ELECTRIC POWER RESEARCH INSTITUTE

Electricity Generation – An EPRI Outllook

2011 Tulane University Engineering Forum

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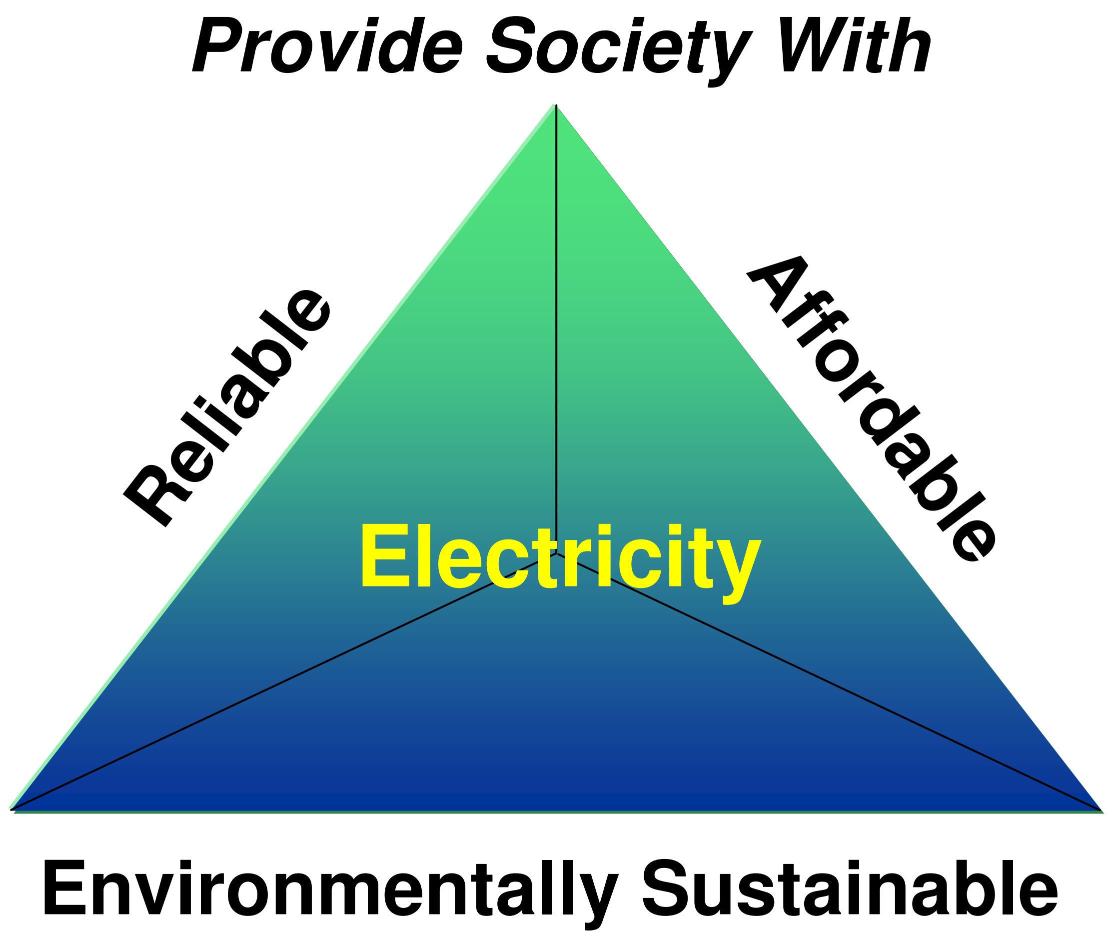
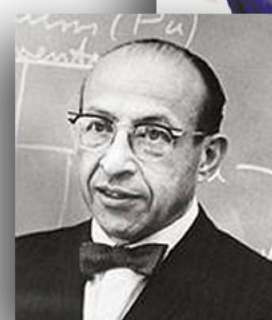
EPRI Focus



Provide Society With
Reliable
Affordable
Electricity
Environmentally Sustainable

Our History…

- Founded by and for the electricity industry in 1973
- Independent, nonprofit center for public interest energy and environmental research
- **Collaborative** resource for the electricity sector
- Major offices in Palo Alto, CA; Charlotte, NC; Knoxville, TN
  - Laboratories in Knoxville, Charlotte and Lenox, MA
  - Office in Washington, D.C.



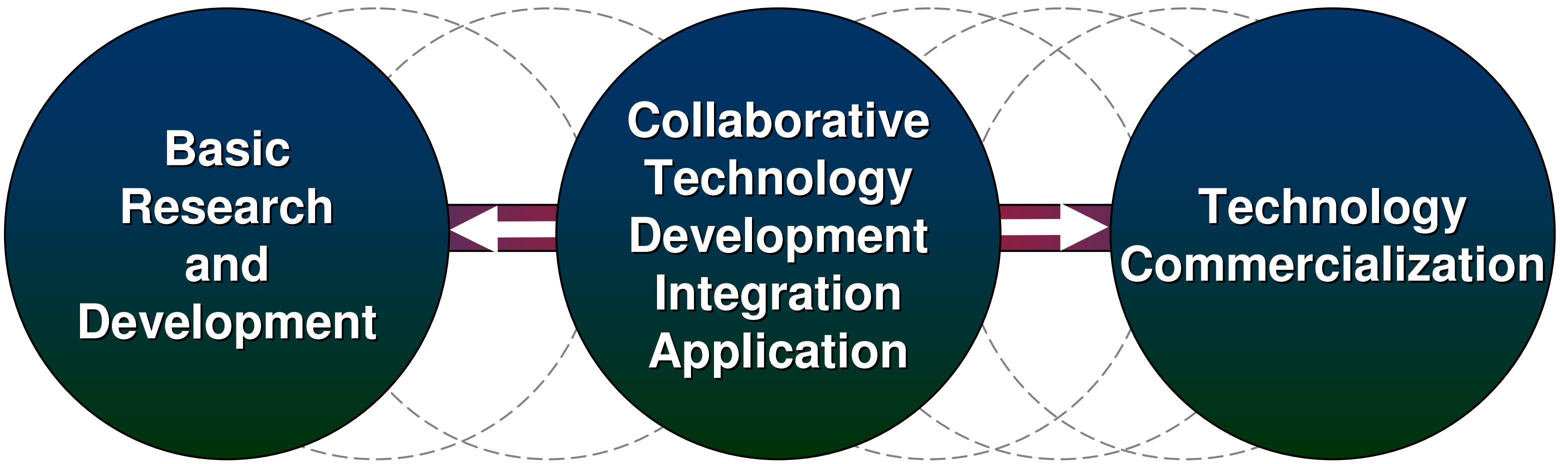
Chauncey Starr
EPRI Founder

Portfolio Spans the Entire Electricity Sector

- Electricity Generation
  - Technology: nuclear, coal, gas, renewables, hydro
  - Cost, performance, fuel markets
- Power Delivery and Utilization
  - Transmission, distribution
  - End-use and efficiency
- Environment
  - Air, land, water
  - Policy and economic impacts

Our Role…

Help Move Technologies to the Commercialization Stage…



National Laboratories

Universities

EPRI

Suppliers

Vendors

Technology Accelerator!

