Electricity Grid of the Future

Program Director: Dr. Sonja Glavaski

Outline

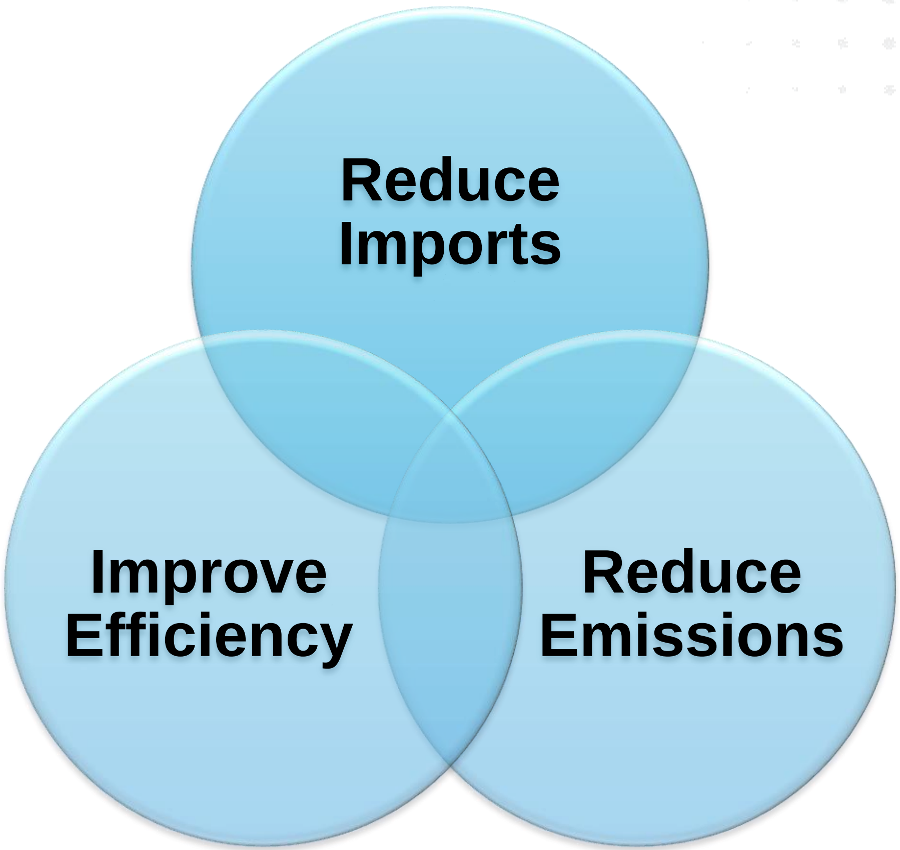
- **ARPA-e Overview**
- US Energy Landscape
- DERs and Grid Integration
- Grid of the Future (Vision & Long Term Goals)
- Going Forward

The ARPA-E Mission

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

Ensure America's

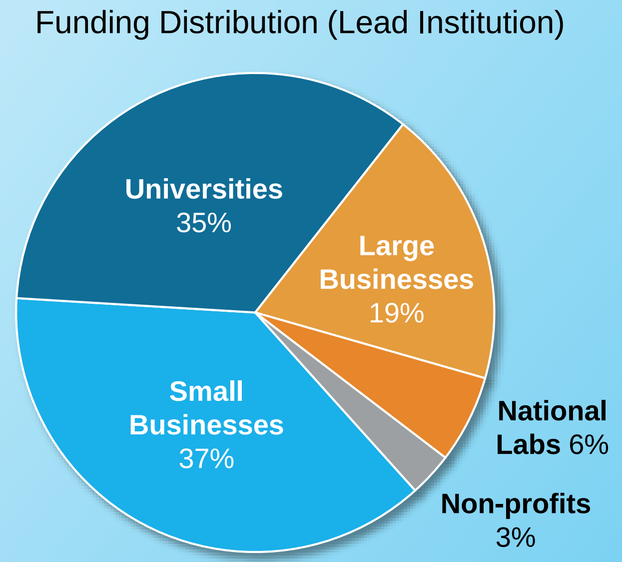
- National Security
- Economic Security
- Energy Security
- Technological Competiveness



