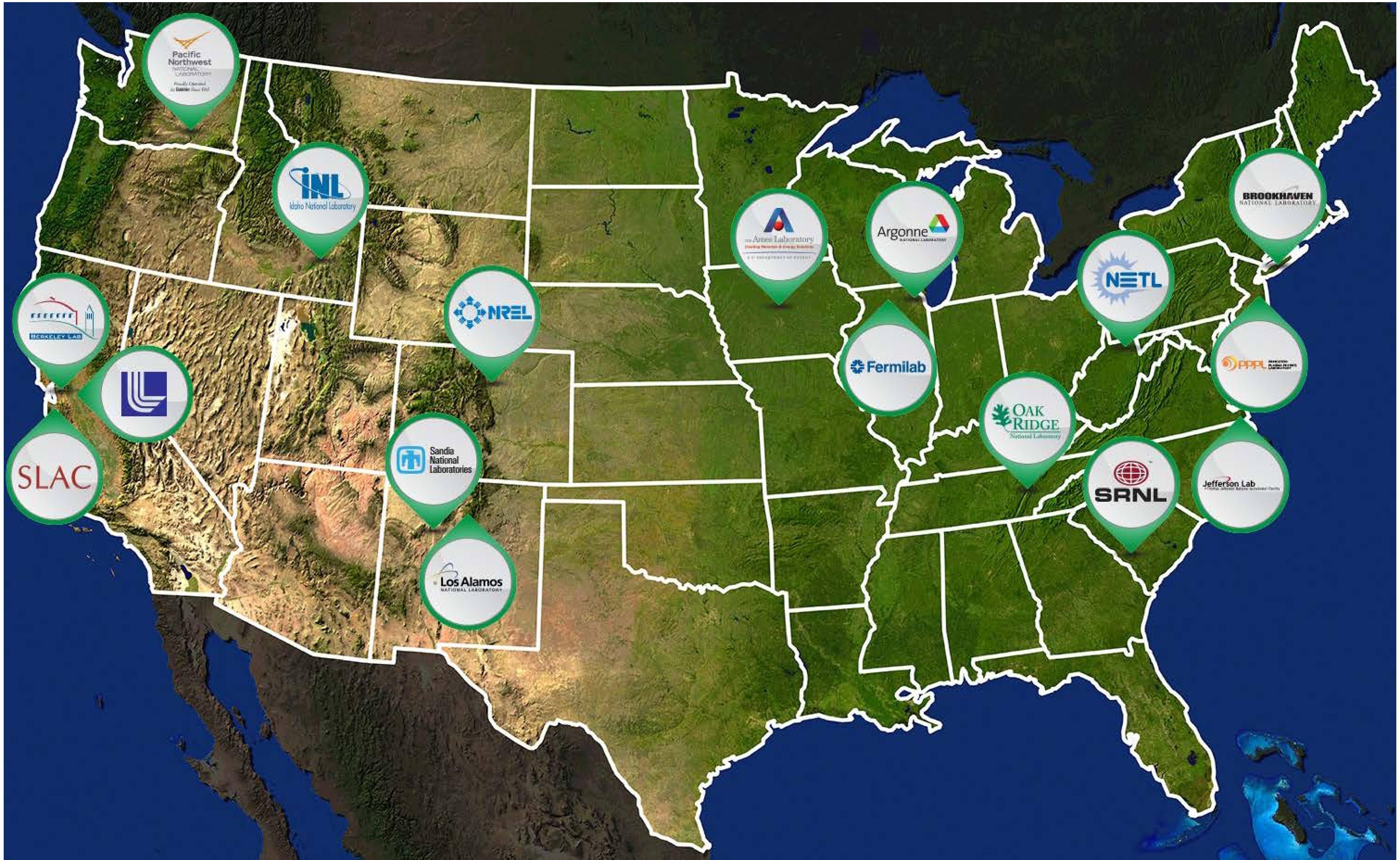
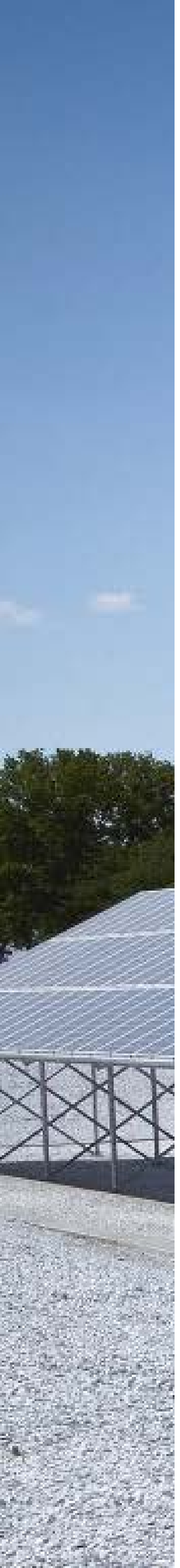
The National Laboratory System







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PNNL – At a Glance

4,486
Employees

221
Inventions

$1.46B
Total Economic Output

$987M
Annual Spending

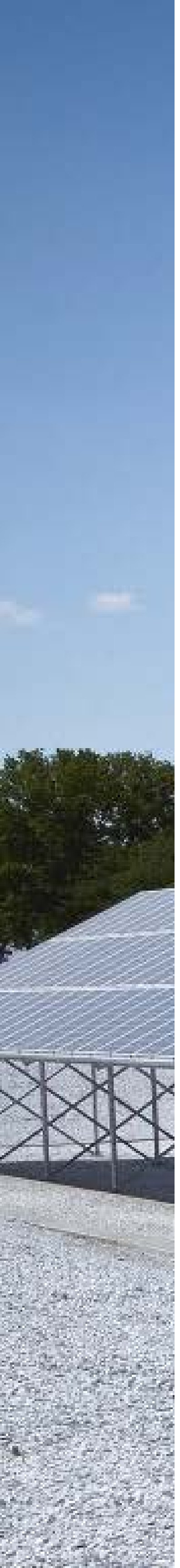
64
Patents
U.S. and Foreign

7,100
Jobs Generated
in Washington

$456M
Total Payroll

37
Licenses

187
Companies
with PNNL Roots



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GridLAB-D: A Unique Tool to Design the Smart Grid

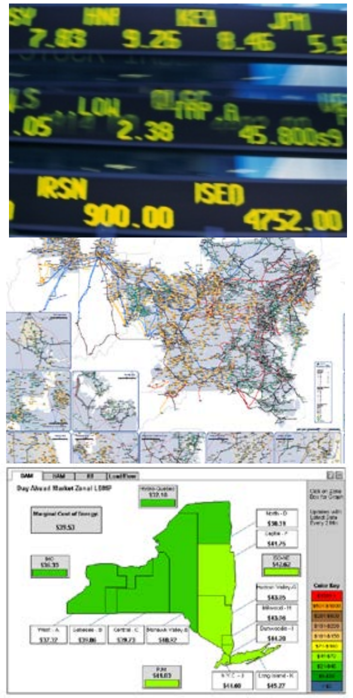
Unifies models of the key elements of a smart grid:

Loads & DERs

Power Systems

GridLAB-D

DSO Markets



Over 80,000 downloads in over 150 countries

- ✓ Smart grid analyses
  - field projects
  - technologies
  - control strategies
  - cost/benefits
- ✓ Time scale: ms to years
- ✓ Open source (BSD-style)
- ✓ Contributions from
  - government
  - industry
  - academia
- ✓ Vendors can add or extract own modules

- Open-source, time-series simulation of an operating smart grid, from the substation to individual end-use loads & distributed energy resources, in unprecedented detail
- Simultaneously solves 1) power flow 2) control systems 3) retail markets 4) electromechanical dynamics 5) end-use load behavior in tens of thousands of buildings and devices