Our Members…

- 450+ participants in more than 40 countries
- EPRI members generate more than 90% of the electricity in the United States
- International funding of more than 15% of EPRI's research, development and demonstrations
- Programs funded by more than 1,000 energy organizations
- Annual funding ~ $350M

Converging Policy Drivers

- CO_2 policy
- Other potential issues
  - Ash
  - Environmental impact of renewables
  - Water availability for power plant cooling
- Existing environmental policies (e.g. SO_x, NO_x)
- Renewable Portfolio Standards (RPS)/ Renewable Energy Standards (RES)

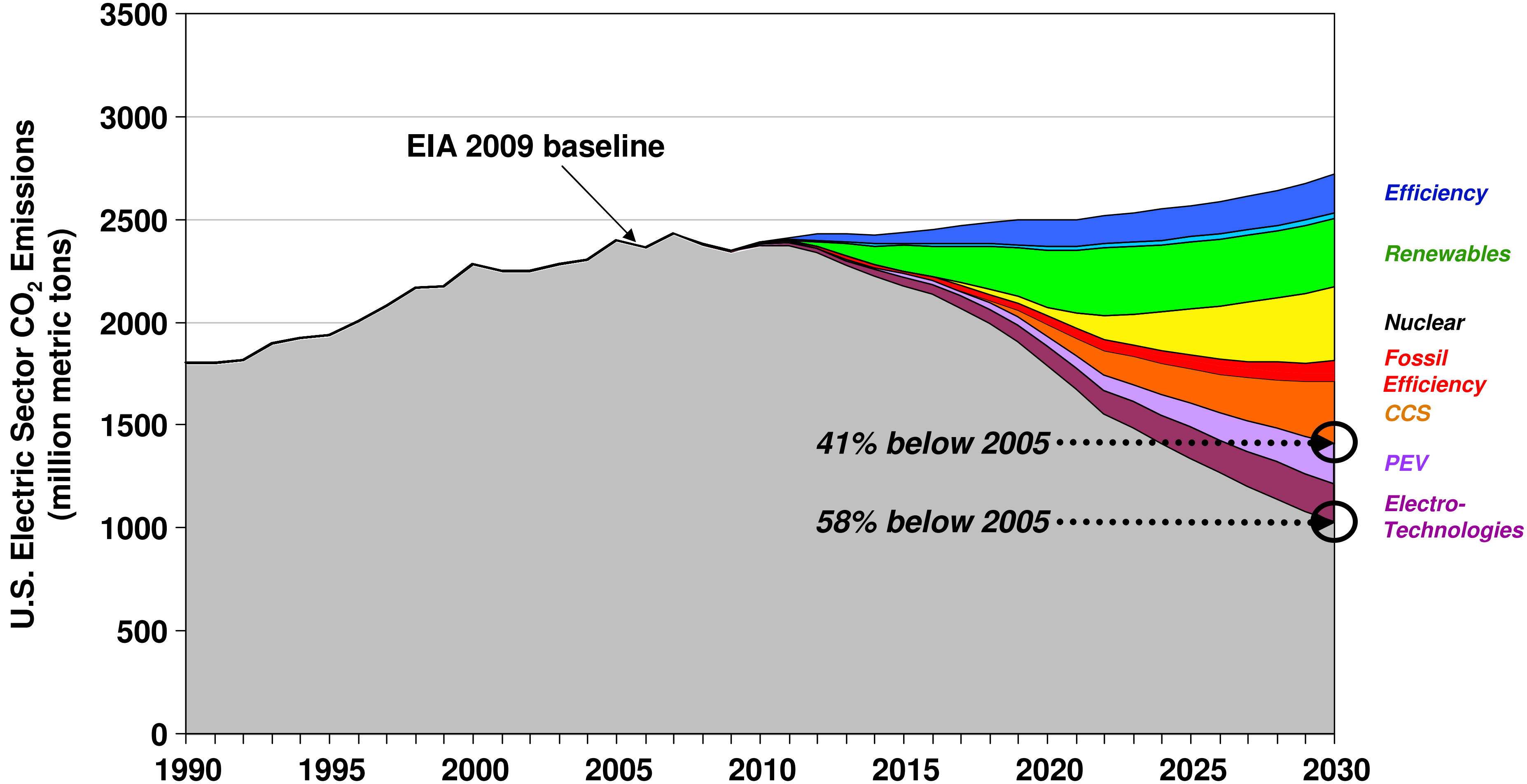
Ever-Present Technical Drivers

- Hedge technology risks
- Recognize long lead times for technology deployment.
- Meet demand
- Maintain reliability
- Minimize cost

2009 Prism Technology Analysis
Performance/ Deployment Assumptions

	Technology	*EIA Base Case*	*EPRI Prism Target*
	Efficiency	Load Growth ~ +0.95%/yr	8% Additional Consumption Reduction by 2030
	T&D Efficiency	None	20% Reduction in T&D Losses by 2030
	Renewables	60 GWe by 2030	135 GWe by 2030 (15% of generation)
	Nuclear	12.5 GWe New Build by 2030	No Retirements; 10 GWe New Build by 2020; 64 GWe New Build by 2030
	Fossil Efficiency	40% New Coal, 54% New NGCCs by 2030	+3% Efficiency for 75 GWe Existing Fleet 49% New Coal; 70% New NGCCs by 2030
	CCS	None	90% Capture for New Coal + NGCC After 2020 Retrofits for 60 GWe Existing Fleet
	Electric Transportation	None	PHEVs by 2010 40% New Vehicle Share by 2025 3x Current Non-Road Use by 2030
	Electro-technologies	None	Replace ~4.5% Direct Fossil Use by 2030

2009 Prism Technology Analysis
U.S. Electricity Sector CO_2 Emissions



Prism Technology Conclusions

- Significant CO_2 emissions reductions could be possible from electric sector, but only through a diverse technology portfolio.
- Contributions needed from new and existing technologies.
- Aggressive technology development needed on several fronts: CCS, nuclear, end-use efficiency, renewables.

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Assess Technology Development Strategies via Energy-Economic Analysis

- Look at electricity sector in context of overall U.S. and global economy
- Focus on economic output as the metric
- Integrate effect of expected CO_2 policy, technology costs and development for different future technology scenarios
- Models competition between options to investment in the electric sector with other opportunities in the rest of the economy.
- Provides a foundation to which additional assumptions/ models re: energy consumption behavior, public policy can be added.

MERGE Energy-Economic Analysis Model

(Model for Estimating the Regional and Global Effects of greenhouse gas reductions)

- Optimization Model of Economic Activity and Energy Use through 2050
  - Maximize Economic Wealth
- Inputs
  - Energy Supply Technologies and Costs for Electric Generation and Non-Electric Energy
- Constraints
  - Greenhouse Gas Control Scenarios
  - Energy Resources
- Outputs
  - Economy-wide Impact of Technology and Carbon Constraints