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*

Investing in America's Best and Brightest



arpa·e
CHANGING WHAT'S POSSIBLE

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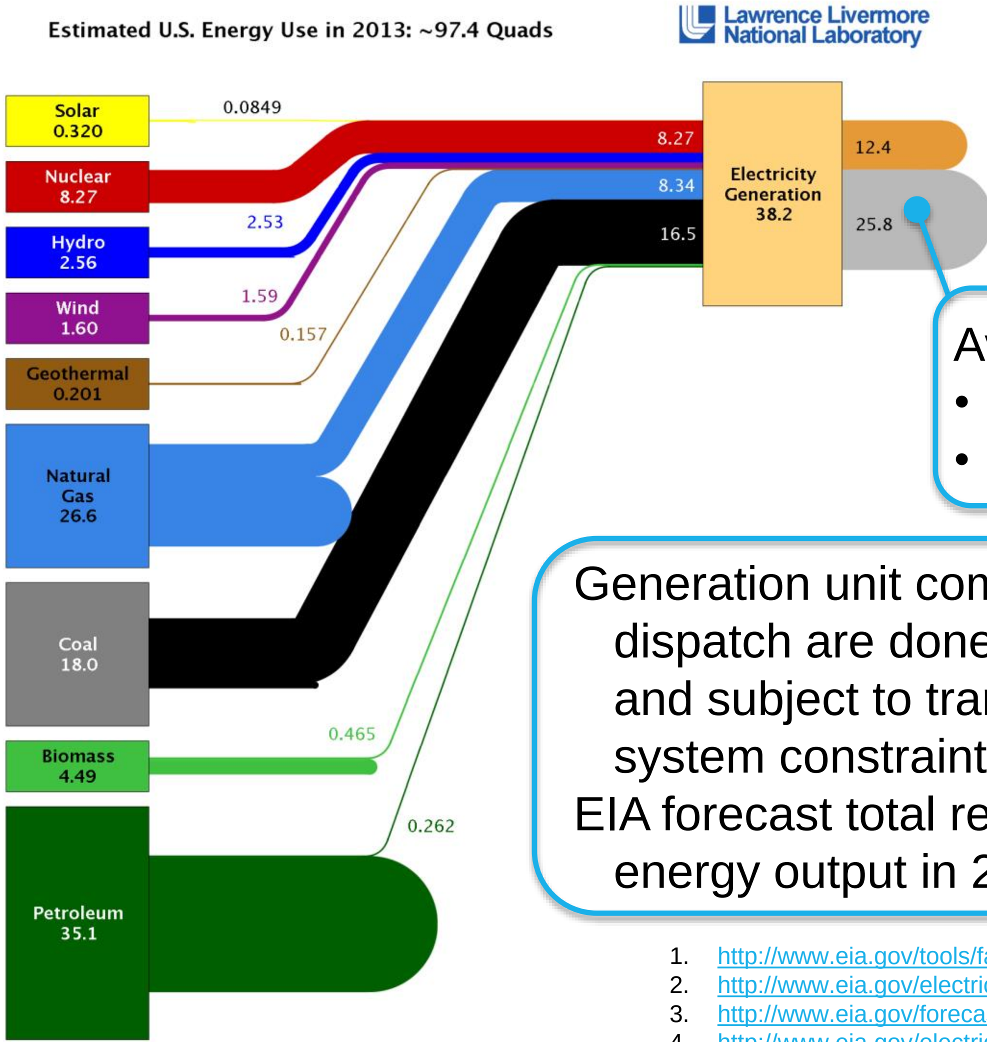
US Grid of Today: Generation



87% of electric energy comes from central-station thermal generation[1]

25% of distributed generation is renewable[4]