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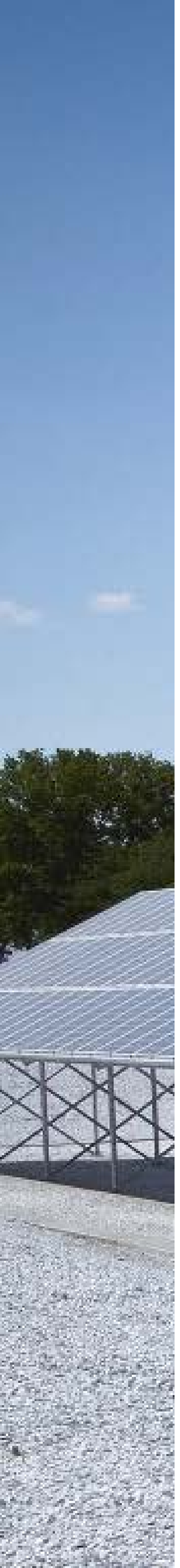
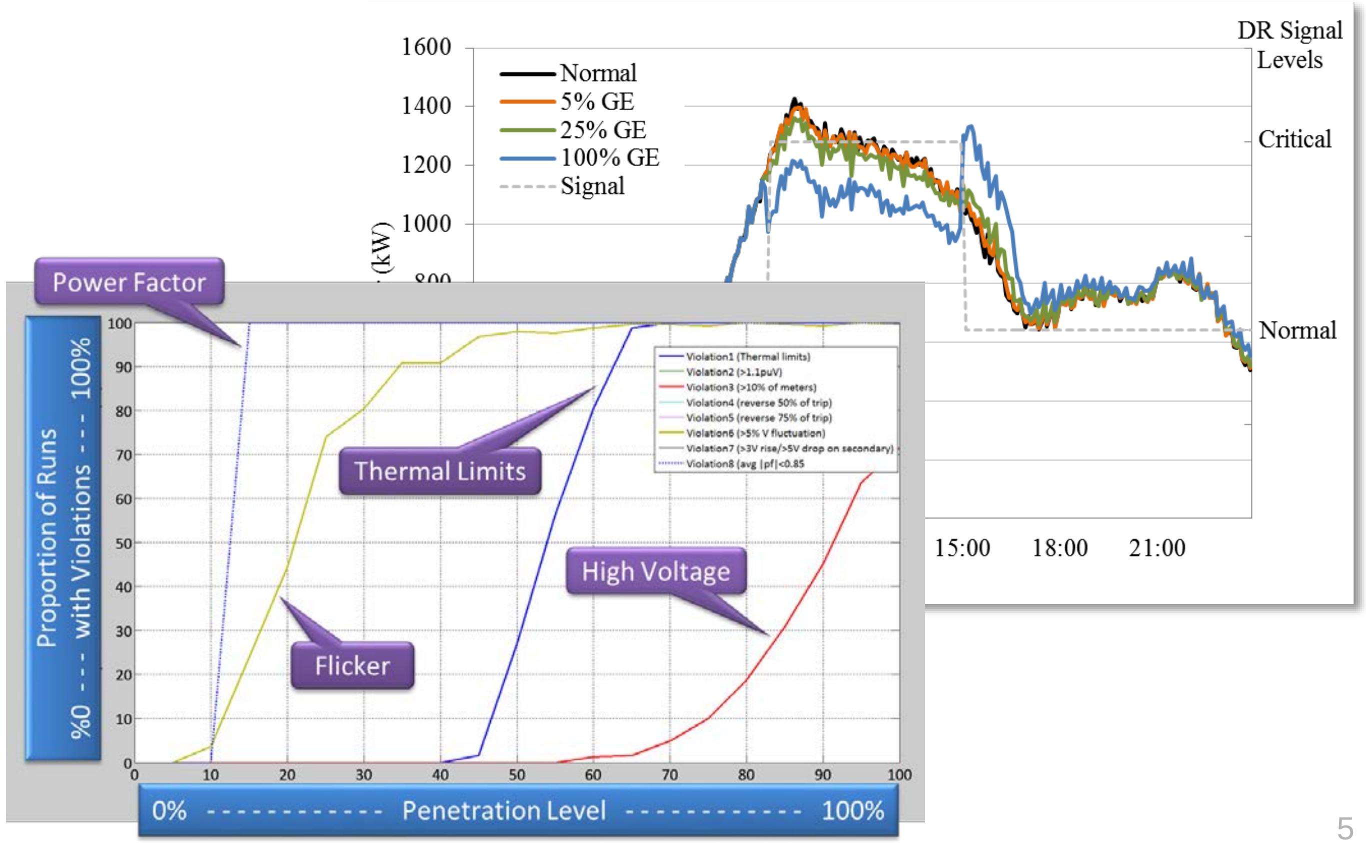
GridLAB-D Capabilities



Unifies models of the key elements of a smart grid:

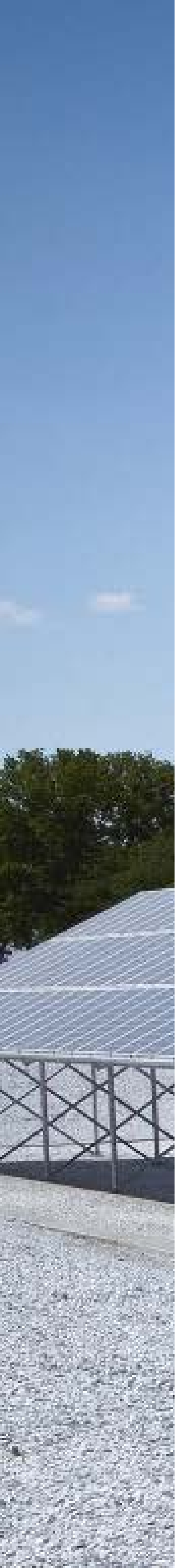
Power Systems *Loads and DERs* *Markets*

- Performs time-series simulations
  - Seasonal effects (days to years)
  - Midterm dynamic behavior (secs to hrs)
  - System dynamics (milliseconds)
- Simulates control system interactions
  - Device- and system-level controls
  - Market interactions



Typical Use Cases

- Interconnection of distributed generation and storage
- New and innovative retail market structures (e.g., DSOs)
- Evaluation of demand response and energy efficiency
- Volt-VAr optimization and conservation voltage reduction design
- Sectionalizing, reconfiguration, automation, and restoration
- Microgrids and resiliency



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Users/Contributors to GridLAB-D

National Rural Electric Cooperative Association
A Touchstone Energy® Cooperative

NRECA CRN
COOPERATIVE RESEARCH NETWORK

SOUTHERN CALIFORNIA EDISON
An EDISON INTERNATIONAL Company

GridLAB-D

GE Energy

Battelle
The Business of Innovation

ProsumerGrid™

OPEX Systems
Enabling Operational Excellence

AEP AMERICAN ELECTRIC POWER

PG&E Pacific Gas and Electric Company®

fortiss

GridUnity

OpenGridMap
"Crowdsourcing power grid data"

MILSOFT Utility Solutions

HITACHI

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Ausgrid

nationalgrid

SIEMENS

SAP

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AALBORG UNIVERSITET

Trinity College Dublin
The University of Dublin

A&M

University of Michigan

UC Irvine

Argonne NATIONAL LABORATORY

NREL

PURDUE UNIVERSITY

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Lawrence Berkeley National Laboratory

INL Idaho National Laboratory

Cornell University Founded A.D. 1865

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

University of Washington 1861

IOWA STATE

WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Sandia National Laboratories

