

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

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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.



Revealing Values +
Communications +
Advanced Controls
≡ Electric infrastructure

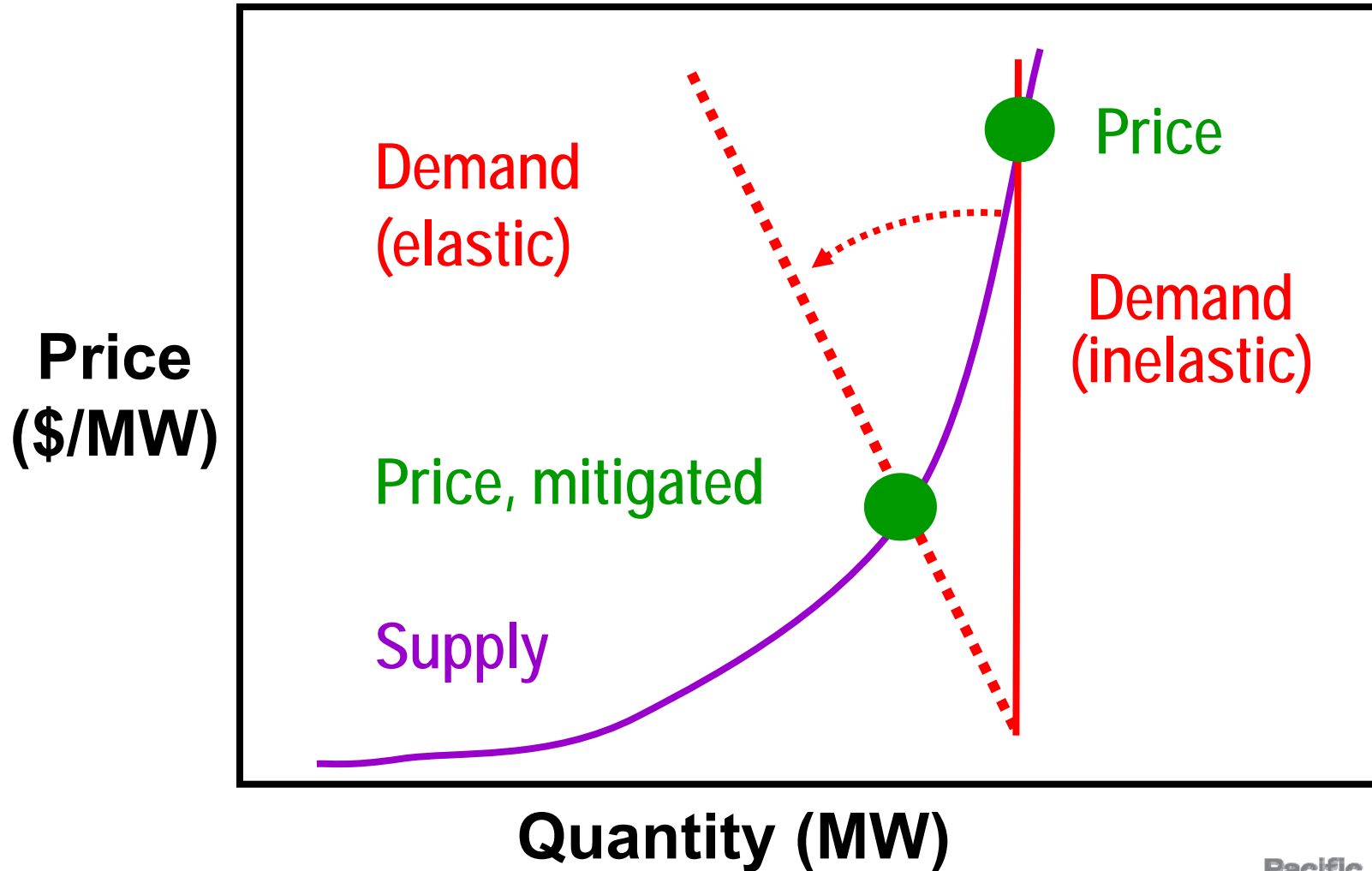
The choice is easy because...

