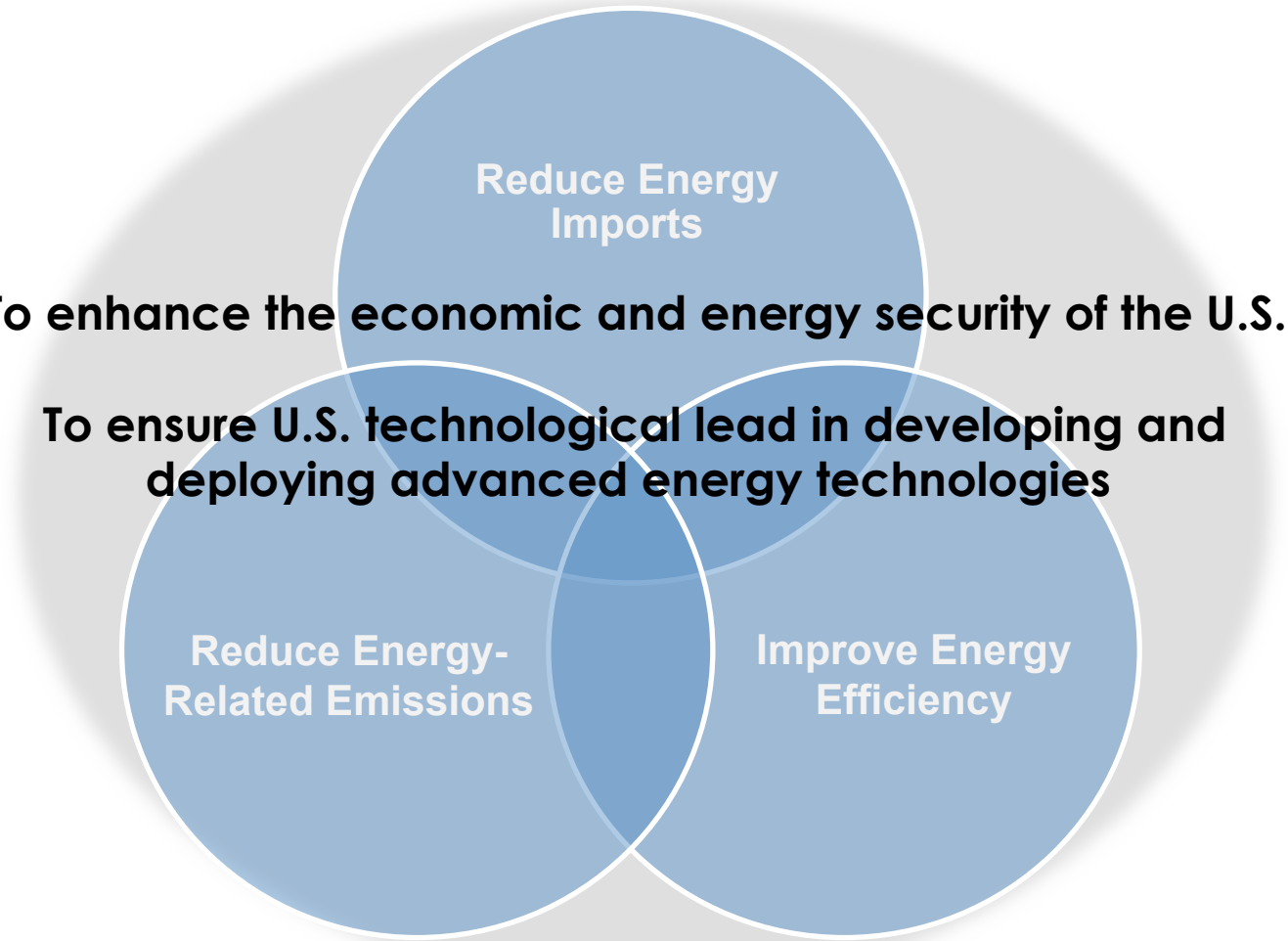
ARPA-E Investments in a More Flexible Grid

Tim Heidel
Fellow
ARPA-E

ARPA-E Mission



- Find and fund high-risk, high-impact projects
- Invest in the best ideas and teams
- Will tolerate and manage high technical risk
- Accelerate translation from science to markets
- Proof of concept and prototyping

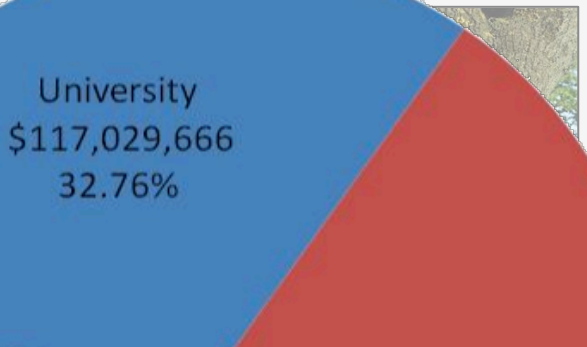
ARPA-E Portfolio

Broad Solicitation

Transportation

Electrofuels

PETRO



End-Use Efficiency

HEATS

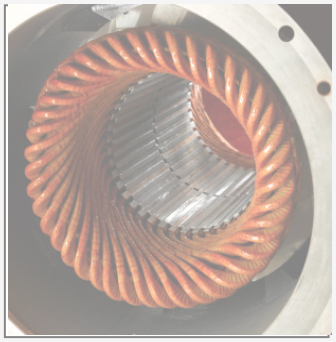
BEETIT

IMPACCT

$1/Watt

ENI

REACT



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What makes an ARPA-E project?

1. Impact

- High impact on ARPA-E mission areas
- Credible path to market
- Large commercial application

2. Transform

- Challenges what is possible
- Disrupts existing learning curves
- Leaps beyond today's technologies

