The Smart Grid and its Role in a Carbon-Constrained World

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What is the Smart Grid?

Seven Characteristics of a Modern Grid

The *Modern Grid Initiative* has defined the smart grid in terms of seven characteristics that are <u>outcomes</u>:

- Enables active participation by consumers
- Accommodates all generation and storage options
- Enables new products, services and markets
- Provides power quality for the digital economy
- Optimizes assets & operates efficiently
- Anticipates and responds to system disturbances (self-heals)
- Operates resiliently against attack and natural disaster

Primary Assets: the Smart Grid's "Prime Movers"

New, typically distributed resources are engaged by the smart grid to positively affect operations:

- Demand response (DR)
- Distributed generation (DG)
- Distributed storage (DS)
- Distribution/feeder automation (DA/FA)
- Electric & plug-in hybrid vehicles (EVs/PHEVs)

Enabling Assets for the Smart Grid

Cross-cutting technologies that <u>enable</u> many Primary assets & applications:

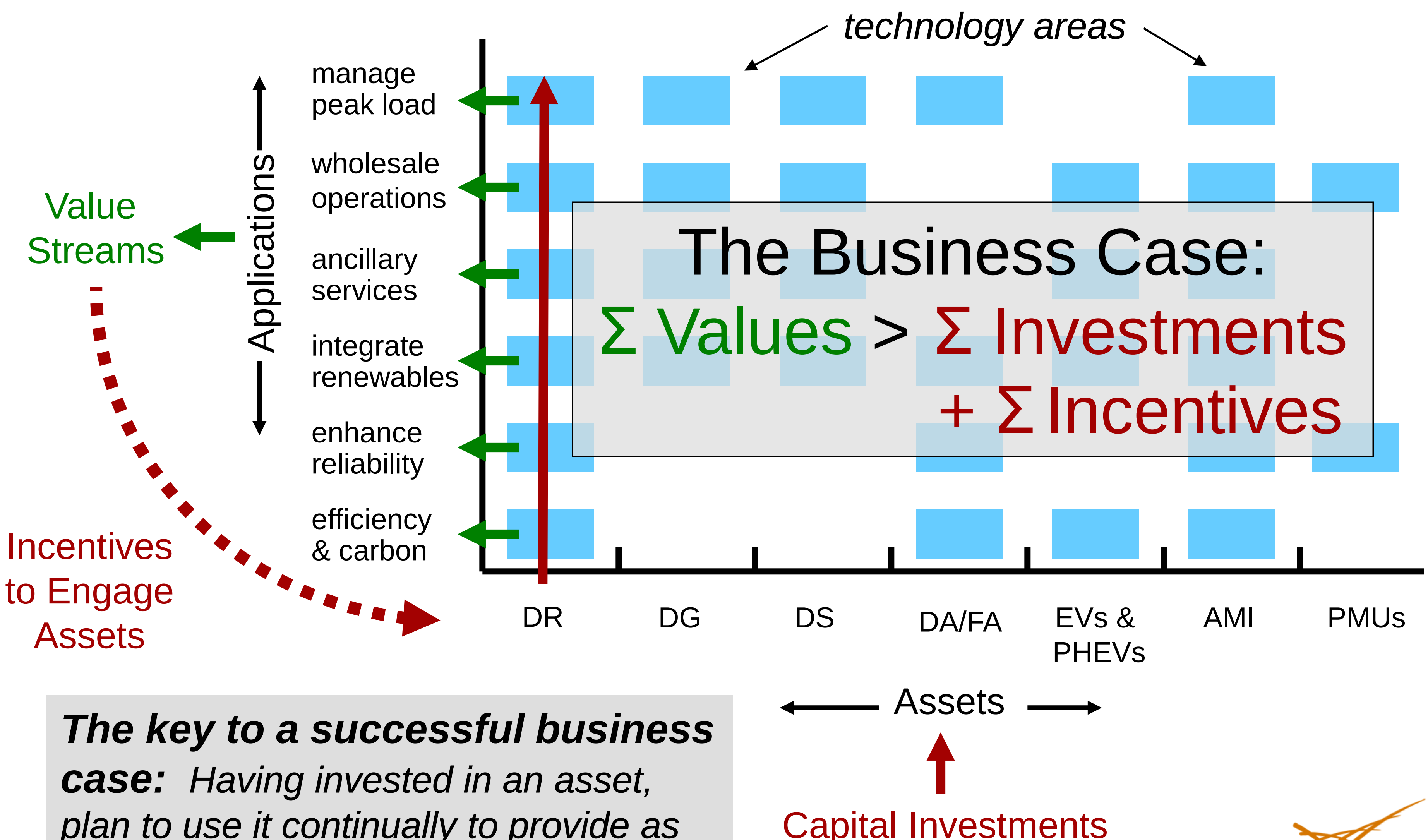
- Communications networks, servers, gateways, etc.
- Smart meters
  - 1 hour→1 min intervals
  - 1-way→2-way communications
  - Instantaneous volts, amps, VARs
  - Auto connect/disconnect
- Home/building/industrial energy management/control systems,
- User information interfaces & support tools
- Utility back office systems,
- Transmission wide-area phasor measurement (PMU) networks & visualization tools
- <u>Other key technical ingredients of the smart grid</u>:
  - Cyber-security for all the above
  - Interoperability framework, standards & protocols

Applications: Operational Strategies that Utilize Smart Grid Resources to Create Benefits

Grid control and operational strategies (*applications*) that engage smart grid *assets* to improve cost effectiveness, reliability, and energy efficiency:

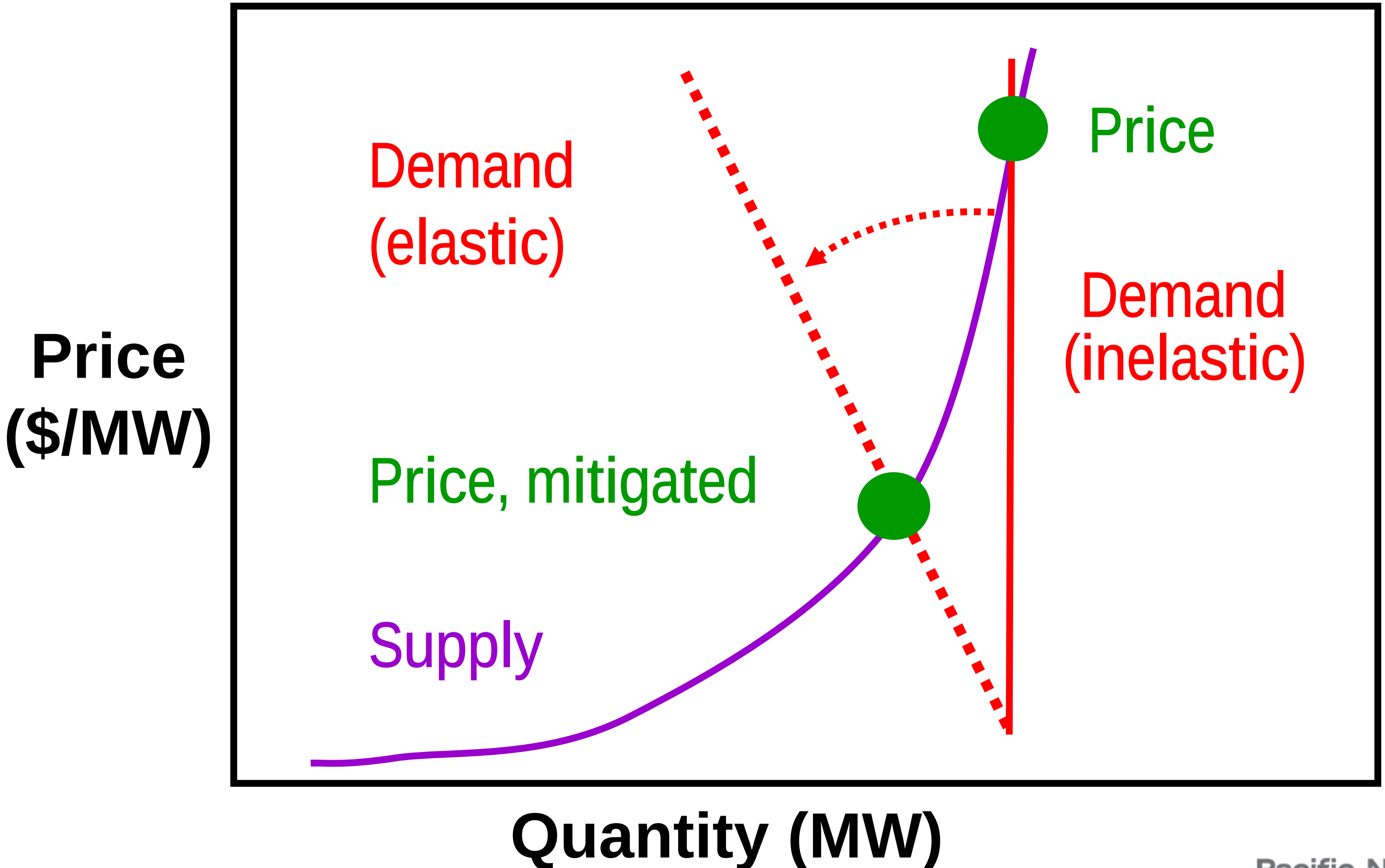
- Manage peak load capacity (G, T, & D)
- Reduce costs for wholesale operations
- Provide ancillary services
- Reduce operational costs of integrating renewables
- Provide enhanced reliability/adequate reliability at less cost
- Leverage network for energy efficiency & carbon savings

The Matrix of Assets & Applications Produce the Smart Grid's Values & Define the Business Case

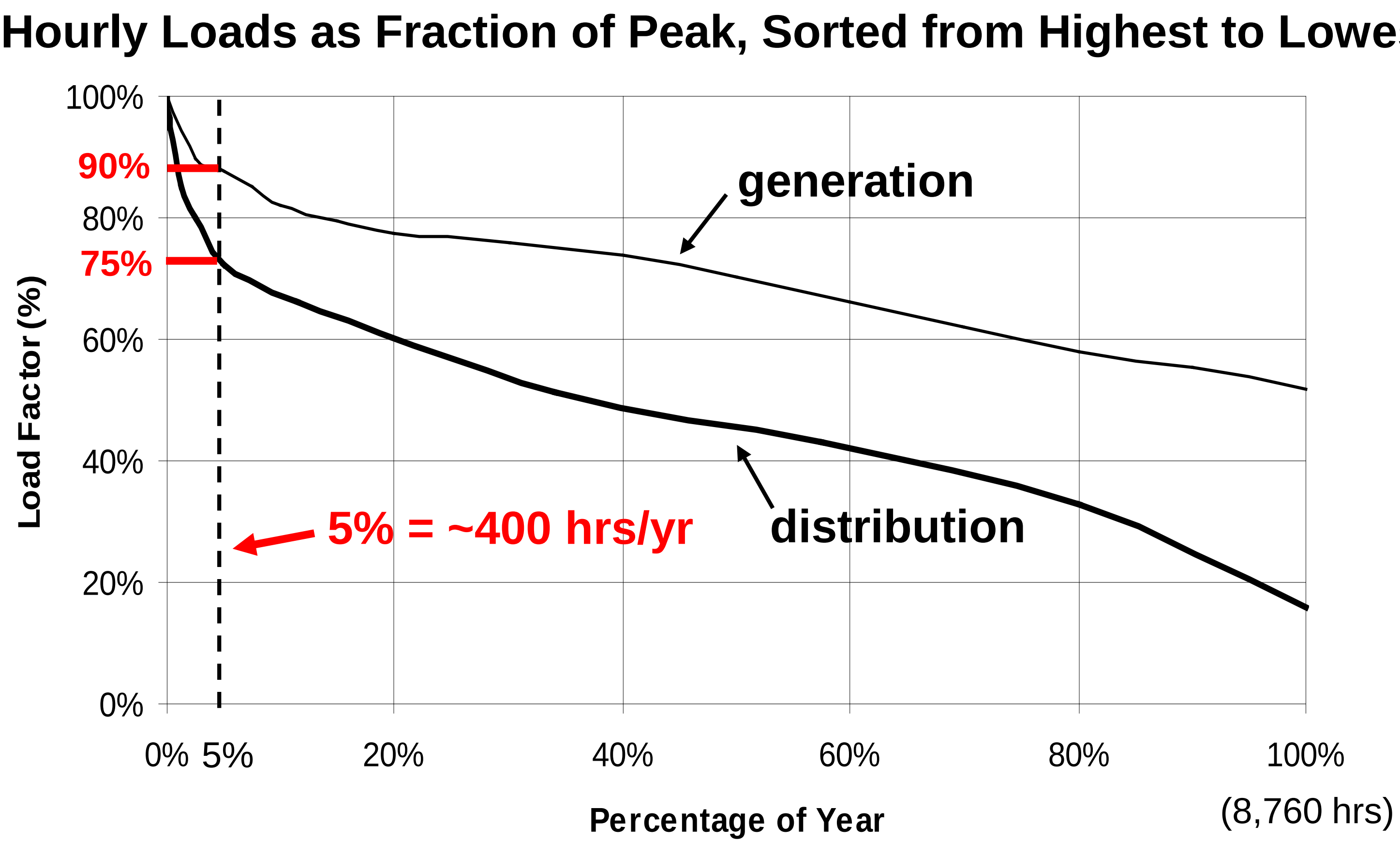


The key to a successful business case: *Having invested in an asset, plan to use it continually to provide as many value streams as possible!*