\$ bits << \$ iron

Some Key Smart Grid Technologies

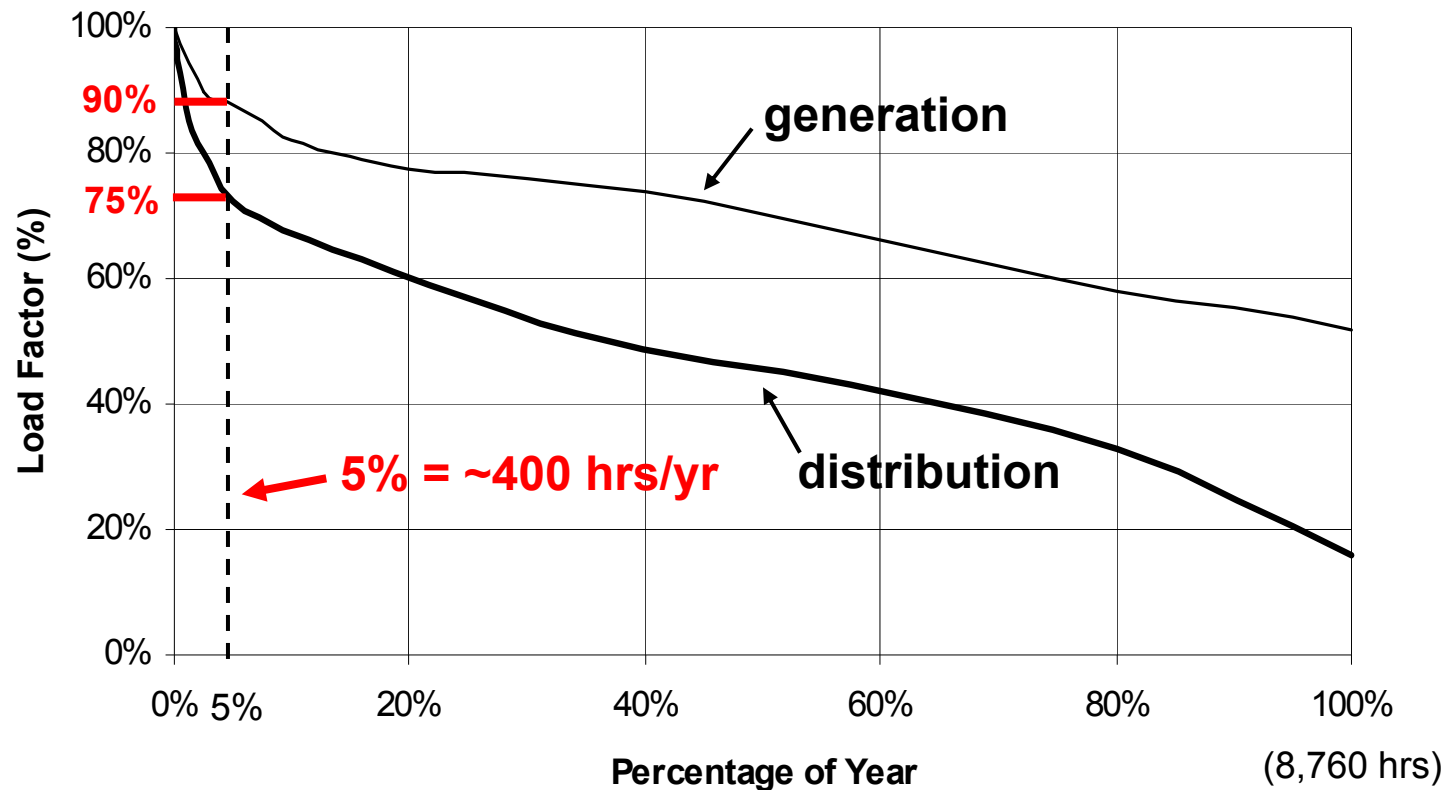
- ▶ Communications
- ▶ Smart meters measure consumption at intervals (1 hour → 5 minutes)
- ▶ Demand response (to prices or other incentive signals)
- ▶ Distributed generation
- ▶ Distributed storage
- ▶ Distribution/feeder automation: smart switching of electric distribution system
- ▶ Advanced transmission visualization & control

