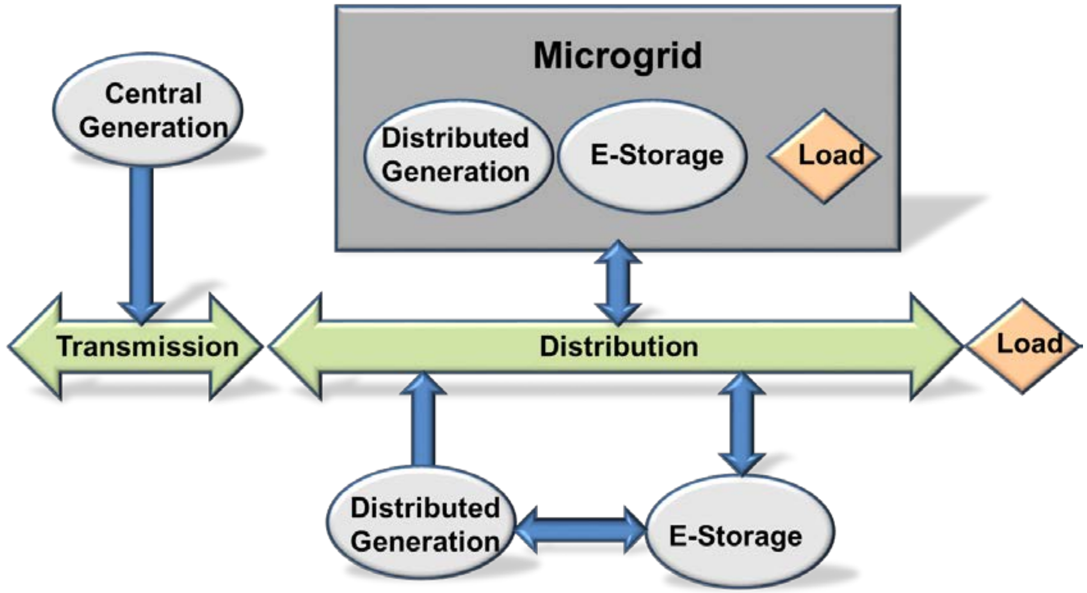
Driving Innovation ♦ Delivering Results



Commercial & Government Microgrids Summit, San Diego, CA
October 20-22, 2015

Selected DOE OE Microgrid Programs

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Topics

Newest

Oldest

- Design Support Tool for Remote Off-Grid Microgrid Projects
- Microgrid Controller R&D Projects
- DOE OE ARRA Microgrid Demonstrations

Design Support Tool for Remote Off-Grid Microgrid Projects

Research Call to DOE National Laboratories

Scope of Work

"…seeking a design support tool that is capable of providing decision support analysis on AC and DC microgrids to meet user-defined objectives and constraints for costs and energy system security"

- Remote community defined as distant, isolated, populated area
  - Limited or no accessibility to distributed power system
  - High cost of electricity due to transporting fossil fuels
- Develop, test, & transition the design support tool into practice
- Expandable to include grid-connected; AC-DC hybrids; and transient dynamics for microgrid survivability

Phase 1 – Development of prototype tool (12 months)

Two projects at $750K per project

Phase 2 – Test and transition tool (12 months with 6 mo. of testing)

One project at $1M

Research Call to DOE National Laboratories

Performance Specifications for Design Support Tool

Architectures	AC and DC
User objectives	Minimize capital cost; maximize NPV
Operational constraints	Fuel will not be depleted before next delivery Reserves must account for renewable/load fluctuations
Energy system security	All load is served under normal operation All critical load is served with loss of single power source
Approximations and relaxations	Sufficient to understand impact on or limitations of microgrid design
Design sensitivity	Quantify sensitivity to a change in sizing of generation and storage
Power flow modeling	Properly assess N-1 security criterion

Awards

- **Two selections for $750K each announced on September 15, 2015**

  LBNL – Continue development of Distributed Energy Resources Customer Adoption Model (DER-CAM)

