Capturing New Smart Grid Value Streams

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The challenge ahead is complex
The grid must meet new expectations

Historical Expectations

- Affordable, Power
- Reliable Power
- Secure Power

Emerging Expectations

Delivering 300 GW of renewable generation by 2025

Maximize benefits of end-use efficiency and storage

Electrify transportation sector to reduce dependence on imported oil

Meet future carbon and emissions constraints

What will it take to get us there?

Policy
- *State & Federal legislation*
- *NERC*
- *FERC*
- *NARUC*

Knowledge and Transparency

Science & Technology
- *Labs*
- *Universities*
- *Private Sector*

Capital
- *Venture capital*
- *Institutional investments*
- *ARRA funding*

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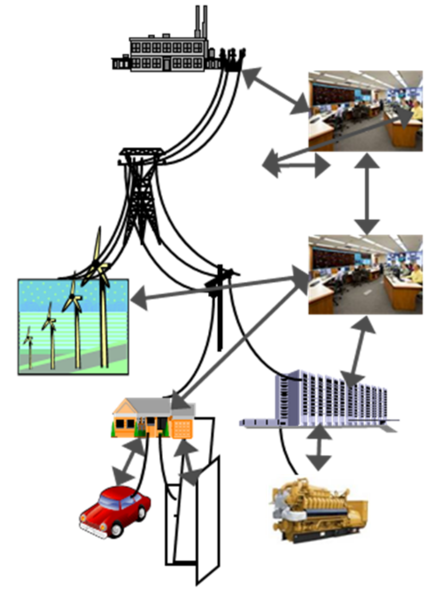
The Power System* of 2020
A fundamental transformation

Today's Power System

- 6 second view of high voltage over limited area, minimal view of distribution / customers
- Radial system, limited DG and storage
- < 2% intermittent generation
- <5% price responsive loads (relatively crude command systems)
- Centralized generation provides significant inertia to help stabilize the grid
- Relatively low asset utilization of large fractions of the system during most hours of the year
- Conservatively rated to avoid blackouts
- End use relatively simple resistance, predictable
- Managed primarily from supply side
- Multiple control centers and regulatory jurisdictions; often not coordinated

The Power System of 2020

- Full Smart grid implementation enables 2-way communication to see entire system (G, T, D & EU) in real time (< 1sec) across entire interconnections
- More DG & storage across system
- > 15% renewable (mostly intermittent) generation (net)
- > 15% price responsive demand
- Substantial new high-efficiency loads, hard to predict
- Substantial new demand from electrification of ~25% light duty transportation
- Demand control part of grid management, along with traditional supply side
- Coordinated control and regulatory frameworks



** Power system (smart grid) includes entire system from centralized generation (G) to transmission (T), and distribution (D), down to consumer loads (EU) and decentralized generation (DG)*

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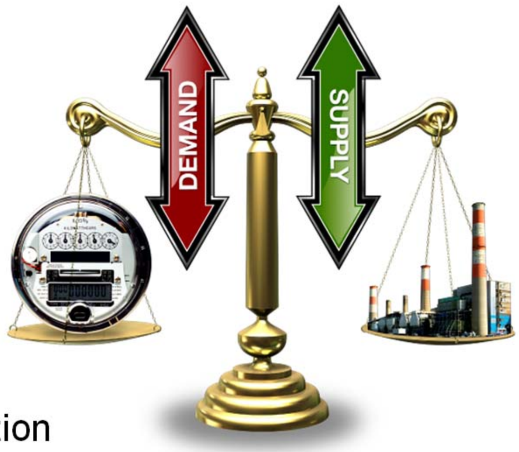
What is the "Smart Grid" and how can it help?

Add substantial IT "smarts" to bring digital intelligence and real-time communications and control through-out the power system to see and operate the grid as never before.