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



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

Hourly Loads as Fraction of Peak, Sorted from Highest to Lowest

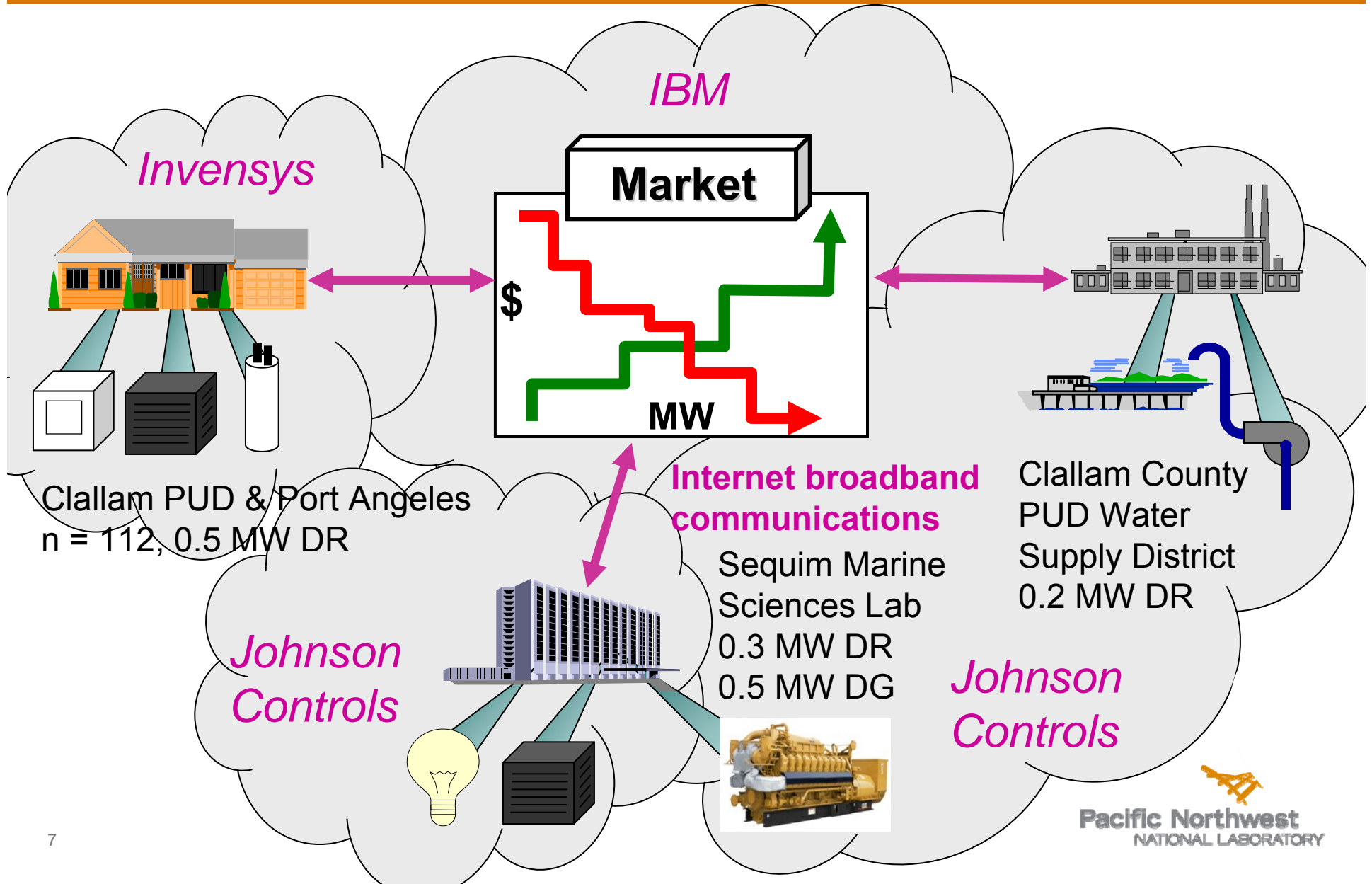


25% of distribution & 10% of generation assets (transmission is similar), worth of 100s of billions of dollars, are needed less than 400 hrs/year!

Fully Engaging Demand: What We've Learned from the Olympic Peninsula Demonstration



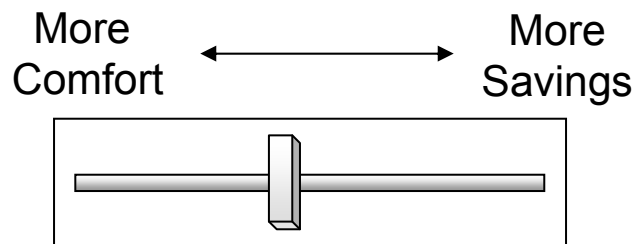
Olympic Peninsula Demonstration



Olympic Peninsula Demo: Key Findings (1)

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

- ▶ 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 control parameters:

K, T_{max}, T_{min} (see *Virtual Thermostat*)

