Renewables Integration and Smart Grid

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Presentation Overview

- Introduction to the Pacific Northwest National Laboratory
- The smart grid landscape in support of renewables
- Renewables integration and smart grid through case studies
- Concluding thoughts

PNNL is operated for DOE by Battelle

- Founded in 1925 as a charitable trust through the Will of Gordon Battelle
- Ohio industrialist; believed research could make American industry more competitive
  - Core Purpose

    Translate scientific discovery into innovative applications

Battelle headquarters
Columbus, OH

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

PNNL's Mission & Business Facts

Mission: Perform basic and applied research in support of energy, environmental, and national security for our nation.

- ~$1.1 billion business volume
- ~4,700 staff

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

Increase U.S. energy capacity and reduce dependence on imported oil

PNNL will provide science, technologies and leadership to:

Transitioning to a renewable, nuclear, and hydrogen energy base while reducing dependence on imported oil. . .

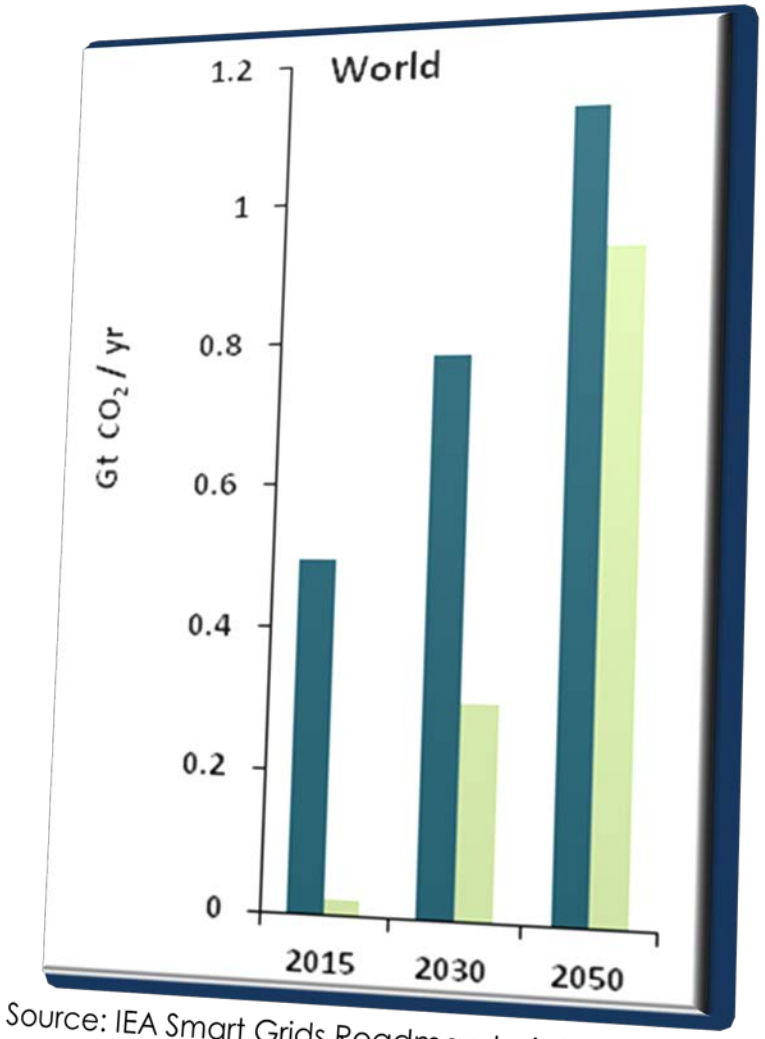
- **Energy Efficiency & Renewable Energy (EERE)**
  - Increase the efficiency of powering vehicles and buildings; and improve economic viability of biofuels
- **Clean Fossil Energy**
  - Enable economically and environmentally sustainable “air and water” neutral hydrocarbon conversion, carbon capture and sequestration
- **Electric Infrastructure**
  - Improve grid reliability and productivity
- **Nuclear Energy**
  - Enable expansion of nuclear energy through a viable closed nuclear fuel cycle

The Smart Grid Enables CO_2 Reduction on a Global Basis

Deployed globally, smart grids have the potential to help reduce global CO_2 emissions by over 2 gigatonnes per year by 2050