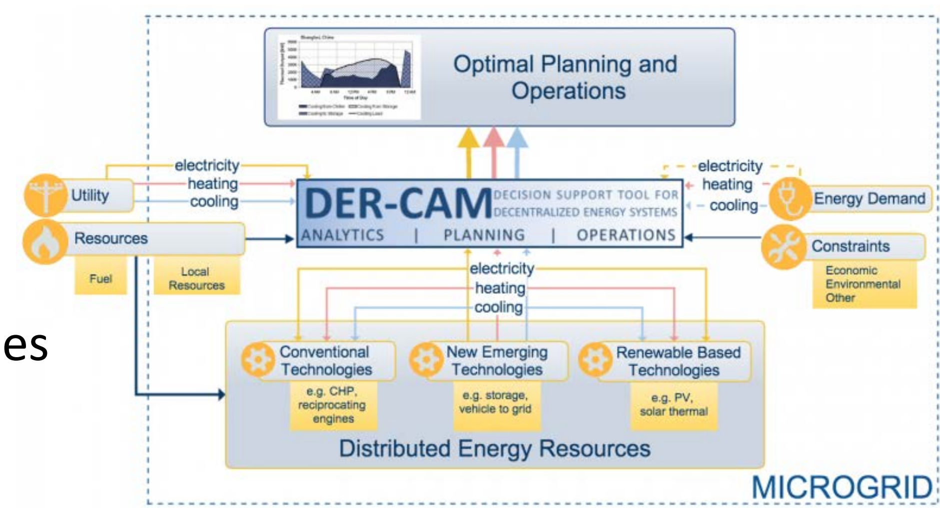
With Project Partners:

ORNL – Three proven tools: ORNL Geospatial Viewer (OGV); Microgrid Integrated Energy and Financial Model (MIEFM); Toolkit for Hybrid Systems Modeling and Evaluation (THYME)

With Project Partners:

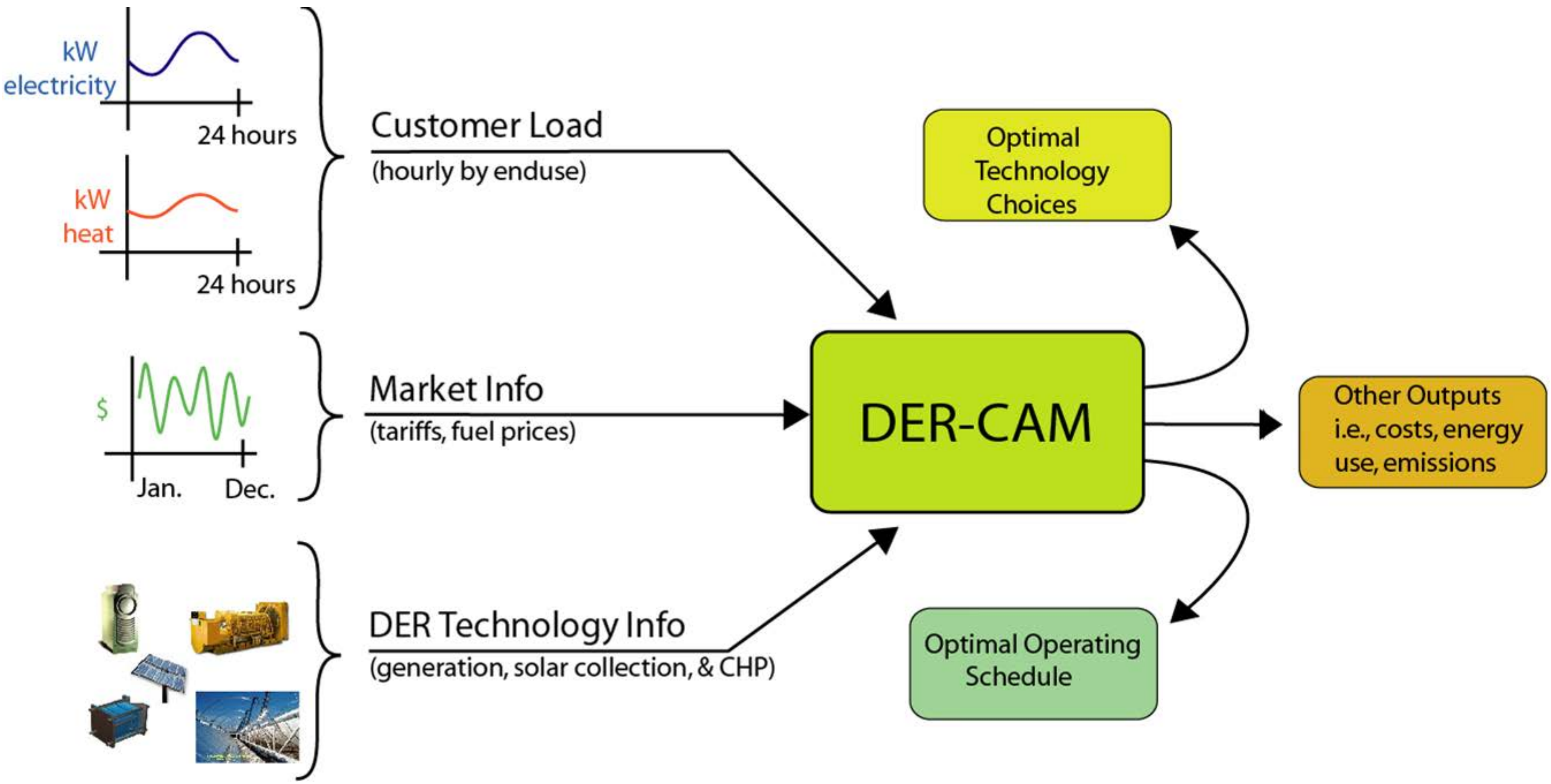
LBNL

- **Distributed Energy Resources Customer Adoption Model (DER-CAM)**
- **Adapt DER-CAM for:**
  - DC or AC microgrids
  - Multiple economic objectives
  - Constraints on fuel availability
  - Active and reactive power flow
  - Component part-load efficiencies
  - Data visualization capabilities



