Smart Grid

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Presentation Overview

- Why smart grid?
- What exactly is smart grid anyway? (The definition still depends on who you ask!)
- Summarize research on smart grid impacts on energy efficiency and demand response.
- Summarize Colorado-specific research on CO_2 and levelized cost implications of smart grid.
- Highlight potential benefit of smart grid to wind integration.
- Discuss transitional challenges.

Why Smart Grid?

- Growing electricity demand;
- Increased political will to integrate renewable resources;
- Plug-in hybrid/electric vehicles (PH/EVs);
- Energy security; and
- System reliability.

Smart Grid Defined? EISAct 2007

It is the policy of the United States to support the modernization of the Nation's electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth and to achieve each of the following, which together characterize a Smart Grid:

1. Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid.
2. Dynamic optimization of grid operations and resources, with full cyber-security.
3. Deployment and integration of distributed resources and generation, including renewable resources
4. Development and incorporation of demand response, demand-side resources, and energy-efficiency resources.
5. Deployment of "smart" technologies (real-time, automated, interactive technologies that optimize the physical operation of appliances and consumer devices) for metering, communications concerning grid operations and status, and distribution automation.
6. Integration of "smart" appliances and consumer devices.
7. Deployment and integration of advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, and thermal-storage air conditioning.
8. Provision to consumers of timely information and control options.
9. Development of standards for communication and interoperability of appliances and equipment connected to the electric grid, including the infrastructure serving the grid.
10. Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services.

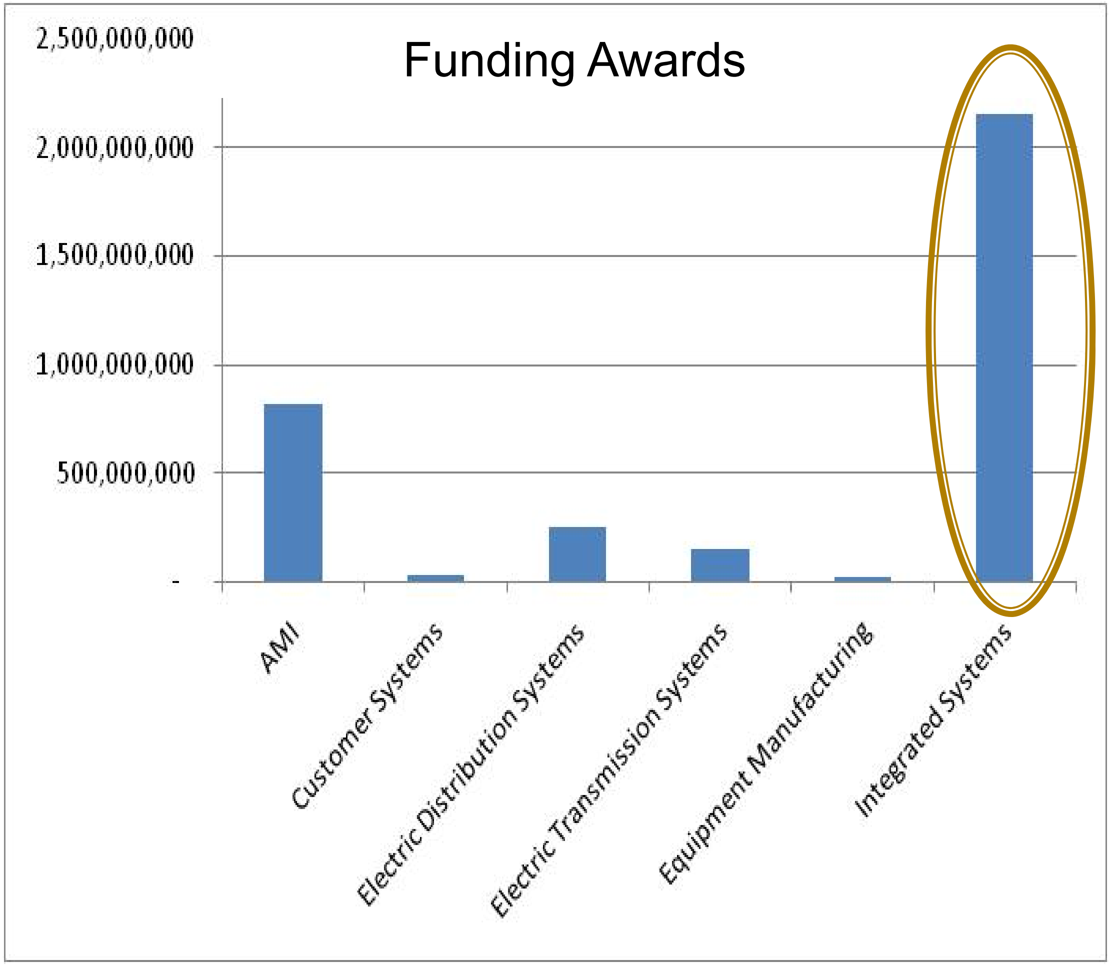
DOE Translation

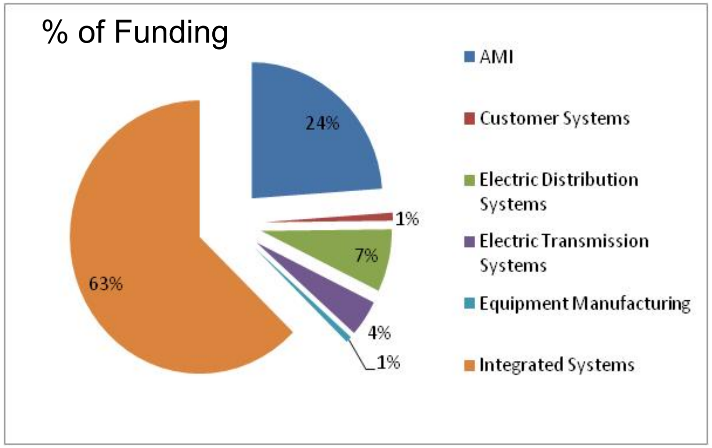
Characteristics of a Smart Grid:

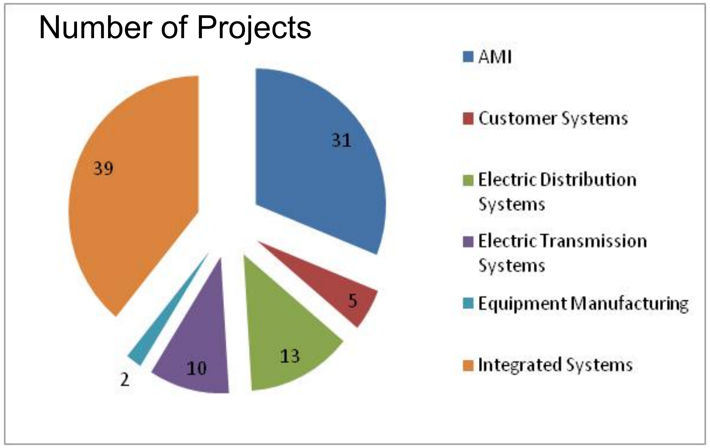
1. Enables informed participation by customers;
2. Accommodates all generation and storage options;
3. Enables new products, services, and markets;
4. Provides power quality for the range of needs in the 21st century economy;
5. Optimizes asset utilization and operating efficiency;
6. Addresses disturbances through automated prevention, containment, and restoration; and
7. Operates resiliently against all hazards.