- Demand-side resources participate with distribution equipment in system operation
  - Consumers engage to mitigate peak demand and price spikes
  - More throughput with existing assets; reduce need for new assets
  - Enhanced reliability: bounds impacts, local resources self-organize to manage contingencies
  - Provide demand-side ancillary services – a boon to wind integration
- The transmission and generation resources get smarter too
  - Improve the timeliness, quality, and geographic scope of the operator's situational awareness and control
  - Better coordinate generation, balancing, reliability, and emergencies
  - Utilizing high-performance computing, sophisticated sensors, and advanced coordination strategies

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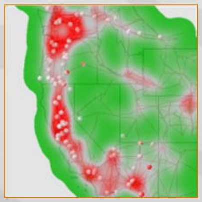
Transforming the U.S. Energy System
PNNL’s Electric Infrastructure Research Agenda

System Transparency – *Seeing and operating the grid as a national system in real-time*



Analytic Innovations - *Leveraging High-Performance Computing and new algorithms to provide real-time situational awareness and models for prediction and response*

End-Use Efficiency and Demand Response – *Making demand an active tool in managing grid efficiency and reliability.*

Renewable Integration – *Addressing variability and intermittence of large-scale wind generation and the complexities of distributed generation and net metering*

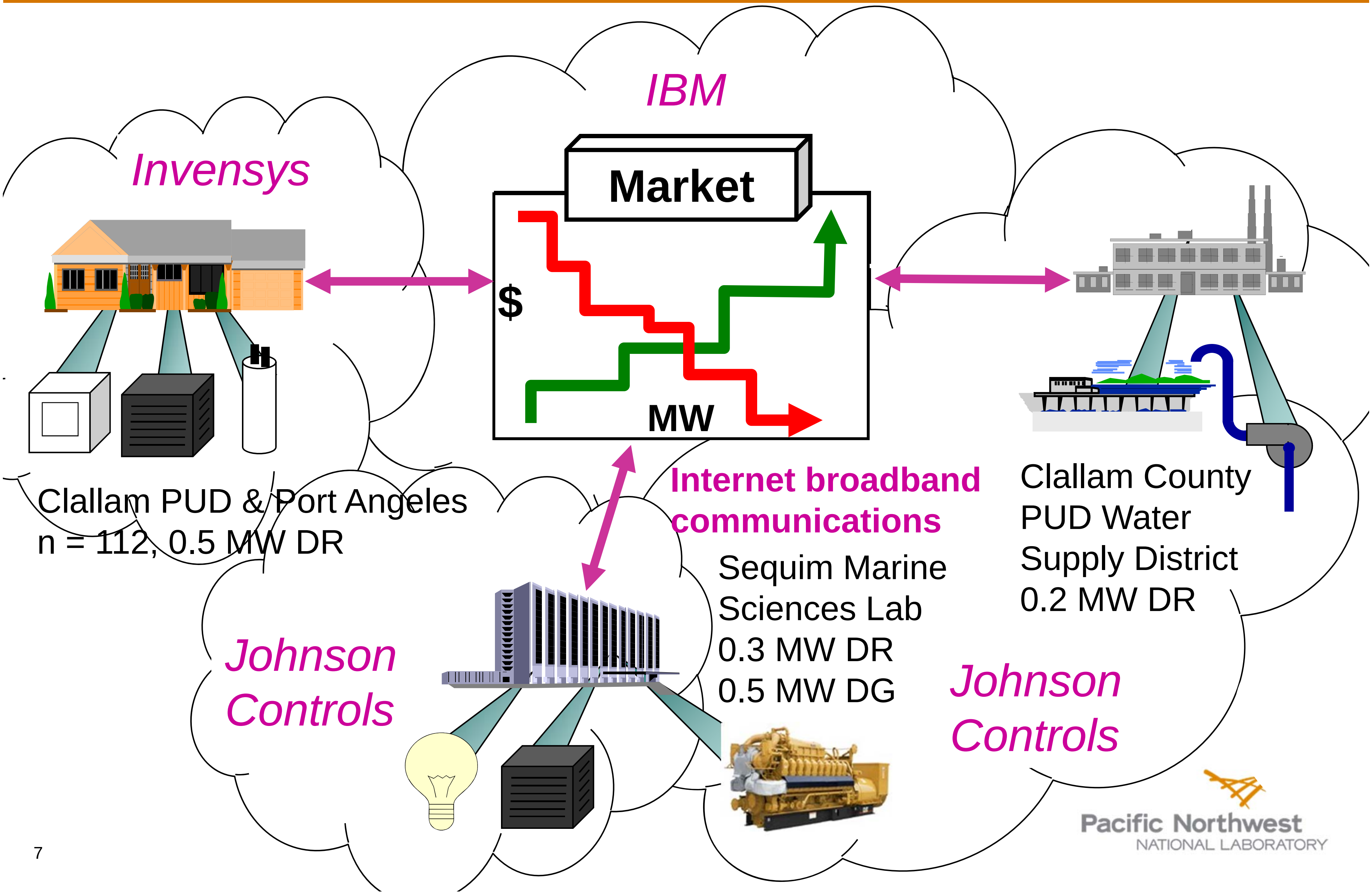
Energy Storage – *Defining the location, technical performance, and required cost of storage; synthesizing nanofunctional materials and system fabrication to meet requirements*