Value of Demand Elasticity: *Lower Peak Demand & Stabilize Prices*

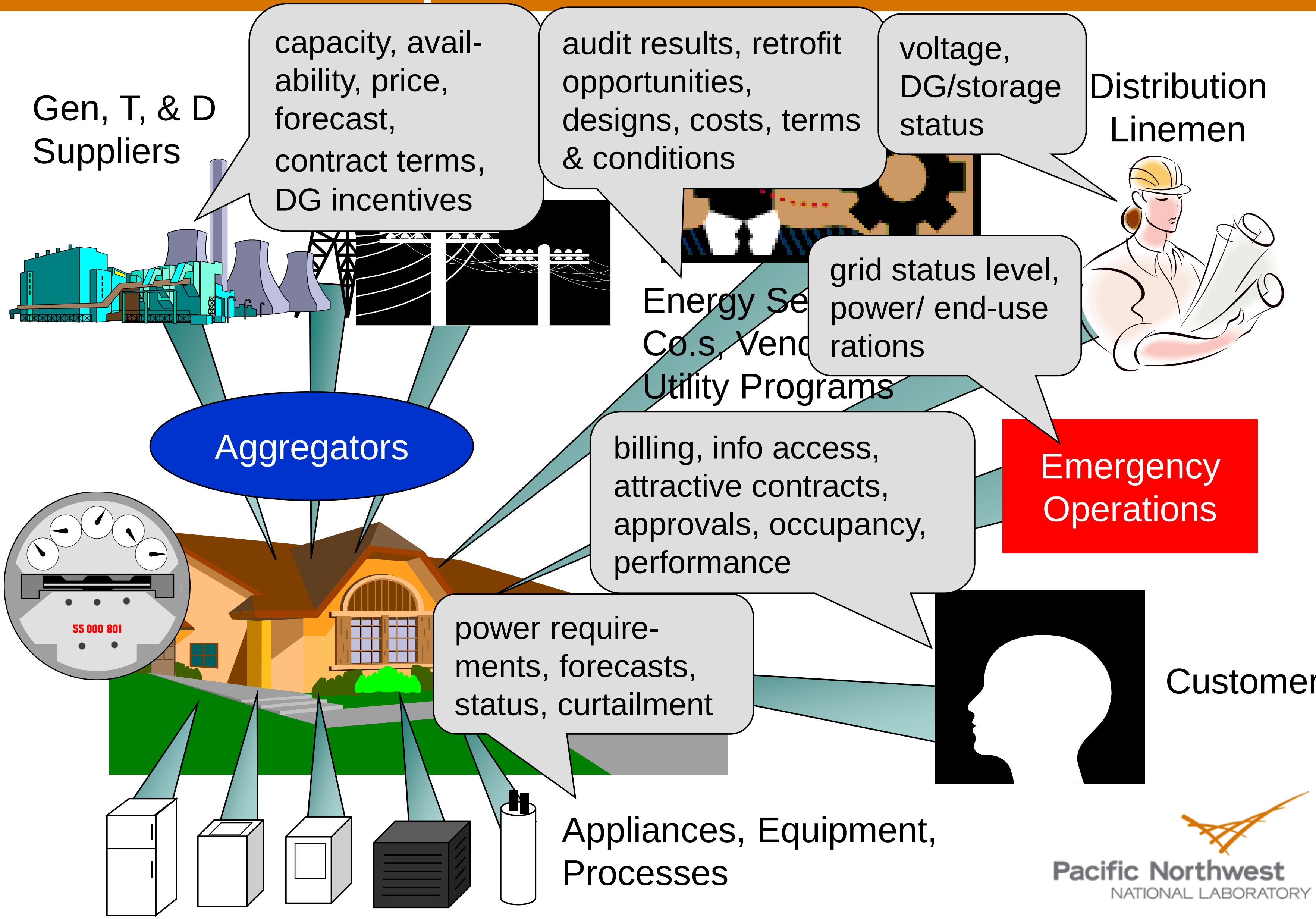


Value of Demand Response: *Lower Peak Demand Reduces Infrastructure Investments*



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

Communicate – With Whom? About What?
A Customer Perspective of the Smart Grid



Information: The Virtual Electric Infrastructure

FACT:

In the next 20 years, the U.S. will spend $450B on electric infrastructure, just to meet load growth.

CHOICE:

Perpetuate a 20th Century solution

OR

Invest in a 21st Century system saving ratepayers $80B while increasing reliability and flexibility.

GRIDWISE™:

Revealing Values +
Communications +
Advanced Controls
≡ Electric infrastructure

The choice is easy because…

$ bits << $ iron

Smart Grid Operational Strategies for Distribution Systems

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The Smart Grid and Carbon

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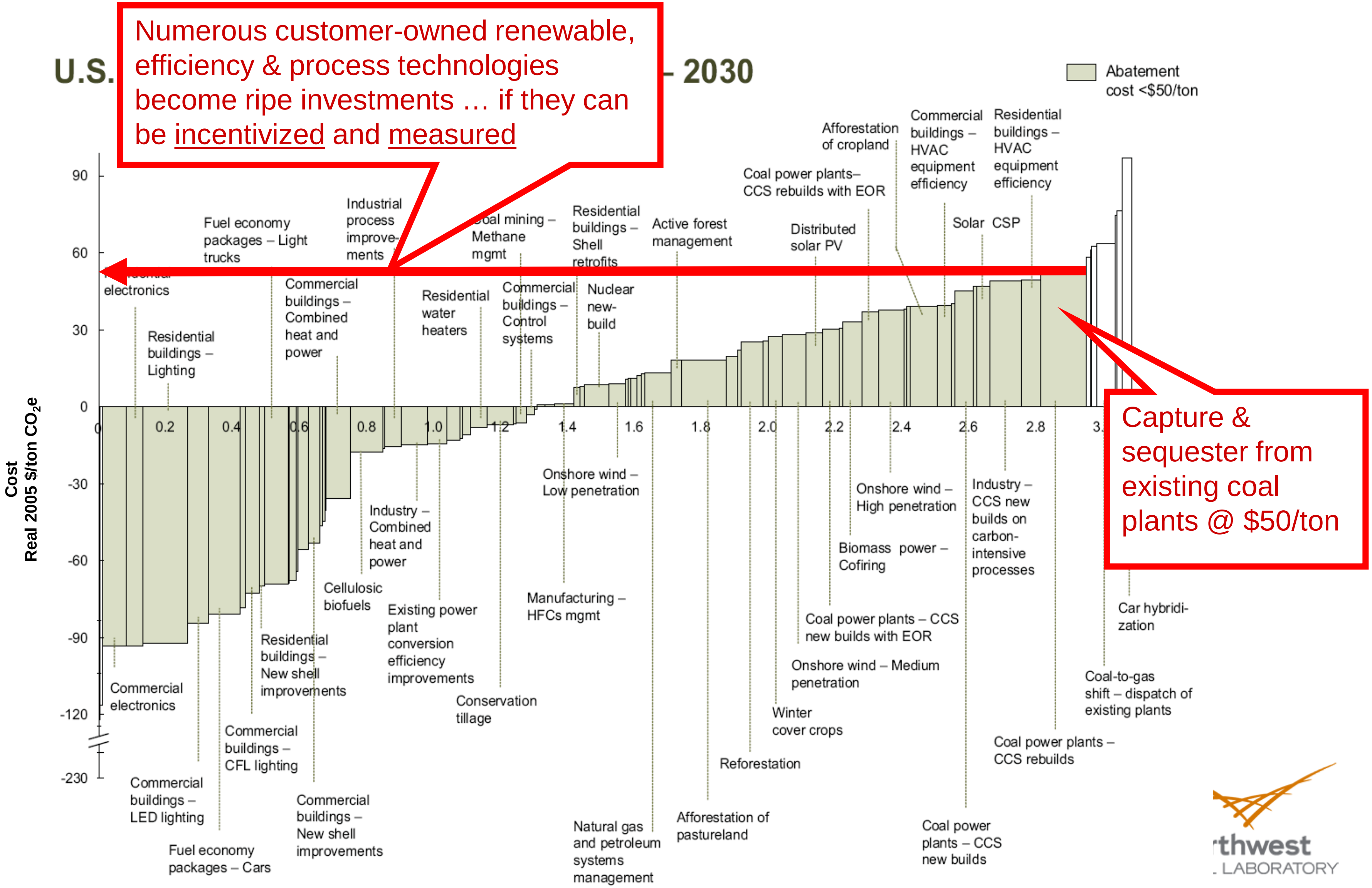
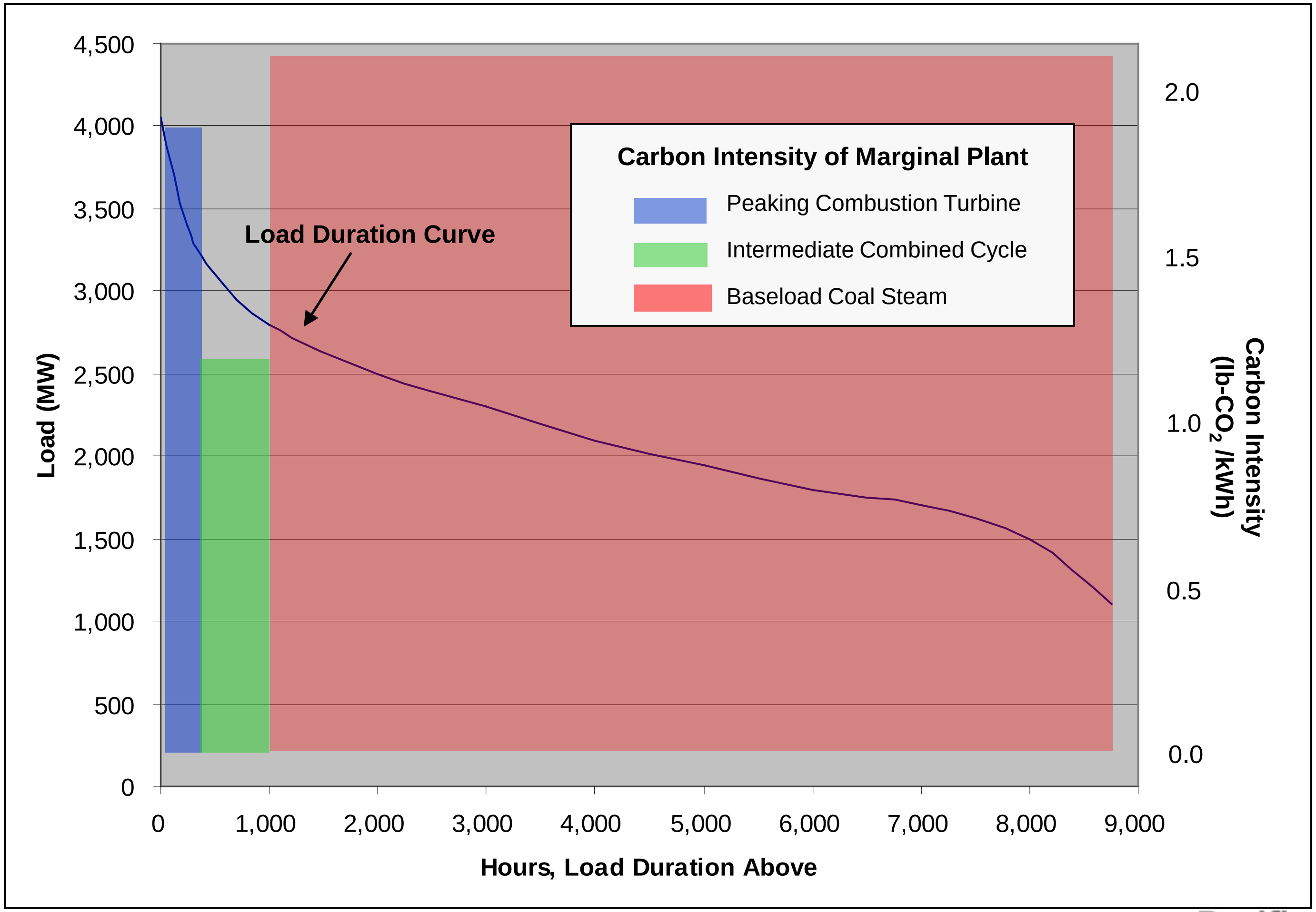
Carbon Supply Curve Suggests Massive Investment in Diverse Set of Resources is Coming



Source: McKinsey analysis

All kWh Are Not Created Equal – DR Load Shifting from Peaking to Intermediate Generation Can Save Carbon

Load Duration Curve and Carbon Dispatch of a Typical Coal-Based Utility



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Smart Grid Can Deliver and Enable Carbon Savings – *A Sample of Mechanisms*