Source: Department of Energy (2009)

ARRA: $3.43 Billion in Smart Grid Investment Grants Awarded

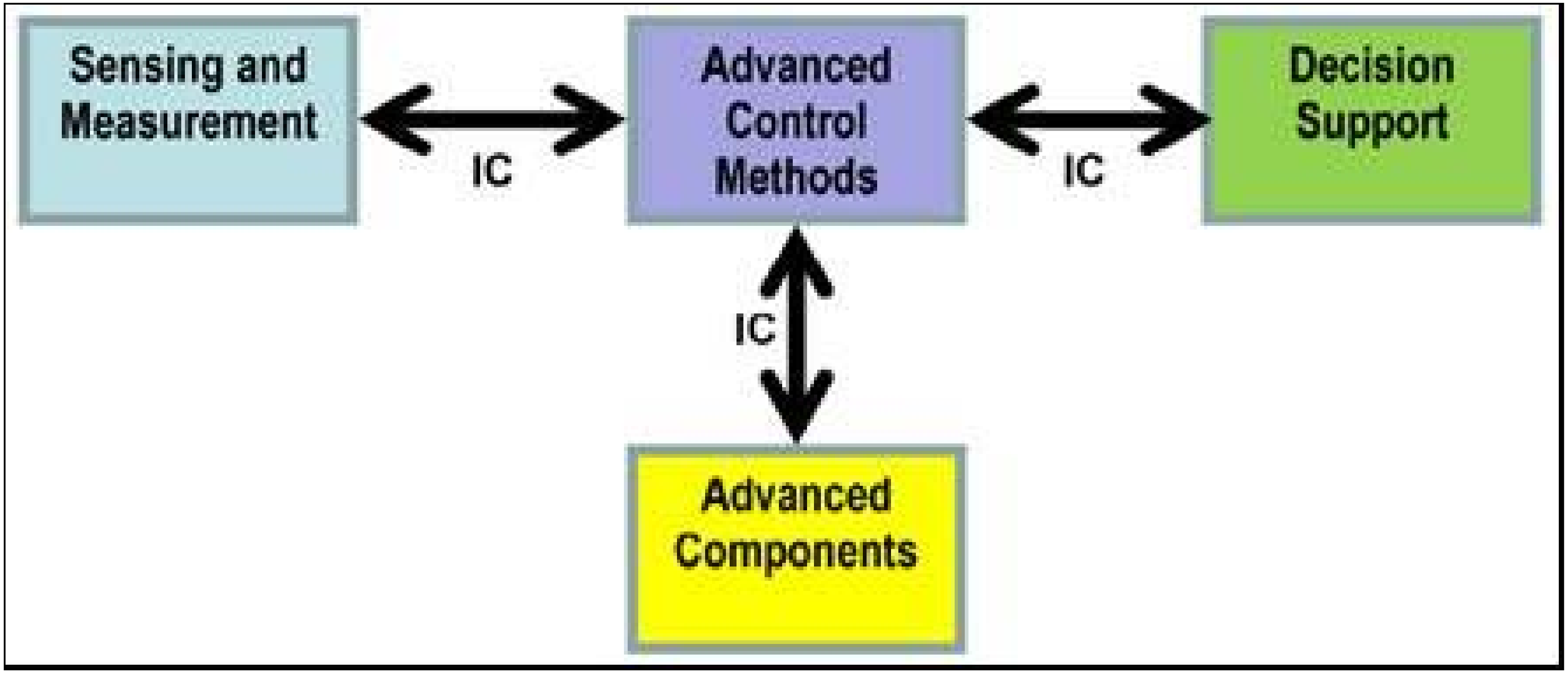






Source: Gridwise Alliance

What Does an 'Integrated System' Include? Smart Grid Technologies



IC = Integrated Communications

Source: (Electric Power Research Institute, 2010)

Smart Grid Technologies

1)	Advanced Interrupting Switch
2)	AMI/Smart Meters
3)	Controllable/Regulating Inverter
4)	Customer EMS/Display/Portal
5)	Distribution Automation
6)	Distribution Management System
7)	Enhanced Fault Detection Technology
8)	Equipment Health Sensor
9)	FACTS Device
10)	Fault Current Limiter
11)	Loading Monitor
12)	Microgrid Controller
13)	Phase Angle Regulating Transformer
14)	Phasor Measurement Technology
15)	Smart Appliances and Equipment (Customer)
16)	Software - Advanced Analysis/Visualization
17)	Two-Way Communications (High Bandwidth)
18)	Vehicle to Grid Two-Way Power Converter
19)	VLI (HTS) Cables

Source: (Electric Power Research Institute, 2010)

Smart Grid Working Definition:

Smart grid is not a single technology, but rather a suite of technologies which enable:

- Demand Response (manage the load curve)
- Efficiency (operational and end-use)
- Renewable Integration (central and distributed)
- Plug-in Hybrid/Electric Vehicle (PH/EV) Integration
- Consumer Choice and Control (price and environmental)

SMART GRID BENEFITS		
Economic	Improved Asset Utilization	Optimized Generator Operation & Dispatch
		Deferred Generation Capacity Investments
		Reduced Ancillary Service Cost
		Reduced Congestion Cost
	T&D Capital Savings	Deferred Transmission Capacity Investments
		Deferred Distribution Capacity Investments
		Reduced Equipment Failures
	T&D Operations and Maintenance Savings	Reduced Distribution Maintenance Cost
		Reduced Distribution Operations Cost
		Reduced Meter Reading Cost
	Theft Reduction	Reduced Electricity Theft
	Energy Efficiency	Consumption Efficiency
		Reduced Electricity Losses
Reliability	Power Interruptions	Reduced Sustained Outages
		Reduced Major Outages
		Reduced Restoration Cost
	Power Quality	Reduced Momentary Outages
		Reduced Sags and Swells
Environmental	Air Quality	Reduced CO2 Emissions
		Reduced SOx, NOx, and PM-10 Emissions
Security	Energy Security	Reduced Oil Usage
		Reduced Wide-Scale Blackouts

Source: (Electric Power Research Institute, 2010)