Cyber Security and Interoperability – *Defining standards for secure, two-way communication and data exchange*

GridWise Demonstration Projects

- Olympic Peninsula GridWise demonstration
  - Explored how consumers respond to real-time pricing
  - Tested smart appliances in 112 homes for one year
  - Real-time, two-way market with real cash incentives
- Grid Friendly™ Appliance demonstration
  - Tested device response to stress on grid and consumer acceptance of device in appliances
  - Installed in 150 dryers for one year

Olympic Peninsula Demonstration

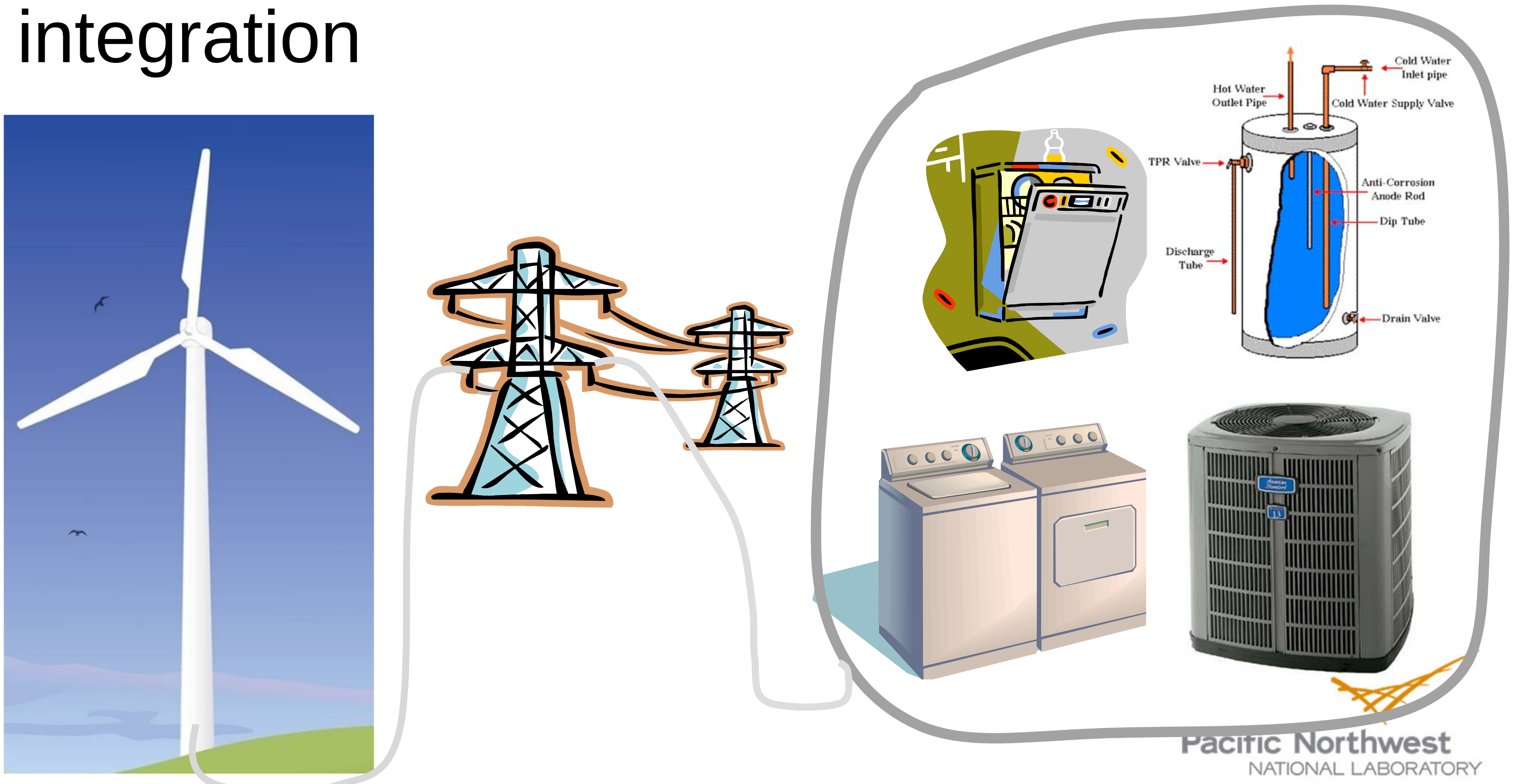


Olympic Peninsula Demo: Key Findings

- Customers can be recruited, retained, and will respond to (~5-min.) real-time prices, **<u>if they are offered</u>**:
  - Opportunity for significant savings on their electric bill (~10% was suggested)
  - A “no-lose” proposition – their bill could <u>not</u> be higher than the normal, fixed rate