3. Bridge

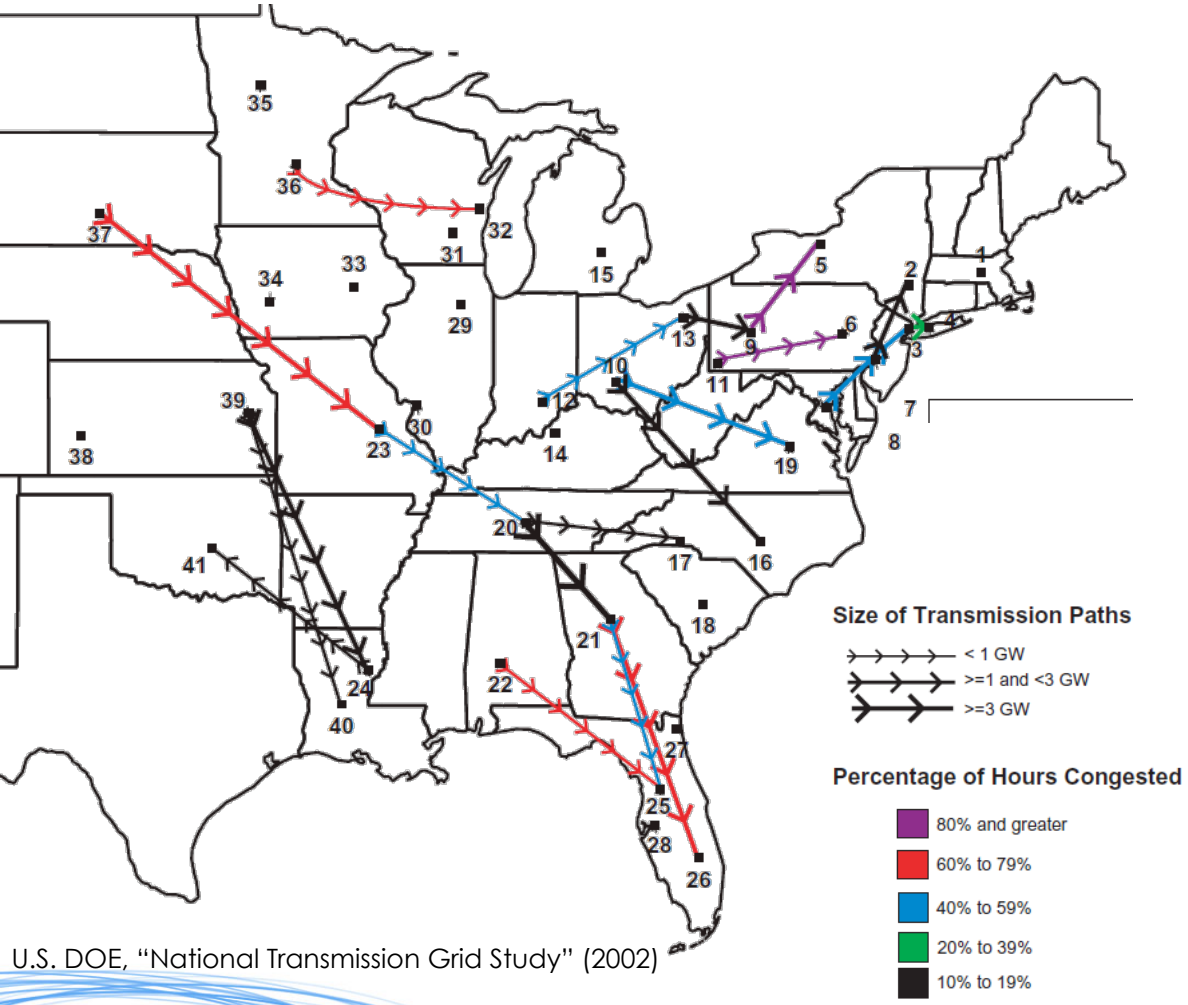
- Translate science into breakthrough technology
- Not researched or funded elsewhere
- Catalyzes new interest and investment

4. Team

- Best-in-class people
- Cross-disciplinary skill sets
- Translation oriented

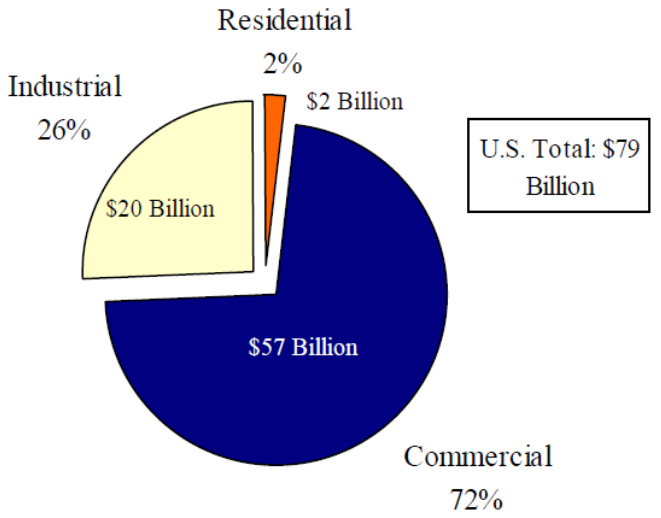
State of the U.S. grid

Congested Paths in the Eastern Interconnection



U.S. DOE, "National Transmission Grid Study" (2002)

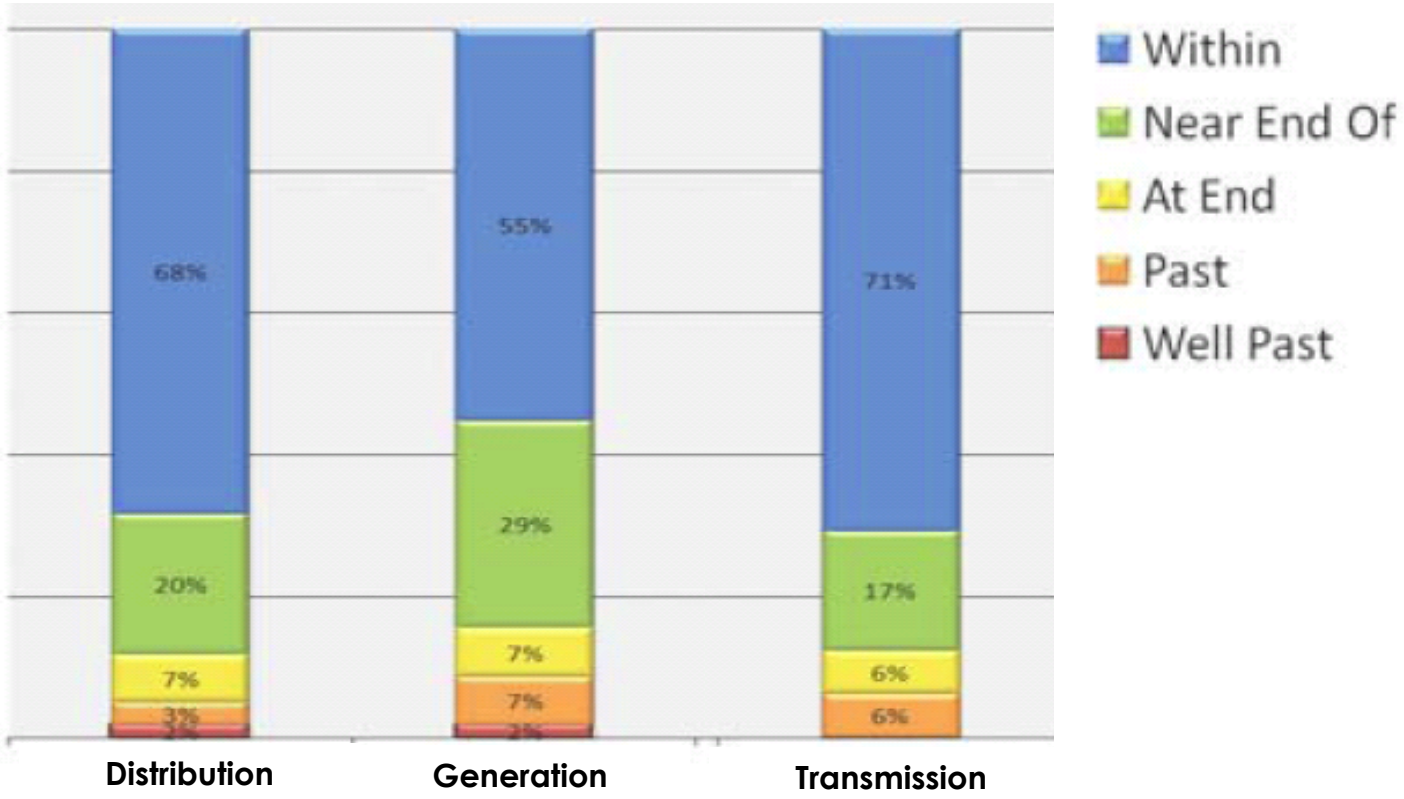
Annual Cost of Power Interruptions



Hamachi LaCommare and Eto, LBNL, "Understanding the Cost of Power Interruptions to U.S. Electricity Consumers," (2004)