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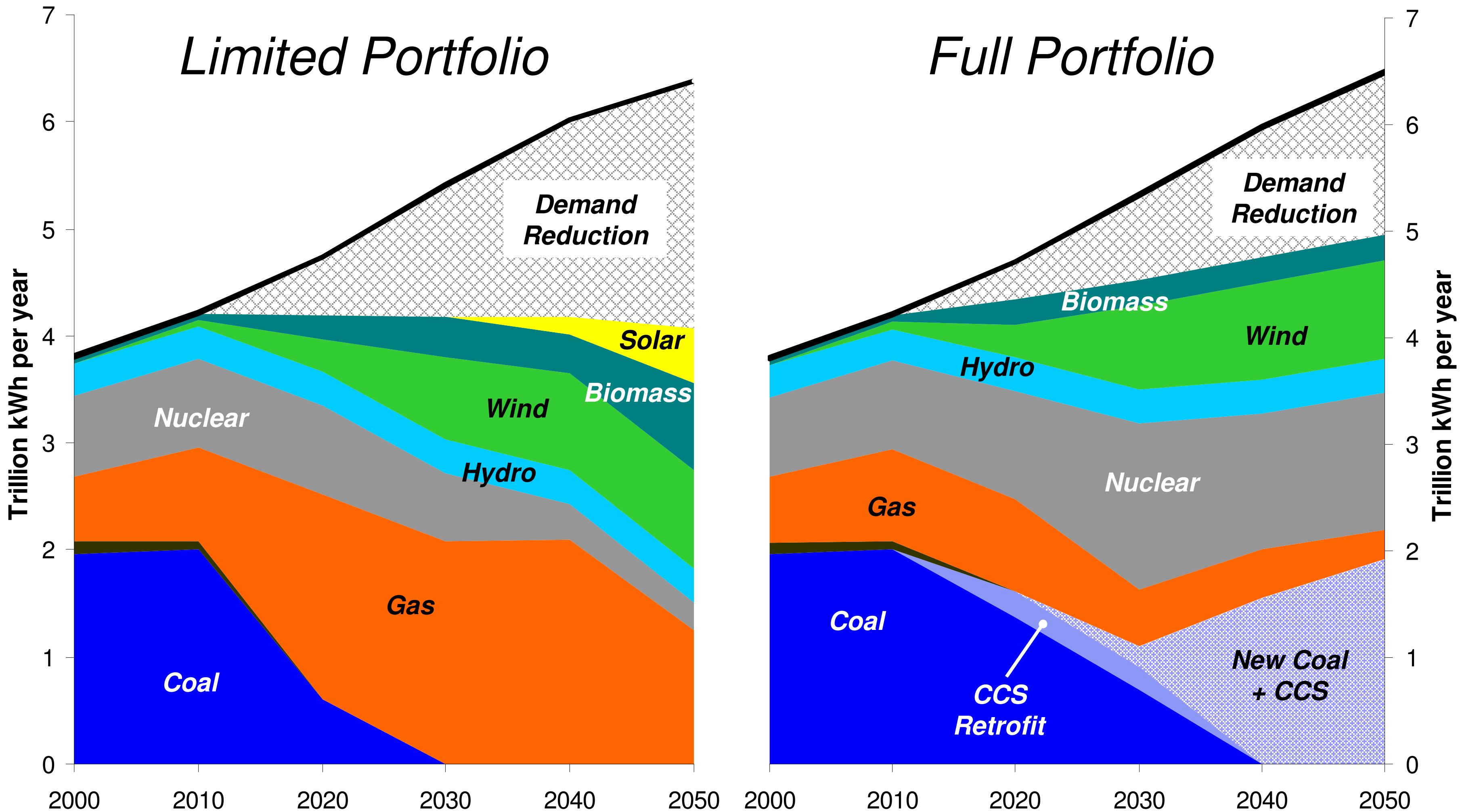
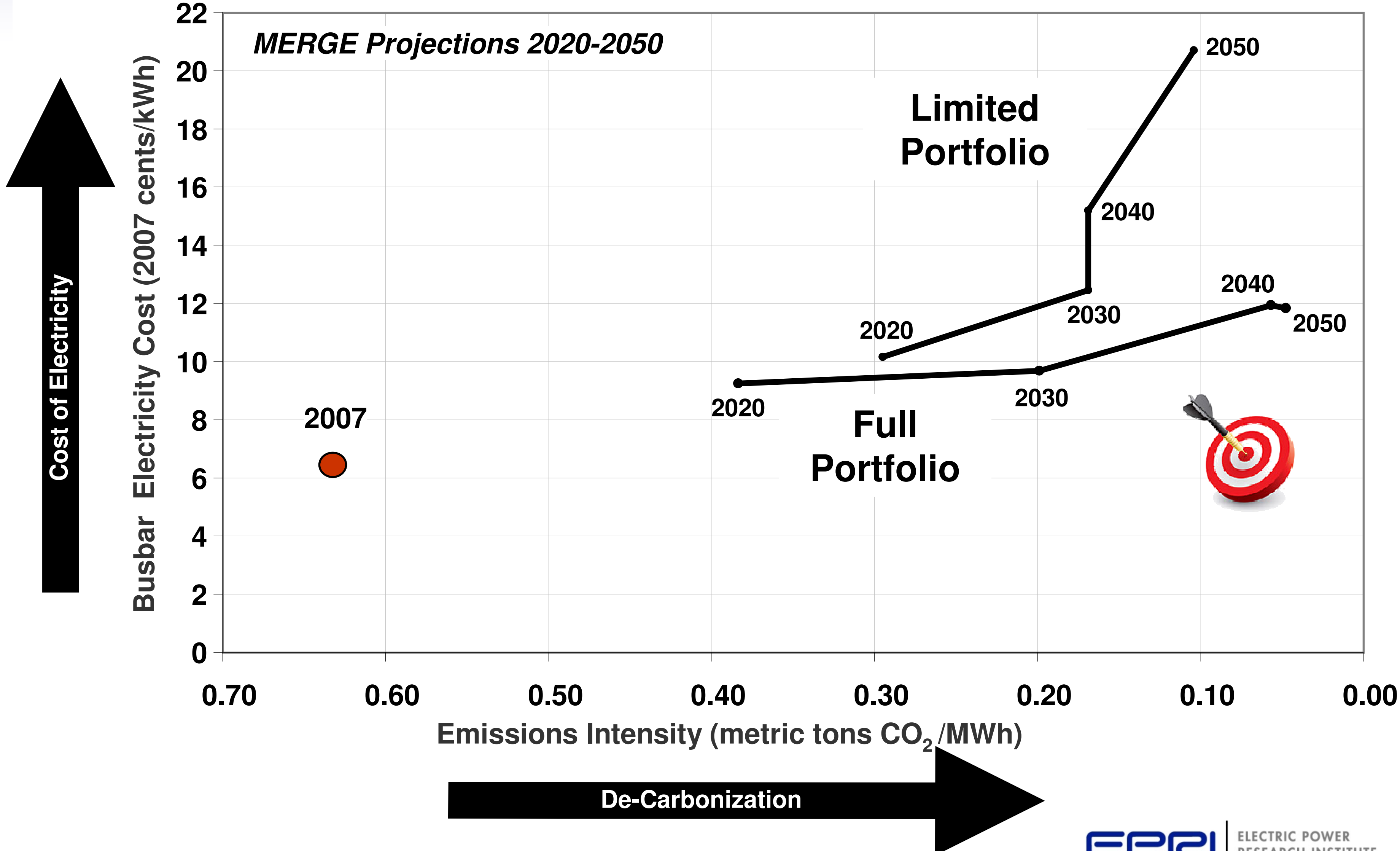
2009 MERGE Energy-Economic Analysis
Analyze Contrasting Technology Scenarios