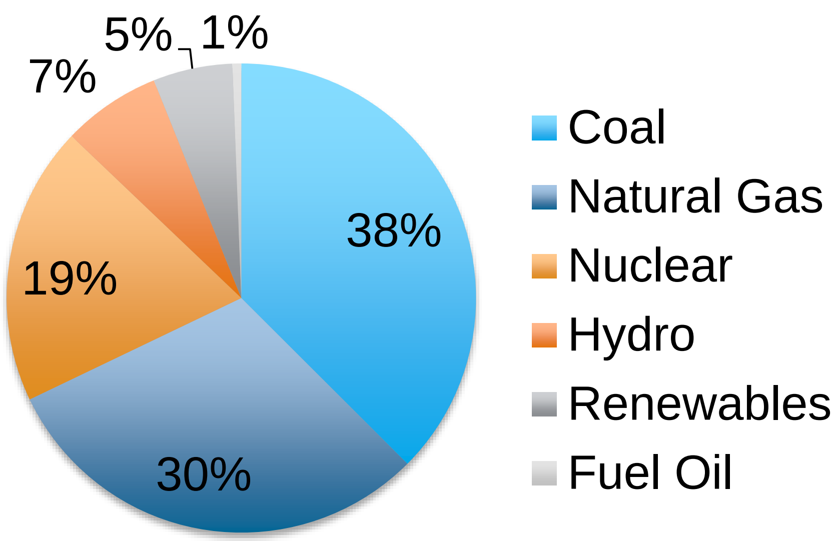
Average efficiency[2]:
- Coal: 32.5%
- Nuclear: 42.4%

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%.[3]

1. http://www.eia.gov/tools/faqs/faq.cfm?id=427&t=3
2. http://www.eia.gov/electricity/annual/html/epa_08_01.html
3. http://www.eia.gov/forecasts/aeo/pdf/0383(2014).pdf
4. http://www.eia.gov/electricity/annual/html/epa_04_09.html

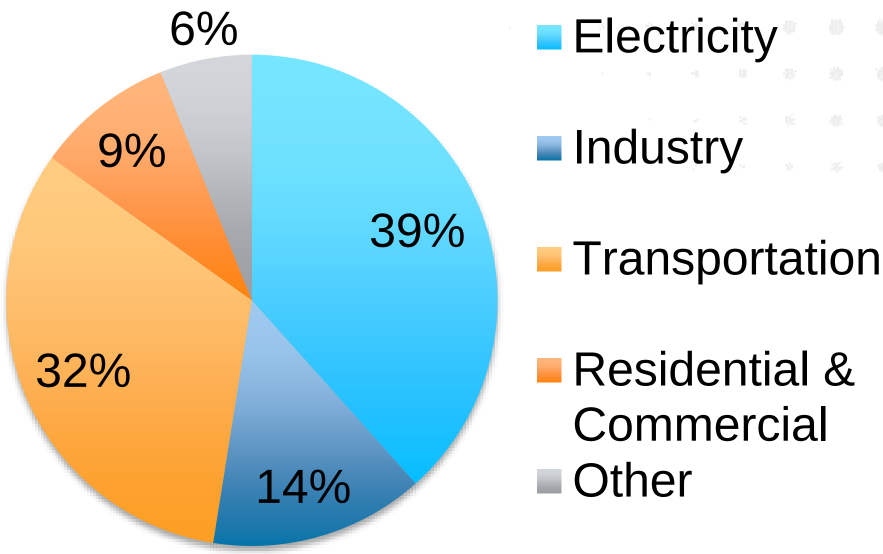
US Grid of Today – Fuel Sources & Emissions