Direct Reductions: Energy savings from peak load management, continuous commissioning of service sector loads, accelerated deployment of energy efficiency programs, reduced line losses, and direct feedback on energy usage

Enabled Reductions: Greater integration of renewables and facilitation of EV and PHEV deployment

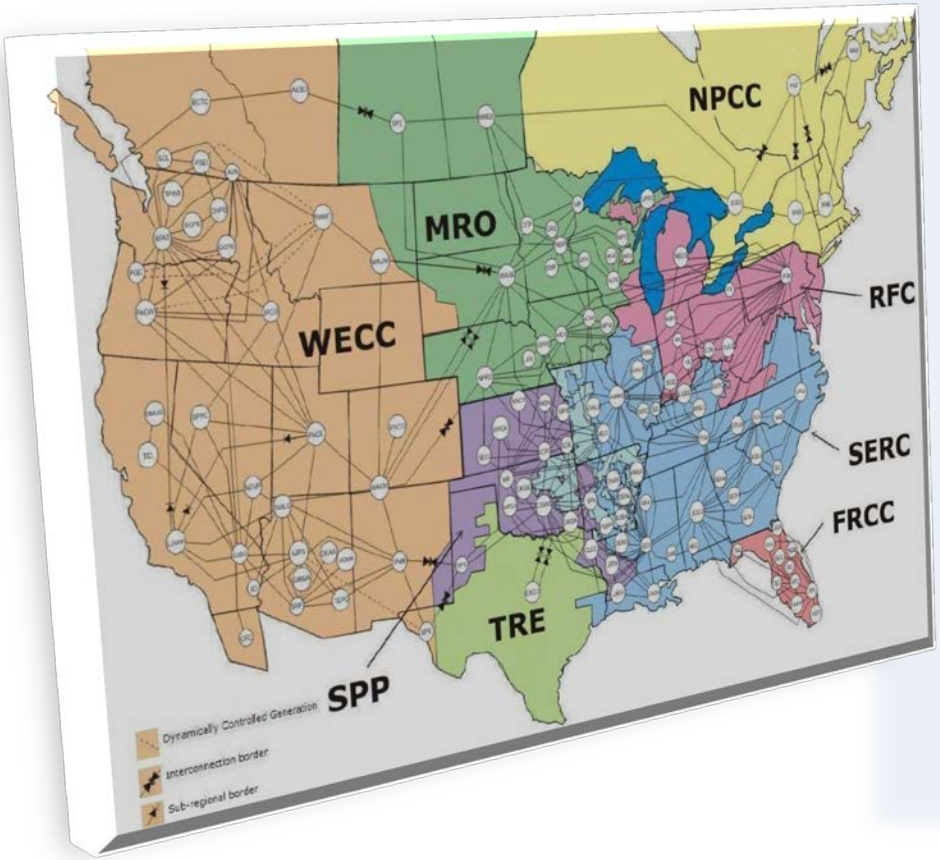


Source: IEA Smart Grids Roadmap Insights, 2011

The North American Electric Grid

U.S. Figures

22% of world consumption

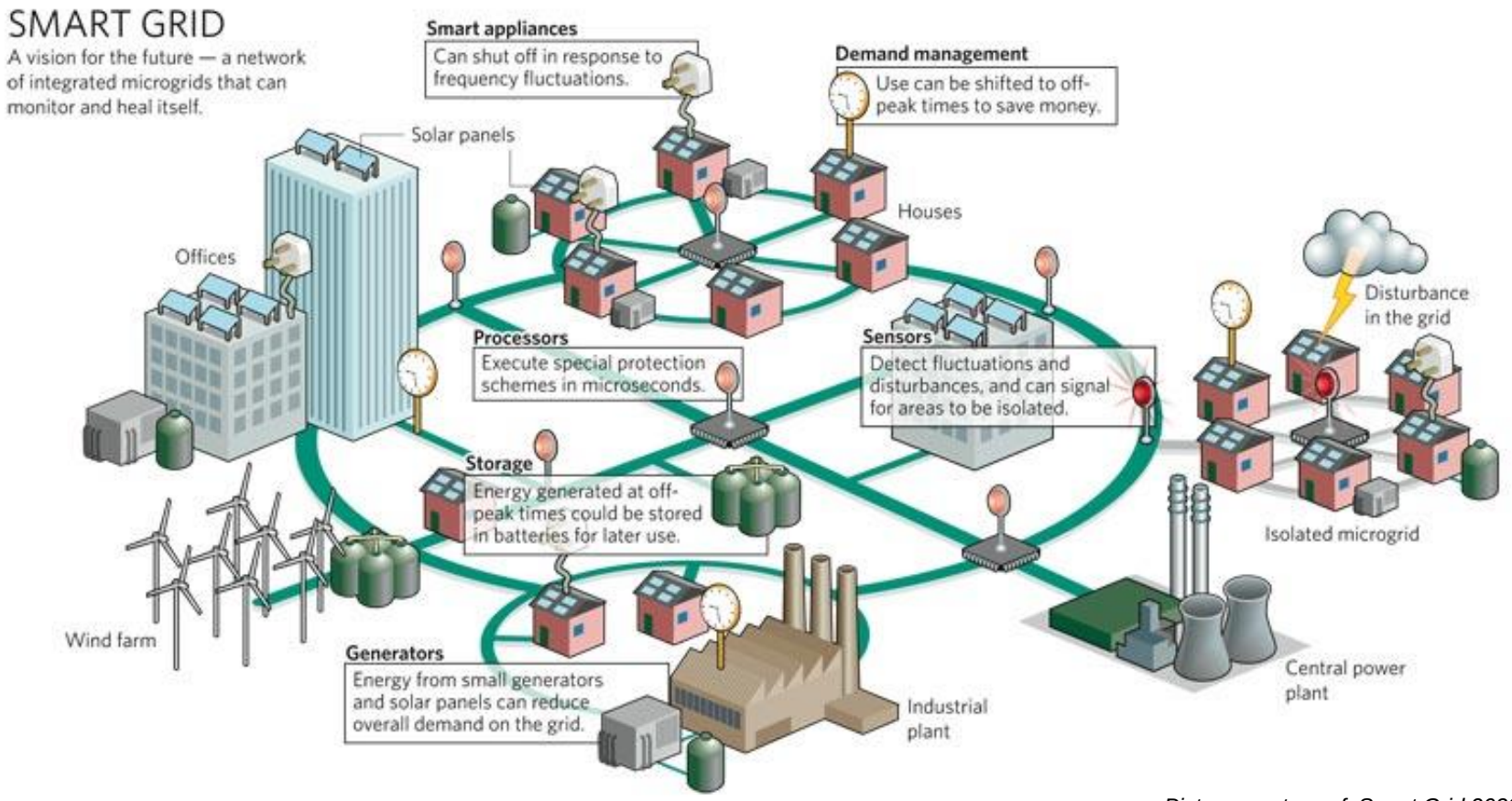


- 3,200 electric utility companies
- 17,000 power plants
- 800 gigawatt peak demand
- 165,000 miles of high-voltage lines
- 6 million miles of distribution lines
- 140 million meters
- $1 trillion in assets
- $350 billion annual revenues

Key Drivers toward the Future of the Electric Grid

2009		2035
• 51% coal • 19% nuclear • 20% natural gas • 3% oil • 6% hydro • 1% other renewable	***Changing Supply Mix*** • Expanding transmission • Increasing system flexibility needs	• More natural gas • More renewables • Same or less coal • Same or less nuclear • Same or less oil
• 3653 billion kWh • Hybrids, No Plug-in Electric Vehicles(PEVs) • Electrically-sensitive equipment (limited power quality considerations)	***Demand Transformation*** • Expanding digital economy • Demand-side management • Demand growth	• More than 5000 billion kWh • Load curves – increased peaking • PEVs (could increase demand 25%) • More electrically sensitive equipment (2.5x)
• 140 control areas • Energy management systems (<1%) • 180,000 miles of wires • ~10 million Distributed Generation (DG) units	***Complexity of Grid*** • Expanding footprint • Overlay of markets • Operating "closer to the edge"	• Nodes within control area increase 5-10x • Energy management systems (70%) • Additional 30,000 miles needed • ~ 22 million DG units (2.5x increase)
• Blackouts • Aging infrastructure • Vulnerability of assets	***Vulnerability of Energy Infrastructure*** • Interdependencies of electric and energy systems • Communications & controls	• Infrastructure protection • Increased globalization • Materials and resource limitations • All-hazard risks will continue to increase