Colorado State University

Cal

VirginiaTech

OAK RIDGE National Laboratory

Lawrence Livermore National Laboratory

CEPRI
中国电力科学研究院
CHINA ELECTRIC POWER RESEARCH INSTITUTE

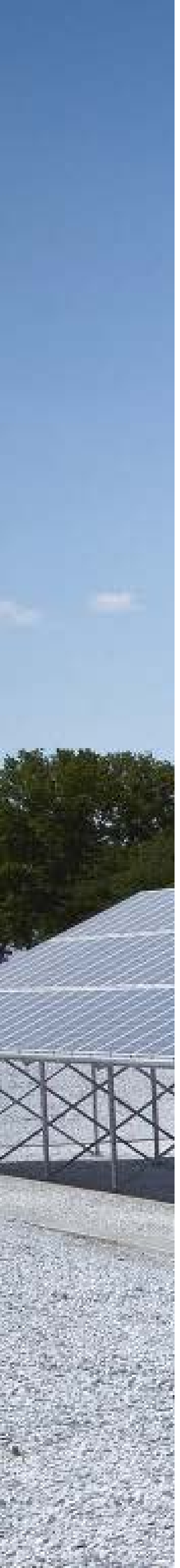
University of Victoria

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY

UNM

WSU Wichita State University

STANFORD UNIVERSITY



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Working with Industry

- Developed Open Modeling Framework with NRECA / CRN
- Open-source, web-based cost/benefit tool
  - Can investigate financial impacts using high resolution simulation without complexity of simulator
  - Captures the complexity of integrated systems with GridLAB-D modeling behind the scenes
- Milsoft embedded a GridLAB-D translator for their utility users

GridUnity

SOUTHERN CALIFORNIA EDISON
An EDISON INTERNATIONAL Company

- Worked with GridUnity (formerly Qado Energy) and SCE to develop an easy-to-use DG integration tool
  - Utilities can quickly (and cheaply) assess new integration requests to accelerate PV adoption
  - Users can explore new and cost-effective mitigation technologies
- Cloud-based, user-friendly
  - Separates users from the complexity of the underlying model (and tools)

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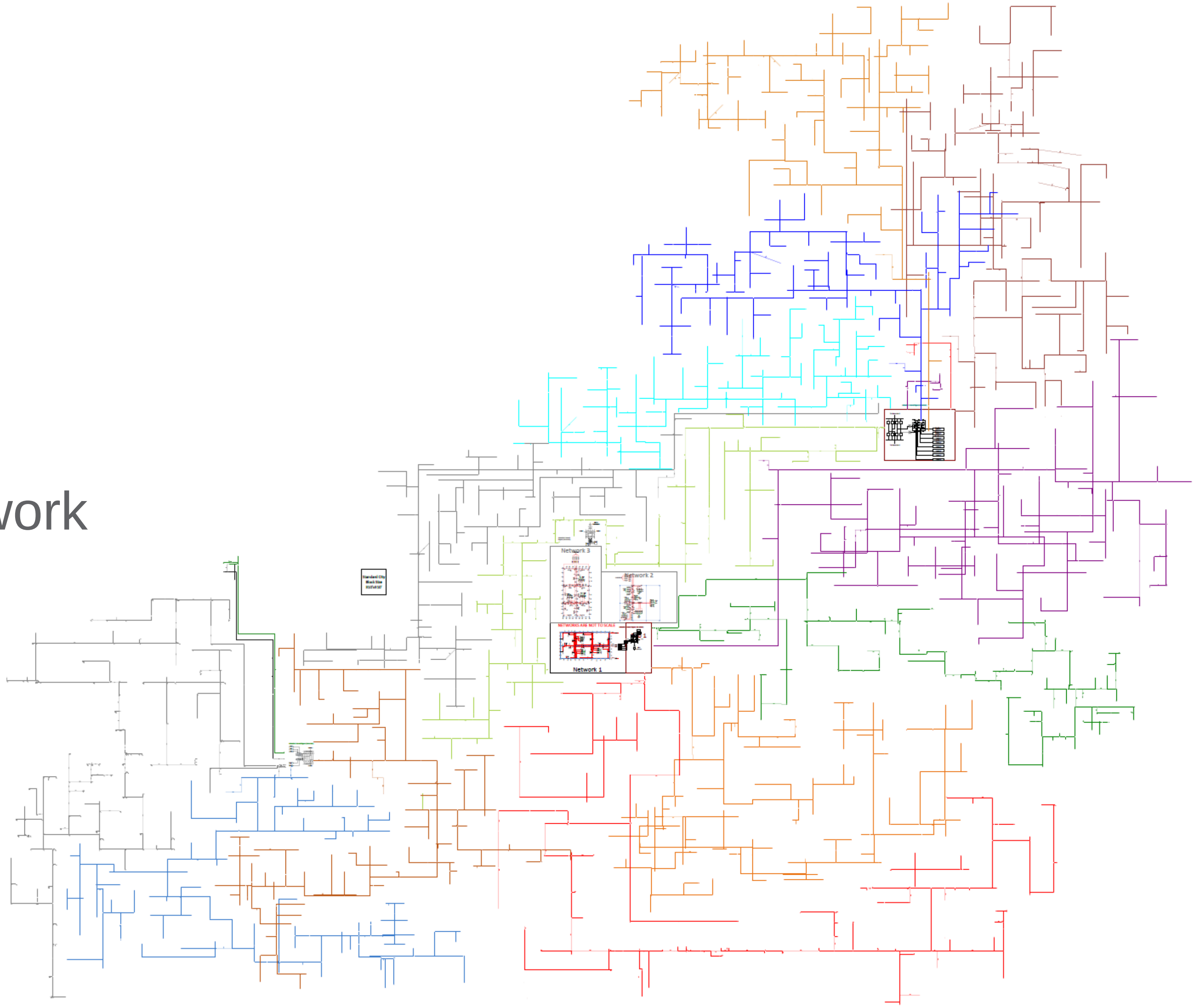
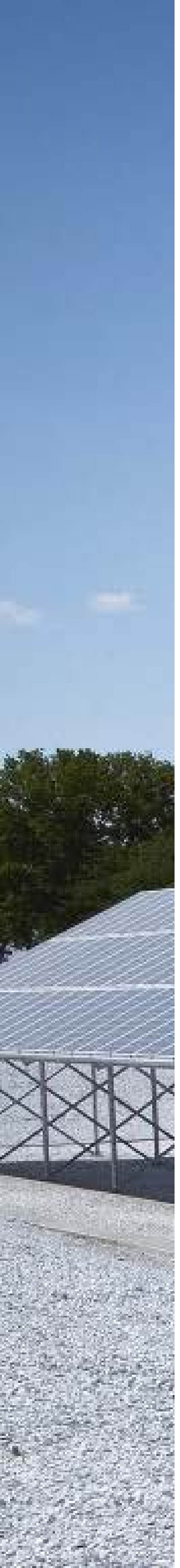
Feeder Models and Systems

- Generalized test models
  - IEEE distribution feeders
  - Taxonomy of prototypical feeders
  - Smart City Model
- Utility-specific test models
  - NRECA-based Open Modeling Framework
  - CYME or SynerGEE conversions
  - One-line diagram “manual extraction”
- Population scripts for feeder models
  - Typical house construction
  - End-use load composition
    - ✓ Appliances
    - ✓ HVAC/heating type
  - End-use demand schedules
  - Distributed generation