  - Technology that automates their desired level of response and <u>keeps it simple</u>
  - Complete control of how much they choose to respond, with which end uses, and a 24-hour override
- Significant demand response was obtained
  - 15% reduction of peak load
  - Up to 50% reduction in total load for several days in a row during shoulder periods
  - Response to wholesale prices + transmission congestion + <u>distribution congestion</u>
  - Able to cap net demand at an arbitrary level to manage local distribution constraint
  - Short-term response capability <u>could provide regulation, other ancillary services</u> (adds significant value at very low impact and low cost)
  - Same signals integrated commercial & institutional loads, distributed resources (backup gensets)

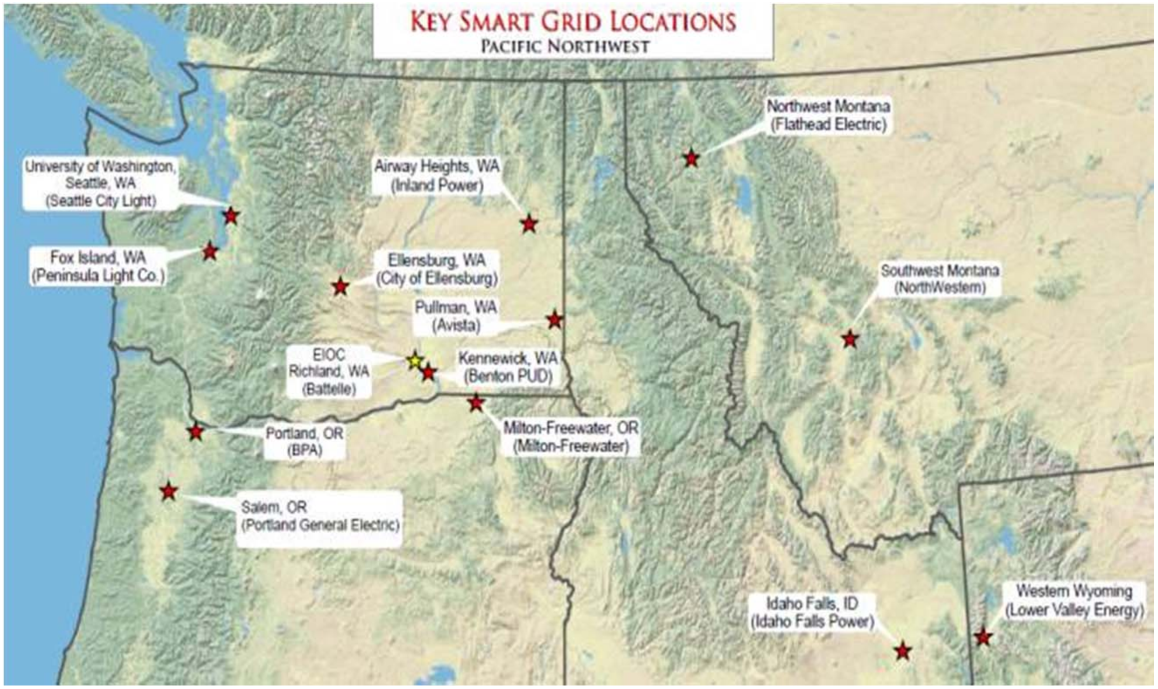
Thermostatically Controlled Appliances Responded to Incentives