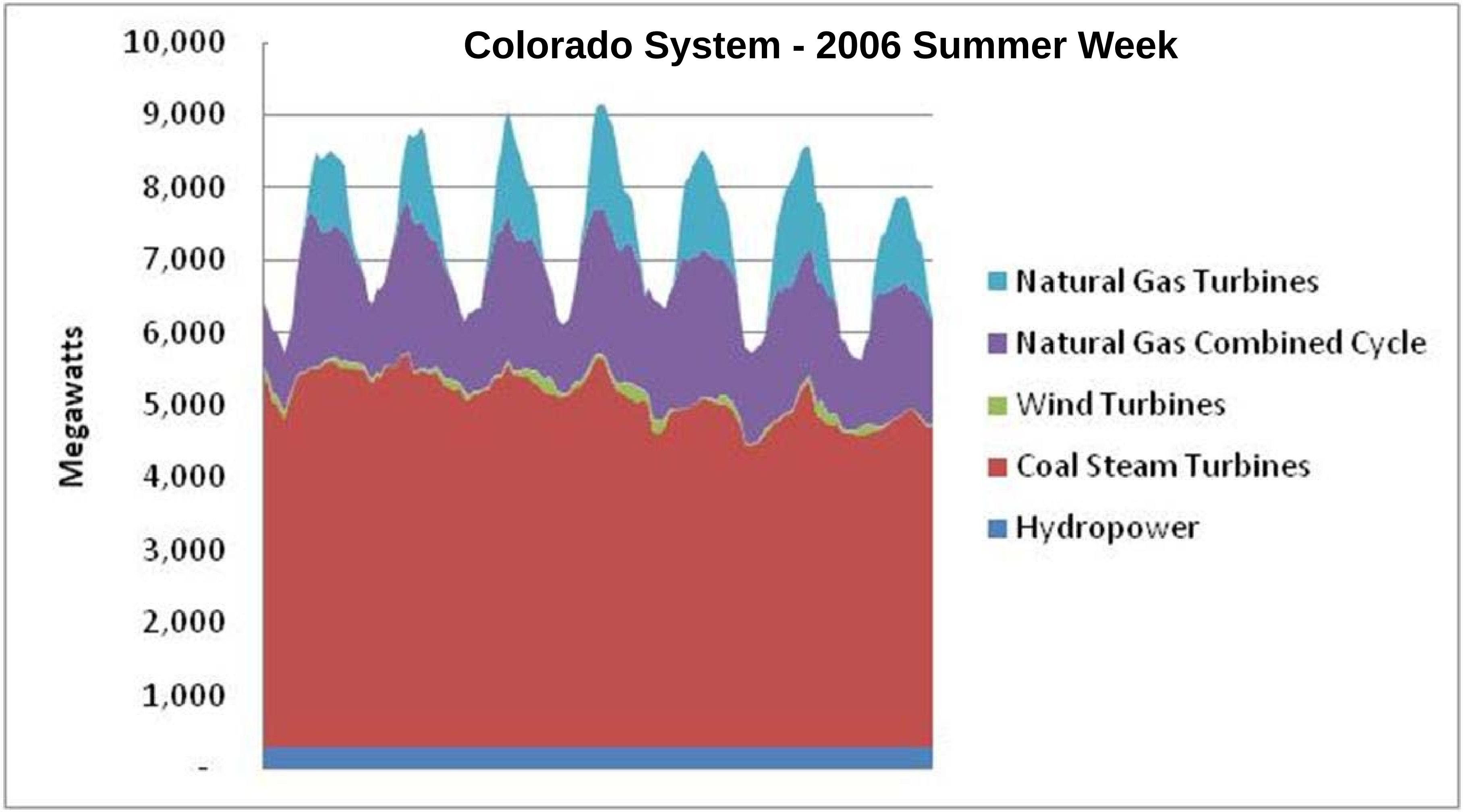
Smart Grid Benefits for Renewables

- Demand response and managed PH/EV charging flexibly align demand with renewable supply.
- Increased system awareness, forecasting, and control facilitate integration of intermittent resources.
- Reduced curtailment reduces integration costs.

The Consumer Side of the Equation

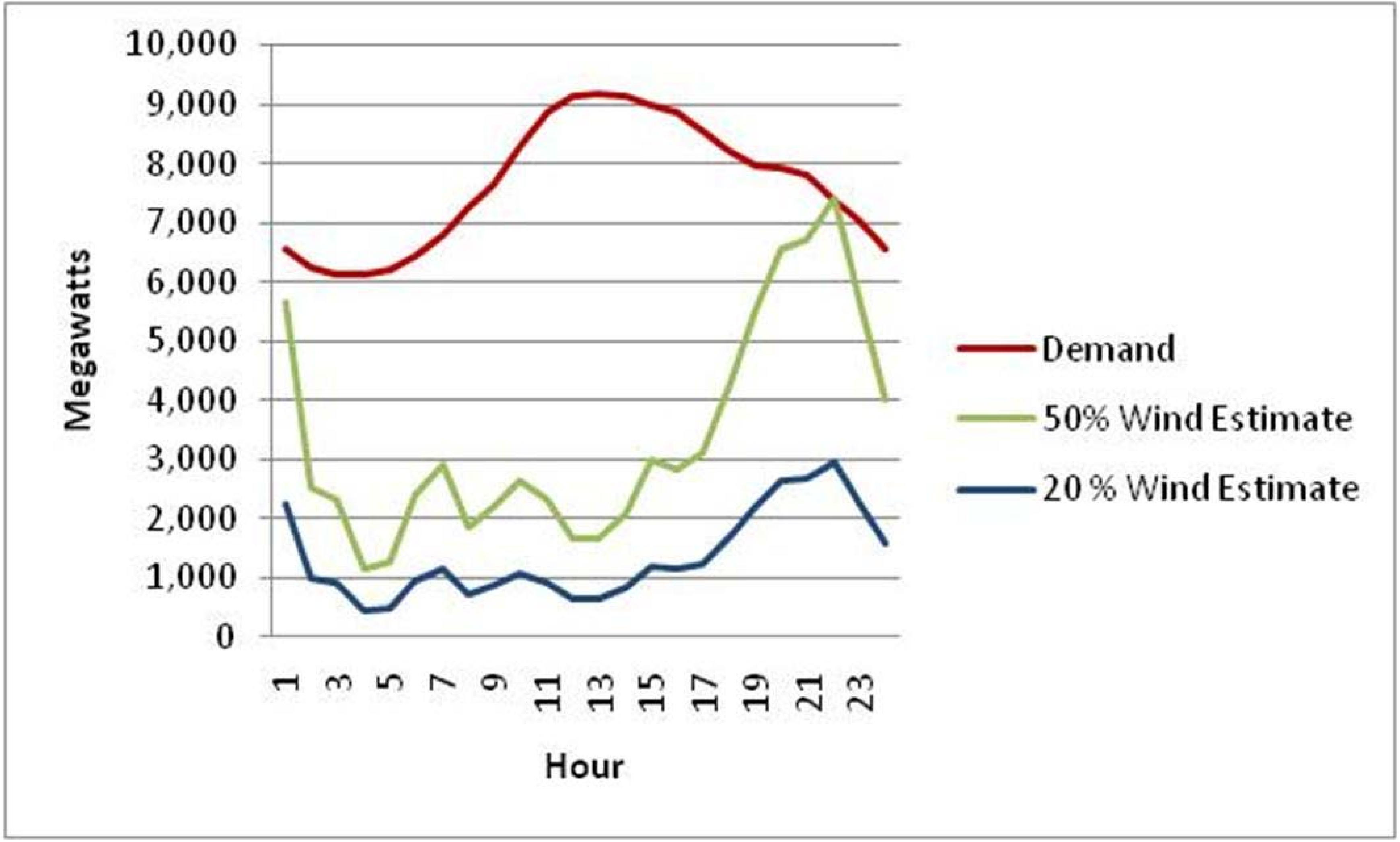
- Much of the potential benefit of smart grid is dependent upon consumer adoption.
- Several studies have attempted to measure consumer responsiveness to smart grid enabled variable pricing and informational displays.
- Greater scientific rigor in study design is essential to develop actionable estimates of changes in consumer behavior.