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)

The Smart Grid and Carbon

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

A smart grid can deliver carbon savings

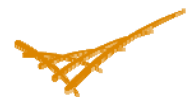
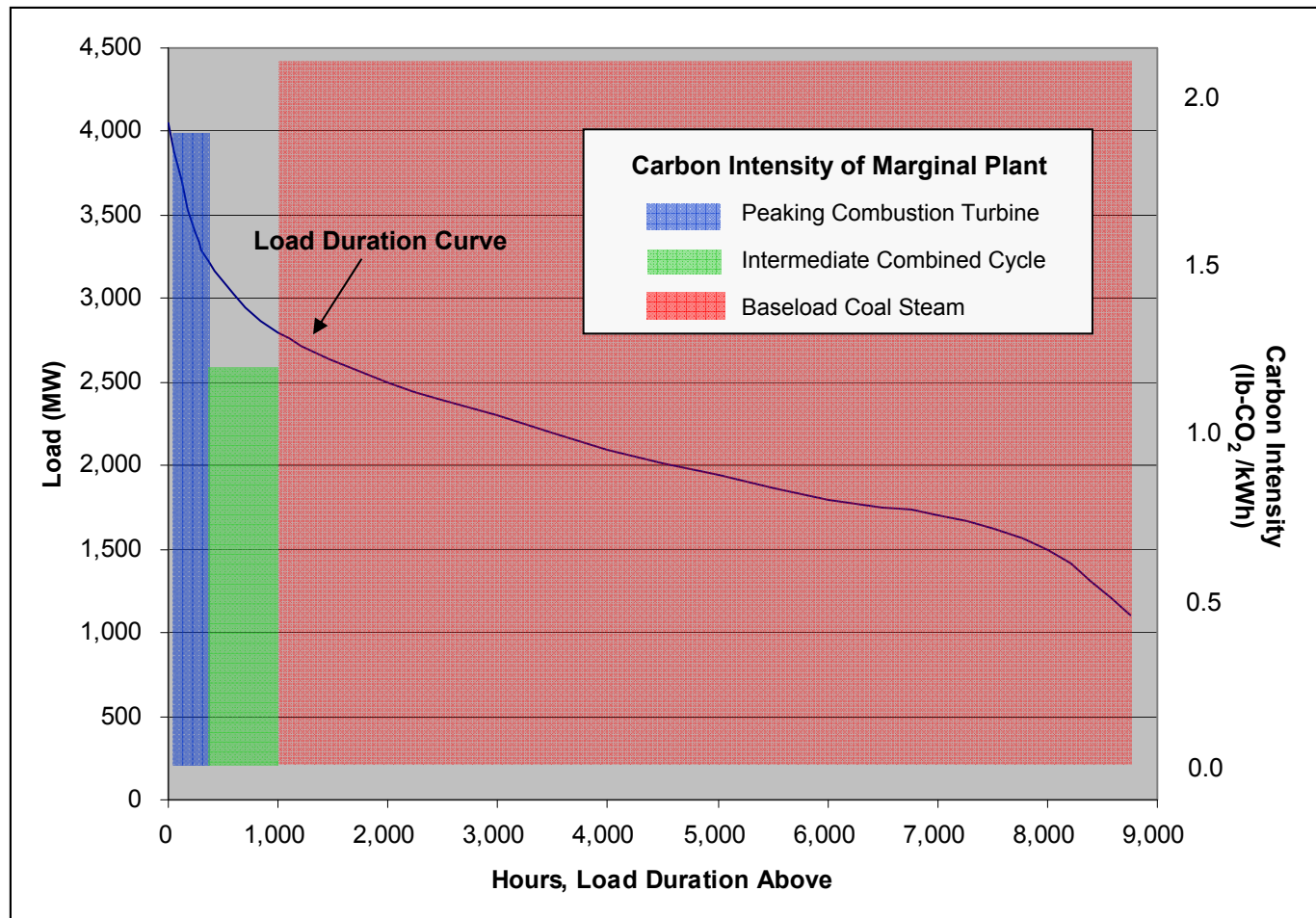
- End-use conservation & efficiency from demand response controls
- Carbon savings from peak load shifting
- Minimize losses & resistive loads by continually optimizing distribution voltage
- Cost effective & increasingly clean energy for electric vehicles
- Improve & sustain end-use efficiency by delivering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

A smart grid can enable 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)