- **Develop component library**

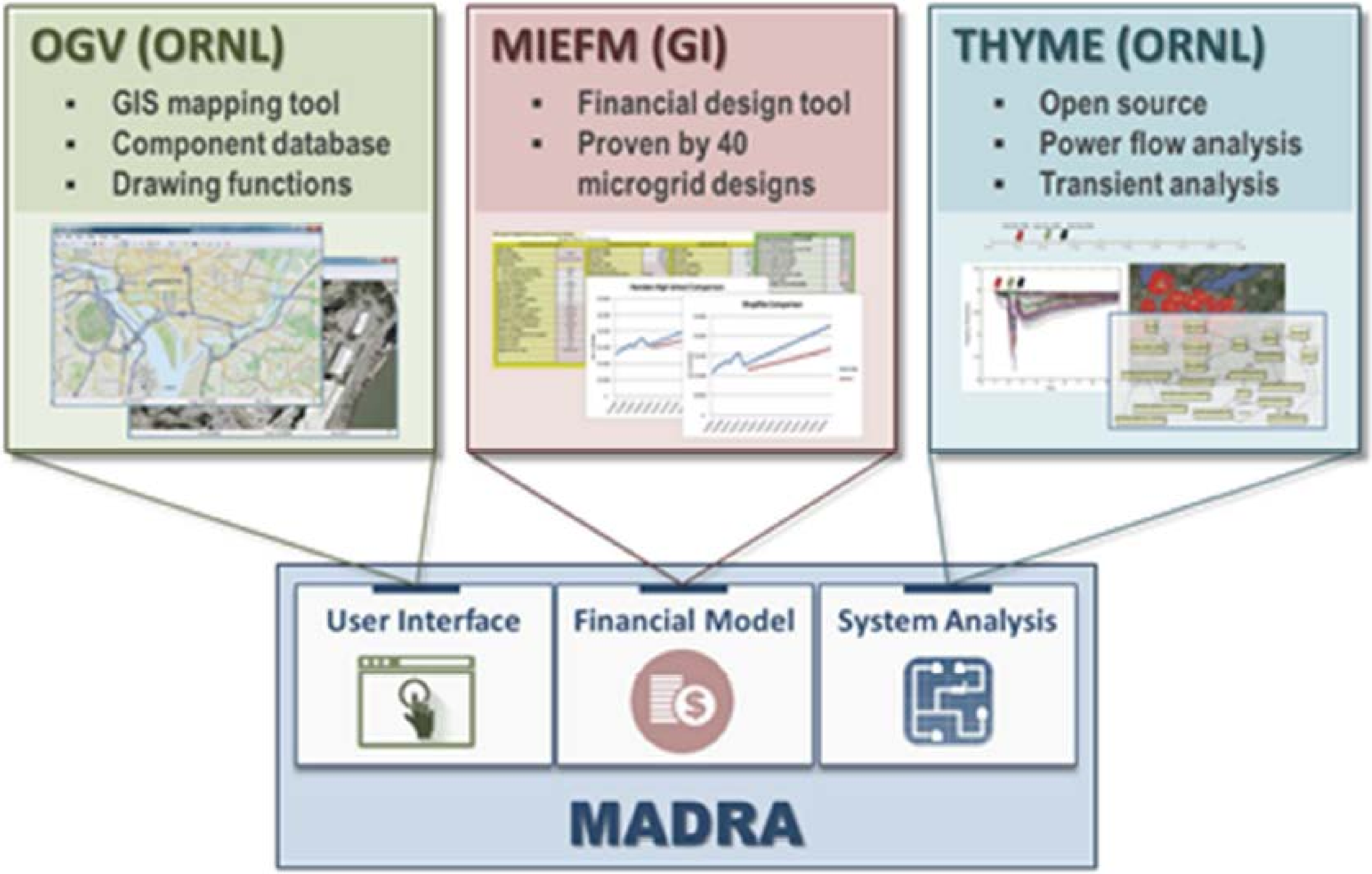
Distributed Energy Resources Customer Adoption Model (DER-CAM)



ORNL

- **Microgrid Assisted Design for Remote Areas (MADRA)**
  - ORNL Geospatial Viewer (OGV)
  - Toolkit for Hybrid Systems Modeling and Evaluation (THYME)
  - Microgrid Integrated Energy and Financial Model (MIEFM)
- **Evaluate financial feasibility and optimize microgrid design**
  - Determine capacity of each technology
  - Determine installation and operating costs
  - Determine present value of future energy cost
  - Aims to minimize capital cost or maximize present value
  - Considers constraints in resources and power flow & N-1 security
- **Four remote communities in Alaska and one in Hawaii as primary sites**

Microgrid Assisted Design for Remote Areas



Microgrid Controller R&D Projects

Objectives

- **R&D of advanced commercial-grade microgrid controllers**
  – 1 to 10 MW of aggregated generation capacity

- **Testing and validation**
- **Enable communities to develop commercial-scale microgrids**
- **Improve resiliency of electric power infrastructure**
  - " building stronger and safer communities and infrastructure" (President's Climate Action Plan)
  - prepare for impacts of climate change (E.O. 13653)