Consumer Adoption => Managing the Load Curve



Sources: Ventyx Consulting, NREL, AWEA, windpower.net

Consumer Demand Versus Wind Generation



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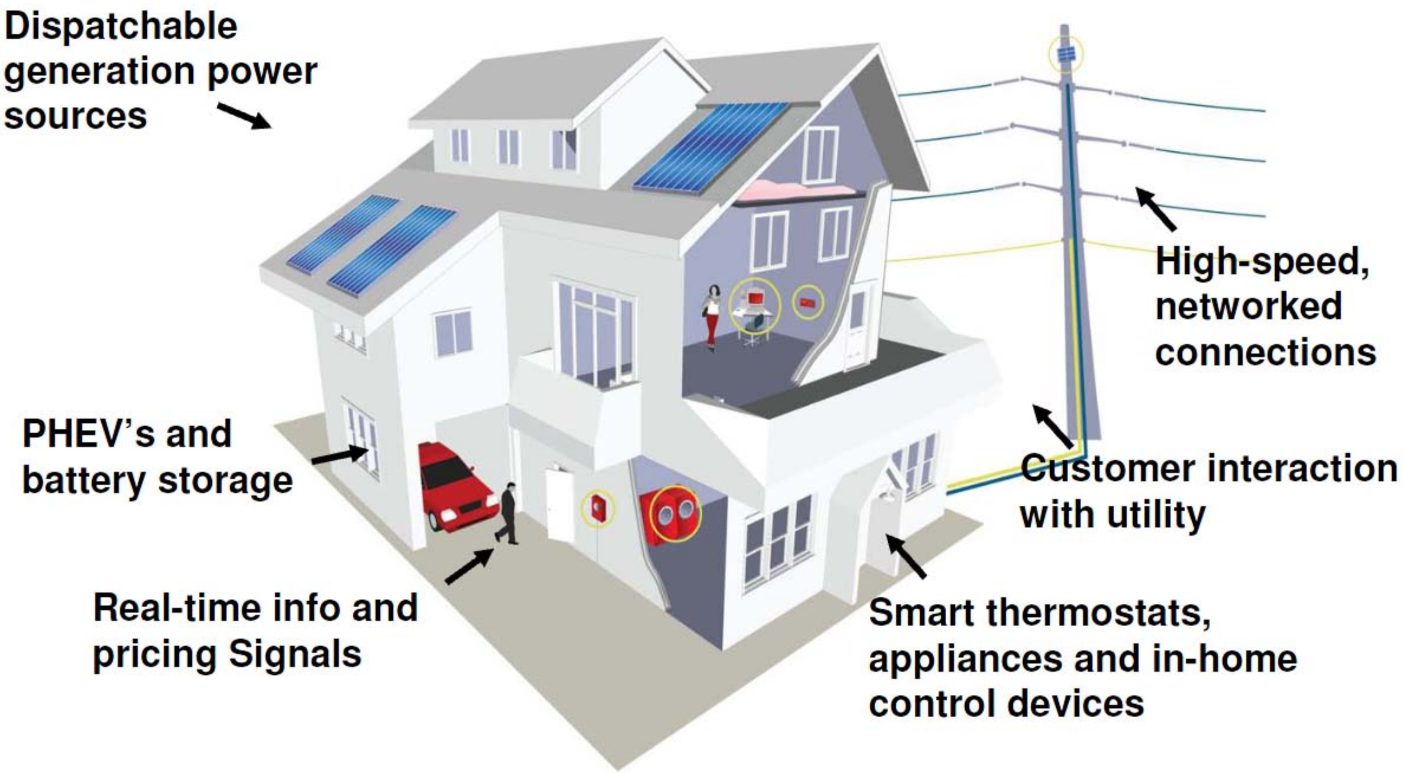
The Smart Home and Demand Management

What’s a Smart Home?



Source: Roy Palmer, Xcel Energy. Presentation to Western Governor’s Association. June 30, 2008.

In-Home Displays (IHDs)

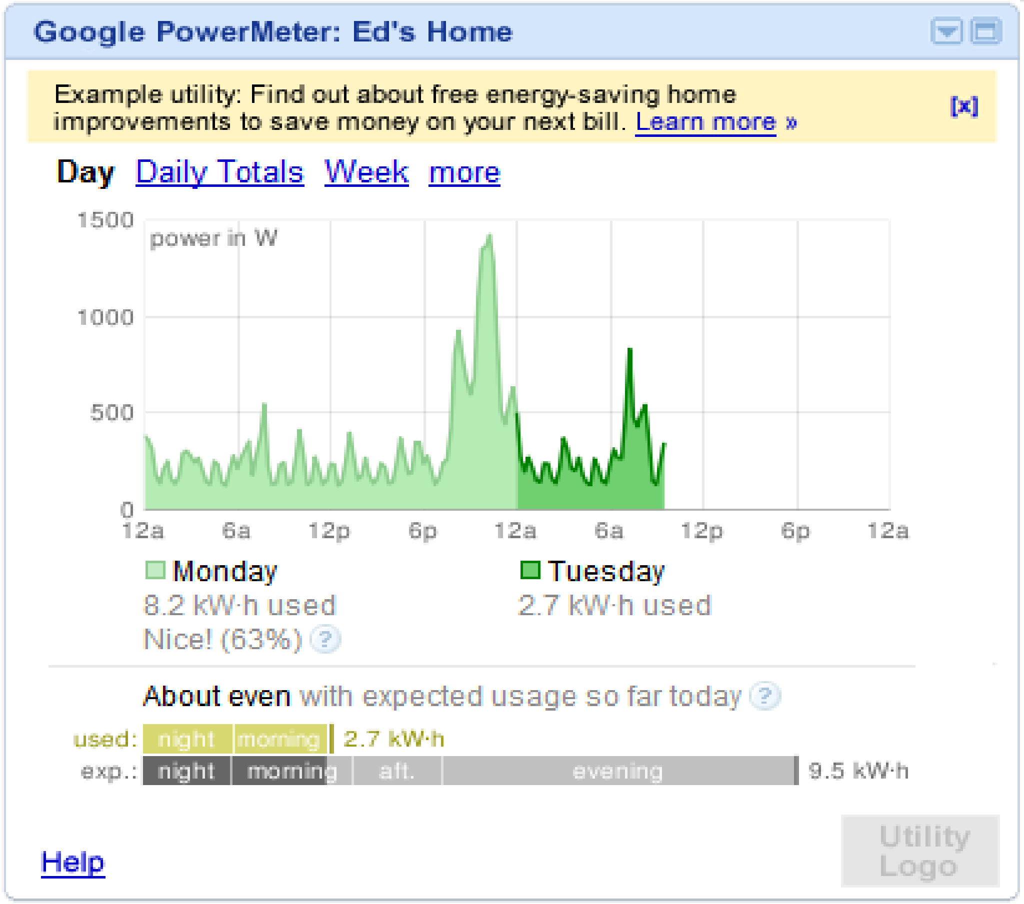
Source: Electric Power Research Institute. May 2008. "The Green Grid: Energy Savings and Carbon Emissions Reductions Enabled by a Smart Grid."

Consumer Interface: Grid Point Smart Grid Web Portal

- Allows customer to monitor and manage their energy use
- Online tools provide more options, choice, and personal control

Source: Xcel Energy (2009). "SmartGridCity: A Blueprint for a Connected, Intelligent Grid Community." http://www.oatioasis.com/PSCO/PSCOdocs/9_Smart_Grid_City.pdf.

Consumer Interface: Google Power Meter



PowerMeter creates a readout of a home's electricity use over the course of a day. (Credit: Google)