	Limited Portfolio	Full Portfolio
Supply-Side		
Carbon Capture and Storage (CCS)	Unavailable	Available
New Nuclear	Existing Production Levels	Production Can Expand
Renewables	Costs Decline	Costs Decline Faster
New Coal and Gas	Improvements	Improvements
Demand-Side		
Plug-in Electric Vehicles (PEVs)	Unavailable	Available
End-Use Efficiency	Improvements	Accelerated Improvements

2009 MERGE Energy-Economic Analysis
Economic Deployment under Different Scenarios



2009 MERGE Energy-Economic Analysis
Electricity Production Cost under Different Scenarios



Energy-Economic Analysis Results

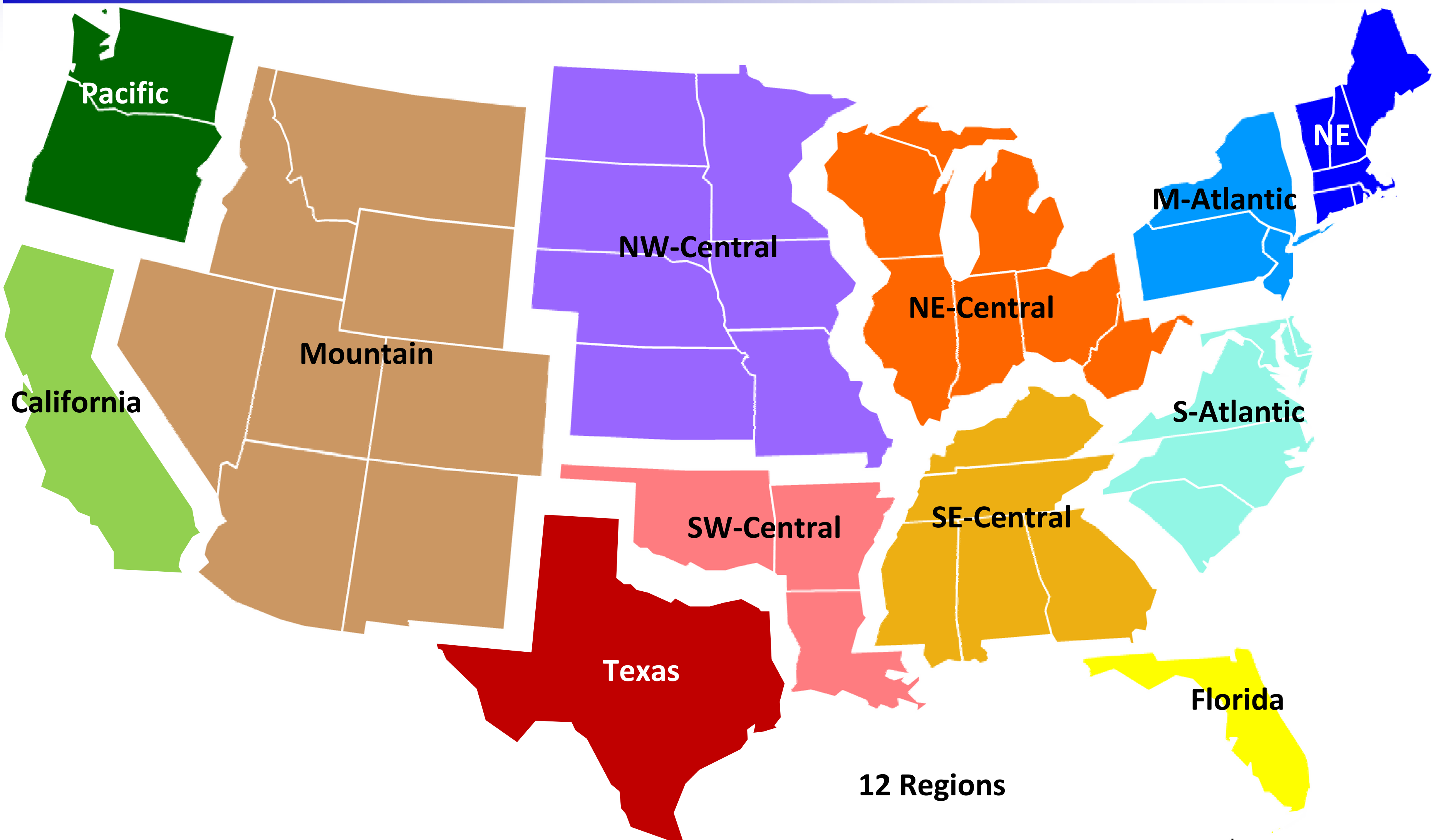
Key Technology R&D Insights

- Smart Grid technologies will be very important, because improved end-use efficiency is likely to play a major role under future policies.
- Energy storage, advanced grid management, and expanded transmission will be essential so that a large amount of electricity can be generation from variable output renewables.
- Reducing cost of nuclear plant construction and operations, and economic penalty for CO_2 capture and storage will be important, because the collective generation from coal and nuclear is likely to remain substantial.

Prism 2.0 Analysis – New Research

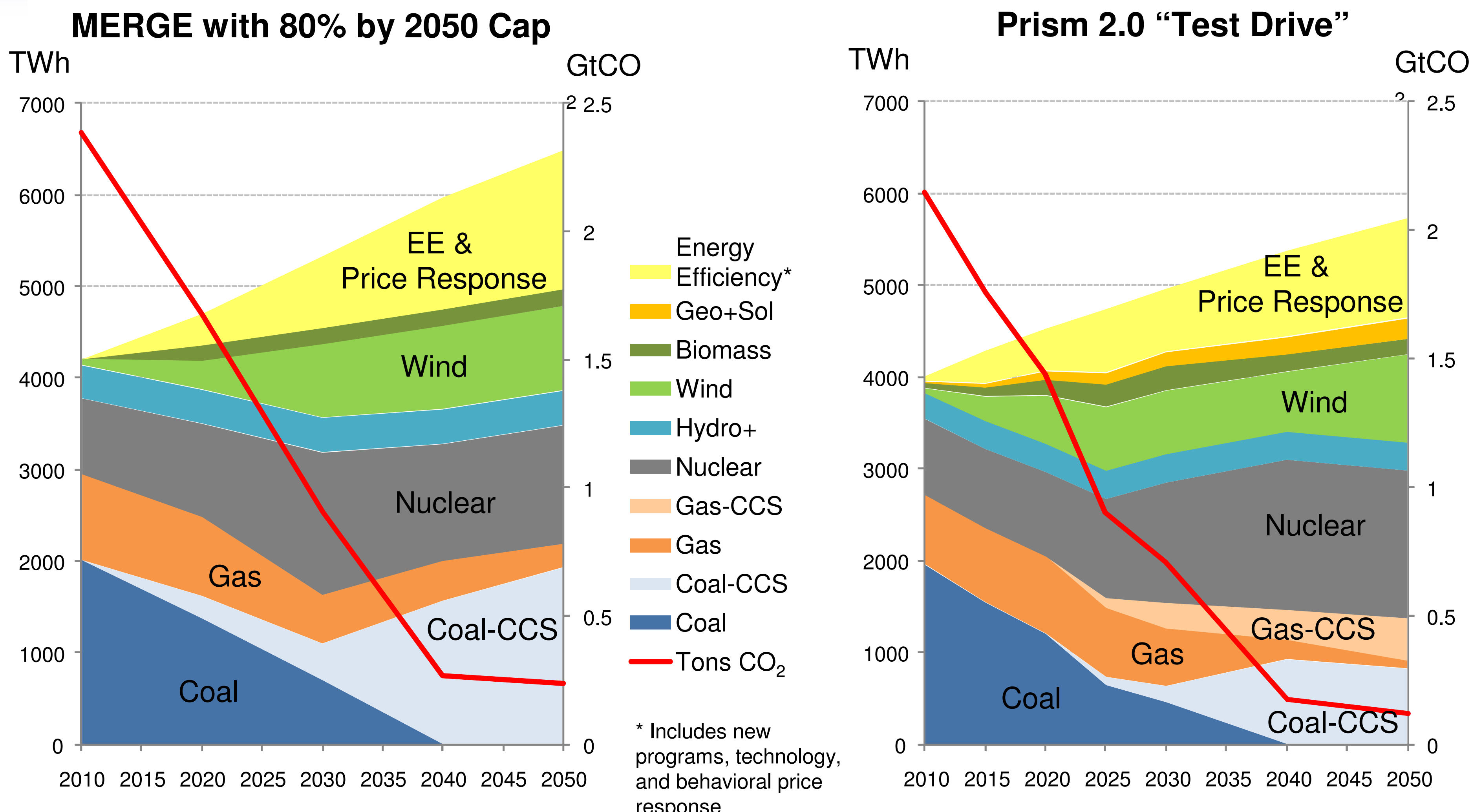
- **New Regional Economic Model (called US-REGEN)**
  - *Dynamic model of overall economy*
  - *Detailed electric power sector module, including dynamically changing loads*
- **Improved treatment of renewable energy**
  - *High-resolution wind and solar resource data*
  - *Full biomass model with resource competition*
- **Expanded demand-side detail**
  - *Energy efficiency potential by region and technology*
  - *Fully developed transportation module*
- **Full complement of environmental regulations**