2012 Generation Fuel



EIA

2012 Emissions



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

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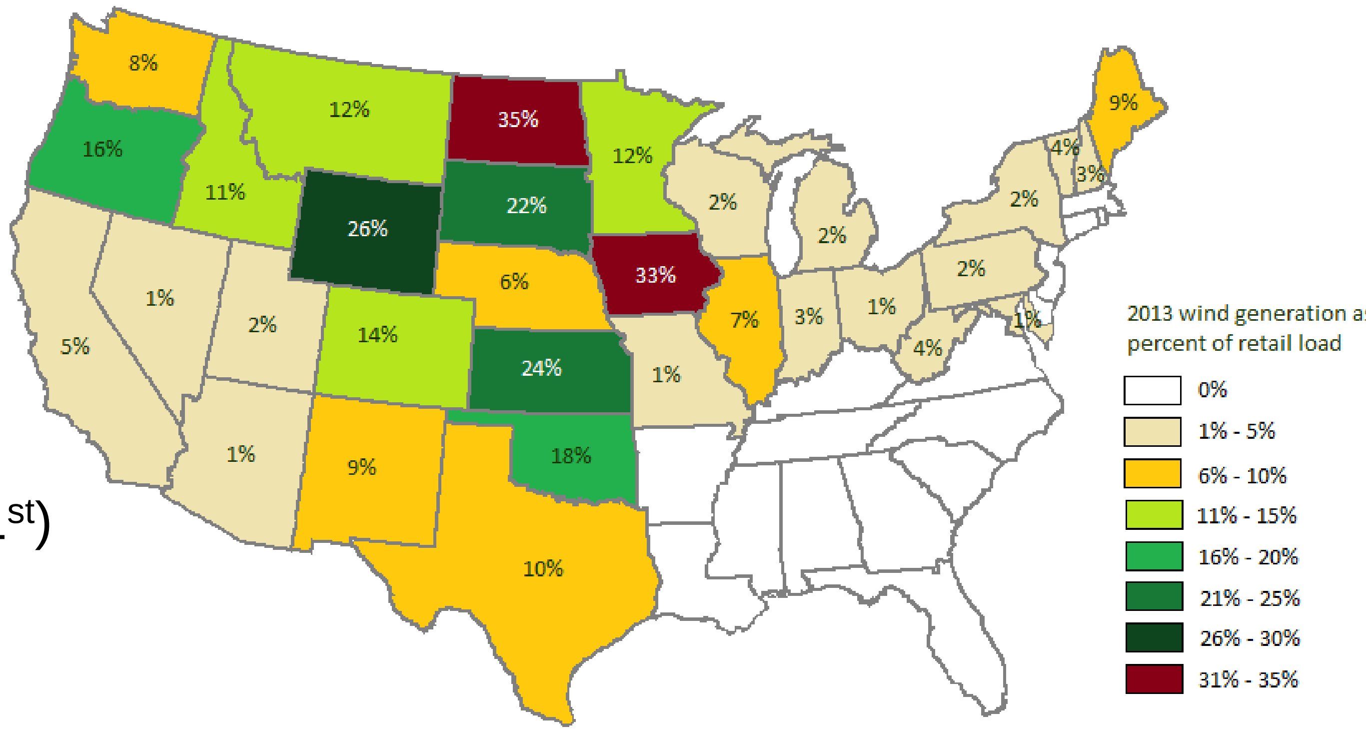
U.S. Wind Power