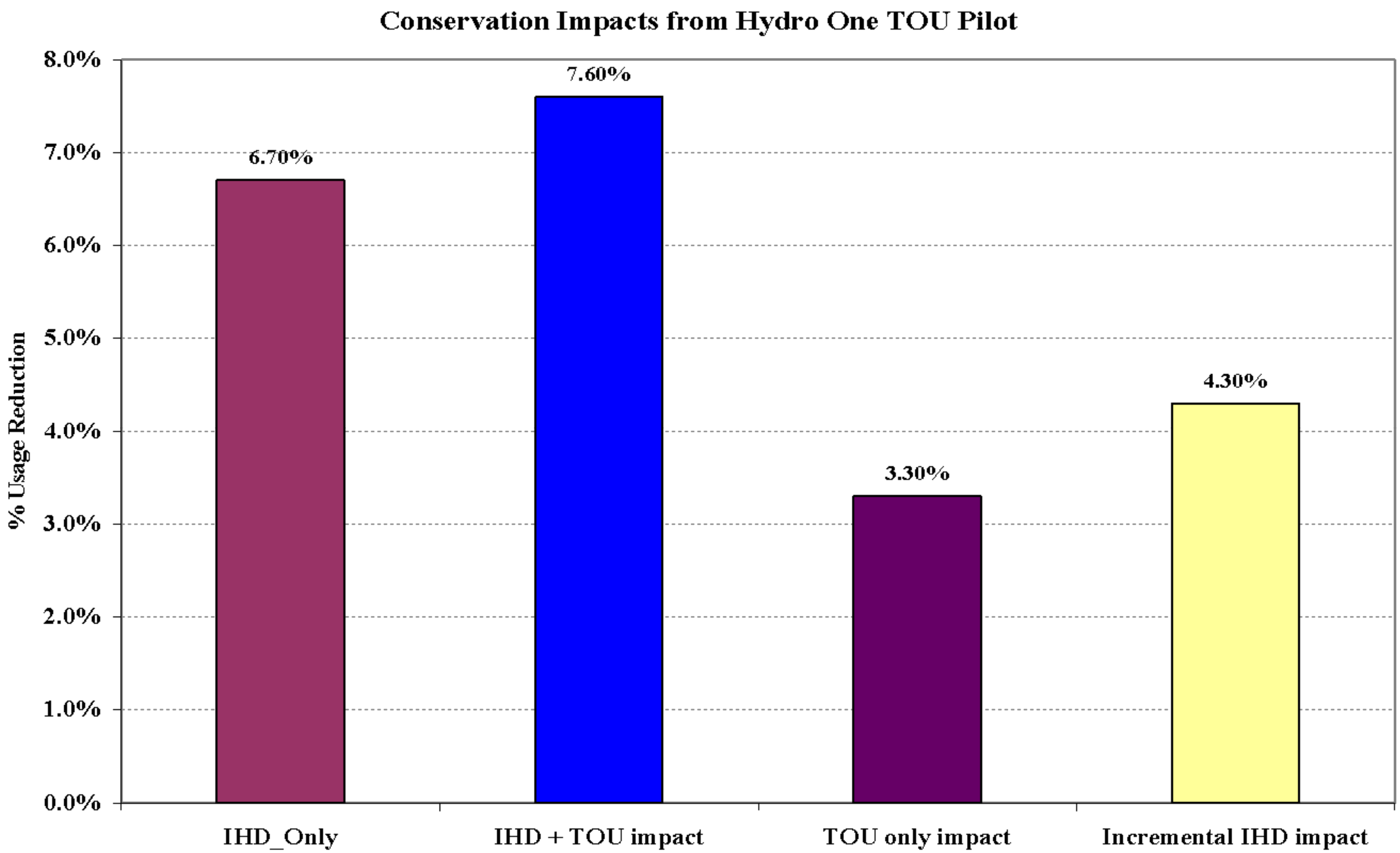
Source: CNET News. Greentech. http://news.cnet.com/8301-11128_3-10245295-54.html

Study 'A' Research Results: Smart Technology and Dynamic Pricing

- 12 month study of the Olympic Peninsula in Washington completed by the Pacific Northwestern National Lab.
- **Highly motivated study group.**
- Combined in-home 'smart' technology with dynamic pricing.
- Average savings of 10% on electric bills.
- Peak demand reduced up to 50%, 15% average for the year.
- Overall energy savings of up to 20%.
- Concluded that technology plus dynamic pricing can save energy and money and also defer/eliminate need to build additional generation and transmission.
- Estimated national savings of $70 billion over 20 year period.

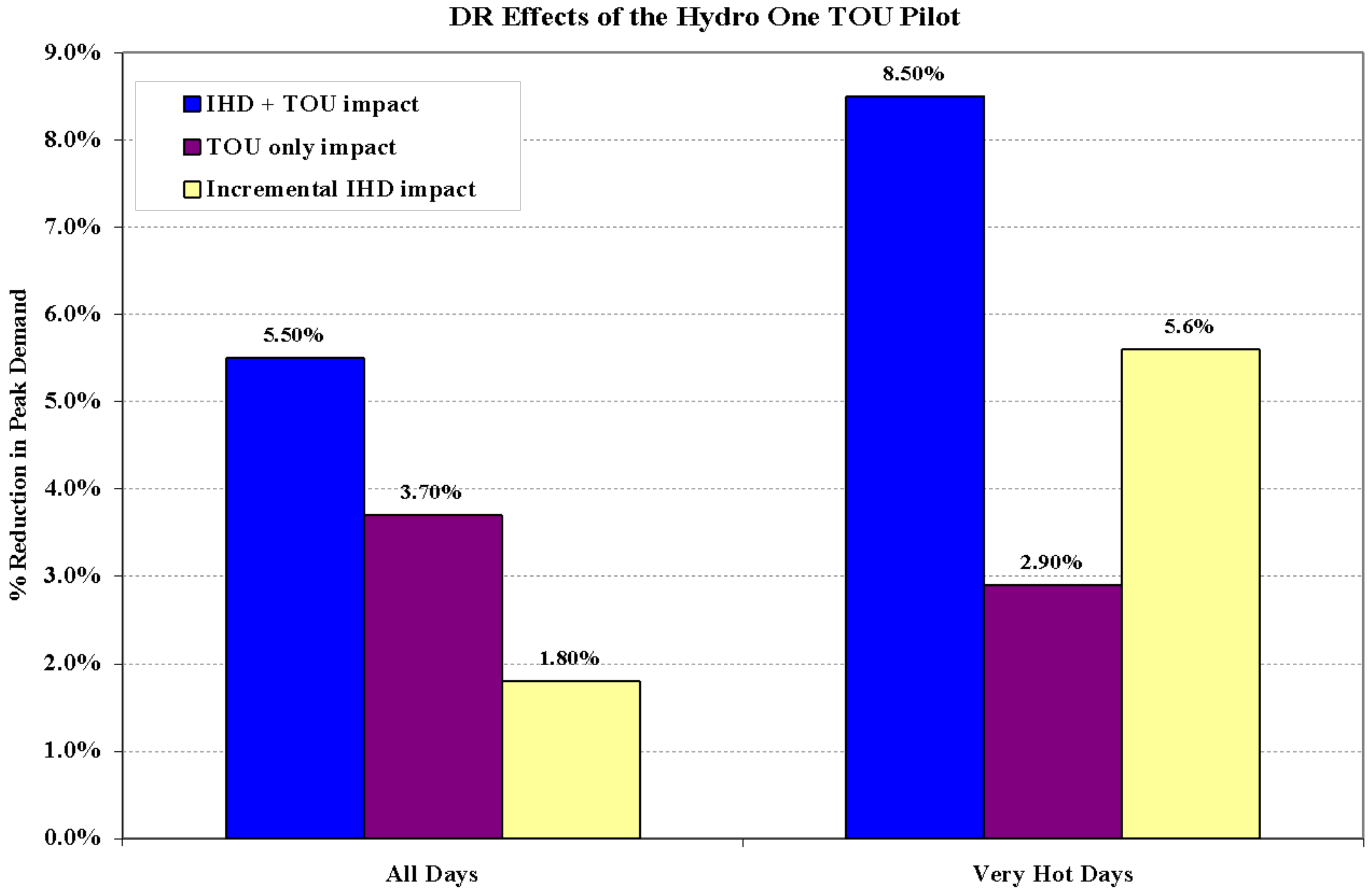
Source: Chassin, D. P., & Kiesling, L. (2008). Decentralized Coordination through Digital Technology, Dynamic Pricing, and Customer-Driven Control: The GridWise Testbed Demonstration Project. *The Electricity Journal*, *21*(8), 51-59.

Study 'B' Results: Conservation Impacts of In-Home Displays (IHD) and Time-of-Use (TOU) Pricing



Source: The Brattle Group. (2010). "Impact of In-home Displays." Presentation to the Colorado PUC.