DOE Microgrid Targets

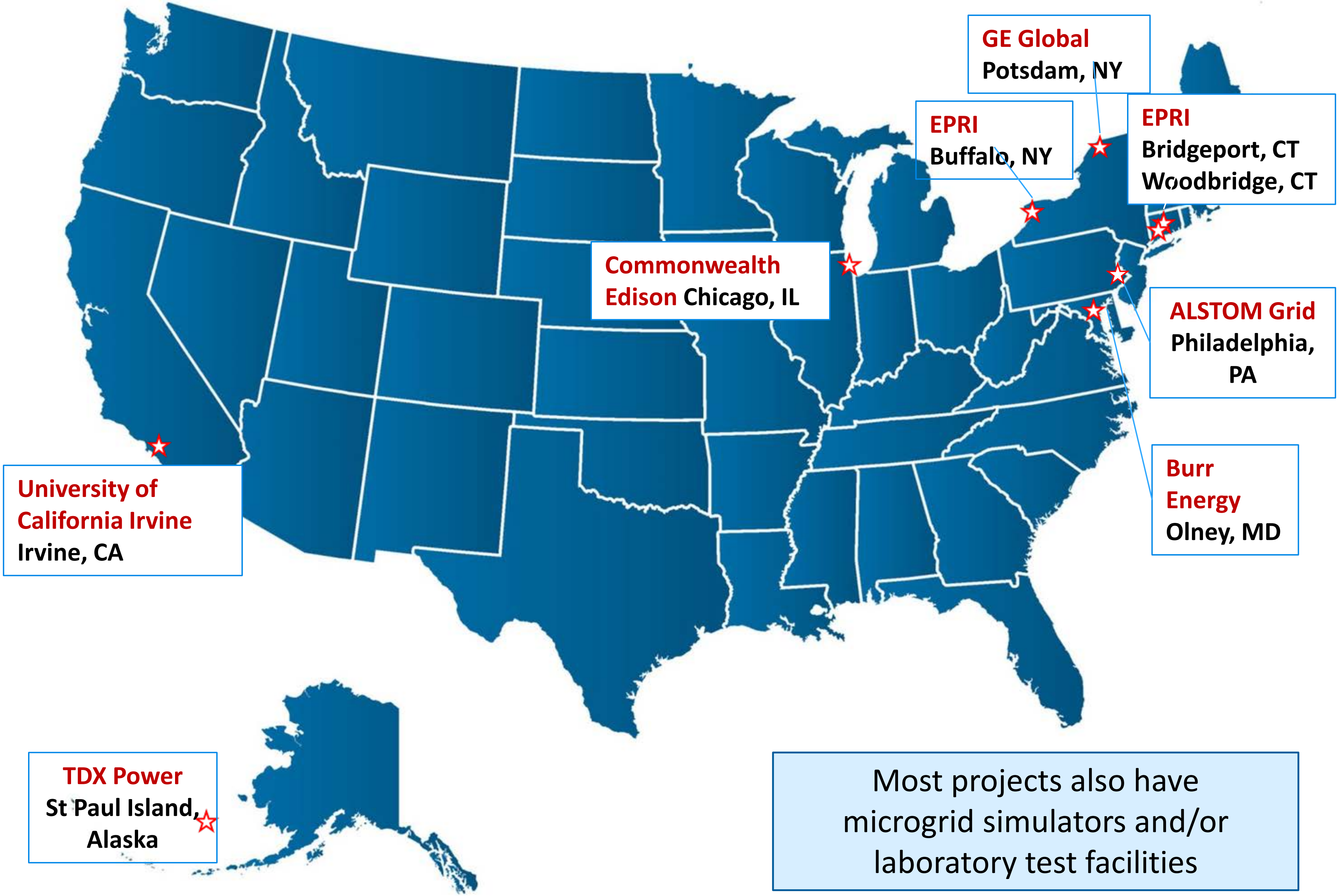
- **> 98% reduction in outage time of critical loads at a cost comparable to non-integrated baseline solutions (e.g., UPS with backup generator)**
  - Basis for outage reduction is SAIDI
  - Baseline cost is UPS, generators, automated transfer switches, installation costs, and O&M costs

- **> 20% reduction in emissions**
  - Basis for emissions in carbon dioxide
  - Determined by simulation
- **> 20% improvement in system energy efficiencies**
  - CHP

Technical & Functional Requirements for Microgrid Controller

- **Capable of sensing grid conditions & monitoring and controlling microgrid operation to maintain electricity delivery to critical loads**
  - Grid-connected, islanded, and transition between both
  - Comply with IEEE 1547 interconnections standards
  - Dispatch microgrid assets
  - Interface with external parties
  - Coordinate with grid protection schemes
  - Requirements for disconnection; resynchronization & reconnection; steady-state frequency, voltage, and power quality; protection; dispatch; and resilience