A *smart grid* can <u>deliver</u> carbon savings

- End-use conservation & efficiency from demand response controls
- Carbon savings from peak load shifting
- Minimize losses & resistive loads by continually optimizing distribution voltage
- Cost effective & increasingly clean energy for electric vehicles
- Improve & sustain end-use efficiency by delivering continuous, remote diagnostic & commissioning services

A *smart grid* can <u>enable</u> more, lower cost carbon savings

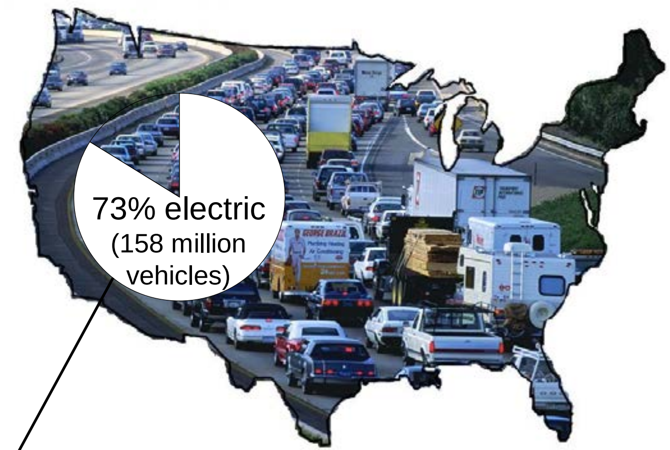
- Lower net cost for wind power by regulating fluctuations with demand response
- Distribution grids capable of safely supporting high penetrations of PV solar
- Lower costs for efficiency programs by leveraging the demand response/AMI network to measure & verifying energy & cost savings – *for each customer, with unprecedented precision, in real-time*
    - Accurate accounting of actual carbon footprint of generation displaced by efficiency & renewables
    - Solid verification enhances value & tradability of carbon offsets (if allowed)

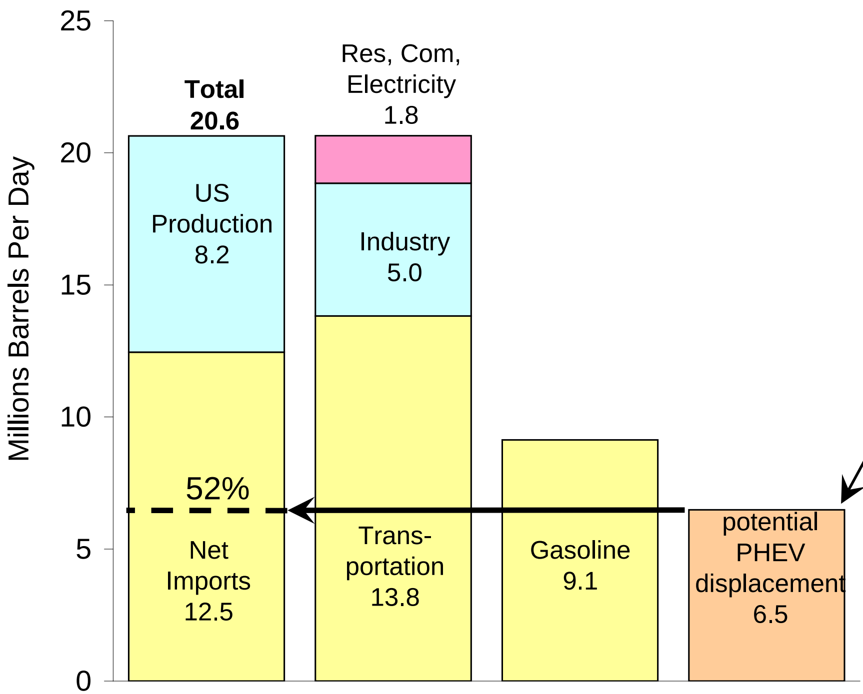
Potential Impacts of High Penetration of Plug-in Hybrid Vehicles (PHEVs) on the U.S. Power Grid*

** PNNL study for DOE Office of Electricity*

The idle capacity of today's U.S. grid **could supply 73%** of the energy needs of <u>today's</u> cars, SUVs, pickup trucks, and vans…

without adding generation or transmission
<u>if vehicles are managed to charge off peak</u>





Source: EIA, Annual Energy Review 2005

- Potential to displace 52% of net oil imports (6.7 MMbpd)
- More sales + same infrastructure = downward pressure on rates
- Reduces CO_2 emissions by 27%
- Emissions move from tailpipes to smokestacks (and base load plants) … cheaper to clean up
- Introduces vast electricity storage potential for the grid

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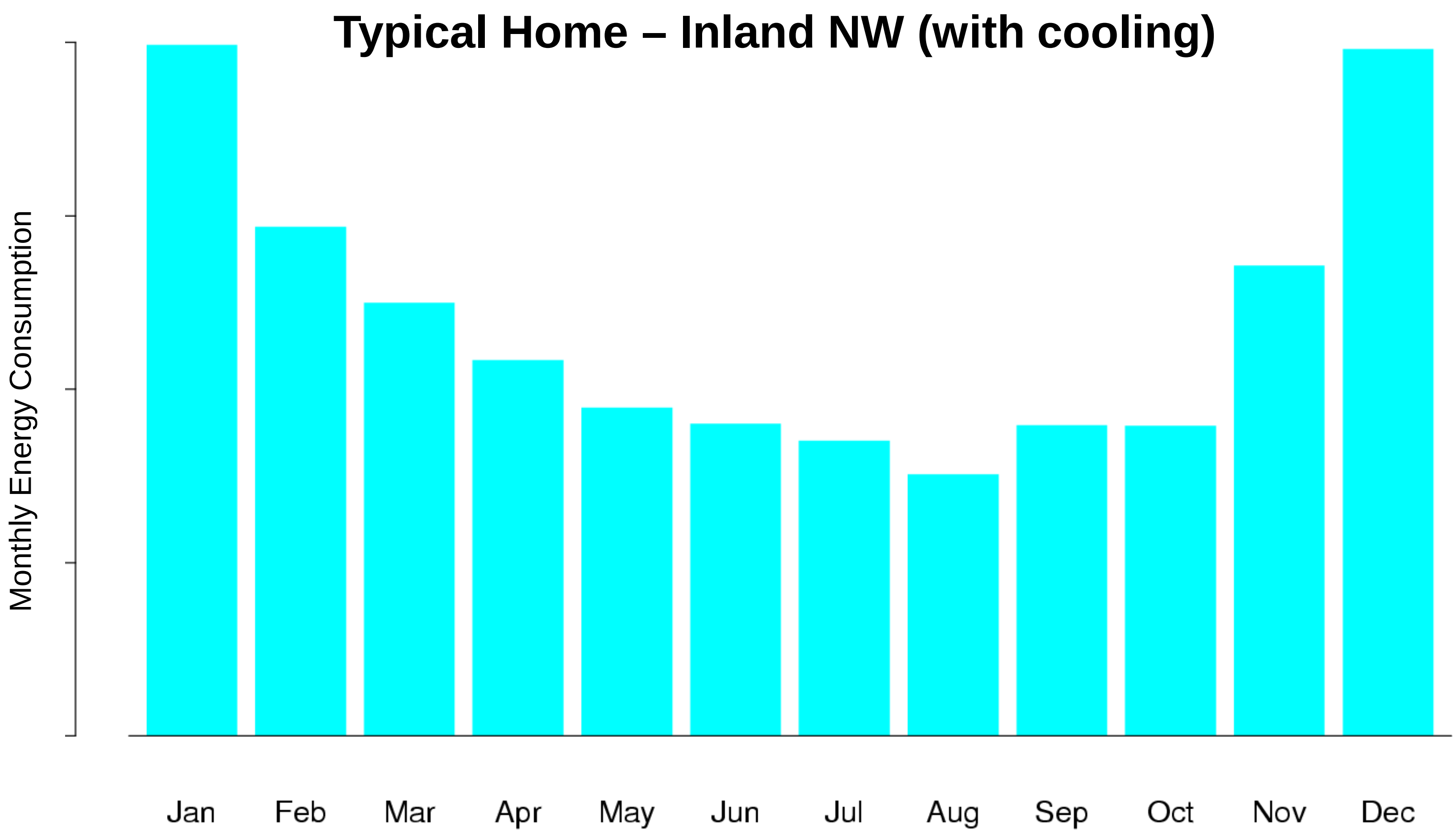
How Does a Smart Grid's Demand Response Capability Deliver Energy Efficiency?