- Linking demand response "ancillary services" with intermittent resource integration



Pacific Northwest Regional Smart Grid Demonstration Project Outlook

- Unique in geographic scale and scope of grid engagement
- Seek to validate both local and regional grid benefits of smart grid
- Touches on key regional/national energy agenda for renewables, efficiency, reliability, consumer engagement and choice
- Positions the region for leadership in smart grid technology and overall national energy agenda



Demonstration Project Overview

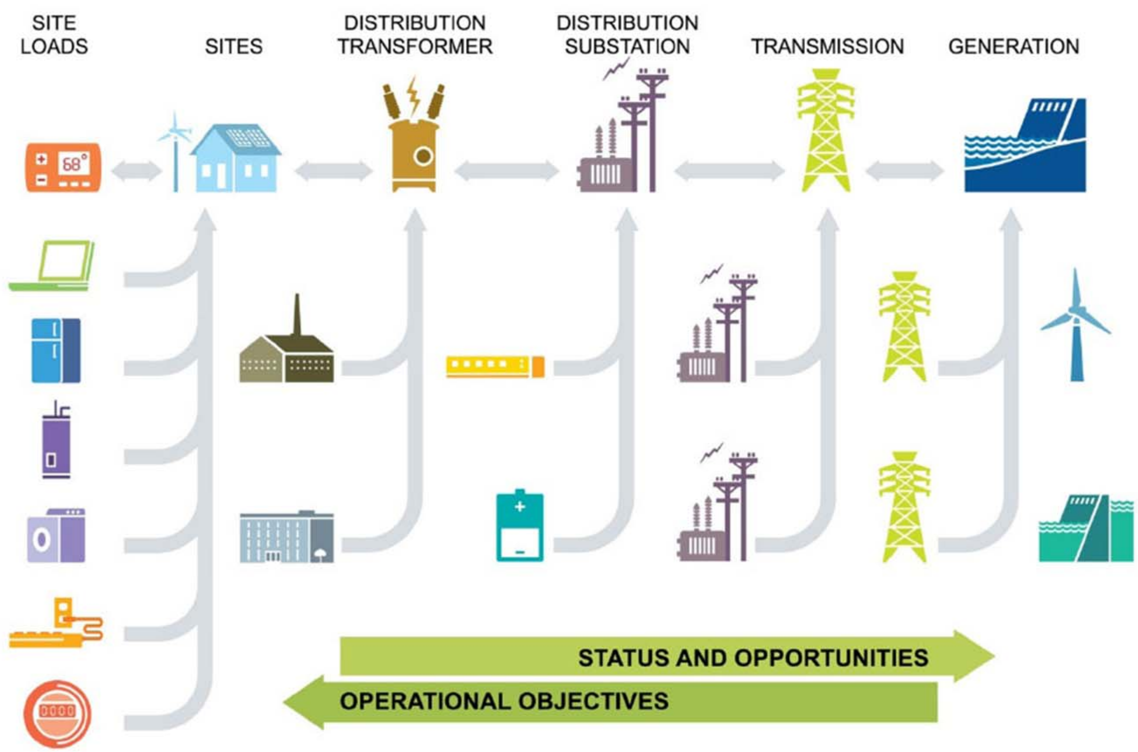
Pacific Northwest SMART GRID DEMONSTRATION PROJECT

- **Substantially increases smart grid asset installation in the region by purchasing and installing smart grid technology**
  - $178 Million project led by Battelle
  - Project participants include BPA ($10M), 11 utilities ($52M), 5 project-level vendors ($27M). DOE matched with $89M.
  - More than 60,000 metered customers directly affected
  - 112 MW of responsive resources (loads and generation) engaged

- **Demonstrates coordination of smart grid assets locally and across the region using innovative communication and control system**
  - Hierarchical communication—from generation through transmission and distribution, and then onward to the end users
  - Transactive control—innovative incentive signal that coordinates smart grid resources to support regional needs for transmission, reliability, renewables, etc.