U.S. Vision: Grid Modernization



Picture courtesy of: Smart Grid 2030

Renewable integration involves multiple technologies and implementation barriers*

- Technologies
  - Renewable energy
  - Distributed generation
  - Energy storage
  - Demand response
- Barriers
  - Technical
  - Economic
  - Regulatory
  - Institutional

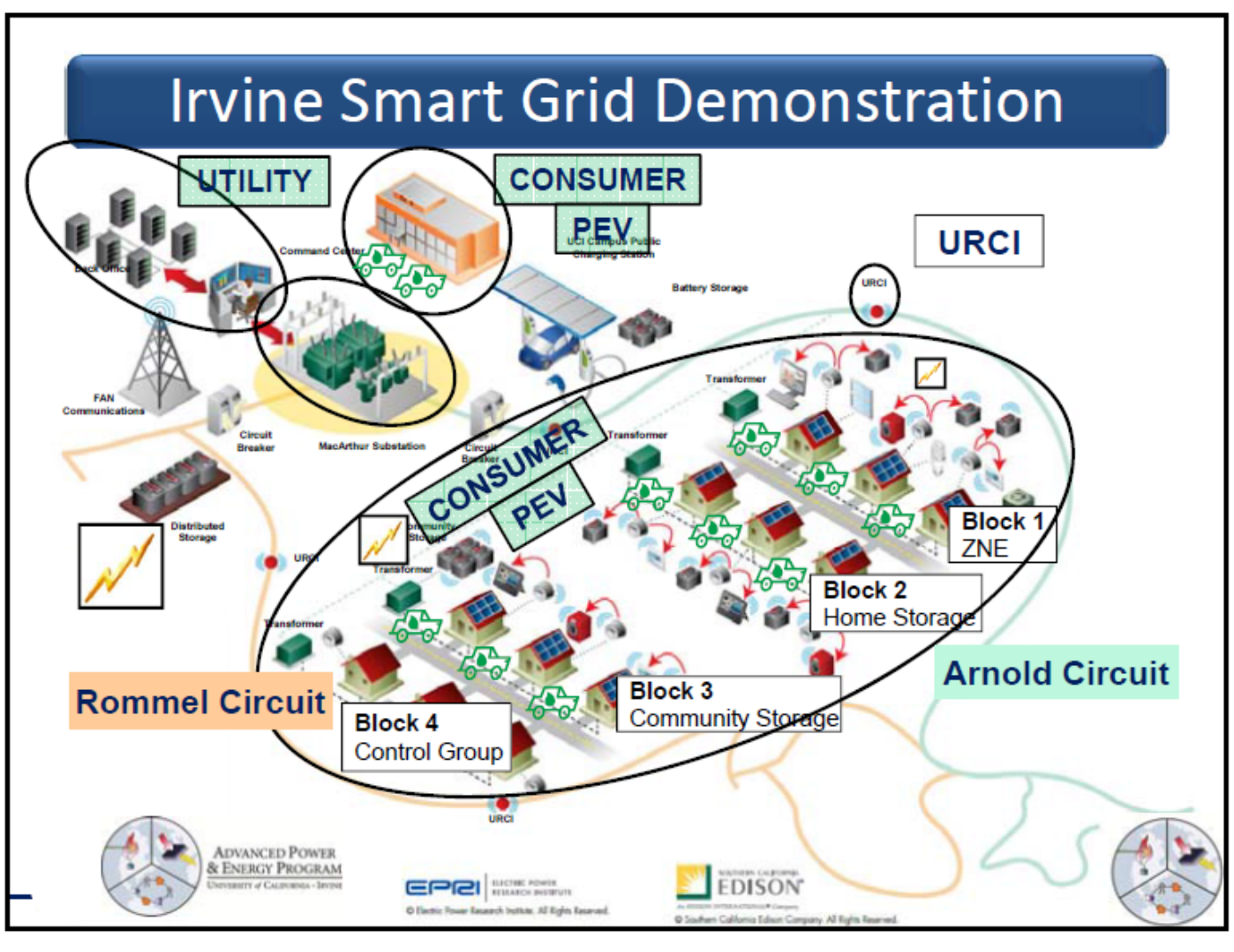
*http://energy.gov/oe/technology-development/renewable-energy-integration