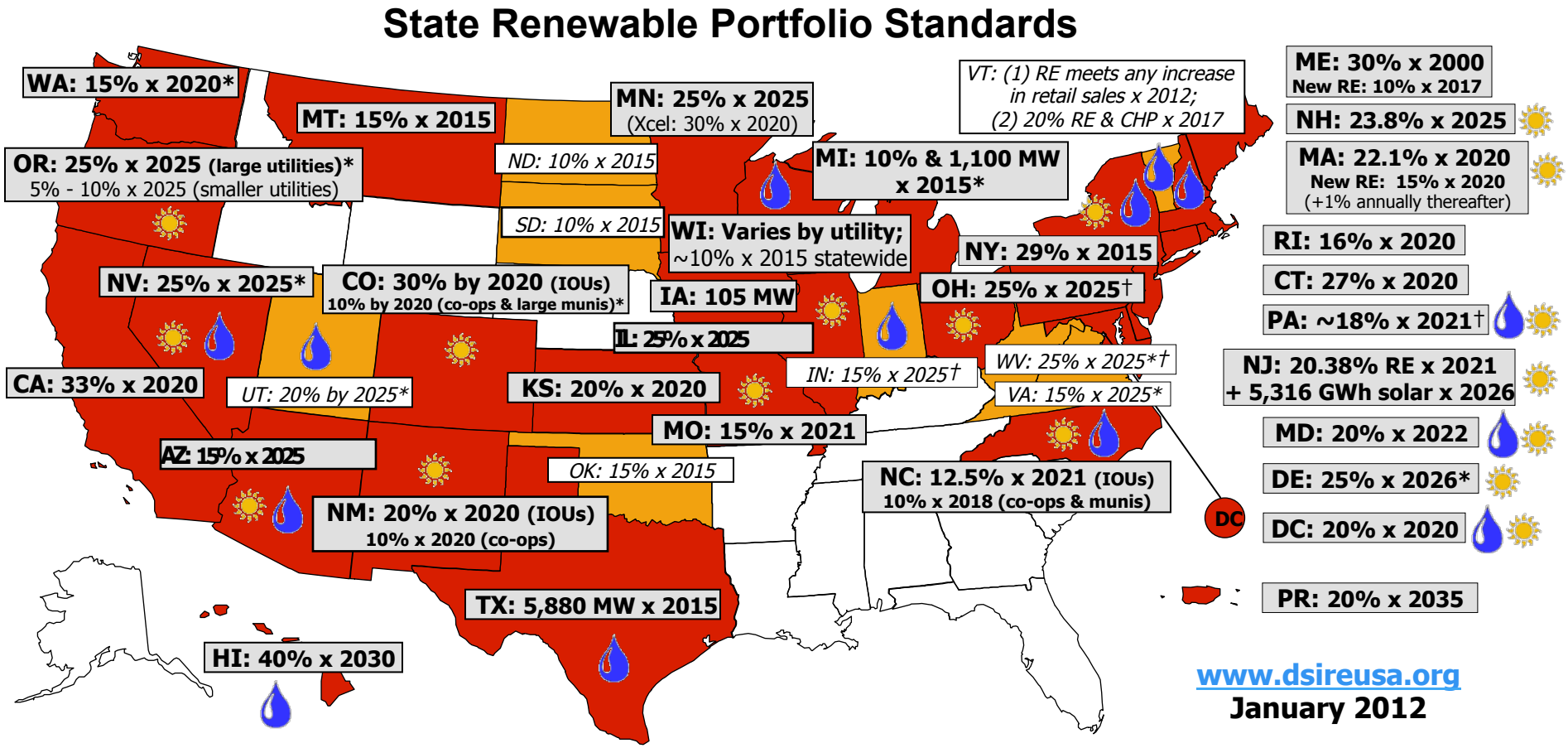
Huge Opportunity for New Technology Adoption

Existing infrastructure lifetimes

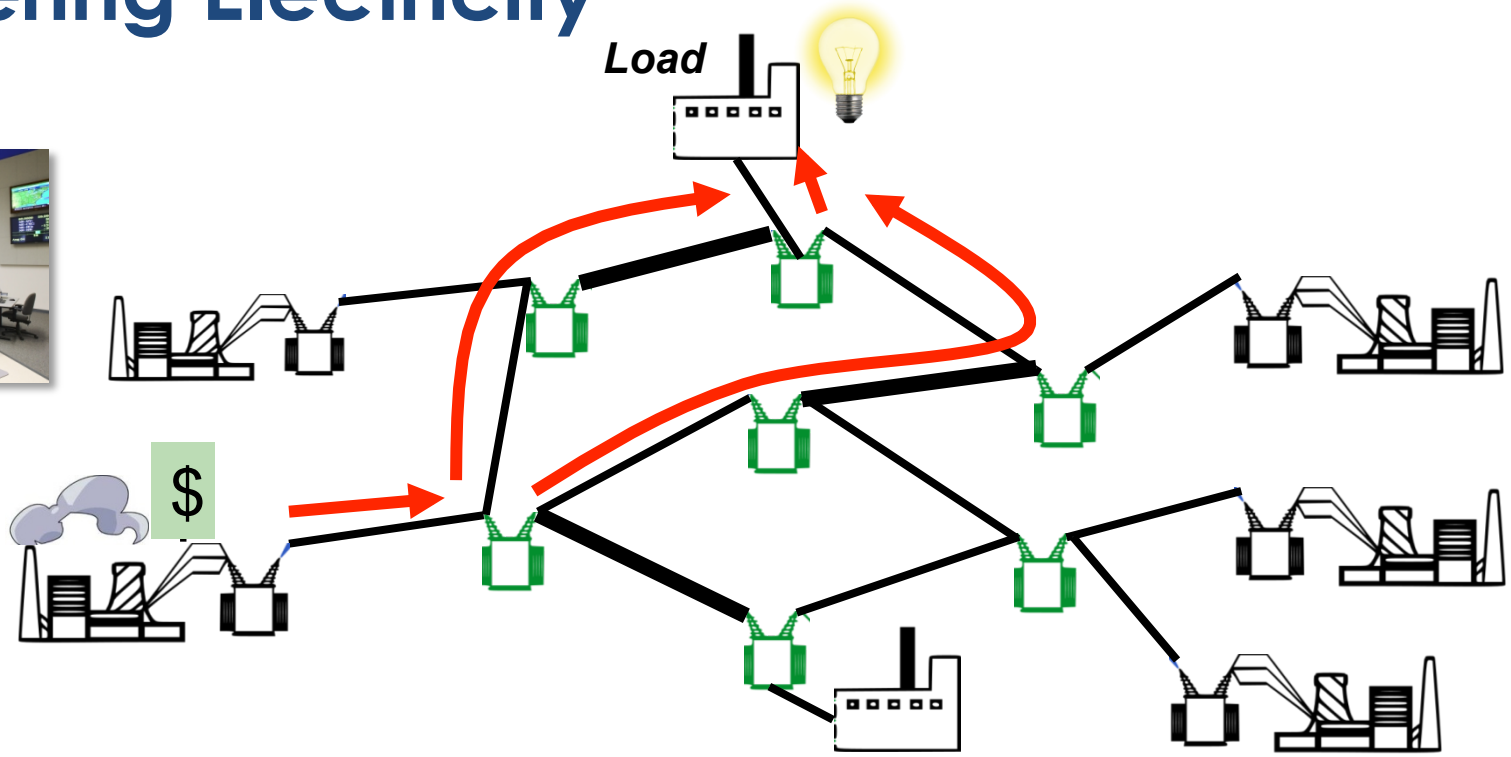


Black & Veatch, "2009/2010 Fourth annual strategic directions In the electric utility industry survey."