Locations of Microgrid Controller Projects



Most projects also have microgrid simulators and/or laboratory test facilities

Generation and Energy Storage Resources

Microgrid Characteristics	Demand Response	CHP	Storage	Renewables	Fuel Cell	Hydro	PEV Charging
Alstom Grid	✓	✓	✓	✓	✓		
Burr Energy	✓	✓	✓	✓			✓
Commonwealth Edison	✓	✓	✓	✓	✓		✓
EPRI		✓	✓	✓	✓	✓	
General Electric Company	✓	✓	✓	✓		✓	
TDX Power		✓	✓	✓			
University of California	✓	✓	✓	✓	✓		✓

Total Program Power: 83 MW (7-30 MW range; 7.5 MW average)

Nameplate Renewables: 5.4 MW (Photovoltaic and Wind)

Energy Storage: 5.5 MW

Combined Heat and Power (CHP): 44 MW

Fuel Cell: 13 MW

Generation Portfolio

Project/Gen/Storage	Gas Turbines	Steam Turbines	Recip	Fuel Cell	Firmed Renewables	Unspecified	Total
Alstom Grid	0	0	0	0.6	1	9.403	11.003
Burr Energy	0	0	0	0	0.085	0.915	1
Commonwealth Edison	16	0	0	1.2	0.148	0	17.348
EPRI-Integrid	0	0	1.8	0	0	0	1.8
EPRI-Woodbridge	0	0	5.16	1.8	0	0	6.96
EPRI-Woodbridge; Alternative 2	2	0	2.2	1.8	0	0	6
EPRI-Bridgeport	0	0	0	0	0	0	0
EPRI-BNMC	6	0	3.9	0	0	0	9.9
General Electric Company	3	0	0	0	2	0	5
TDX Power	0	0	6.4	0	0.16	0	6.56
University of California	13.5	5.5	0	11.4	2	0	32.4
	38.5	5.5	10.3	13.2	5.393	10.318	83.211

Unique Features of Microgrid Controller Projects

Types of Generation/Storage

- Biogas plant
- Hydroelectric power
- Combined heat and power
- Fuel cell
- Flywheel

Types of Services

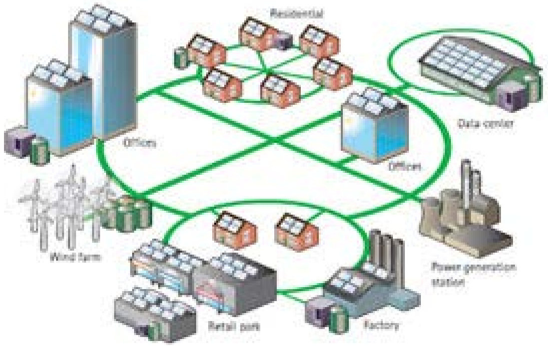
- Power quality management
- Ancillary services (e.g., frequency and voltage regulation)
- Emergency demand response
- 100% guaranteed supply of power

Types of Infrastructure

- Underground distribution feeders
- Nested microgrid

Status of Microgrid Controller Projects

- Started simulations
- Analyze existing circuits (e.g., load profile)
- Started to define functional requirements microgrid
- Started to design microgrid and microgrid controller
- Started stakeholder interactions
- Develop test plans
- Develop approach to analyze microgrid performance (e.g., cost, emissions)
- Developed energy and financial models
- Address policy and regulatory factors, rate designs, and business models
- Analyze use cases and scenarios impacting designs
- Clarify application of IEEE 1547 requirements