- 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

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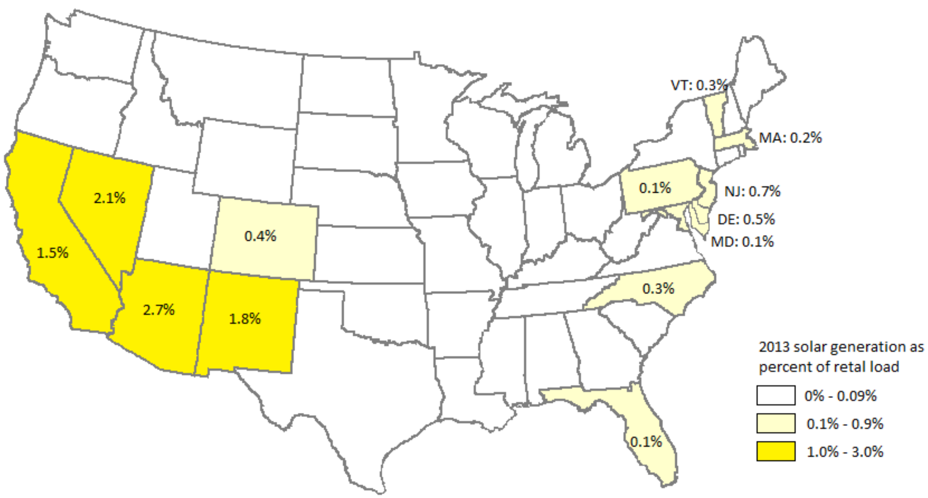
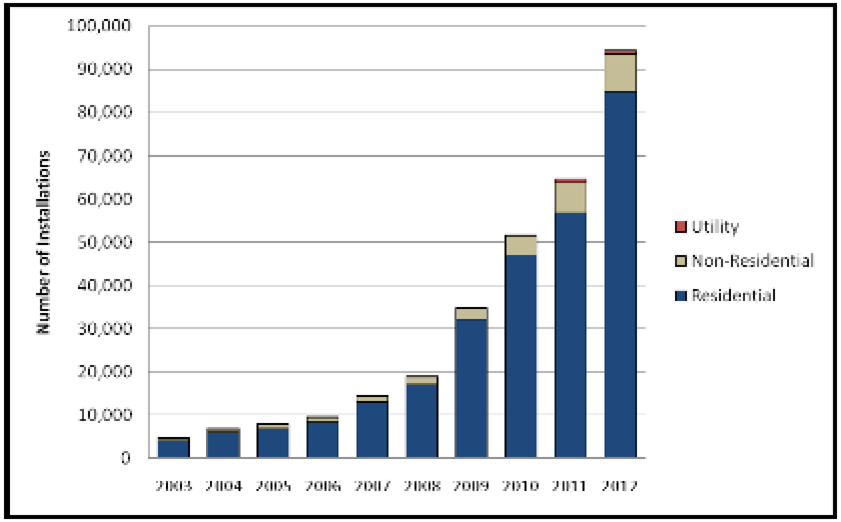
U.S Solar Energy