Substantial growth of non-dispatchable generation



Delivering Electricity



As demand varies…

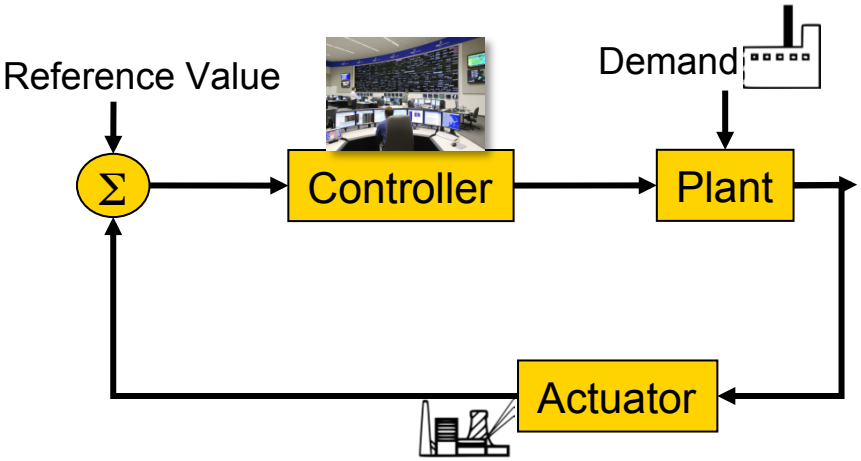
…day-ahead & spot markets coordinate generation

…generators startup/shutdown and spin up/down

…power flows are inversely proportional to path impedances

…loads draw power from the grid.

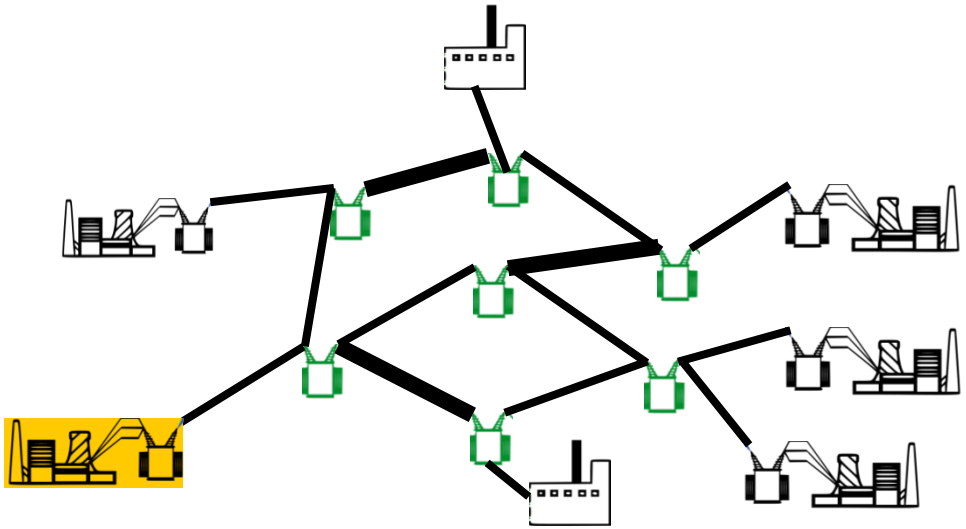
Delivering Electricity: Actuators



Responsive Demands

Scheduling demand (eg. industrial loads)

Mobilizing large numbers (100k) of small assets



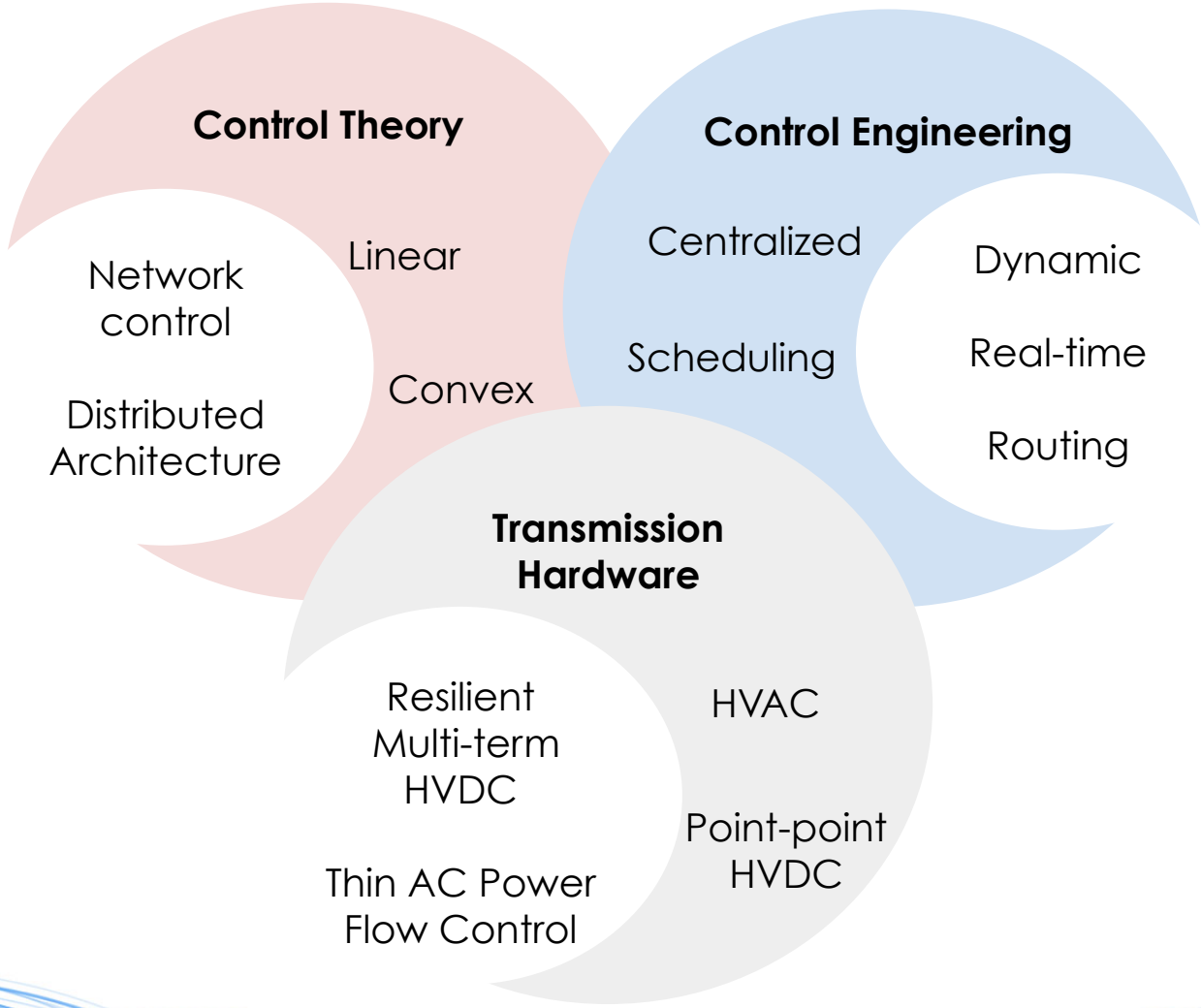
Control in the Grid (Routing Power)