DOE OE ARRA Microgrid Projects

DOE-OE ARRA Primary Microgrid Field Projects

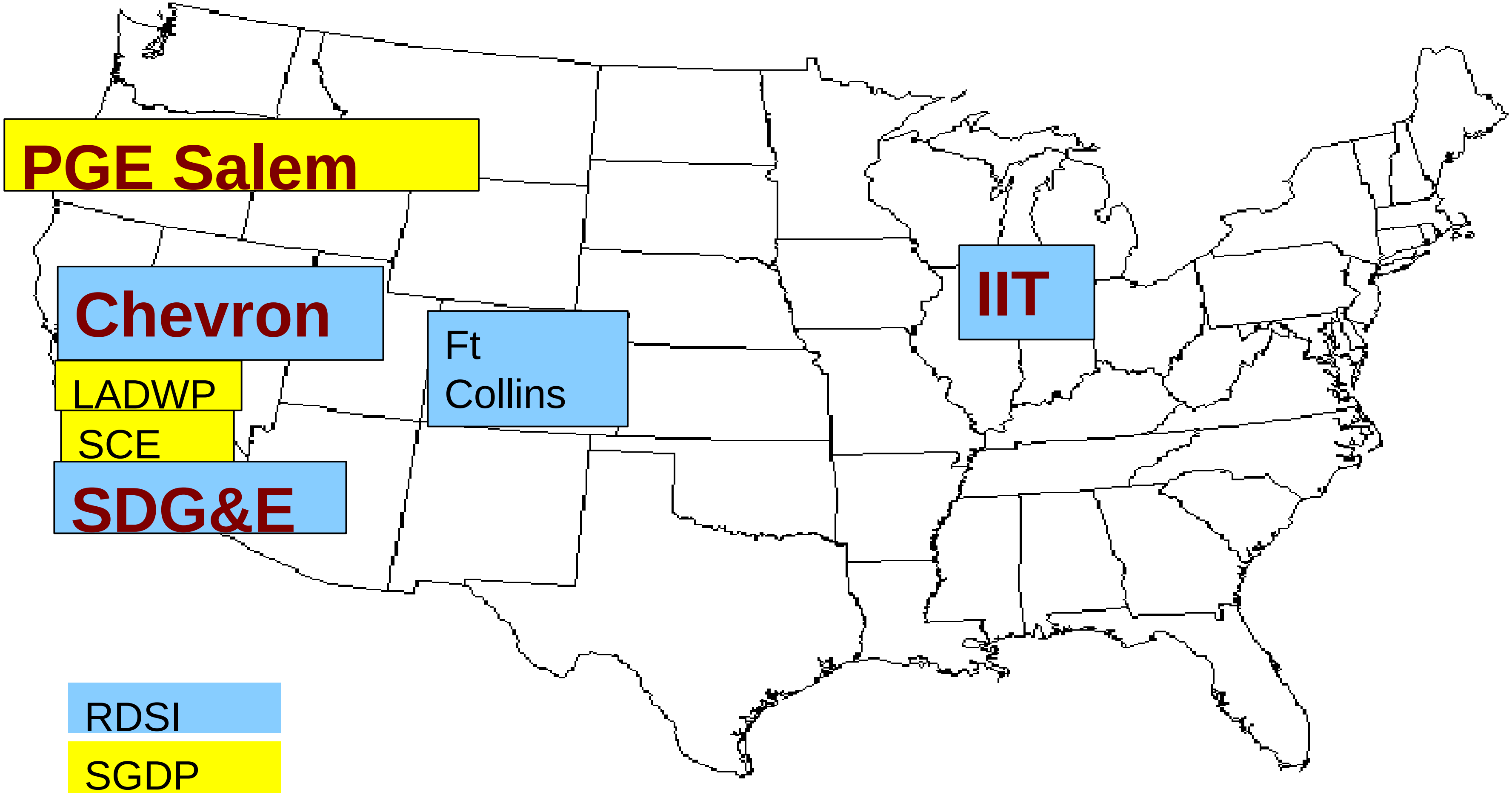
RDSI Projects

- Chevron Energy Solutions — Santa Rita Jail
- Illinois Institute of Technology — Perfect Power
- San Diego Gas & Electric — Borrego Springs Microgrid

SGDP Project

- PGE Salem Microgrid (part of Battelle–Pacific Northwest Smart Grid Demonstration)

DOE OE ARRA Primary Microgrid Project Locations



Common Areas Evaluated

Performance Features

- Reduce peak load
- Improve reliability
- Enable integration of renewables
- Enhance security and resiliency
- Increase consumer engagement
- Improve system efficiencies
- Create economic value

Microgrids Work

The technical viability of microgrids was demonstrated

All four projects demonstrated by operating in islanding mode that a microgrid can deliver substantial value in terms of reliability and security to the customers within the microgrid footprint. In general, the operation of the CBMs was more sophisticated than the operation of the UDMs as they optimized operations economically and environmentally in addition to improving reliability and resiliency.