The IEA Grid Integration of Variables Renewables (GIVAR) program identified four flexible resources that support renewables integration*

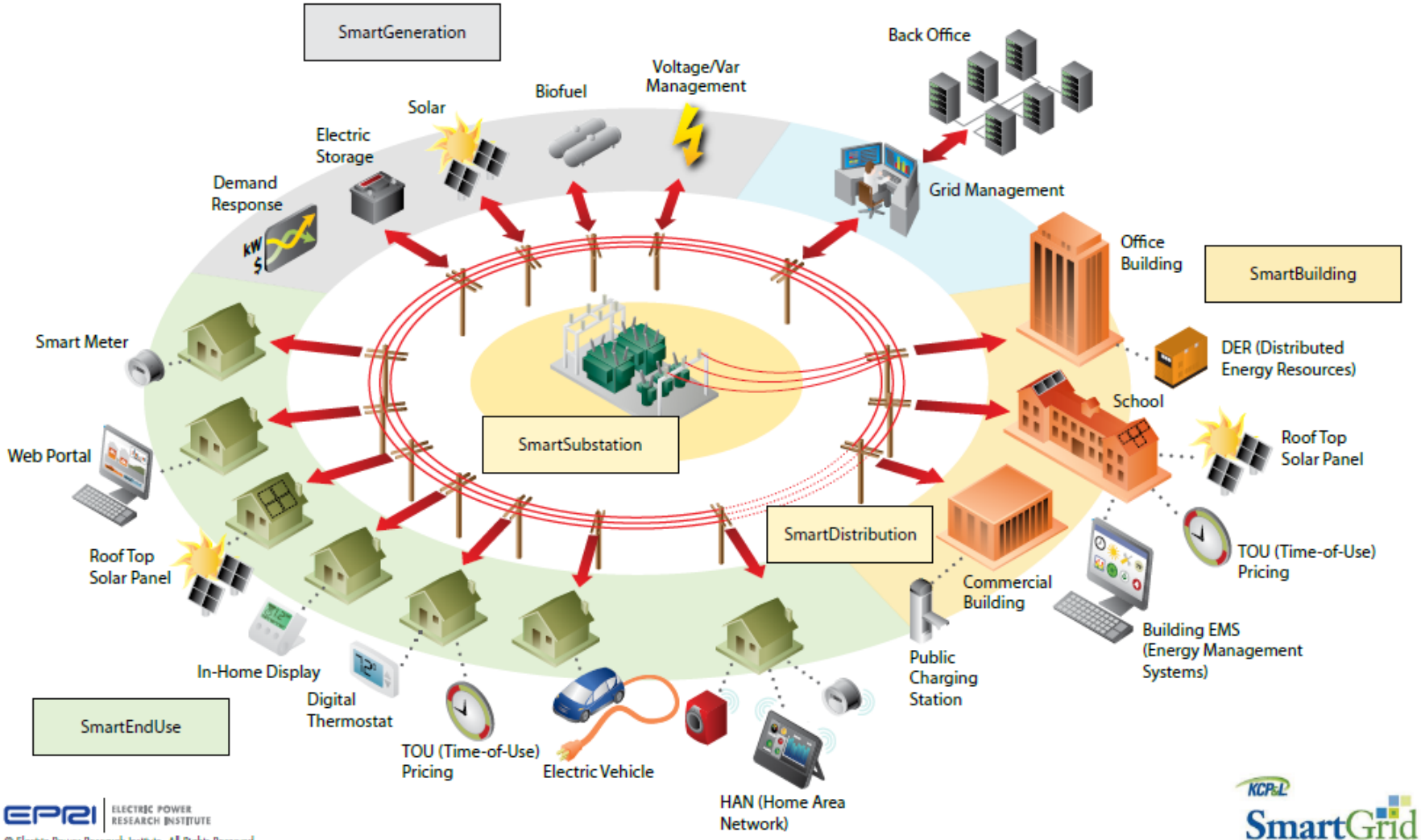
- Flexible generation
- Grid infrastructure
- Electricity storage
- Demand-side integration