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

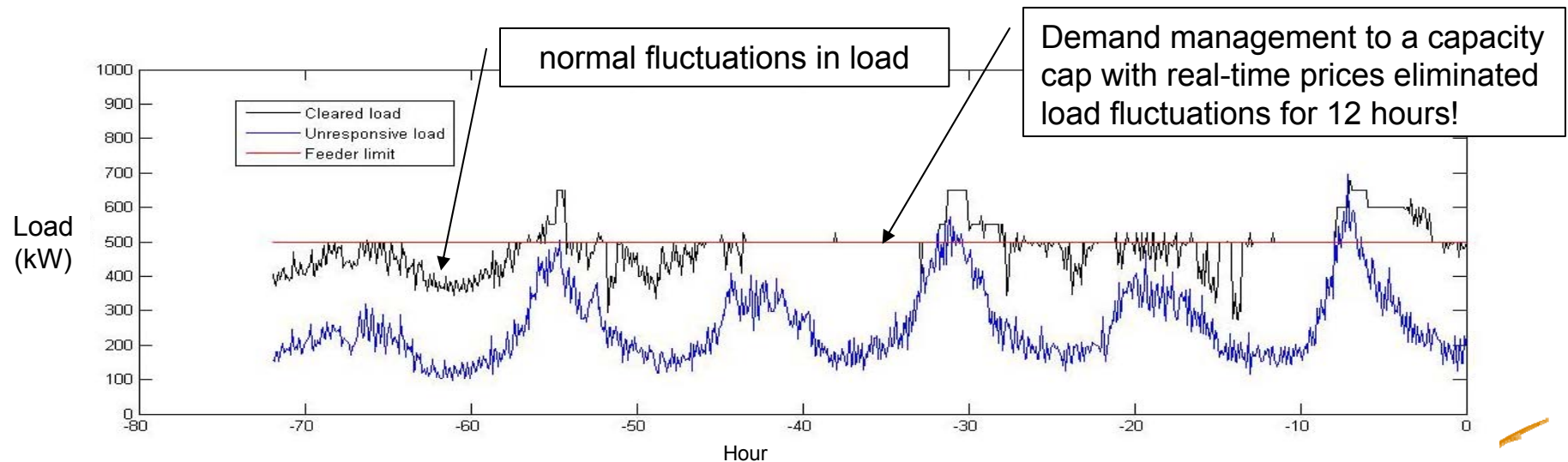


Potential for Demand Response to Help Manage the Large Infusion of Wind Power Implicit in a Carbon Strategy

Regulation: one or more fast-responding power plants continually throttle to match normal fluctuations in load

Highest cost generation in markets (zero energy sales, wear & tear, fuel consumption)

Fluctuations in wind farm output greatly exacerbate need for regulation, reduce cost effectiveness of wind power at high penetrations

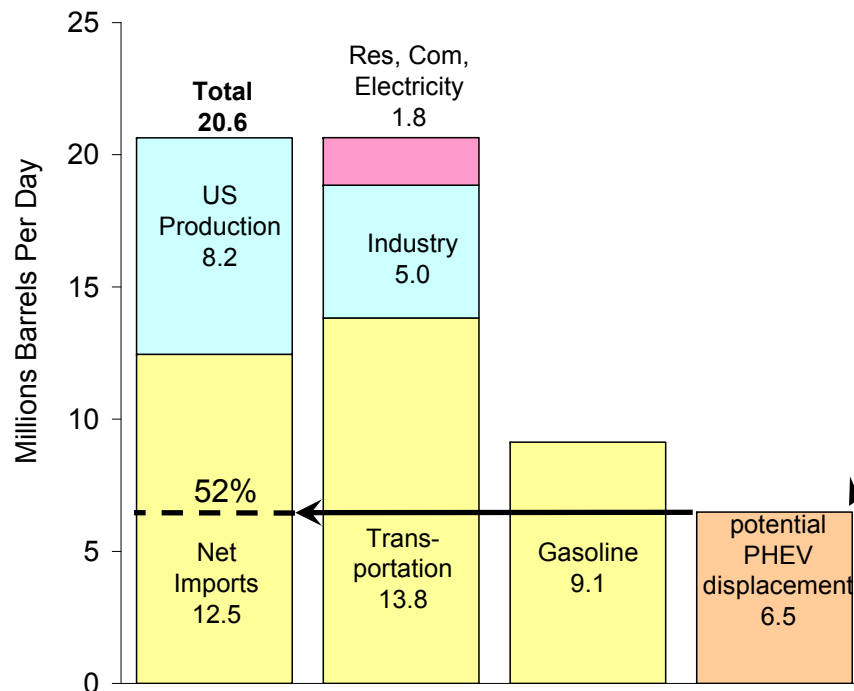
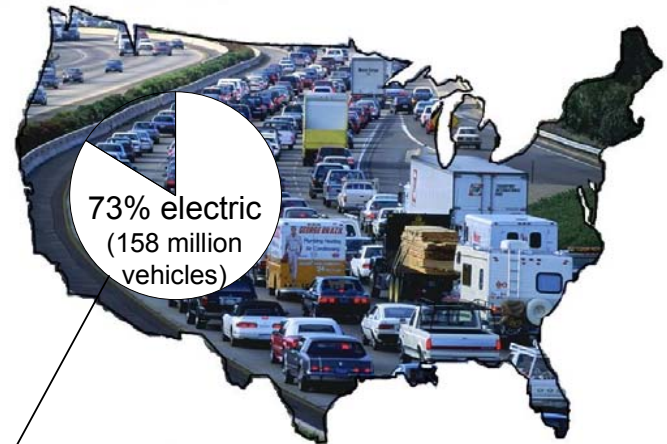


