Electricity Grid of the Future

Program Director: Dr. Sonja Glavaski
Outline

- ARPA-e Overview
- US Energy Landscape
- DERs and Grid Integration
- Grid of the Future (Vision & Long Term Goals)
- Going Forward
The ARPA-E Mission

Catalyze and support the development of transformational, high-impact energy technologies

Ensure America’s

- National Security
- Economic Security
- Energy Security
- Technological Competitiveness

Reduce Imports

Improve Efficiency

Reduce Emissions
A Brief History of ARPA-E

- **2007**
  - *America COMPETES Act* signed, authorizing ARPA-E

- **2009**
  - *American Recovery & Reinvestment Act* signed, providing $400M to establish ARPA-E

- **2014**
  - Over $900M invested in 362 projects funded
  - 22 projects have attracted >$625M in private-sector funding
  - 24 new companies formed
  - >16 projects partnered with other agencies for further development

---

Funding Distribution (Lead Institution)

- **Universities**: 35%
- **Small Businesses**: 37%
- **Large Businesses**: 19%
- **National Labs**: 6%
- **Non-profits**: 3%
Outline

› ARPA-e Overview

› **US Energy Landscape**

› DERs and Grid Integration

› Grid of the Future (Vision & Long Term Goals)

› Going Forward
US Grid of Today: Generation

Average efficiency:
- Coal: 32.5%
- Nuclear: 42.4%

Generation unit commitment and dispatch are done in merit order and subject to transmission system constraints.

EIA forecast total renewable energy output in 2040 to be 16%.

87% of electric energy comes from central-station thermal generation

25% of distributed generation is renewable

US Grid of Today – Fuel Sources & Emissions

2012 Generation Fuel

- Coal: 38%
- Natural Gas: 30%
- Nuclear: 19%
- Hydro: 7%
- Renewables: 5%
- Fuel Oil: 1%

EIA

2012 Emissions

- Electricity: 39%
- Industry: 32%
- Transportation: 9%
- Residential & Commercial: 14%
- Other: 6%

Emission estimates from the Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2012 - EPA

Improved energy efficiency in the electricity sector could significantly reduce CO$_2$ emissions
Total U.S. wind capacity reached 60 GW in 2012 (expected energy production of roughly a quarter of installed nuclear power)

Expansion of wind surpassed gas in capacity, not in expected energy production

30% Denmark (1st)
4.4% U.S. (12th)

LBNL
2012 Wind Technologies Market Report
The capacity of PV systems installed in 2012, 3.3 GW$_{DC}$, was more than 10-times the capacity of PV installed in 2008.

Continued growth is anticipated owing to state renewable portfolio standards (RPS) and decreasing system costs.

Photovoltaic arrays are being installed at costs similar to wind’s $3/W or less per panel.
29 states + Washington DC and 2 territories have Renewable Portfolio Standards (8 states and 2 territories have renewable portfolio goals).
Outline

- ARPA-e Overview
- US Energy Landscape
- DERs and Grid Integration
- Grid of the Future (Vision & Long Term Goals)
- Going Forward
Distributed Energy Resources (DERs)

- New DERs technology
  - Smaller power generation (CHP, fuel cells, residential PV)
  - Demand Response
  - Storage
  - PEVs
- Future electricity systems will consist of billions of smart devices and millions of interconnected decision makers.
- Deploying DERs in a reliable, and cost-effective manner while achieving system level efficiency and emission reduction requires complex integration with the existing grid.

DERs may reach 33% of US installed capacity by 2020; EIA, DOE, FERC
DERs Grid Integration

- Homogeneous bulk power grid is rapidly evolving into a composition of the old power grid and many loosely coupled local distribution grids and stand-alone micro-grids.
- Traditional top-down (VERTICAL) planning and dispatching of electric power from central station generators to end-use customers does not leverage DERs and is thus sub-optimal.
- Make Distributed Energy Resources (DERs) including power generation at distribution level part of the optimal system performance equation (FLAT).
Grid Challenges with DERs

**Grid Today**
- Dispatched generation
- Predictable load
- Voltage stability
- Capacity available

**Future Grid**
- Intermittent DG
- Stochastic loads
- Dynamics
- Capacity constrained

“We need to be able to respond an order of magnitude faster to be able to respond to grid dynamics”
Doug Kim, VP Technology, Southern Cal Edison
Outline

- ARPA-e Overview
- US Energy Landscape
- DERs and Grid Integration
- **Grid of the Future (Vision & Long Term Goals)**
- Going Forward
The Grid of the Future: From Vertical to Flat

- **Plug-and-play architecture** for seamless integration of DERs
- **Real-time adaptation** to power events and environmental changes enabling increased DERs penetration resulting in
  - Substantial decrease in CO₂ emissions
  - Increased thermal efficiency of central power fleet
- **Relaxing transmission limits** unlocking ability of DG and DERs to positively contribute to dynamic system recovery
Potential Grid Management Approaches

- **Network of micro-grids**
  - Locally supply power
  - Aim for independence
  - Grid supplies backup

- **ISO & IDSO**
  - ISO manages transmission & wholesale
  - IDSO manages distribution & retail
    - Mechanisms for retail generation

- **ISO & aggregators**
  - Corporation aggregate DERs
  - Aggregated DERs bid into bulk market
    - Regulation
    - Unit commitment
    - Planning

- **‘Top-to-bottom’ ISO**
  - Single entity manages entire grid
  - Very complex optimization problem
The Grid of the Future: Long Term Goals

- Demonstrate ability to enable at least 50% of generation from renewable energy, with 15% coming from distributed generation.
- Enable the reduction of CO$_2$ emissions from the electric grid by at least 15% (300 MT).
- Enhance system asset utilization (>90% REU) without reducing customers’ QoS or increasing operational costs.

Source: IREC: 2013 Annual Updates and Trends, October 2013
Grid of the Future Enabling Technologies

**Novel Capabilities**

- Dispatching both central plant and distributed generation
- Proactive shaping of load over all relevant time horizons
- Consumers and central stations (both with advanced coordination control systems deployed) adapt their operation to achieve system-wide energy efficiency and emissions targets

**Enabling Technologies**

- Distributed Sensing – new data streams
- Data Analytics – uncertainty management
- Decentralized Control – scalability, flexibility, and resiliency
Outline

‣ ARPA-e Overview

‣ US Energy Landscape

‣ DERs and Grid Integration

‣ Grid of the Future (Vision & Long Term Goals)

‣ Going Forward
Going Forward

- **Define architectures**: How will the future grid enable large scale Distributed Energy Resources (DERs) integration?
- **Identify technologies**: What developments in grid control and monitoring will increase grid reliability and efficiency?
- **Quantify adoption** penetration of new monitoring and control technology required to achieve long term goals.
- **Identify paths** to technology adoption and other initial markets.
- **Define benchmarking** platforms and processes for the technology developments.
Thank You!