*http://www.iea.org/topics/renewables/renewablesiea/renewablesintegrationgivar/

Southern California Edison Demonstration Including PEV Charging at Work



KCP&L Demonstration
True End-to-End Smart Grid



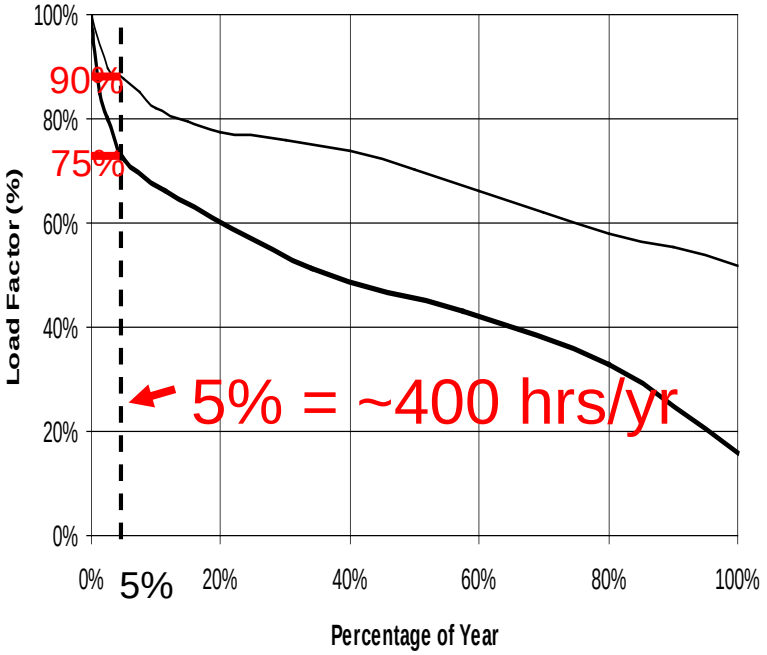
The APEC Smart Grid Initiative looked specifically at renewable integration

- Using Smart Grids to Enhance Use of Energy-Efficiency and Renewable- Energy Technologies” (EWG 01/2009S) (USA)
- Addressing Grid-interconnection Issues to Maximize the Utilization of New and Renewable Energy Resources (EWG 02/2009) (Japan)
- Promoting Stable and Consistent Renewable Energy Supply by Utilizing Suitable Energy Storage Systems (EWG 22 2012A) (China)
- Research on the Application of Physical Energy Storage Technology to Enhance the Deployment of Renewable Energy in an APEC Low Carbon Town (EWG 16 2012A) (China)

Renewable and Distributed Systems Integration (RDSI) at U.S. DOE

- 9 demonstration projects in 8 states to integrate use of Distributed Energy Resources (DER) to provide at least 15% peak demand reduction on distribution feeder or substation
- Projects are either microgrids or are developing technologies that will advance microgrids
- Systems must be capable of operating in both grid parallel and islanded modes
- $55 million of DOE funds were awarded in 2008 and spent over five years (total value of awards will exceed $100 million, including participant cost share)

Lower Peak Demand Reduces Infrastructure Investments



25% of distribution & 10% of generation assets (transmission is similar), worth 100s of billions of US dollars, are needed less than 400 hrs/year!

U.S. DOE RSDI Projects (1)*

- **Chevron Energy Solutions**—CERTS Microgrid Demo at the Santa Rita Jail - large-scale energy storage, photovoltaics (PV), fuel cell (California)
- **SDG&E**—Borrego Springs Microgrid - demand response, storage, outage management system, automated distribution control, AMI (California)
- **U of HI**—Transmission Congestion Relief, Maui - intermittency management system, demand response, wind turbines, dynamic simulations modeling (Hawaii)
- ***UNLV****—"Hybrid" Homes - Dramatic Residential Demand Reduction in the Desert Southwest - PV, advanced meters, in-home dashboard, automated demand response, storage (Nevada)*
- **ATK Space System**—Powering a Defense Company with Renewables - Hydro-turbines, compressed air storage, solar thermal, wind turbines, waste heat recovery system (Utah)

*http://www.smartgrid.gov

U.S. DOE RSDI Projects (2)