Flexible AC Transmission Systems

Storage

Make renewables dispatchable

December 2010 Workshop Results



Advanced Research Projects Agency • ENERGY

GENI

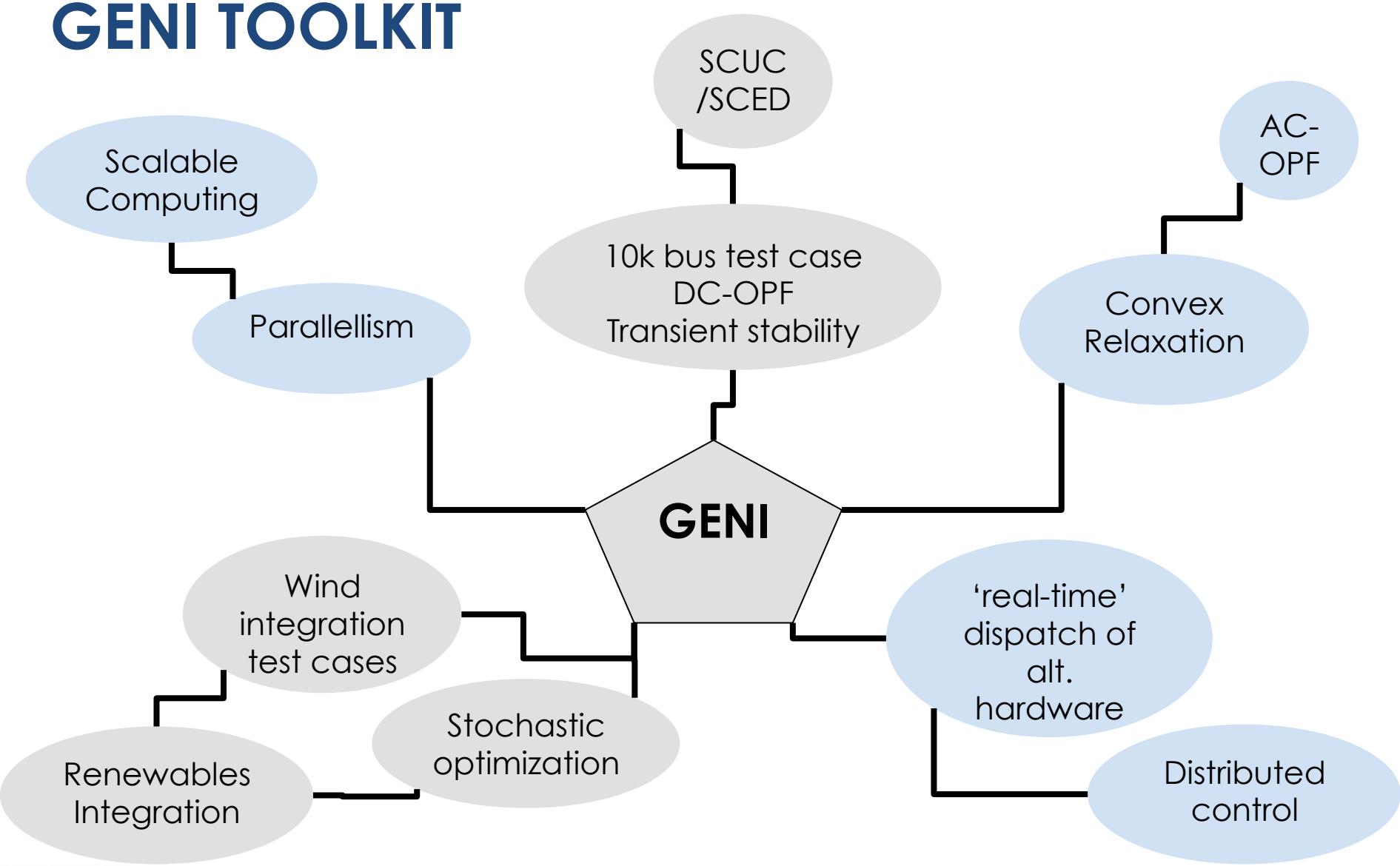
GRID HARDWARE & SOFTWARE

PROJECTS:	15	FUNDING YEAR:	2011
TOTAL INVESTMENT:	$39.4 million	PROGRAM DIRECTOR:	Dr. Rajeev Ram
PROJECT DETAILS:	www.arpa-e.energy.gov/ProgramsProjects/GENI.aspx		

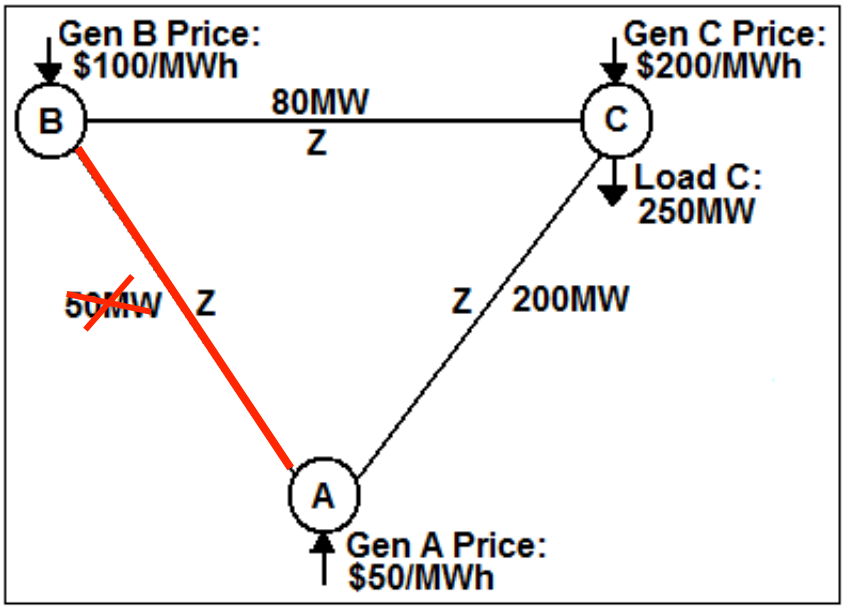
Hardware advancements to more efficiently direct the flow of power on the grid, help stem energy losses, and enable the grid to be more responsive and resilient.

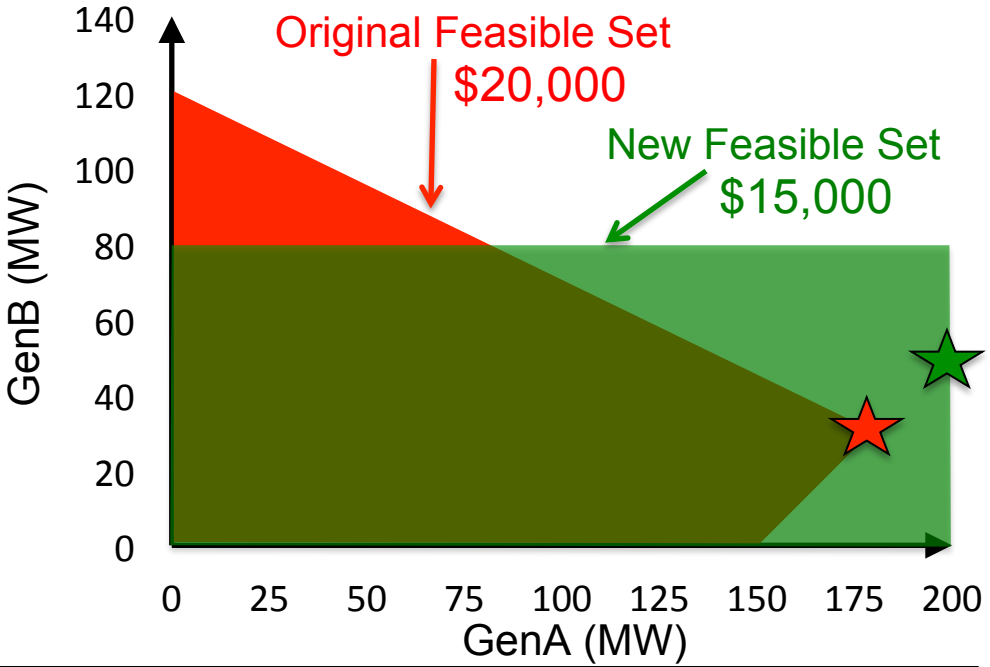
Software technologies to leverage advances in computing and data communications to optimize grid operations, match power delivery to real-time demand, and find effective ways to manage renewable power sources and grid-level power storage.