Potential Impacts of High Penetration of Plug-in Hybrid Vehicles (PHEVs) on the U.S. Power Grid*

* PNNL study for DOE Office of Electricity

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

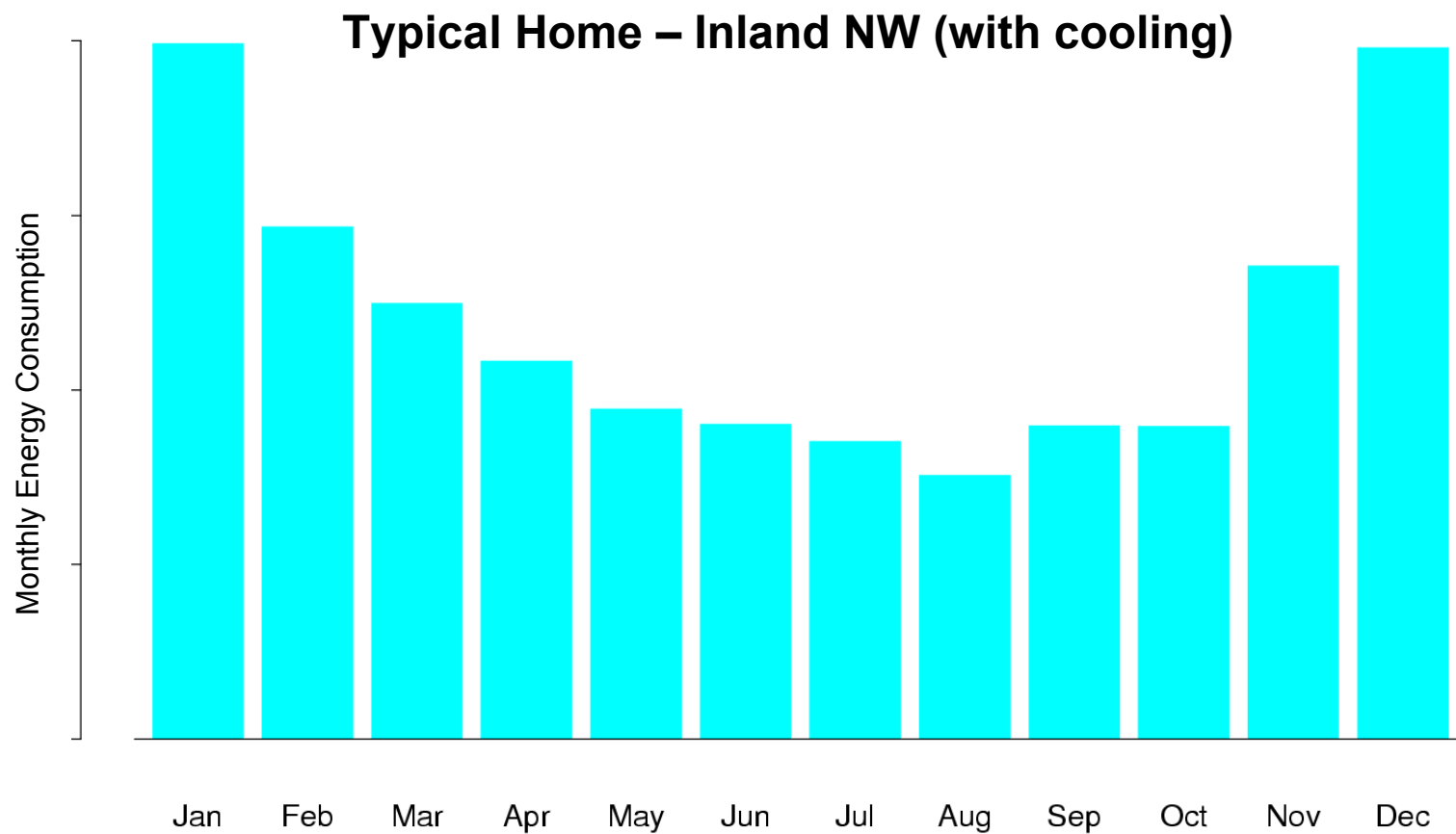
without adding generation or transmission if vehicles are managed to charge off peak