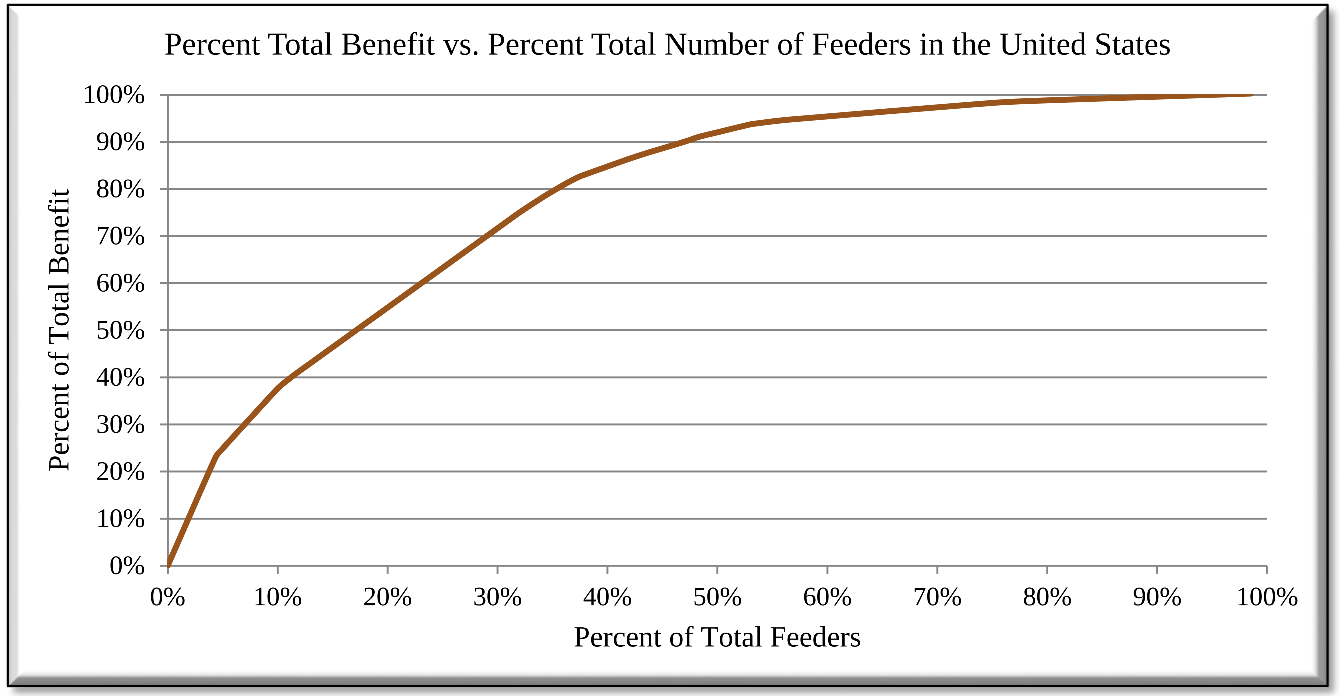


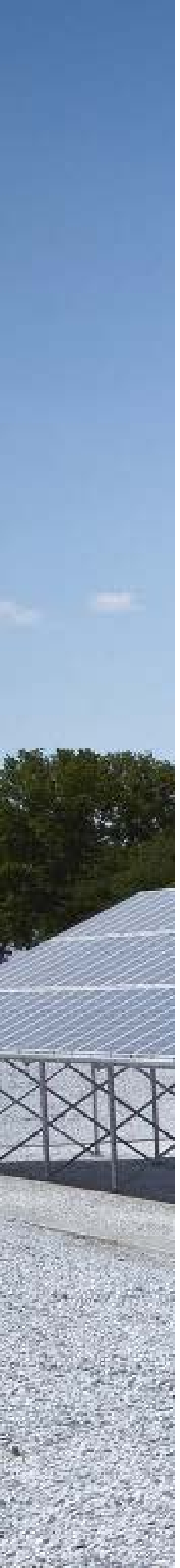
Smart Cities Model – Meshed urban core and outlying feeders



Evaluation of SGIG Grants: Potential Impacts of Primary Technologies

- Distribution automation benefits
  - Volt-VAR optimization (annual energy saved) — 2% – 4%
  - Reclosers & sectionalizers (SAIDI improved) — 2% – 70%
  - Distribution & outage management systems (SAIDI improved) — 7% – 17%
  - Fault detection, identification, & restoration (SAIDI improved) — 21% – 77%
- Demand response
  - Instantaneous load reductions — 25% – 50%
  - Sustainable (e.g., 6-hour) load reductions — 15% – 20%
- Thermal storage (commercial buildings)
  - Peak load reduction @ 10% penetration: up to 5%
- Residential photovoltaic generation
  - 3-5 kW each, 0% – 6% penetration (0.1% - 3% annual energy saved)
  - Low penetration: losses generally decreased
  - High penetrations, deployed in an uncoordinated manner, can increase system losses



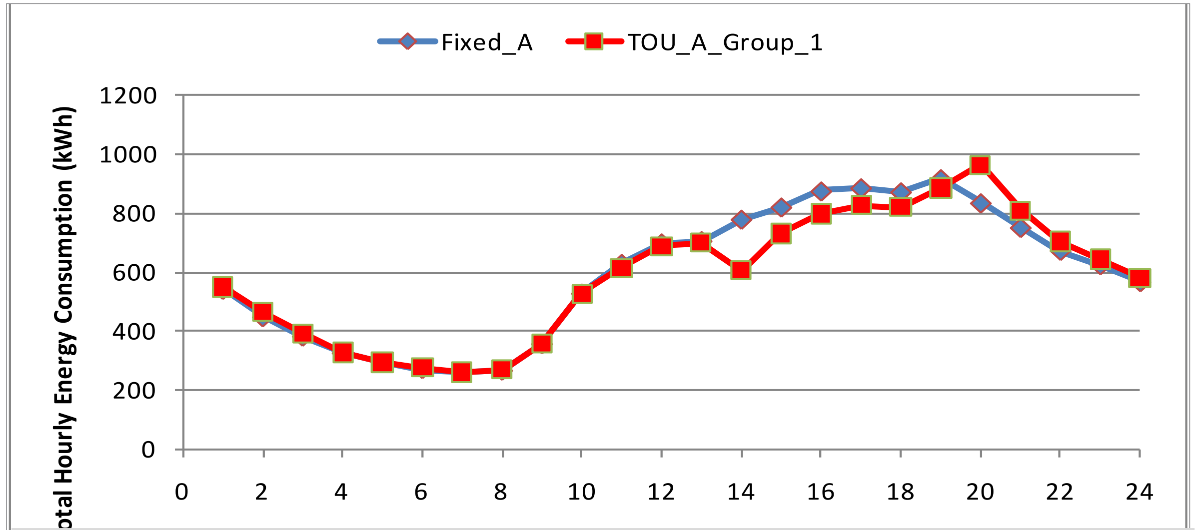


Business Case for Scalable Demand Response w/ Dynamic Pricing (NRECA)

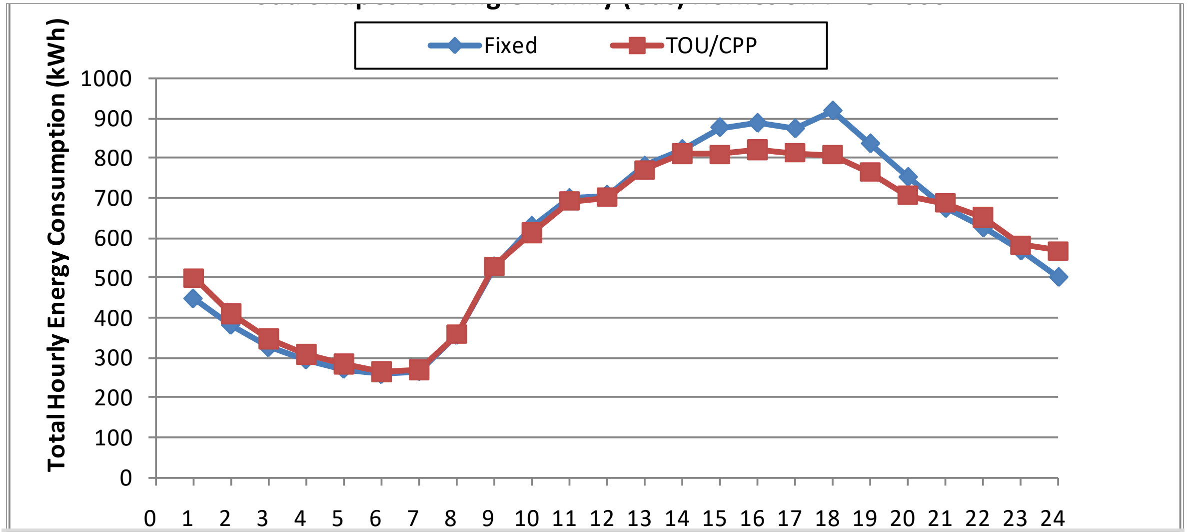
- Analyzed price responsive thermostats and water heaters.
  - Revenue neutral TOU/CPP and RTP rates.
  - Seven classes of residential & small/medium commercial buildings.
  - Generation and T&D capacity benefits & wholesale cost reductions.