Regional Model Geography

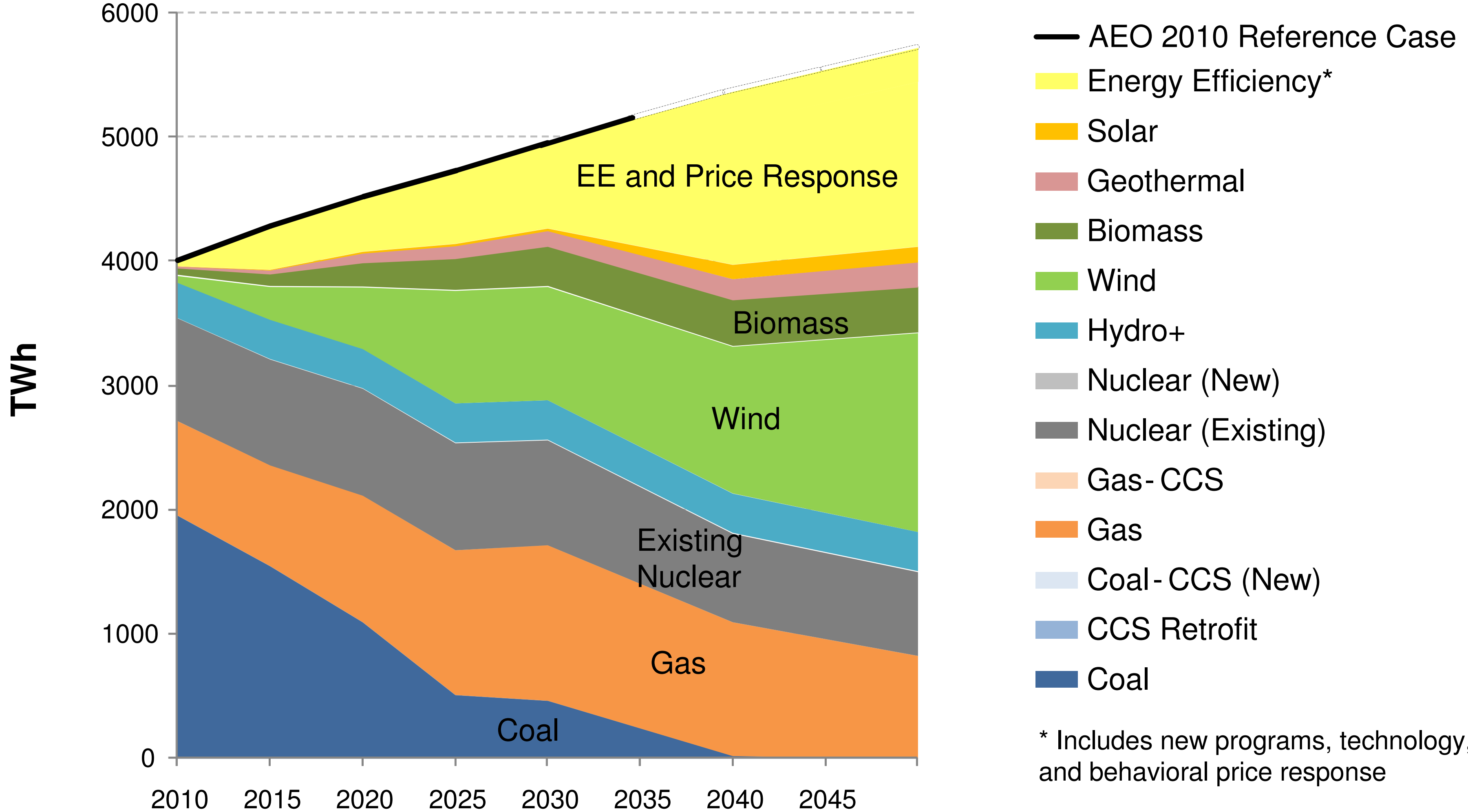


2010-2011 Energy-Economic Analysis
MERGE vs. Prism 2.0 "Test Drive"