Study 'B' Results: Demand Response Impacts of In-Home Displays (IHD) and Time-of-Use (TOU) Pricing



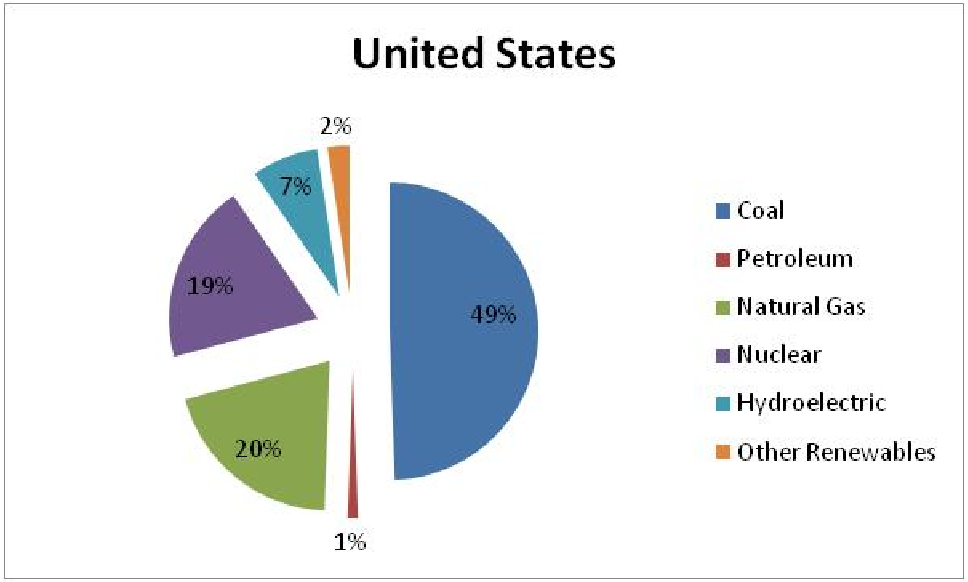
Source: The Brattle Group (2010). "Impact of In-home Displays." Presentation to the Colorado PUC.

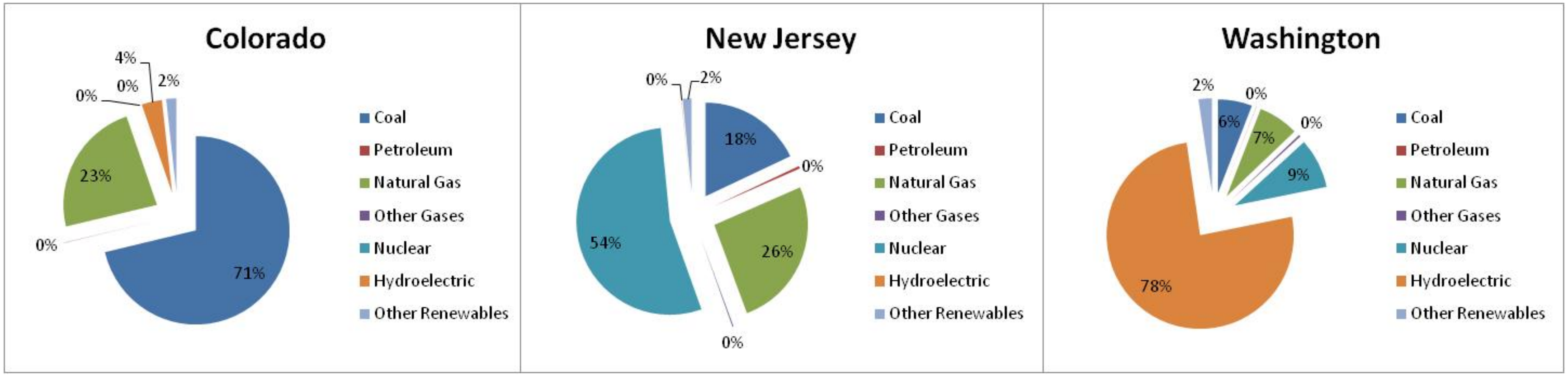
Smart Grid and CO_2 Emissions: A Colorado Case Study

- What if system operators had near-perfect ability to match supply and demand; and
- What if system operators were able to optimally dispatch both supply and demand resources?

Why it is Important to Understand Smart Grid Implications at the State Level

- National-to-state and state-to-state electricity fuel mixes vary dramatically.
- Changes in CO_2 due to changes in the electricity infrastructure are fuel mix dependent and are therefore state specific.
- Electricity policy is largely developed at the state level.





Source: EIA 2006 Electricity Profiles

Smart Grid and CO_2 Emissions: A Colorado Case Study

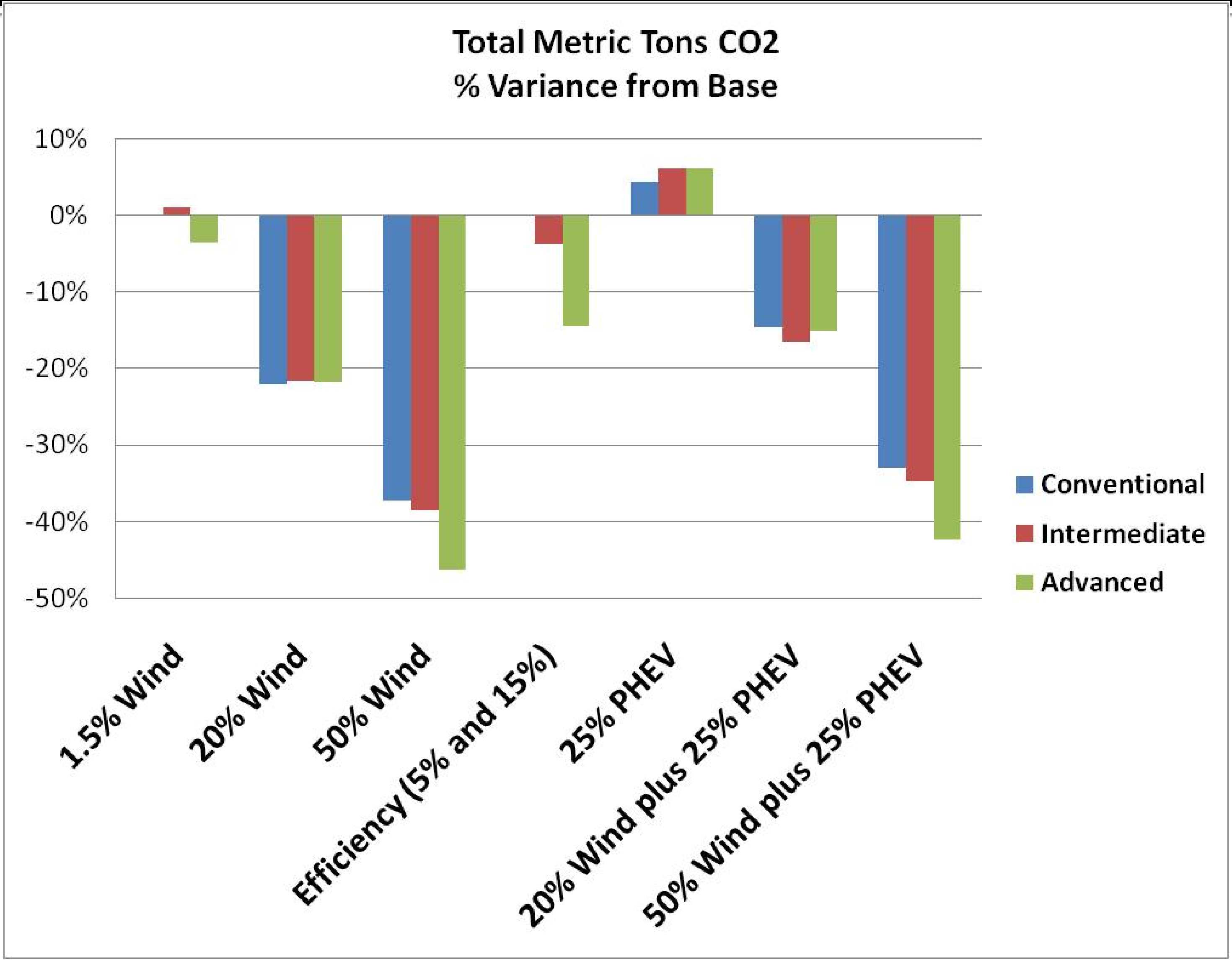
Evaluated Colorado-specific potential CO_2 and levelized cost changes assuming:

- Efficiency
  - 5% efficiency improvement
  - 15% efficiency improvement
- Demand response
  - Ability to flatten load
  - Ability to match load to renewable generation
- Wind Generation
  - 20% wind generation
  - 50% wind generation
- Plug-in Hybrid Electric Vehicles (PHEVs)
  - 25% PHEV penetration

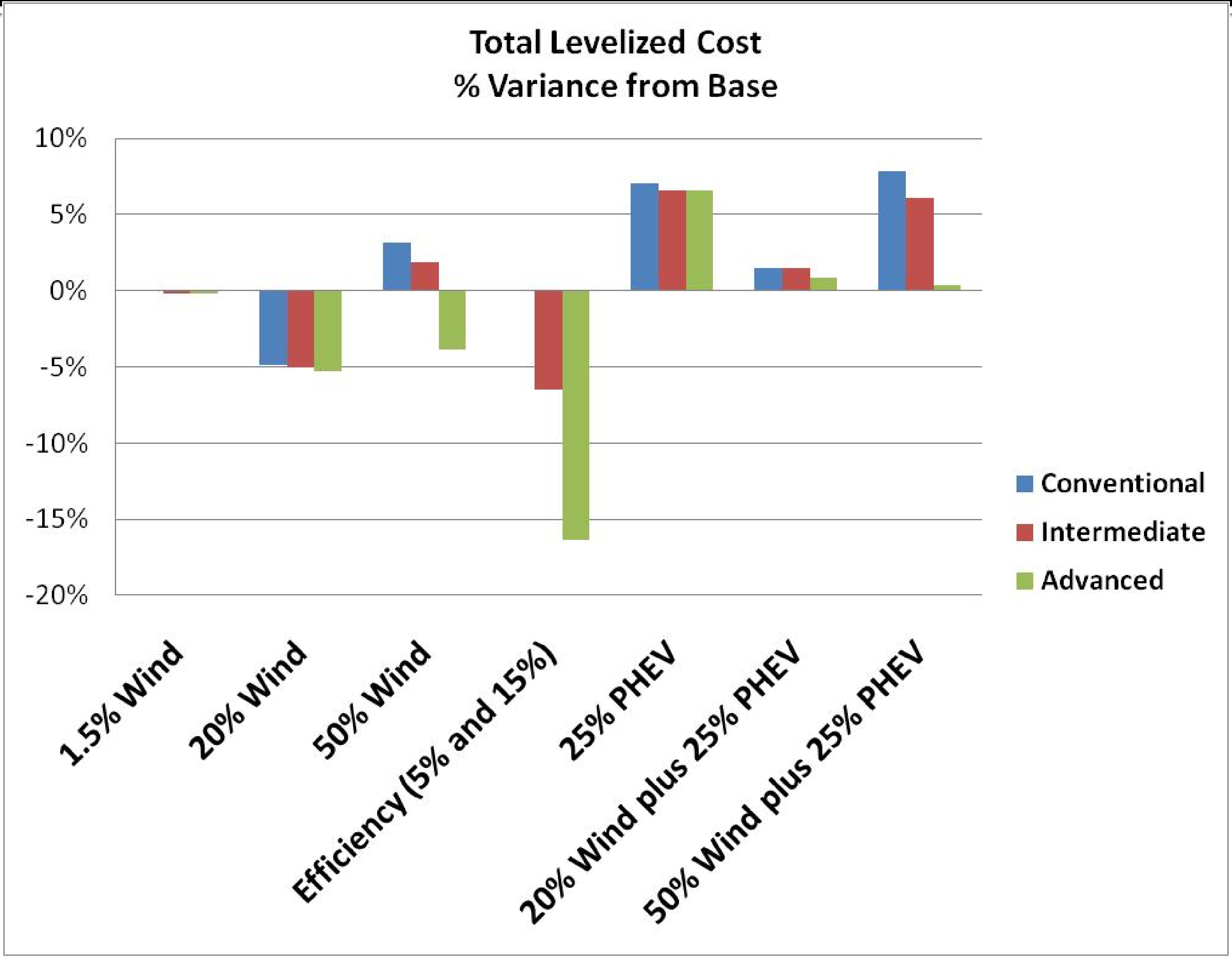
Degrees of Grid Intelligence

- Conventional Grid
  - Business-as-usual operation.
- Intermediate Grid (non-dynamic load shaping)
  - Time-of-use pricing, enhanced consumer information, and programmable appliances shift demand from peak to off-peak.
  - Demand curve is flattened in a predictable way, but system does not have the ability to dynamically shape demand to match supply.
- Advanced Grid (dynamic load shaping)
  - Dynamic demand shaping via real-time pricing, enhanced consumer information, price-responsive programmable appliances, and direct load control.
  - System dynamically matches supply and demand using all generating options, storage, and demand response.
  - Managed PHEV load follows renewable generation.