- **City of Fort Collins**—Mixed Distributed Resources - PV, bio-fuel Combined Heat and Power (CHP), thermal storage, fuel cell, microturbines, Plug-in Hybrid-Electric Vehicles (PHEV), demand response (Colorado)
- **Illinois Institute of Technology**—The Perfect Power Prototype - advanced meters, intelligent system controller, gas fired generators, demand response controller, uninterruptable power supply, energy storage (Illinois)
- **Allegheny Power**—West Virginia Super Circuit Demonstrating the Reliability Benefits of Dynamic Feeder Reconfiguration - biodiesel combustion engine, microturbine, PV, energy storage, advanced wireless communications, dynamic feeder reconfiguration (West Virginia)
- **Con Ed**—Interoperability of Demand Response Resources - demand response, PHEVs, fuel cell, combustion engines, intelligent islanding, dynamic reconfiguration, and fault isolation (New York)

ISGAN Award of Excellence

- **Annual international competition showcases global excellence, leadership and innovation in smart grids**

2015 Theme:

Excellence in Smart Grids for Renewable Energy Integration

- Winners were selected by an international jury of smart grid experts
- Official Rules and other information are posted at www.iea-isgan.org/award2015

The ISGAN Award of Excellence competition is supported by GSGF Global Smart Grid Federation

CLEAN ENERGY MINISTERIAL
Accelerating the Transition to Clean Energy Technologies

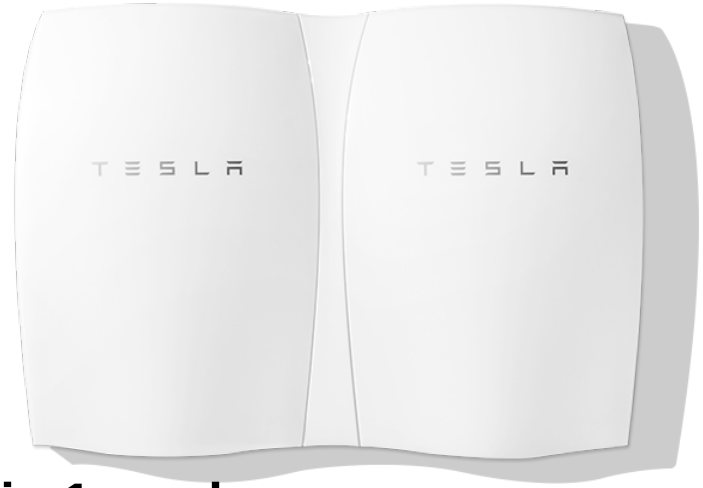
iea Energy Technology Network

2015 ISGAN Award of Excellence Winner: GRID4EU – Large-Scale Demonstration of European Smart Grid Distribution Networks*

- Led by six European Distribution System Operators (DSOs)
  - Électricité Réseau Distribution France (ERDF)
  - Czech Republic, Italy, Spain, Germany, and Sweden
- With 27 partners
  - Utilities, manufacturers
  - Universities and research institutions
- Focus areas are renewable energy integration, EV development, grid automation, energy storage, energy efficiency and load reduction
- Examines how DSOs can dynamically manage electricity supply and demand and integrate large amounts of renewables

*http://www.iea-isgan.org/?c=395/397

Could advanced batteries be a game changer?



- **Tesla Gigafactory 1**
  - 2020 pack output of 50 GWh/yr
  - Cost of US$5 billion
  - Reno, Nevada, USA
- **Received US$800 million in orders in 1 week**
  - US$179 million for PowerWall
  - US$625 million for PowerPack

- **Tesla Energy's goal? Changing the "energy infrastructure of the world"** Batteries could change traditional grids to make micro-grids and smart-grids possible (Arstechnica)
- **Can Tesla's Battery Hit $1 Billion Faster Than the iPhone?** (Bloomberg Business)

Renewable grid integration is on an upward trend

- Maximum renewable energy grid integration will always be location and resource dependent

- IEA believes up to 45% annual generation is possible without significantly increasing long run power system costs with favorable conditions*

* The Power of Transformation-Wind, Sun and the Economics of Flexible Power systems
http://www.iea.org/topics/renewables/renewablesiea/renewablesintegrationgivar/

Thank you for your attention!

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