Electric sector module only

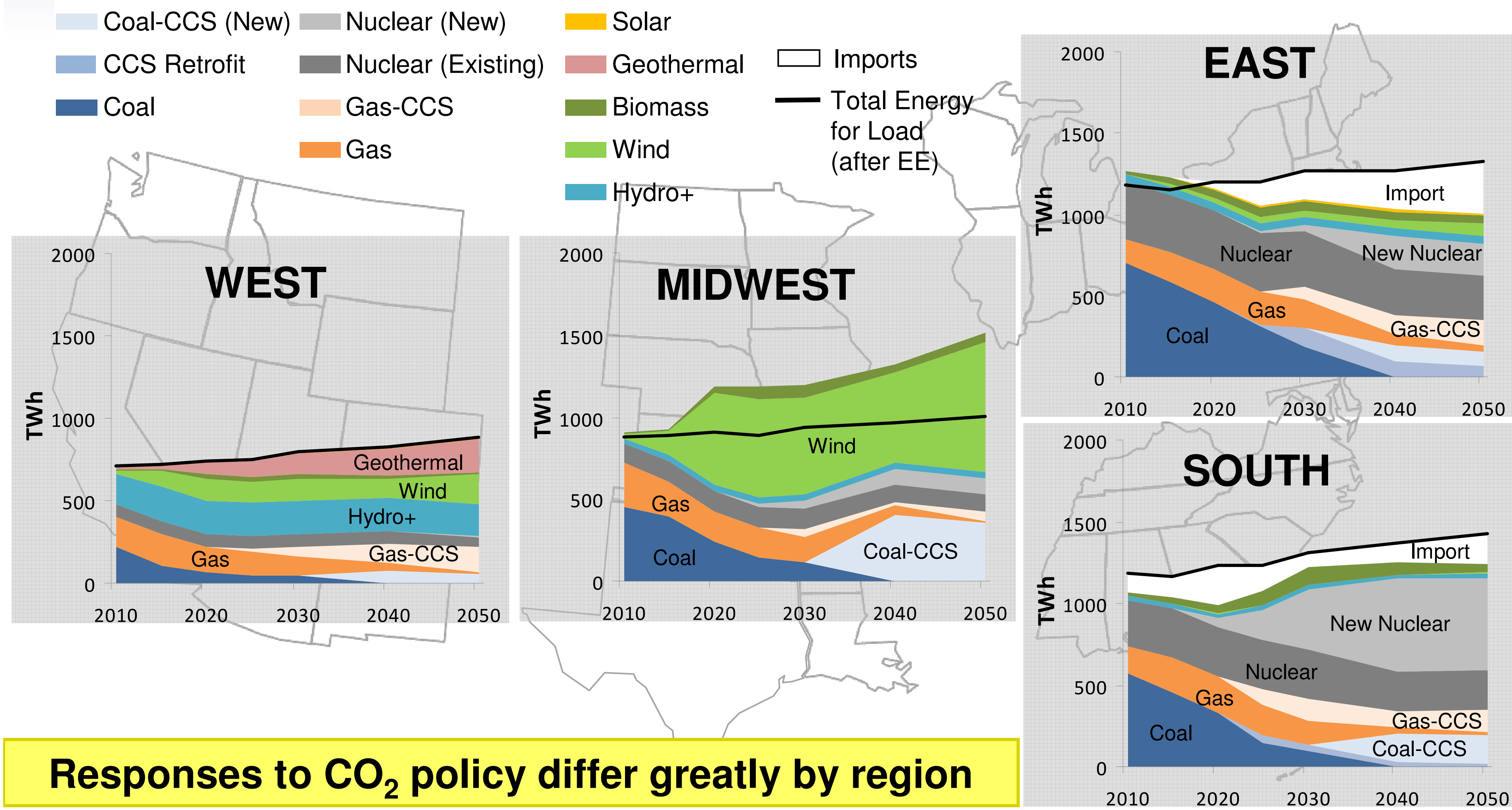


2010-2011 Energy-Economic Analysis
Prism 2.0 "Test Drive" Insights…
What if no new nuclear or CCS?



* Includes new programs, technology, and behavioral price response

2010-2011 Energy-Economic Analysis
Prism 2.0 "Test Drive" Insights … Regional Generation Mix



Responses to CO_2 policy differ greatly by region

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2010-2011 Energy-Economic Analysis
What We Are Seeing …

- **Near term response to high CO_2 price likely dominated by renewables, efficiency and natural gas**
  – Coal retirements offset by new renewables, efficiency
  – Natural gas fills any remaining demand
- **Wind integration costs significant at high penetration**
  – New balancing resources required (transmission, storage, smart grid, PHEVs)
  – Cycling impacts on thermal fleet → increased O&M
- **Longer term, nuclear and CCS will be important**
  – Without them, rely on more costly renewables, efficiency

Key Points

- A unique convergence of major challenges currently faces the electric sector.
- Analysis by EPRI and others underscores the economic value of a diverse portfolio of electricity generation technologies through investment in technology research and development.
- CO_2 limits drive higher levels of electrification.
- Technology diversity is also vital as a hedge against unexpected barriers in technology development or deployment.
- The strategic challenge is not to choose between technologies, but to choose the appropriate mix.
- Recent EPRI analyses of policy scenarios provide insights regarding the optimum future mix of electricity generation technologies.
- Decisions over the next decade will shape the electricity future of 2050.

For More Information

2009 Prism-MERGE

EPRI Report #1020389

www.epri.com

2010 Preliminary Prism 2.0

www.epri.com,
"Newsroom",
"2010 Summer Seminar"

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Together...Shaping the Future of Electricity

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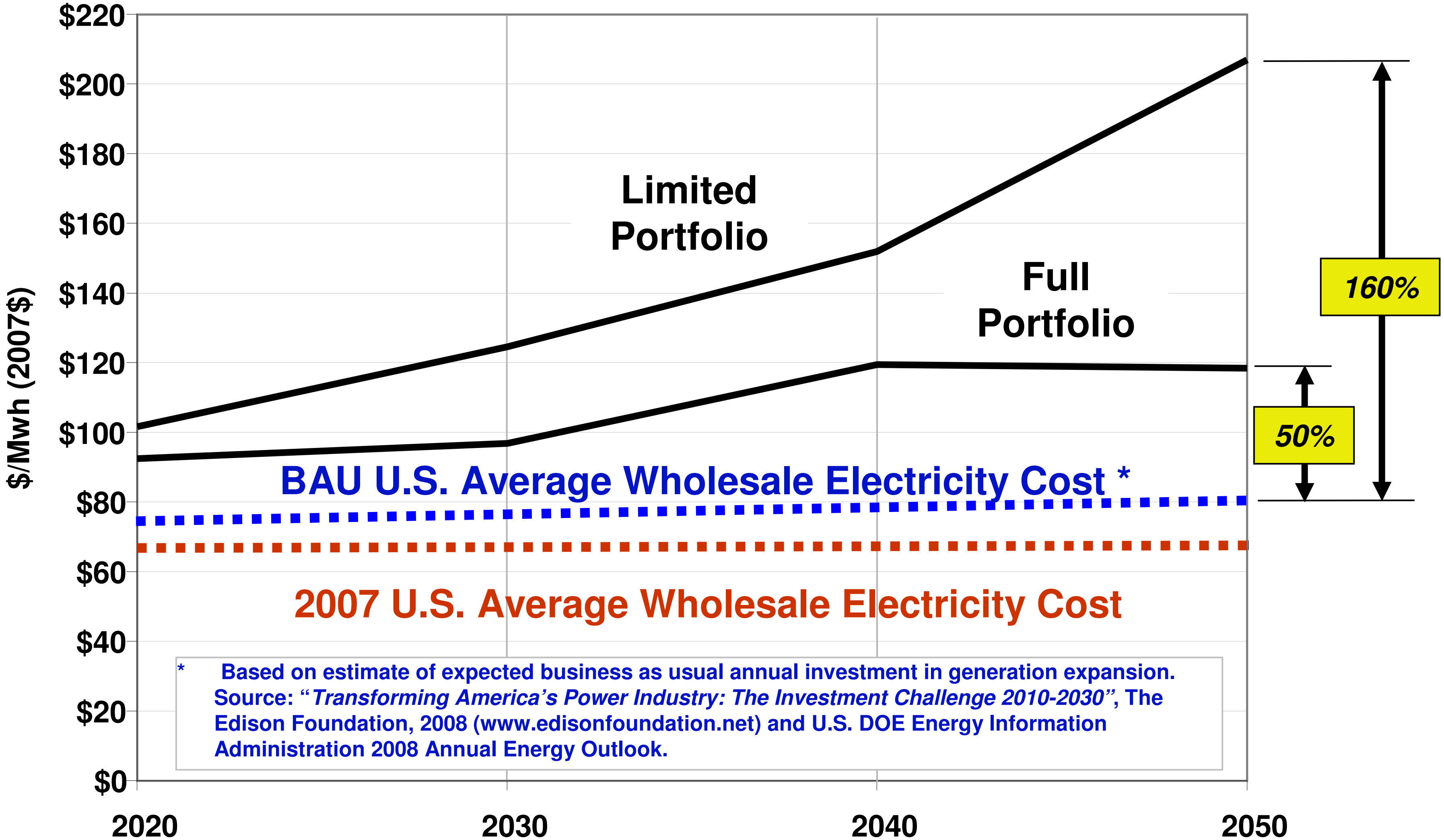
Image from *NASA Visible Earth*