Results: CO_2 Emissions

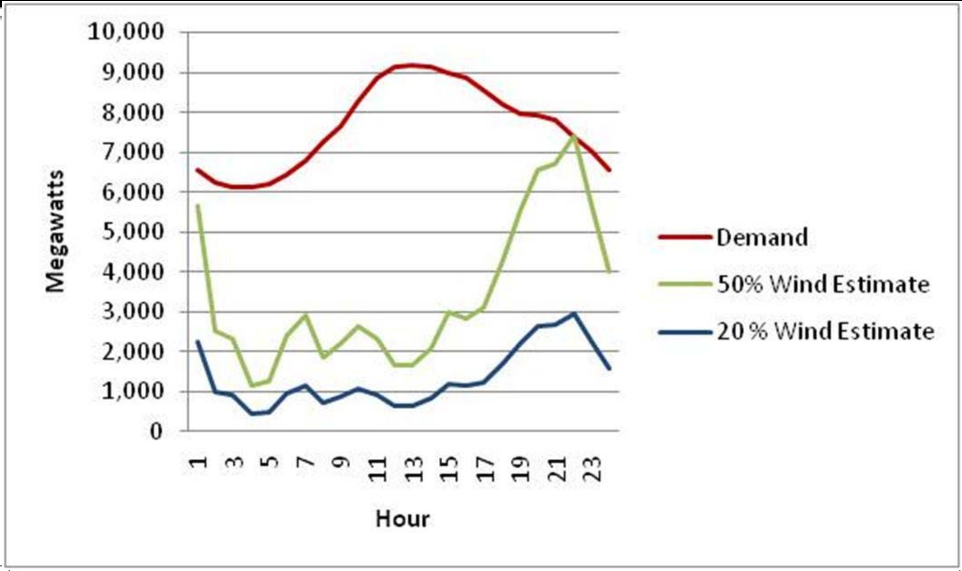


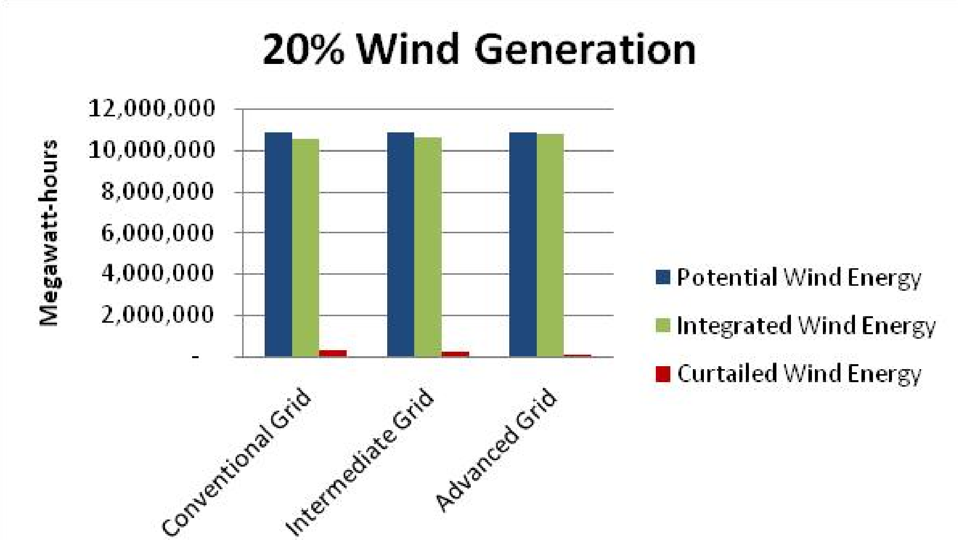
Results: Levelized Costs

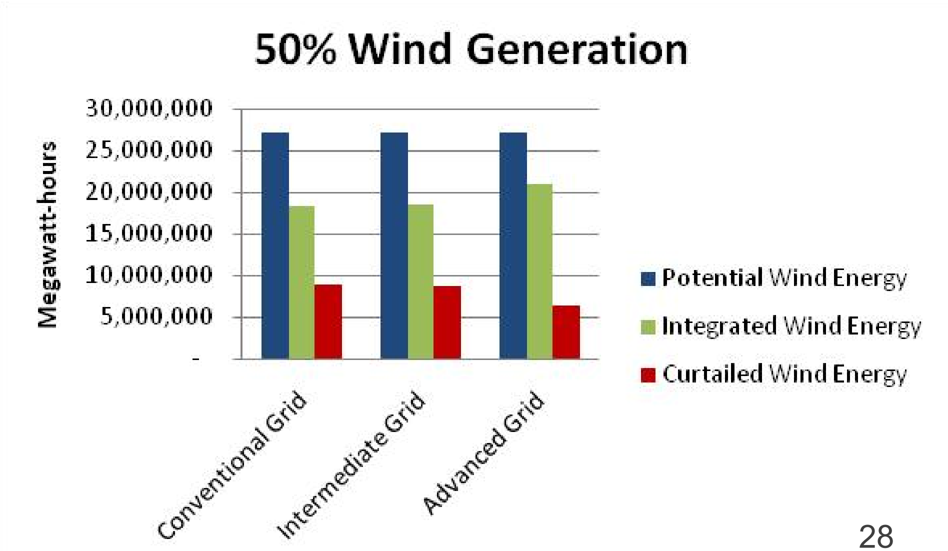


Smart Grid and Wind Integration

- Smart grid supports wind integration by aligning demand with renewable generation.
- At 20% wind generation, the benefit is relatively small.
- At 50% wind generation, the benefit is significant.



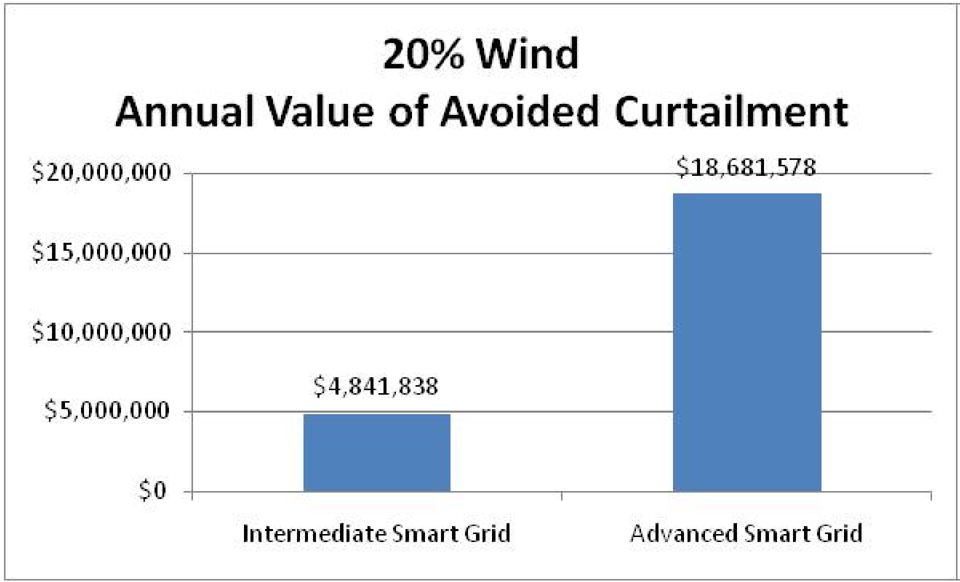


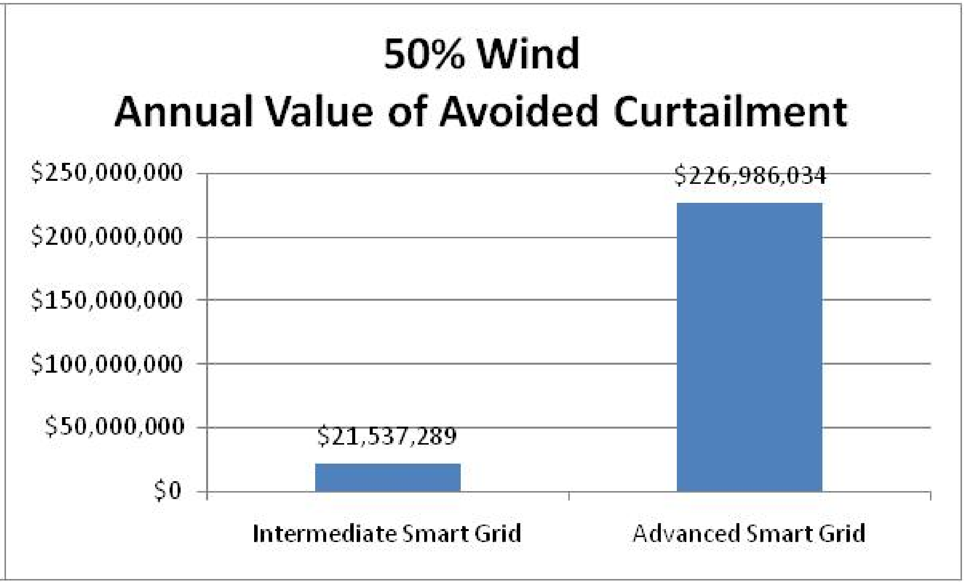


Sources: Ventyx Consulting, NREL, AWEA, windpower.net

Smart Grid and Wind Integration

- Smart grid reduces wind integration costs by reducing curtailment.
- Curtailment expense is calculated as levelized cost plus foregone production tax credit.





Wind-Relevant Conclusions

- Smart grid without wind generation in the portfolio may increase CO_2 emissions.
- Smart grid enables greater integration of wind by aligning demand with wind generation.

Transitional Challenges

- Policy
  - Utility revenue model
  - Data ownership, privacy, and cyber-security issues need to be addressed
- Consumer
  - Adoption uncertain; risk of backlash
  - Education is critical
- Technology
  - Interoperability
  - Stranded assets and legacy systems
  - Storage
- Business
  - See policy

Questions?

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