Customer Type	N	Peak Demand (kW)	Peak Demand Reduction (%)	Peak Demand Reduction (kW/ea.)	Existing Customers Installed Cost ($/ea.)	Existing Customers Cost per kW ($/kW)	New Customers Installed Cost ($/ea.)	New Customers Cost per kW ($/kW)
Residential	23,318	79,120	15.7%	0.53	$441	$825	$135	$253
SFg	10,532	36,280	15.6%	0.54	$415	$773	$135	$251
MHg	3,511	9,762	11.5%	0.32	$415	$1,302	$135	$424
MFe	2,358	6,189	14.8%	0.39	$480	$1,237	$135	$348
Sfe	5,188	21,491	17.3%	0.71	$480	$672	$135	$189
MHe	1,729	5,397	11.4%	0.36	$480	$1,347	$135	$379
Commercial	1,903	24,843	5.3%	0.69	$916	$1,329	$385	$559
COg	951	14,575	5.1%	0.78	$1,210	$1,542	$525	$669

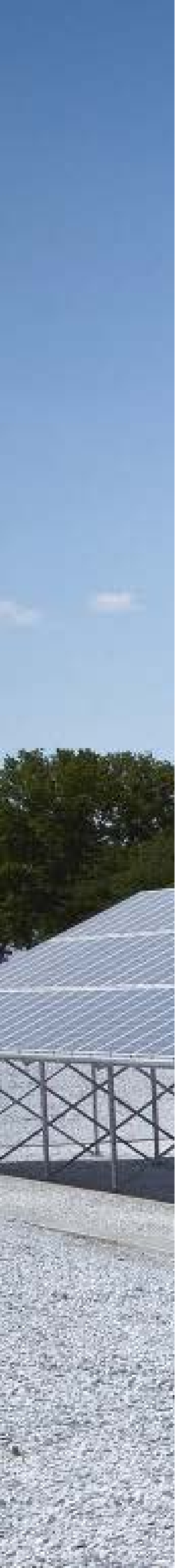
Compare the cost-to-benefits ratio of household types or green- vs. brown-field growth.



Traditional CPP program – "rebound" from peak prices can set new, even higher peak!



Staggering CPP start times over four hours reduced peak distribution demand by 11.5%



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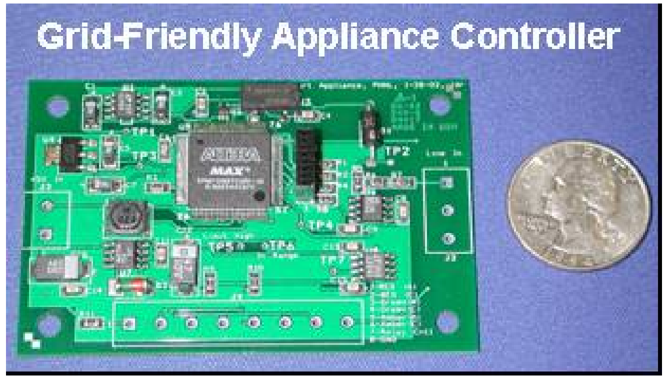
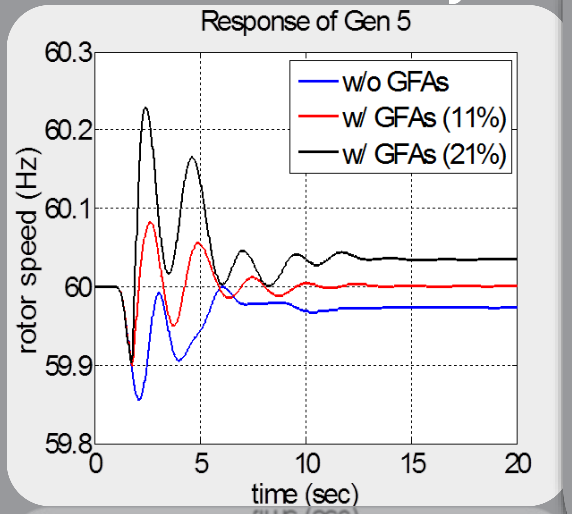
Demand Response as a Reliability Resource

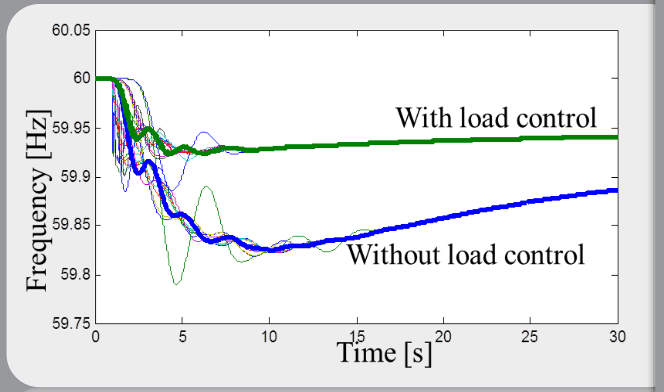


- PNNL GridWise Initiative developed, field tested original concept of fully-autonomous under-frequency load shedding
- Loads-as-a-Resource project addressed primary frequency control: theoretical basis, need to arm response across time & space
- Transactive Ancillary Services project added resource acquisition, signaling, M&V for frequency regulation

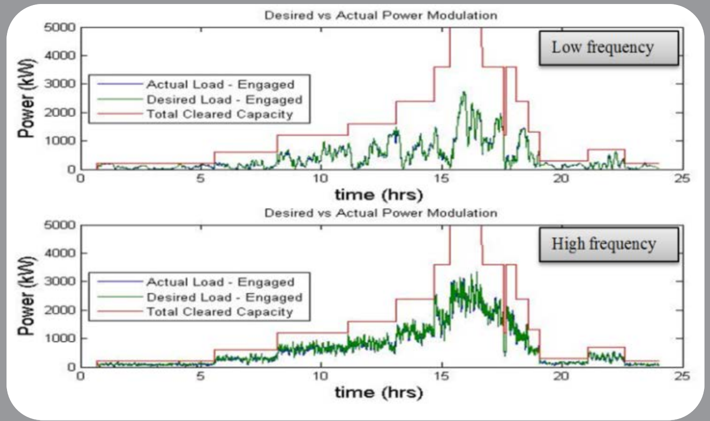
Grid Friendly



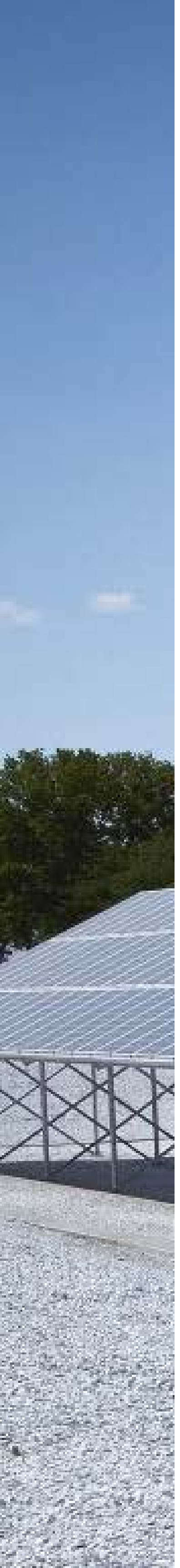
Loads as a Resource



Transactive Control for Ancillary Services



Autonomous (2006) → Distributed (2012) → Transactive (2014)