Backup Slides

Impact on Busbar Electricity Production Costs



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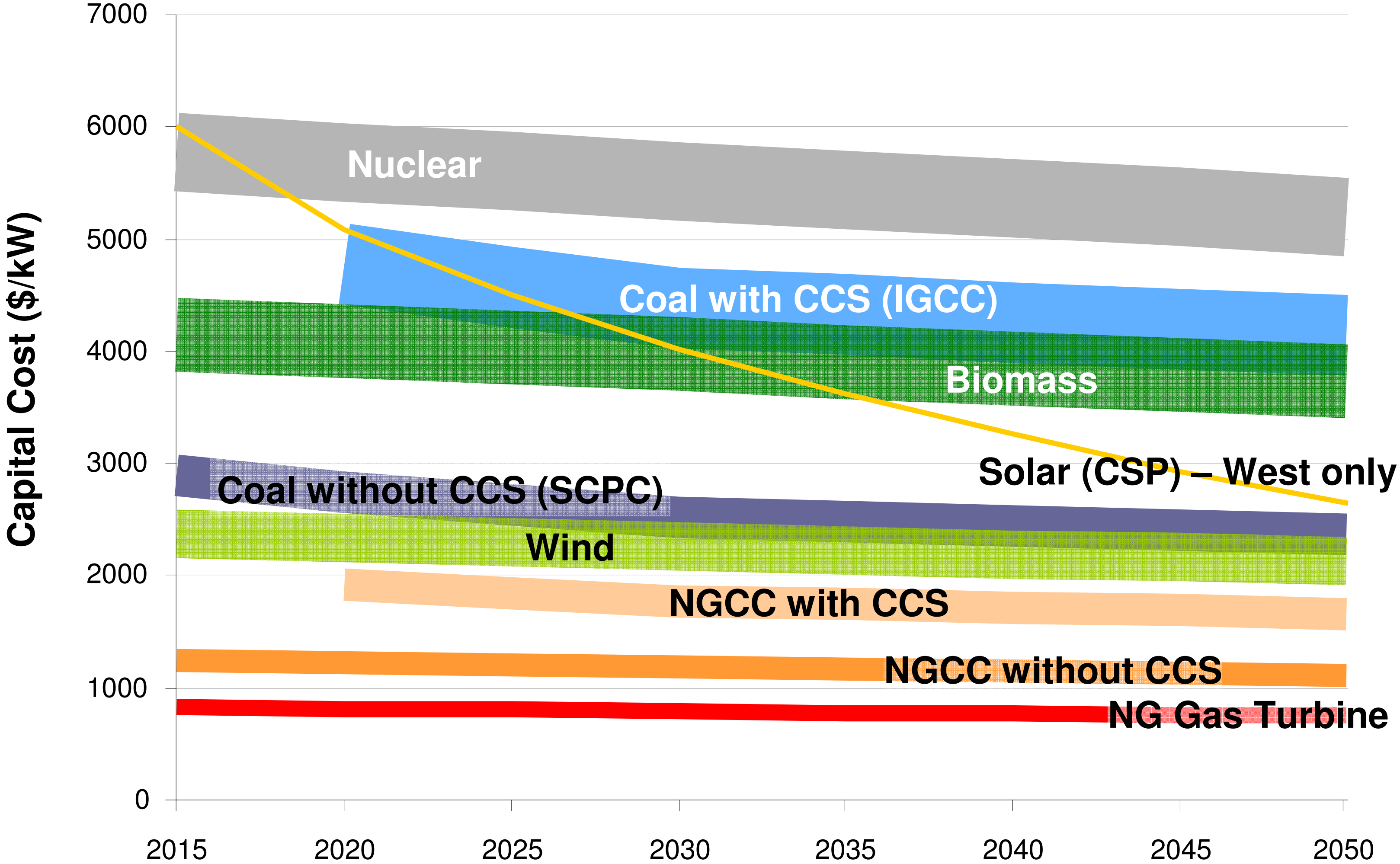
New Generation Technology Options: Capital costs vary across regions



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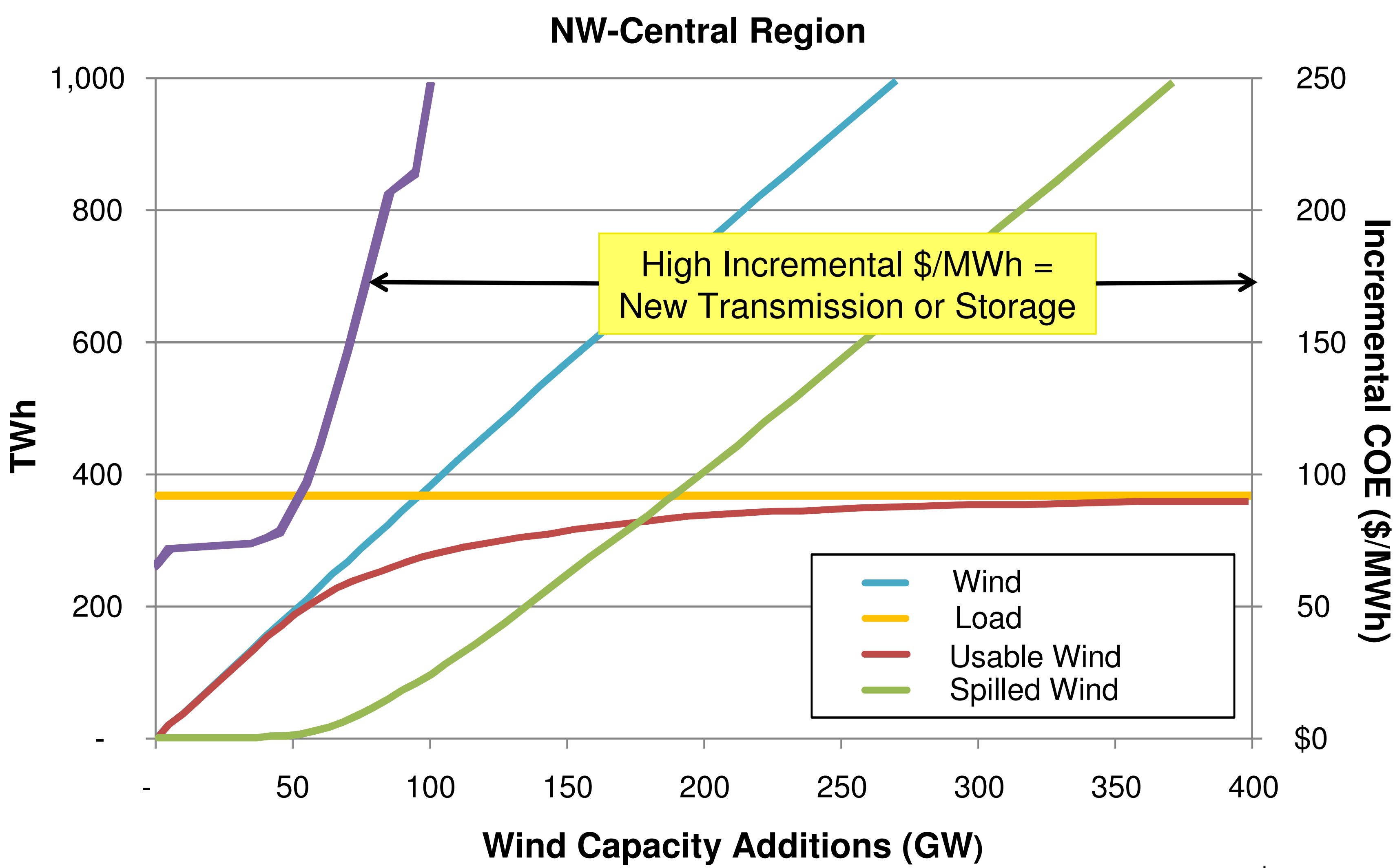
What Happens When Wind Exceeds Available Load?