- Customers can use scheduling and control capabilities of DR equipment to save energy in addition to peak
  - Water heater setbacks (especially)
  - Thermostat setbacks: TOU/CPP customers particularly
  - Shifting AC loads to off-peak hours results in run times during cooler morning evening hours when AC is more efficient (higher COPs)
- DR networks can be leveraged to provide remote diagnostics that improve efficiency (and reduce peak)
  - Load or run-time signals from DR load controls can be basis for diagnostics
  - Communications network allows diagnostic services to be provided remotely, universally

Measurement of Efficiency Savings Today: Basis is 12 Monthly Bills



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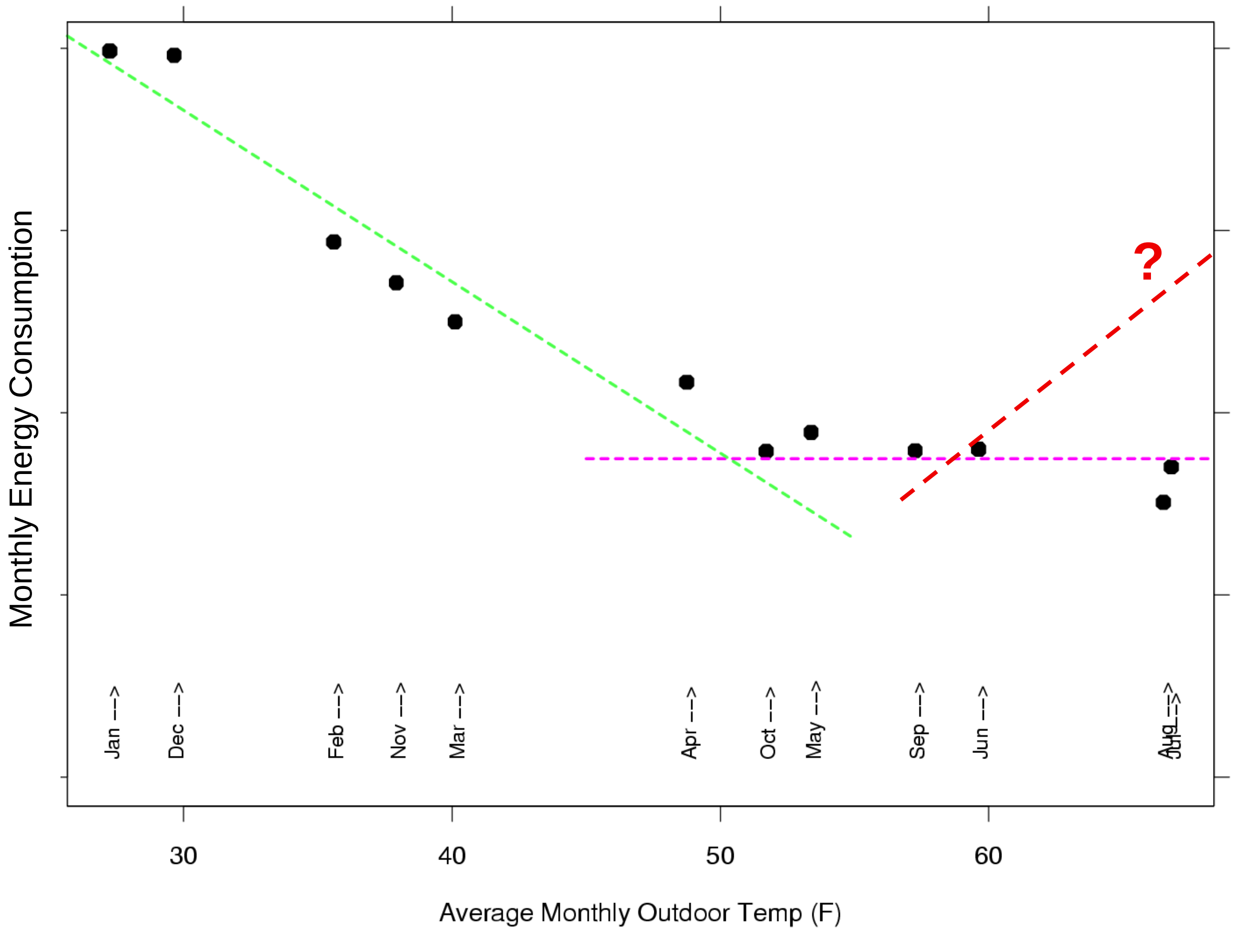
Using the DR Network to Measure and Verify Savings from Efficiency

- Measure and verify peak, energy, and cost savings, by customer, by end use category
  - Utilize AMR and demand response network and controls to disaggregate load into major end uses
  - Time-series and end-use detail provides much higher validity to savings estimates
  - Build & continually update models of customer loads for use in both verification and diagnostics
- Tabulate renewable, efficiency, and carbon credits by integrating with back office systems
  - Weight consumption by CO_2 footprint of generation in real time to gain carbon benefits of load shift
  - Solid verification enhances value