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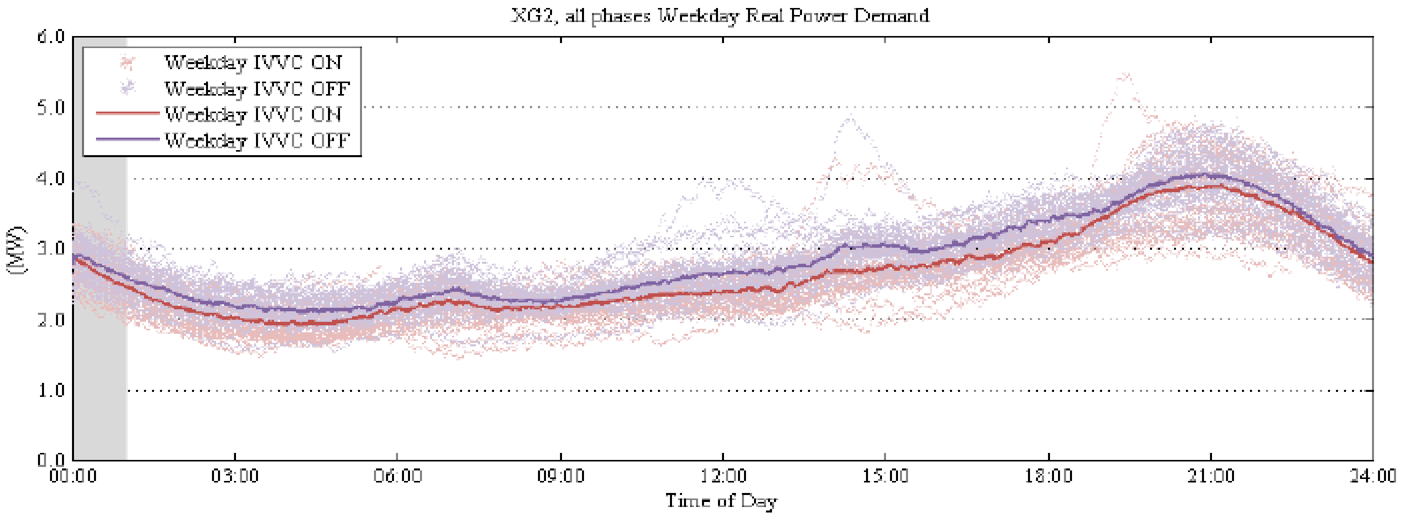
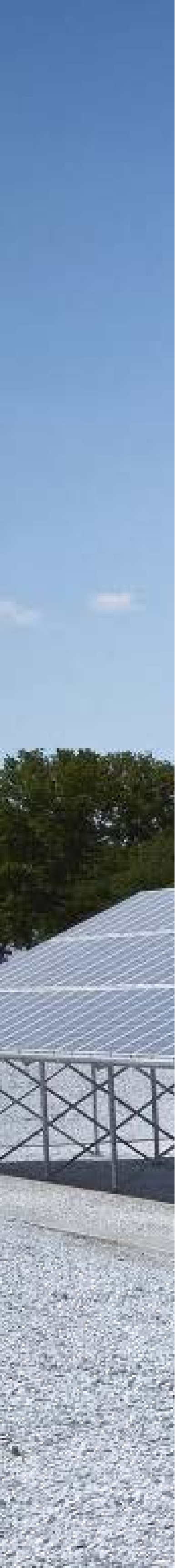
PNNL Volt-VAr Optimization (VVO) and Conservation Voltage Reduction (CVR) Work

- Initial work with AEP
  - Modeled a commercial VVO system in GridLAB-D on 8 AEP distribution feeders
  - Performed field evaluation of VVO on 8 feeders to validate GridLAB-D model and verify system performance
- Initial work with DOE
  - Initial CVR paper cited 400+ times (2010)
  - Follow-on report examined VVO as part of the SGIG grant projects (2011)
- Follow on work with Industry
  - Conducted field evaluations of VVO for industry as an impartial 3rd party evaluator
  - Developed a VVO evaluation method that improved on existing methods
  - Developed an on-line VVO evaluation method in partnership with AEP (patent pending)

Volt-VAr Optimization

Validating and improving the performance of control systems



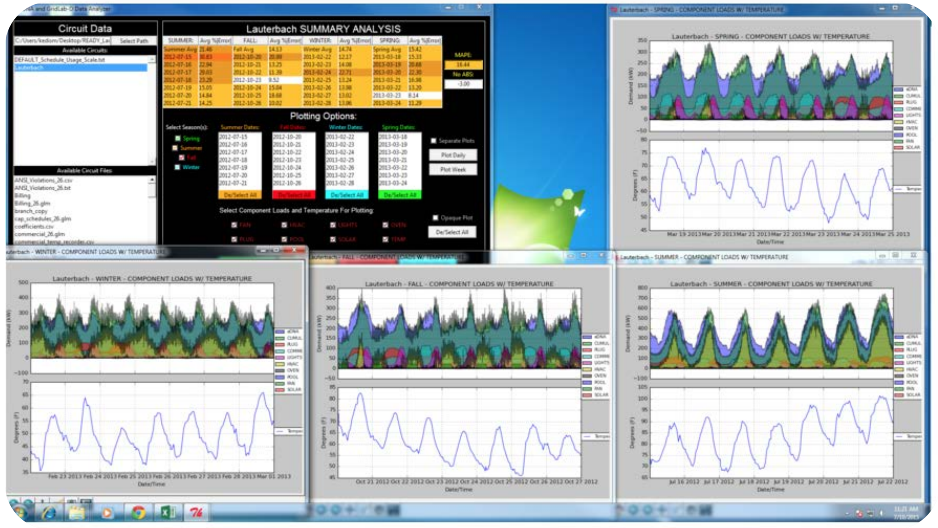


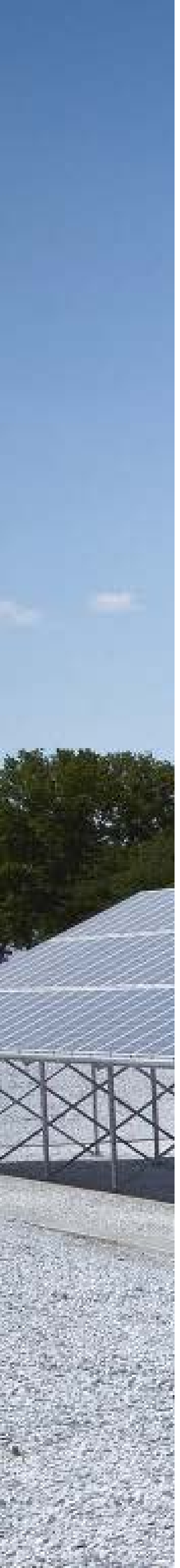
Solar Integration and Mitigation Strategies

- Solar/inverter models validated in partnership with NREL
  - Incorporates weather data
  - Define-able smart inverter controls
- Developed a user-friendly, cloud-based tool to speed up PV integration (w/ SCE, GridUnity [formerly Qado Energy])
  - Utilities can quickly asses new integration requests and identify circuit issues
    - ✓ Voltage flicker and rise, overloads, power factor
  - Utilities can evaluate mitigation deployment strategies to increase penetration levels in an economically efficient manner
    - ✓ DR, DS, smart inverters, traditional upgrades
- Transitioning to practice
  - Development under California Solar Initiative with co-funding from DOE-OE
  - GridUnity (small business) developed front end and workflow to deploy to other utilities
  - However, much of the development is open-source

Solar Integration

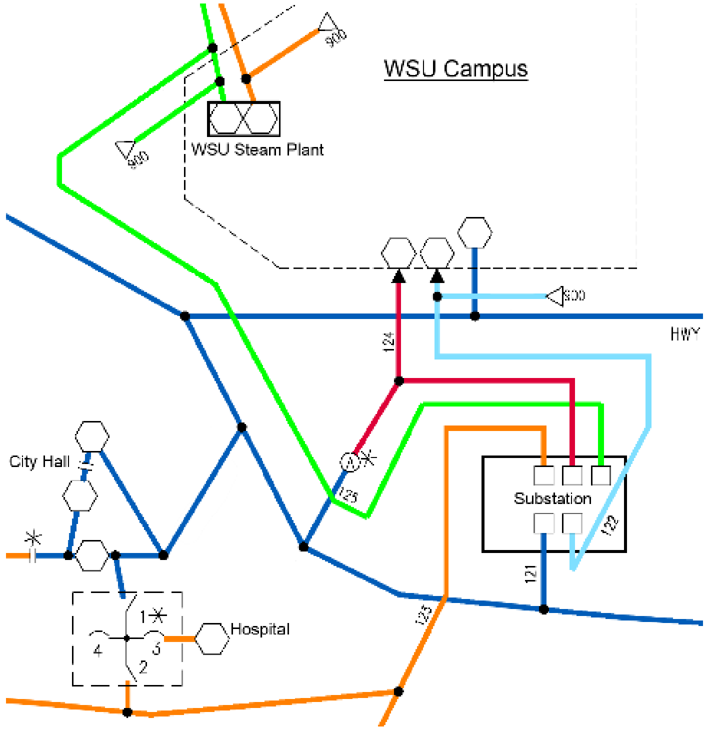
Helping utilities to speed-up interconnection and adoption