- 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

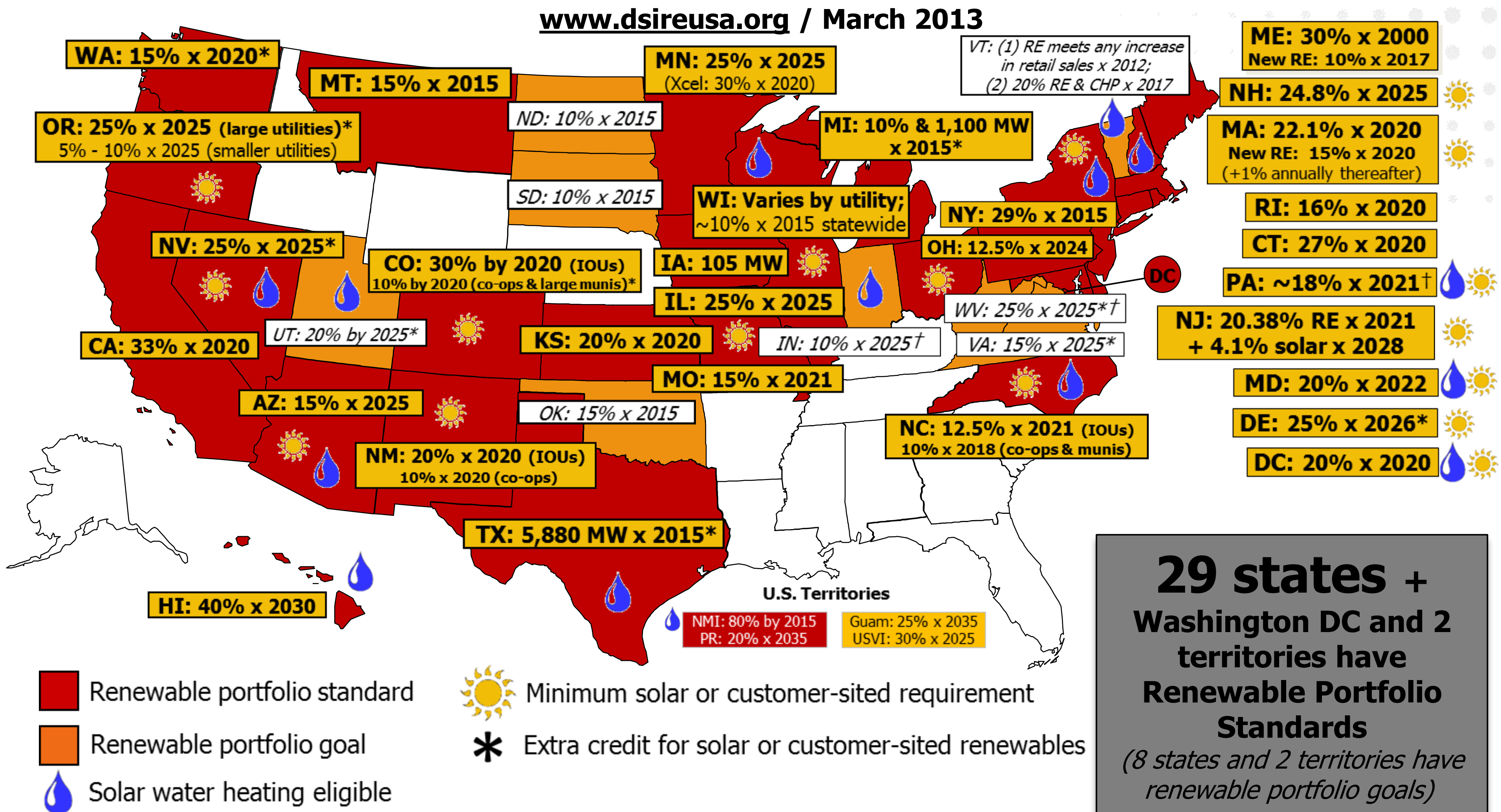


Cumulative U.S. Grid-Connected PV Installations



Technical Report NREL/TP-6A20-56290 June 2013

States Renewable Portfolio Standard (RPS)$_{2013}$



29 states + Washington DC and 2 territories have Renewable Portfolio Standards

(8 states and 2 territories have renewable portfolio goals)

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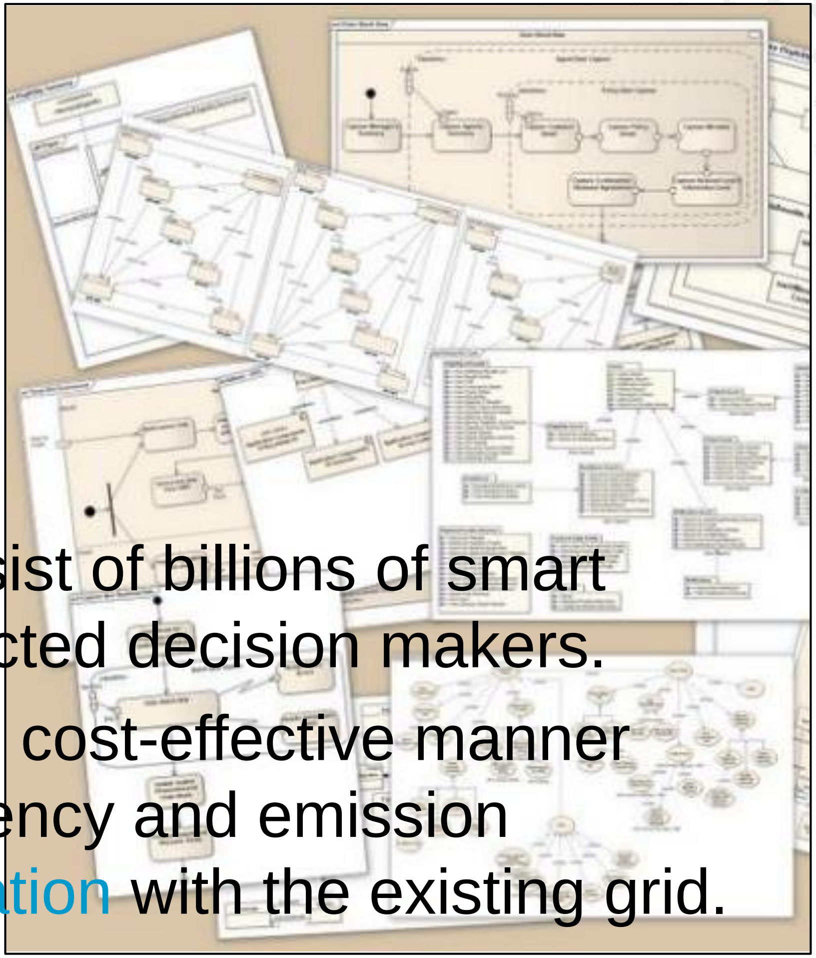
Distributed Energy Resources (DERs)