Generation to End-Use

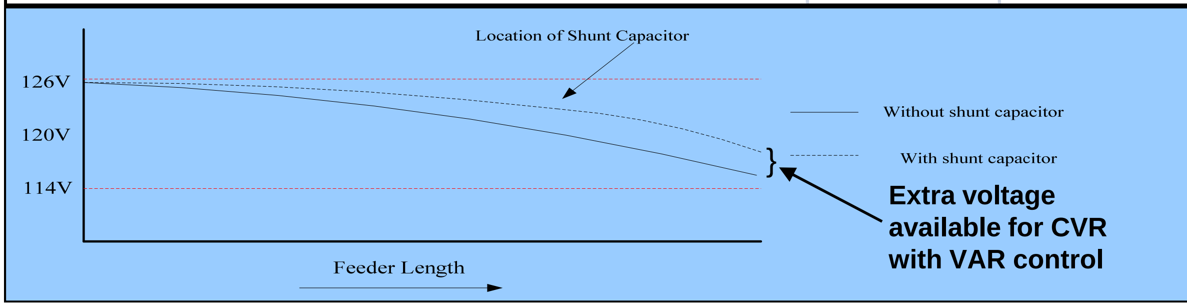
- Managing peak demand
- Facilitating renewable resources
- Addressing constrained resources
- Improving system reliability and efficiency
- Selecting economical resources (optimizing the system)



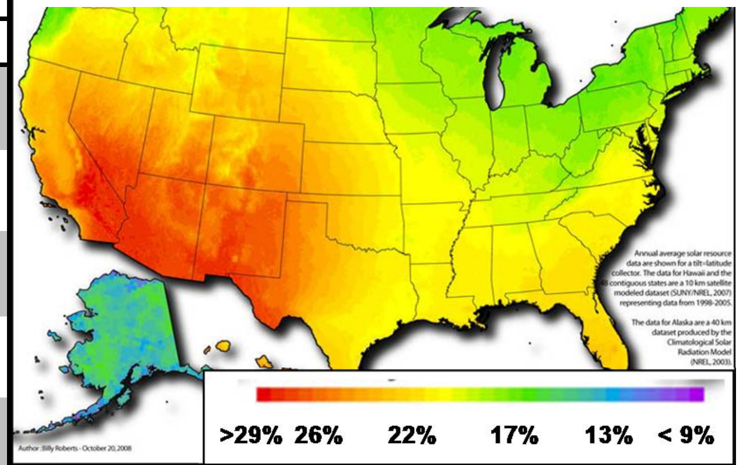
Aggregation of Power and Signals Occurs Through a Hierarchy of Interfaces

Carbon Impacts of SG and Demand Management

Mechanism	Electric Sector Energy CO_2 Reductions	
	Direct	Indirect
Conservation Effect of Consumer Information and Feedback Systems	3%	-
Joint Marketing of Efficiency and Demand Response Programs	-	0%
Diagnostics in Residential and Small/Medium Commercial Buildings	3%	-
Measurement and Verification for Efficiency Programs	1%	0.5%
Shifting Load to More Efficient Generation	< 0.1%	-
Support Additional Electric Vehicles (EVs) / Plug-In Hybrid Electric Vehicles (PHEVs)	3%	-
Conservation Voltage Reduction and Advanced Voltage Control	2%	-
Support Penetration of Solar Generation (RPS > 25%)	(1)	(2)
Support Penetration of Wind Generation (25% RPS)	< 0.1%	5%
Total, Share of U.S. Electric Sector Energy and CO_2 Emissions	**12%**	**6%**



Annual Residential Solar Load Fraction at which Reverse Power Flow Begins



- Strategic link between SG and Carbon agenda
- Critical for SG to engage carbon policy debate
- Adopted by IEA as the EU SG/Carbon benefits framework

Concluding Observations

- Engaging demand via smart grid infrastructure is offering value to a broad range of grid operations today
  - Peak shifting
  - Peak reduction
- Emerging value streams are being tested in upcoming demonstrations across the globe
  - Ancillary services for the bulk system (reliability, renewables integration)
  - Voltage management and renewable integration support at distribution level
- The long-term agenda to reduce the carbon content of our energy system will benefit from demand response and other SG offerings
  - Facilitate transportation electrification
  - Enhanced efficiency (end-use and system)
- **Challenge is to consider flexibility in todays demand response investments to enable future emerging benefits as power systems transform to meet new challenges across the globe**