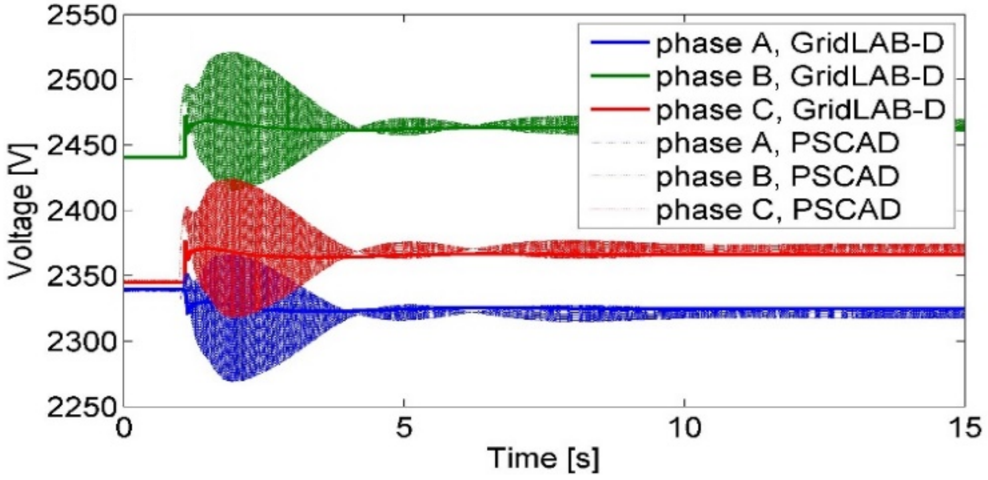


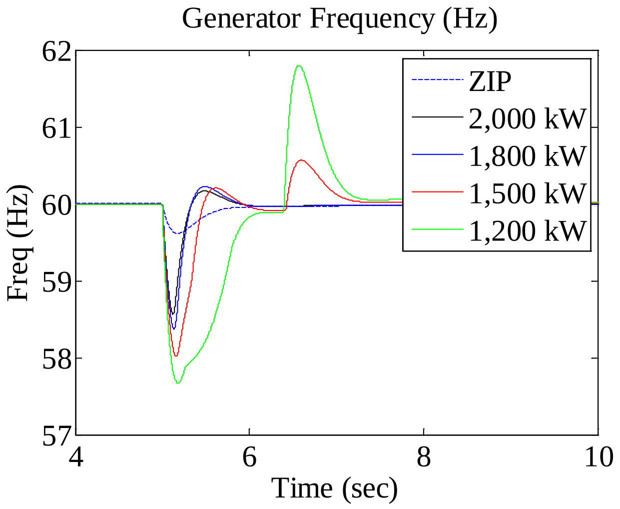


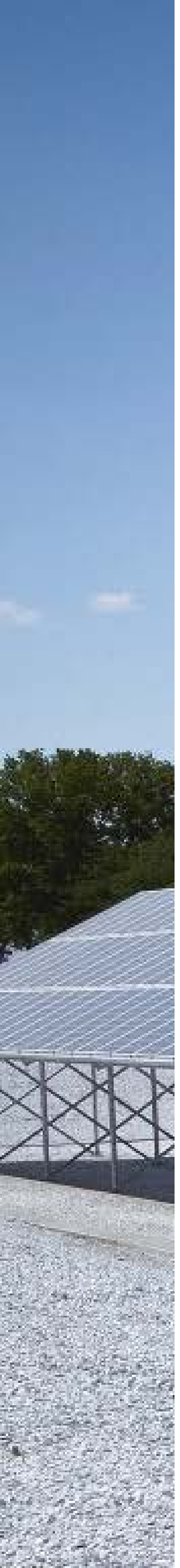
Resilient Distribution Systems: Microgrids

- Microgrids can offer important (albeit expensive) opportunity to provide resiliency in extreme events
- Microgrid designs based on resource adequacy fall far short of ensuring they are operable in practice
- Developed GridLAB-D simulation & analysis capabilities to examine practical, operating potential of “optimized” designs … including full system dynamics
  - Properly size equipment to handle start-up transients
  - Operate low-emission systems, with correspondingly low inertia
  - Engage existing system assets for advanced controls: more capability without more infrastructure