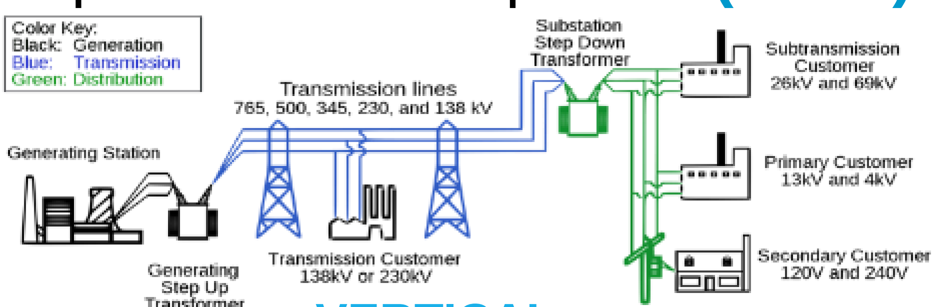
- New DERs technology
  - Smaller power generation (CHP, fuel cells, residential PV)
  - Demand Response
  - Storage
  - PEVs
- Future electricity systems will consist of billions of smart devices and millions of interconnected decision makers.
- Deploying DERs in a reliable, and cost-effective manner 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**

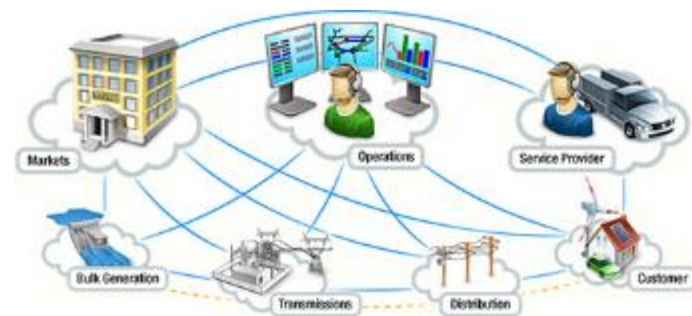
DERs Grid Integration

- **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)**

NIST Special Publication 1108R2



VERTICAL



FLAT

Grid Challenges with DERs

Grid Today		*Future Grid*
Dispatched generation	→	**Intermittent DG**
Predictable load	→	**Stochastic loads**
Voltage stability	→	**Dynamics**
Capacity available	→	**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