GENI TOOLKIT



Transmission Topology Optimization





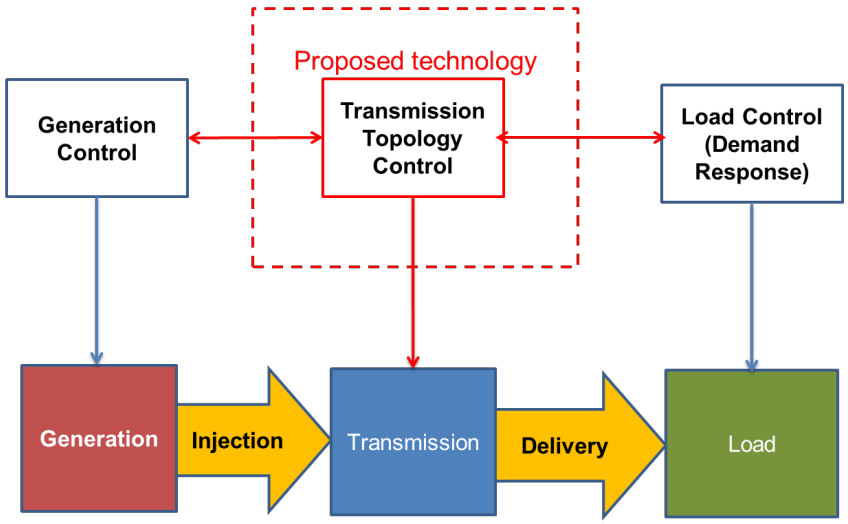
Potential Impact Example:

- ISO-NE: 689 generators, 2209 loads, 4500 bus, 6600 binary variables
- Topology control (DC-OPF) to optimize state **of only 4** transmission lines
- Solution Time: 82 hrs [CPLEX on dual-core 3.4GHz, 1GB RAM]
- **Savings 5% for summer peak conditions/ 7% for a medium load summer condition.**

Hedman, K. W., O'Neill, R. P., Fisher, E. B., and Oren, S. S. (2011), "Smart flexible just-in-time transmission and flowgate bidding," IEEE Transactions on Power Systems,Feb 2011.

Implementation of TC in the entire US electrical grid could save of $1-2 billion in generation costs per year and reduce transmission investments needs.

Transmission Topology Optimization



LAWRENCE LIVERMORE NATIONAL LABORATORY
Science and Technology in the National Interest

ASU Arizona State University

OAK RIDGE National Laboratory

GRID PROTECTION ALLIANCE

Berkeley University of California

TVA

Telcordia

Charles River Associates	Project management, algorithms, impact assessments, integration, commercialization
Boston University	Optimization algorithms, market design issues
Tufts University/ Northeastern University	Express algorithms for voltage and transient stability analysis
Polaris Systems Opt./ Paragon Decision Technology	Software implementation
PJM Interconnection	Operation and implementation consulting and review

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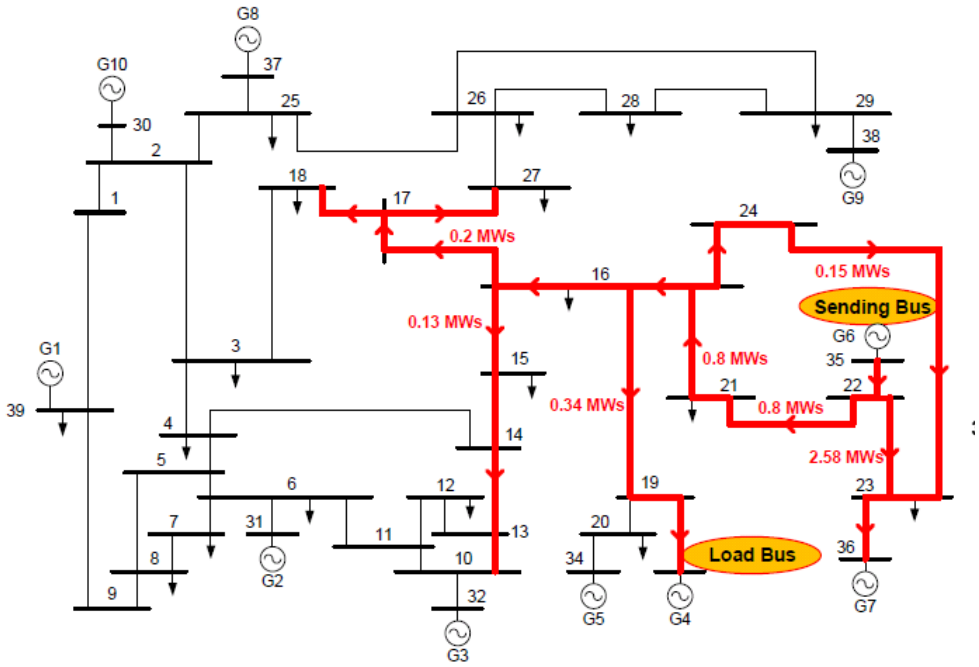
Routing Power

Today: Uncontrolled Flows



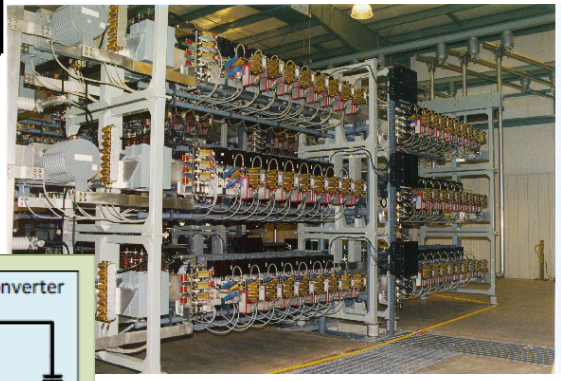
Power Routing

Potential Impact Example:

- GA Tech study of simplified IEEE 39 Bus system with 4 control areas.
- Operation simulated for 20 years, 20% RPS phased in over 20 years, sufficient transmission capacity added each year to eliminate curtailment of renewable generation.)
- Power flow control to route power along underutilized paths → 80% less new transmission infrastructure required.