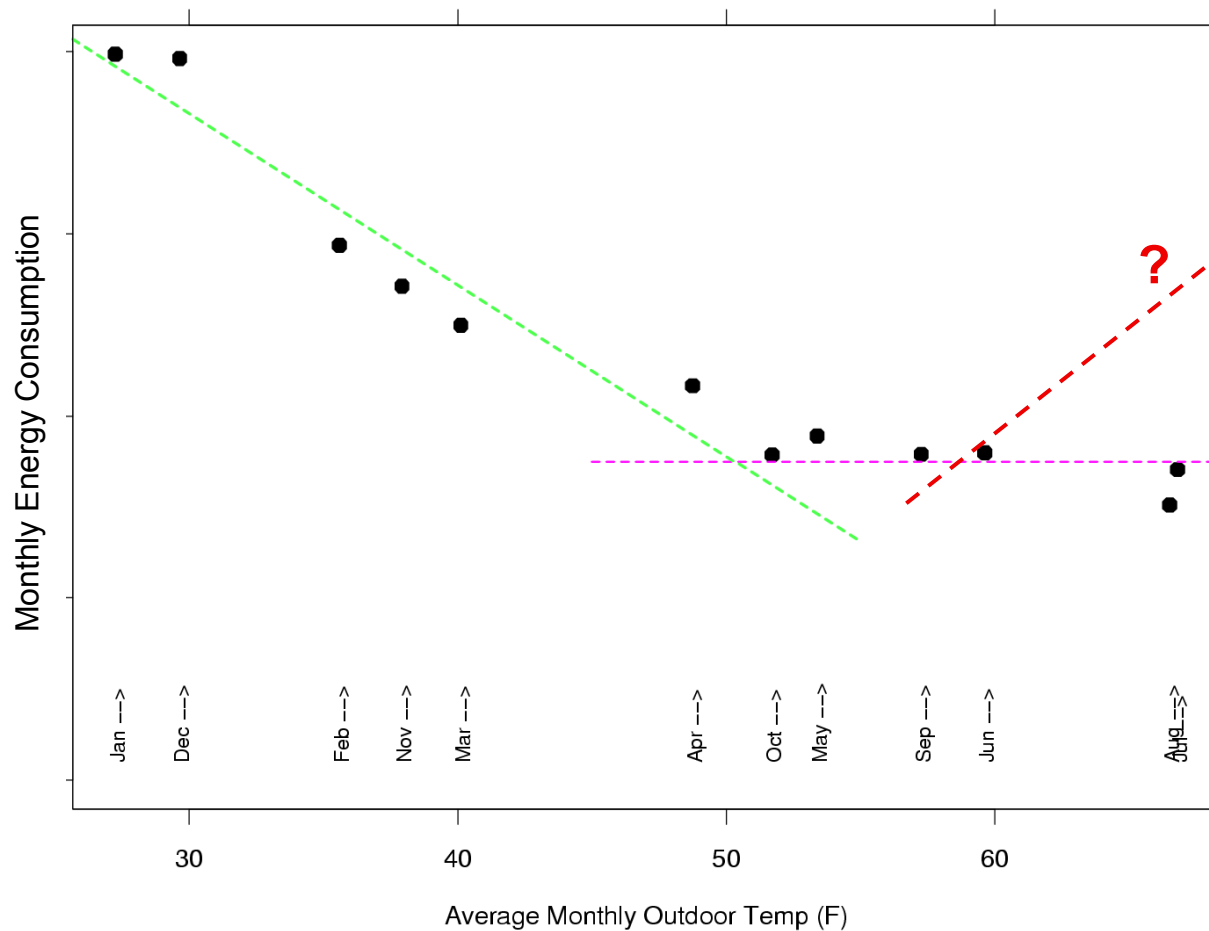
Source: EIA, Annual Energy Review 2005

- ▶ Potential to displace 52% of net oil imports (6.7 MMbpd)
- ▶ More sales + same infrastructure = downward pressure on rates
- ▶ Reduces CO₂ 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