Analysis of Monthly Billing Data vs. Outside Temperature Yields Minimal Information



- State-of-the-art is 20-yr old PRISM billing data analysis
- Heating vs. base load is apparent, but with significant uncertainty
- Note AC is invisible

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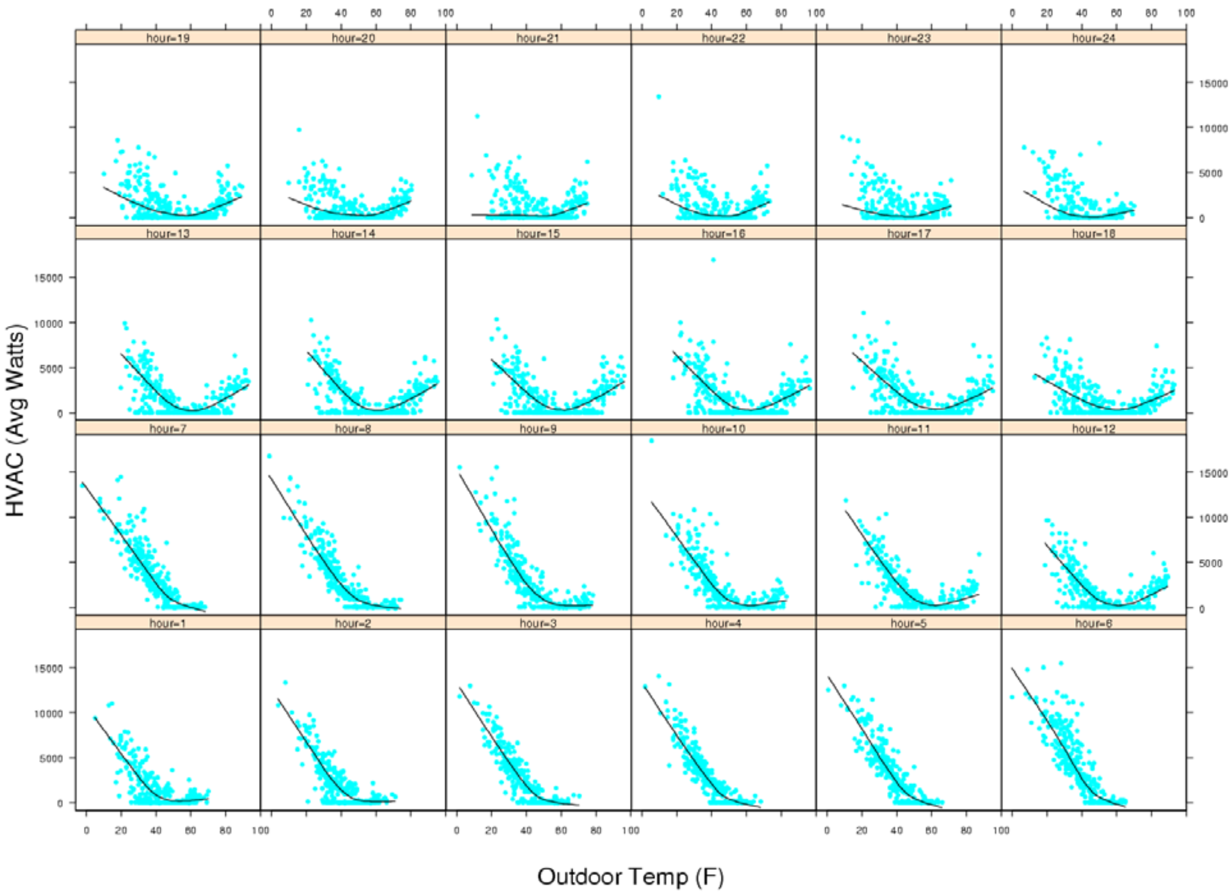
Smart Grid Provides Time-Series Data with End Use Resolution



- Vastly improved resolution allows detailed analysis of end-use savings
- Note AC load is now apparent

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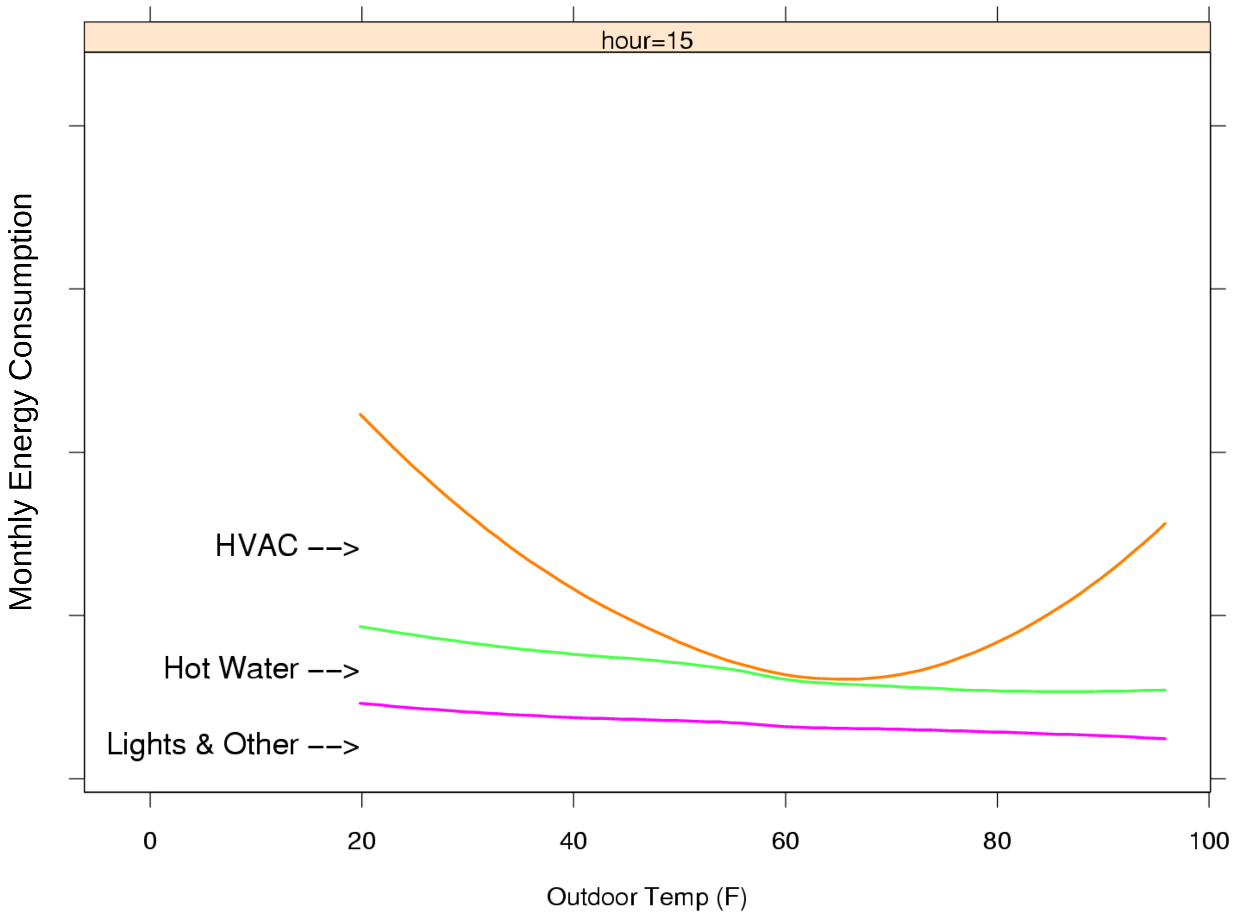
DR Networks Can Support Detailed Analysis of Most Types of Efficiency Savings