AC Universal Power Flow Controller

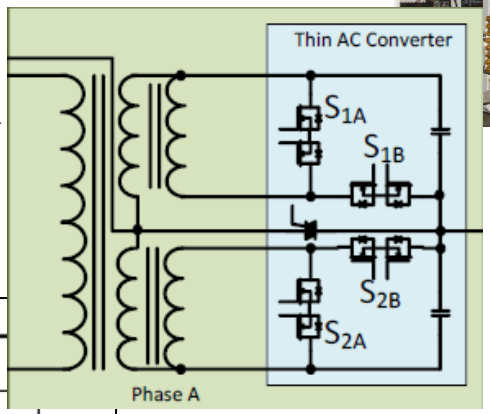
NYPA UPFC

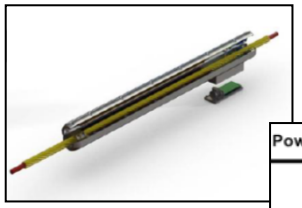


$140-300/kVA

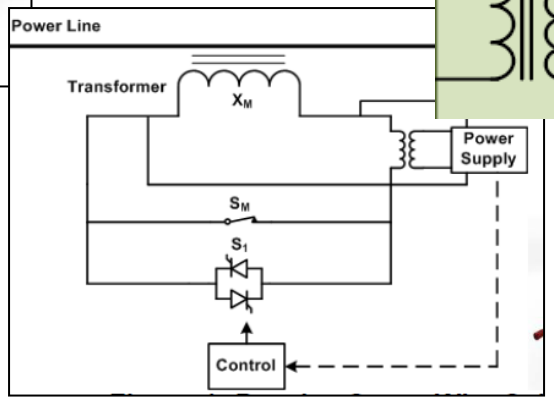
Fractionally rated electronics

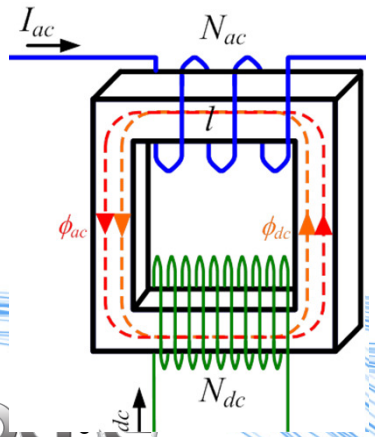
Varentec
$20-30/kVA



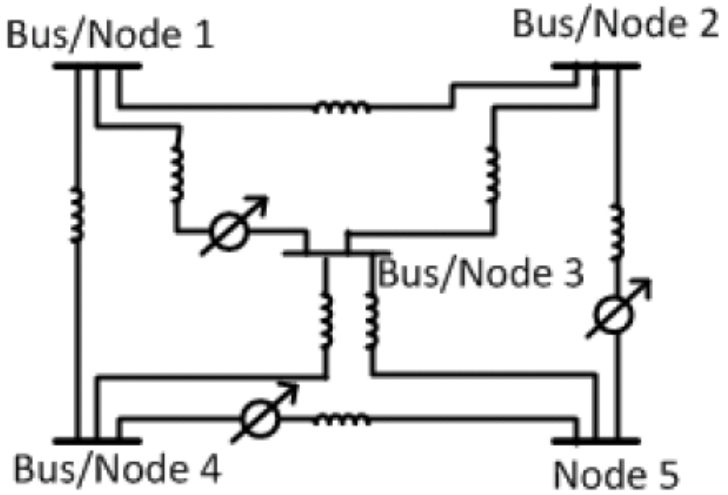


Smart Wire Grid
$36k-60k/mile





ORNL
$4/kVA



Cloud Computing for the Power System

Strong reliability guarantees are rarely required in commercial cloud computing software and hence not supported, but are crucial for increasingly stressed grids facing renewable integration. This project will develop a comprehensive suite of software with such strong guarantees to enable the next generation of control software while not requiring power engineers to become experts in reliable computing and cyber-security.

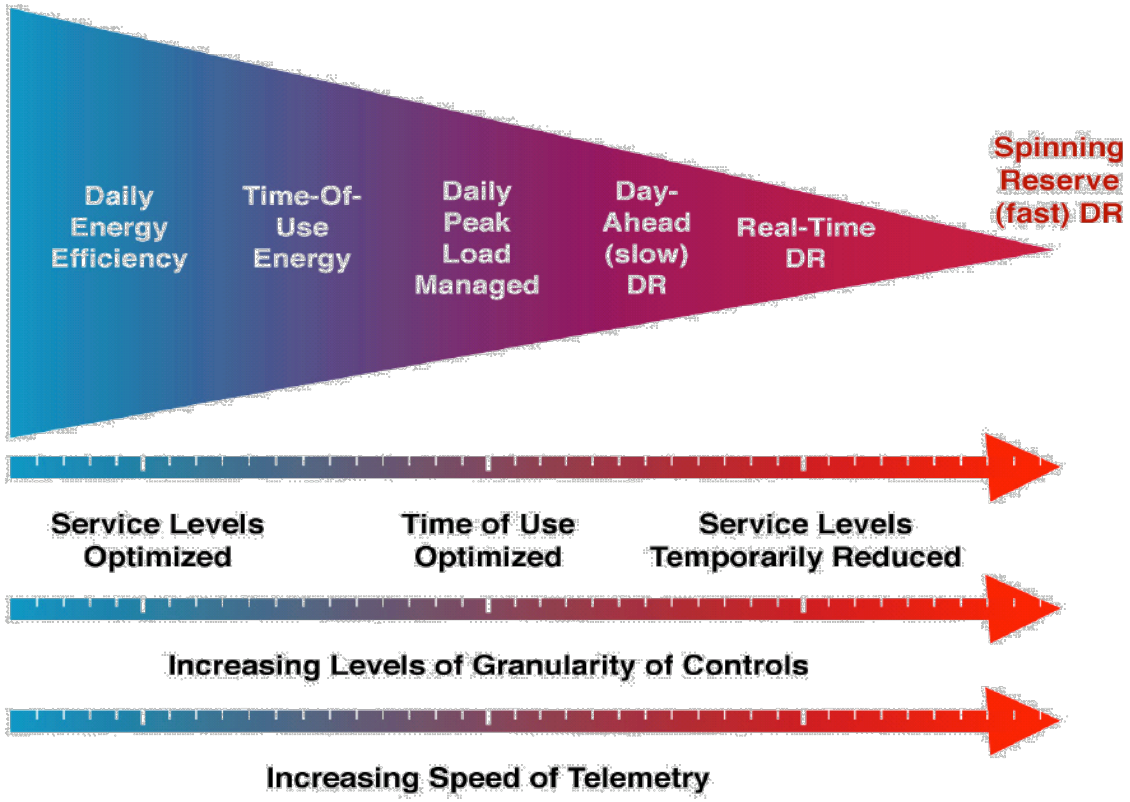
Cornell University

WASHINGTON STATE UNIVERSITY

Potential Impact

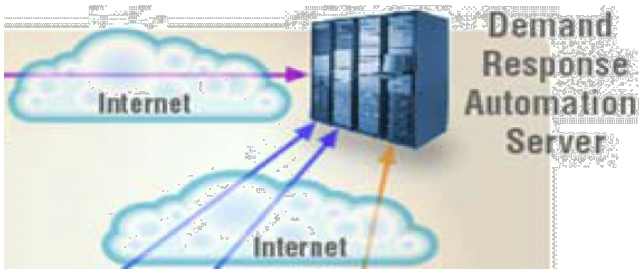
- Slash time and difficulty to prototype and demo new smart-grid control paradigms
- Enable networked control software to be used to build fault-tolerant, scalable actuation logic
- Enable a new kind of cloud-computing "hosted service" tailored to the properties of emerging smart-grid uses
- Enable robust and timely delivery of large amounts of synchrophasor and other data
- Simulation validation of all above

Highly Dispatchable and Distributed Demand Response for Integration of Distributed Generation



COLUMBIA UNIVERSITY
DIGITAL KNOWLEDGE VENTURES

BERKELEY LAB



• OpenADR, IP-based telemetry solutions, and intelligent forecasting and optimization techniques to provide "personalized" dynamic price signals to millions of customers in timeframes suitable for providing ancillary services to the grid

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Questions?