CBM =Customer Based Microgrids

UBM = Utility Distributed Microgrids

Storage Systems are Complex

The nascent nature of advanced energy storage systems requires extra attention

The continued evolution of energy storage systems requires extra effort on the part of microgrid developers to ensure they have a complete understanding during the design, procurement, installation, commissioning and operational phases for these systems. Often the vendors for battery systems and inverter systems are different creating potential issues at the interface of the two systems.

Negawatts are Helpful

Load shedding capability is an important microgrid resource

The ability to shed load rapidly (noncritical loads) or using direct load control is a valuable resource when transitioning to and operating in island mode. Load shedding provides rapid response during transients, particularly during an unplanned separation from the main grid.

The use of customer incentive based DR for load shedding was not shown to be reliable enough to act as a load shedding resource.

Need "Someone in Charge"

A supervisory level controller (MMC) is essential for supporting microgrid operation

Real time response to load changes and transients is best done locally at the microgrid resource. A higher level control system is needed to re-dispatch the microgrid resources periodically to ensure their optimal participation. The need for a supervisory level of control is essential for CBMs that actively operate 24/7 to optimize performance.

Need an "Off the Shelf MMC"

The limited availability of a commercial MMC is a barrier to future microgrid development

The development of standardized MMC technologies that support interoperability with the many possible microgrid resources and legacy systems is needed. In addition, an architecture that enables microgrid developers and operators to easily program microgrid-specific algorithms is needed.

Check the Regulations

[Regulations impacting the installation and operation of microgrid resources should be fully researched early in the planning and design phase]

Changing regulations can impact the operation of microgrid resources in ways that may limit their value as a resource. For example, restrictions on when diesel generators may operate may prevent them from responding to economic dispatch signals. Other limitations may exist for wind turbine generators and power electronics.

Are Microgrids a Good Deal?

Microgrids do not have a positive business case except in special cases

The following conditions may be needed to give microgrids the potential for achieving a positive business case:

- Large portion of DER portfolio requirements are pre-existing
- Opportunity exists to defer large capital investments
- Cost of utility supplied energy is very high
- Significant production tax credits or investment tax credits exist that apply to the DER portfolio
- A method is created for valuing (monetizing) increased resiliency and reliability

What is Resiliency Worth?

A mechanism for monetizing the value of resiliency and improved reliability is needed to support microgrid business cases

The greatest value provided by microgrids is resiliency and improved reliability. But standard methods do not exist for monetizing these benefits which often results in a non-compelling business case for many microgrids. The inability to monetize these substantial benefits is a barrier for future microgrid development.

Use Cases

Development of use cases during the design and planning phase is a good practice

The use case development process can be helpful in identifying interfaces and impacts that need to be addressed in the planning and design phase to meet project objectives. Identifying and addressing these issues early can prevent costly rework later on.

Integration of Renewables

Advanced energy storage resources in conjunction with the MMC give microgrids the capability to integrate renewables at two levels

The first level is to integrate and manage the intermittency and variability of renewable resources within the microgrid footprint. The CBMs accomplished this. The second level is to assist in the integration of renewables outside the microgrid footprint or not owned by the microgrid owner. This can be done as an ancillary service by CBMs or as part of distribution system operations by UDMs. Both UDMs were able to support the operation of renewables on their systems.

Contact Information

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Some Key Microgrid Resources:

DOE OE www.oe.energy.gov

Smart Grid www.smartgrid.gov

DOE Microgrid Workshops:
www.e2rg.com/reports