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What We've Learned from the Olympic Peninsula Demonstration

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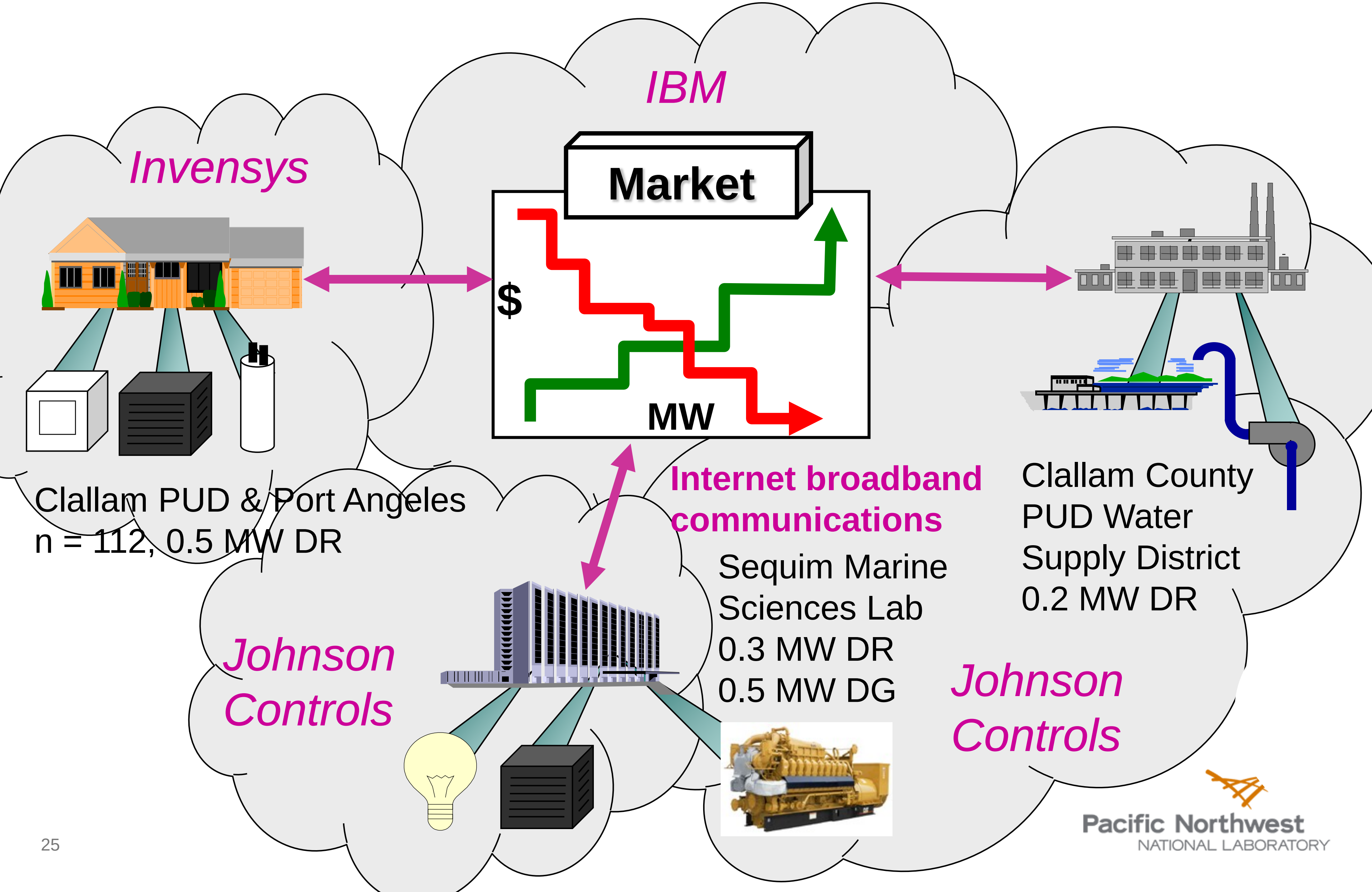
Olympic Peninsula Demonstration



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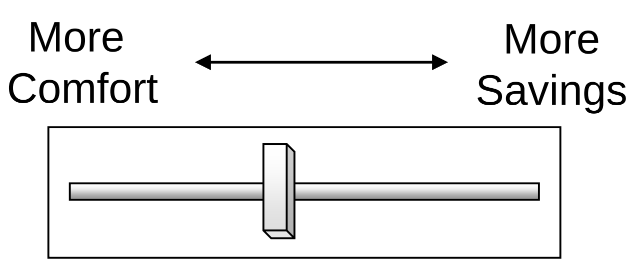
Olympic Peninsula Demo: Key Findings (1)

Customers can be recruited, retained, and will respond to *dynamic pricing* schemes **<u>if they are offered</u>**:

- Opportunity for significant savings (~10% was suggested)
- A “no-lose” proposition compared to a fixed rate
- Control over how much they choose to respond, with which end uses, and a 24-hour override
  - prevents fatigue: reduced participation if called upon too often
- Technology that automates their desired level of response
- A simple, intuitive, semantic interface to automate their response



Translates to thermostat control parameters

Olympic Peninsula Demo: Key Findings (2)

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 + distribution congestion
- Able to cap net demand at an arbitrary level to manage local distribution constraint
- Short-term response capability could provide regulation, other ancillary services adds significant value at very low impact and low cost)
- Same signals integrated commercial & institutional loads, distributed resources (backup generators)

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