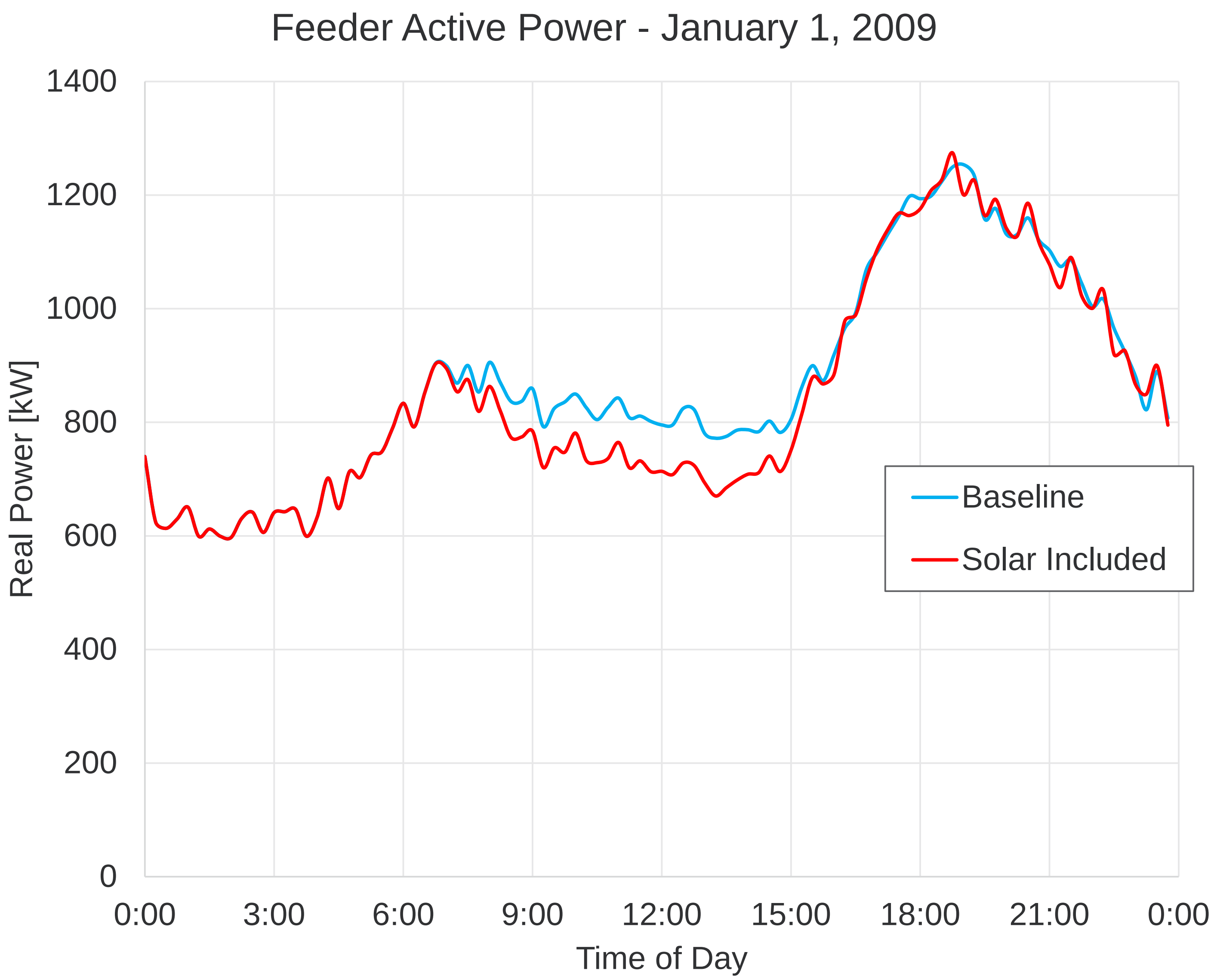


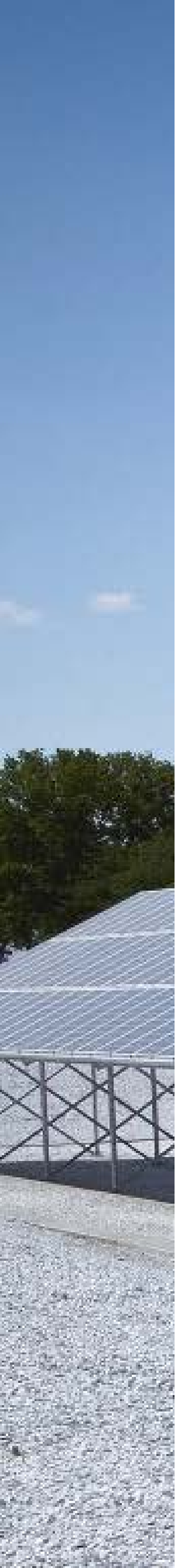




Using GridLAB-D: Simple Solar Simulation on Prototypical Feeder

- Very simple analysis demonstration
- Scenario similar to one ran for the SGIG evaluation mentioned earlier
  - Only for a single day – January 1, 2009
  - Feeder active power measurements compared
  - Very small solar (3% of feeder rating)





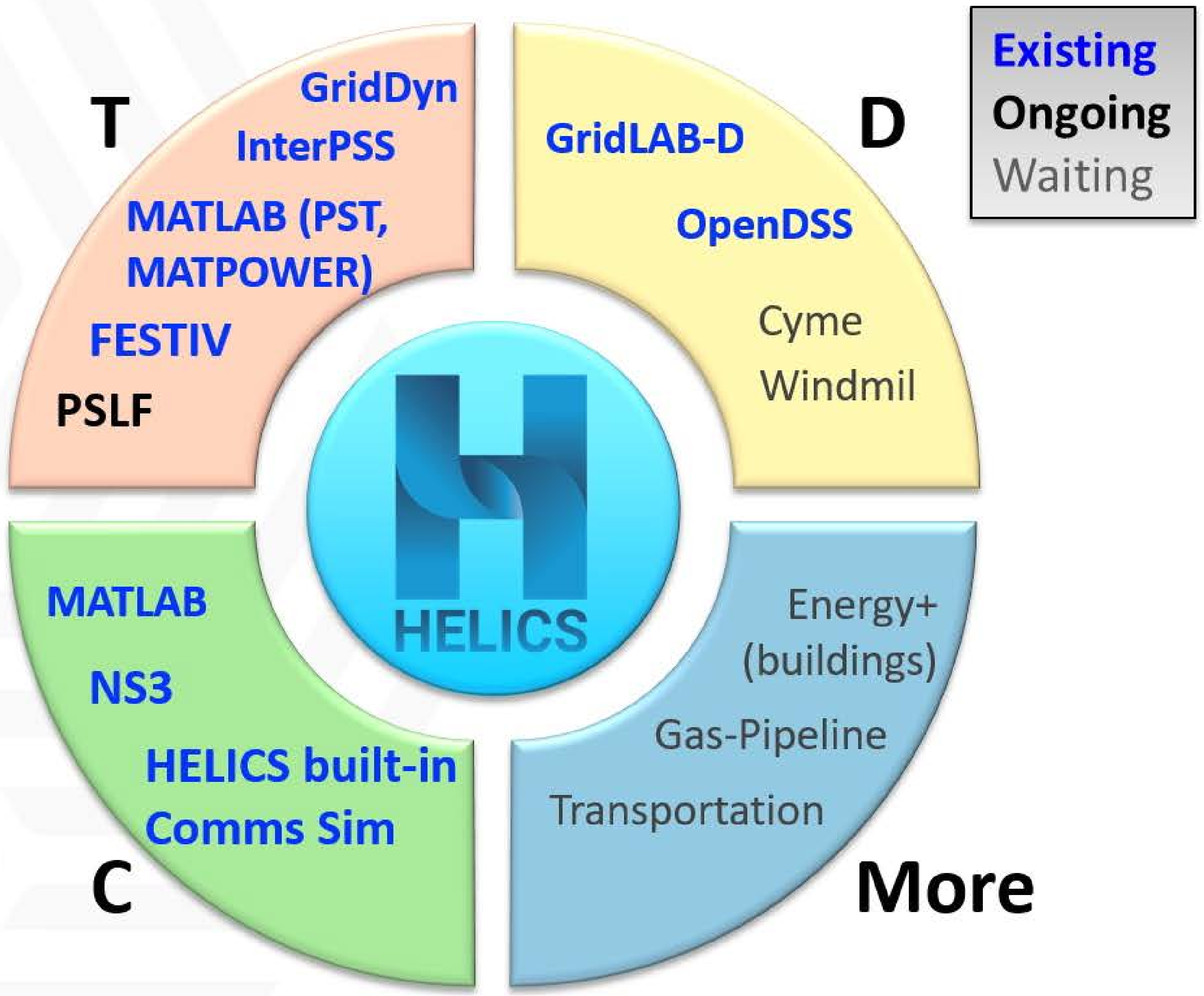
Highlighted Current Research with GridLAB-D

- Flexibility as a Resiliency Resource
  - Project with Duke Energy, ORNL, NREL, UNC Charlotte, UTK, SEPA, and GE Grid Solutions
  - Investigate usage of both utility- and non-utility-owned DERs for resiliency
- Microgrids as a Resiliency Resource
  - Investigate operational considerations for microgrids under different scenarios
  - Explore new types of control on both generation and load to improve grid resiliency
  - Investigate uses and impacts of voltage-sourced, grid-forming inverters on distribution/microgrids
- Networked Microgrid Optimal Design & Operations Tool
  - Project with LANL, SNL, NREL, and ORNL
  - Develop an optimal design tool to evaluate the networking of multiple microgrids
- Advanced Distribution Management System Platform
  - Project with NREL, WSU, UAF, Incremental Systems, and Modern Grid Solutions
  - Common Information Model (CIM) and MultiSpeak interfaces
  - Hosting advanced application and state estimation
- Transactive Energy Simulation Platform
  - Upgraded water heater model, metrics, and model order reduction for DSO+T study set in Texas
  - External Python, Java, and C++ agents link to GridLAB-D, bulk system, and large-building simulators

HELICS Interfaces to Domain Simulators

- Growing mix of tools
- Enable large-scale interdependency all-hazards studies: scale to 100,000+ domain simulators
- Diverse simulation types:
  - Continuous, discrete event, time series
  - Steady-state/dynamic/transient
  - Any energy system
- Support standards: HLA, FMI, …

Not exhaustive lists.



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Additional Information

GridLAB-D Resource page:

https://www.gridlabd.org/

GridLAB-D Source Code:

https://github.com/gridlab-d/gridlab-d

GridLAB-D Wiki:

http://gridlab-d.shoutwiki.com/wiki/Main_Page

Thank you for attending our webinar

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Upcoming Webinar

Enabling High Penetrations of Distributed Solar through the Optimization of Sub-Transmission Voltage Regulation

Thursday, March 28, 1-2pm ET

In this webinar, Nader Samaan, a power systems engineer and the lead for PNNL's Grid Analytics team, will present CReST-VCT and how it works in a real-world use case for Duke Energy.

Read more and register at: www.cesa.org/webinars