Measurement of Efficiency Savings Today: Basis is 12 Monthly Bills

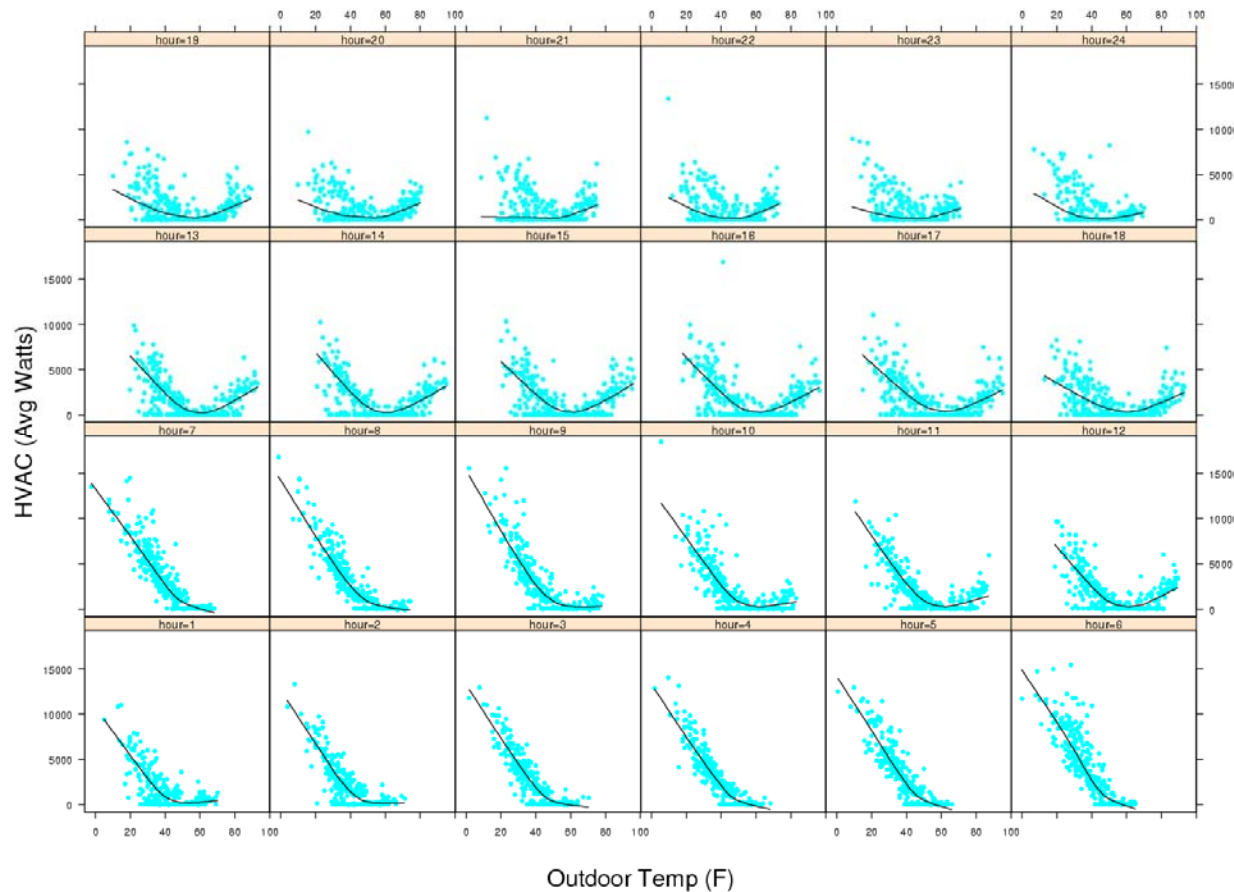


Analysis of Monthly Billing Data vs. Outside Temperature Yields Minimal Information



- ▶ 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

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

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