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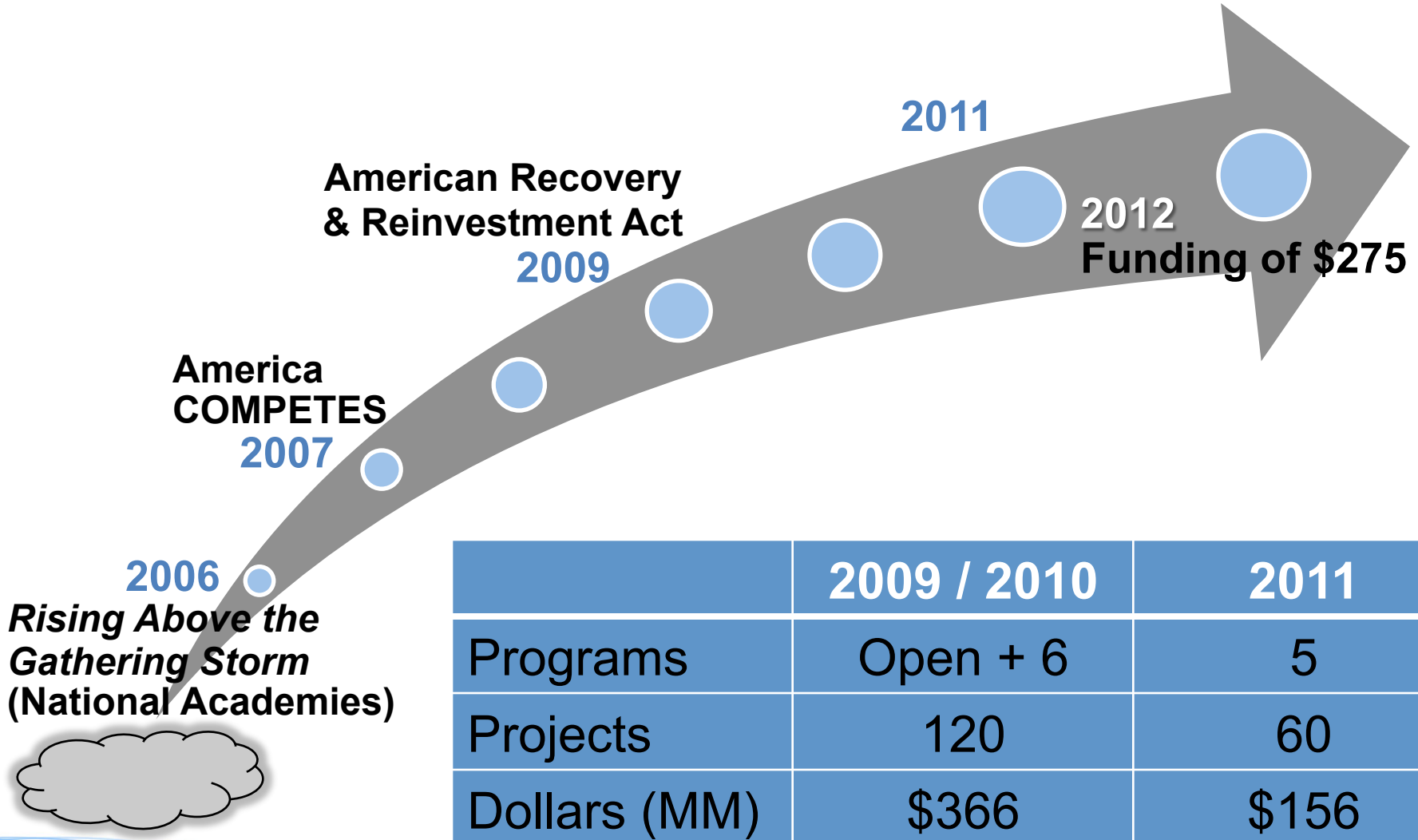
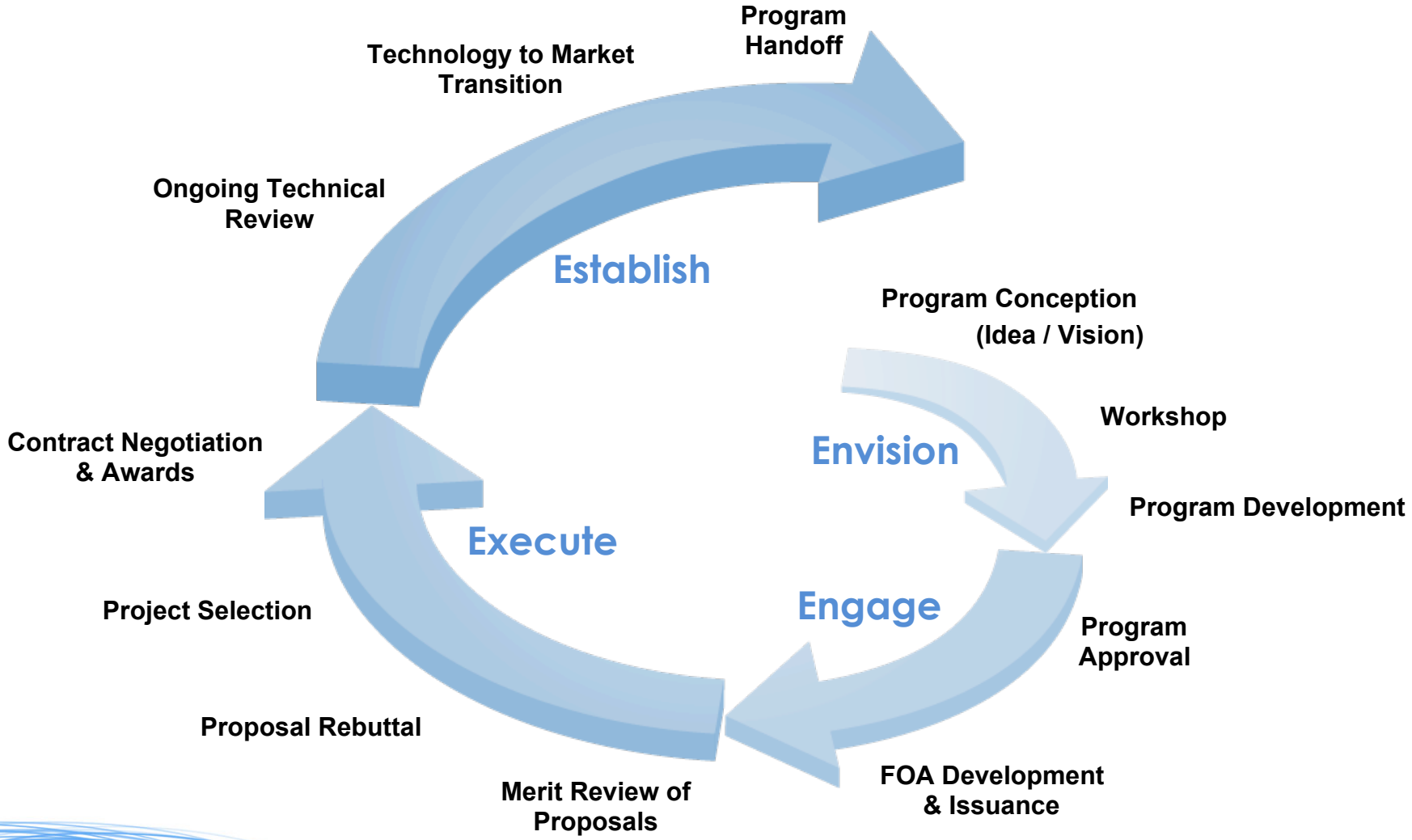
ARPA-E's History



	2009 / 2010	2011
Programs	Open + 6	5
Projects	120	60
Dollars (MM)	$366	$156

ARPA-E's program development process is extremely fast



Creating New Learning Curves