SOUTHERN CALIFORNIA EDISON

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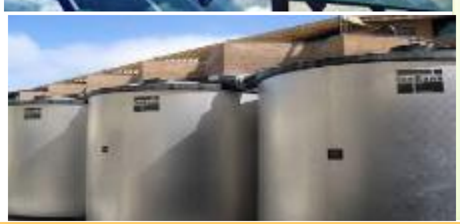
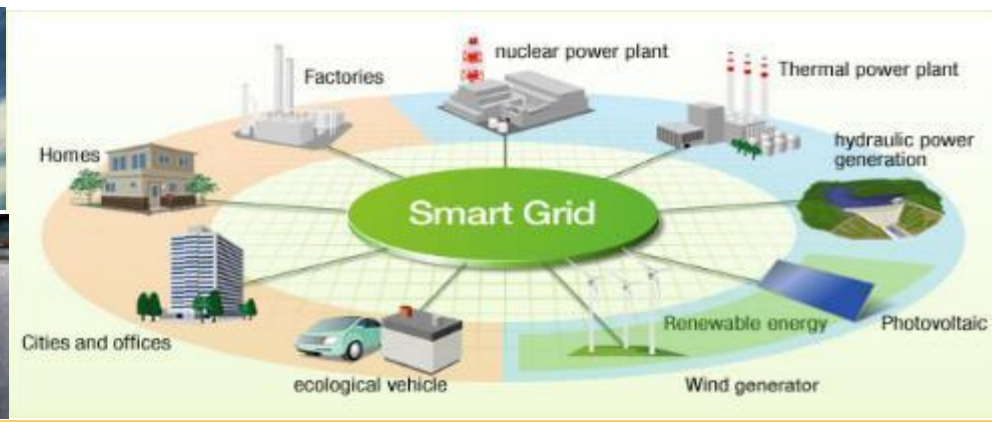
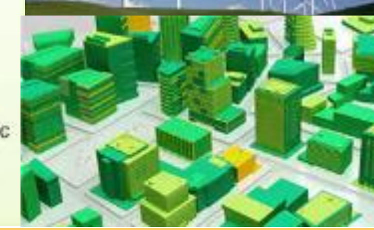
The Grid of the Future: From Vertical to Flat

- **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 CO_2 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 & aggregators**
  - Corporation aggregate DERs
  - Aggregated DERs bid into bulk market
    - Regulation
    - Unit commitment
    - Planning

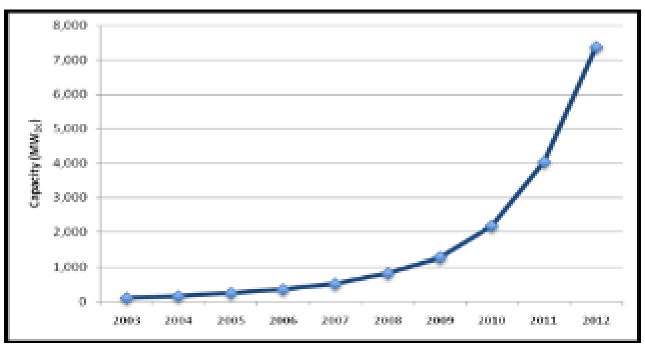
- **ISO & IDSO**
  - ISO manages transmission & wholesale
  - IDSO manages distribution & retail
    - Mechanisms for retail generation

- **‘Top-to-bottom’ ISO**
  - Single entity manages entire grid
  - Very complex optimization problem

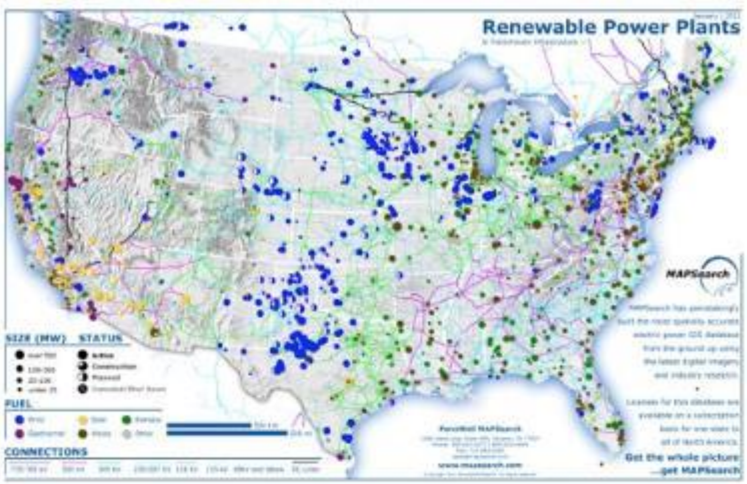
The Grid of the Future: Long Term Goals

- 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.

Cumulative U.S. Grid-Connected PV Installations



Source: IREC: 2013 Annual Updates and Trends, October 2013



CHANGING WHAT'S POSSIBLE

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

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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!