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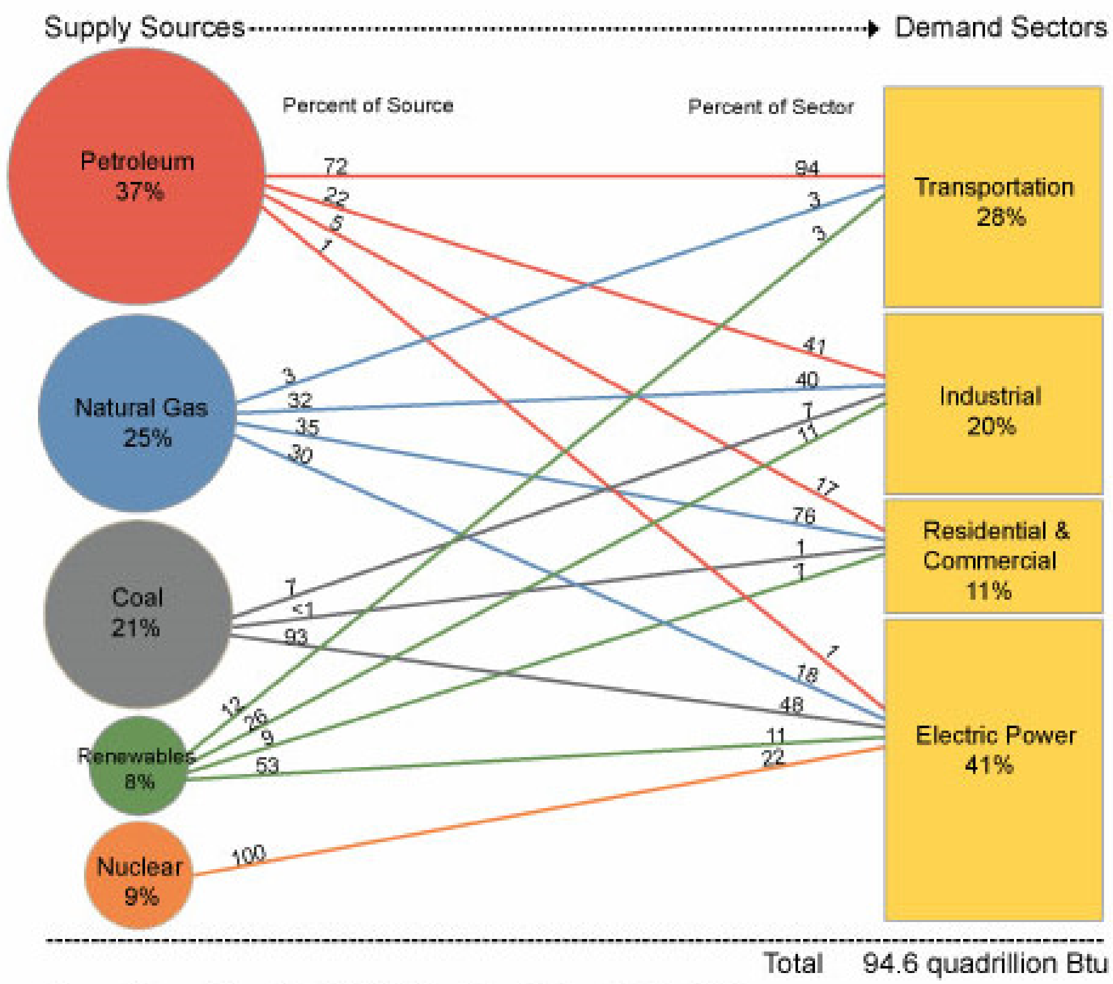
Natural Gas Use

- 25% of total energy
- 18% of total electricity



Source: Energy Information Administration, *Annual Energy Review 2009*

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Drivers of Fleet Transformation
Natural Gas Helps/Hurts?

• Environmental Policies		
– CO_2 policy	↔	• *long-term problem*
– RPS/RES	↔	• *good (backup); bad (competes)*
– Ash	↑	
– Env. impacts/renewables	↑	
– Water impacts	↑	
– HAPS	↑	
– Shale gas/hydro-fracking	↓	• *potential environmental issues*
• Hedge technology risk	↔	• *good (diversity); bad (too much)*
• Capital cost/long development lead times	↑	
• Long-term demand growth	↓	• *expensive bulk energy*
• Load curve/capacity needs	↑	
• Grid reliability	↑	
• Minimizing electricity costs	↓	• *long term price volatility*

Do Electric Cars Make Sense?

- Electric Sector Perspective
  - Will add to demand, but on order of a few % in bulk energy terms.
  - More important is recharging patterns and impact on demand management.
- Societal Perspective
  - Diversifies energy sources that can support transportation => contributes to energy self-sufficiency.
  - One of few means by which transportation sector could reduce CO_2 emissions.

Do We Need a Smarter Grid?

- Power Company Perspective
  - Provides opportunities for aggregated, automated load management.
  - Enables collection, analysis of key data.
- Consumer Perspective
  - Enables automated, transparent energy management.
  - Lowers economic hurdles for development, deployment of end-use efficiency technologies.
  - Enables electric vehicle, distributed energy resource deployment.

Contrast: the Future w/Smart Grid

Today

- **Transmission Applications**
  - Synchrophasor enabled grid management
- **Distribution Applications**
  - Integrated voltage/var management
- **Consumer Applications**
  - Feedback and dynamic pricing

Future

- **Transmission Applications**
  - Automated condition assessment
- **Distribution Applications**
  - Integrating distributed resources and PHEV
- **Consumer Applications**
  - Prices to Devices and Home Automation Networks

Will we find a technical solution to the CO_2 sequestration problem?

- Technical
  - Unlikely that the U.S. will achieve ~80% reductions in CO_2 emissions without carbon capture and sequestration (CCS) for fossil plants.
  - The technologies required for transport, and geologic sequestration of CO_2 exist.
  - Geoscientists generally believe that risks associated with sequestration are modest and manageable.
- Non-technical
  - Wide-spread adoption of CCS will require a large pipeline infrastructure for which a regulatory framework does not fully exist.
  - Legal access to and use of appropriate deep geological formations for sequestration could present barriers.
  - Adequacy of financial, regulatory, and liability arrangements for long-term stewardship of sequestration sites is uncertain.

Electrochemical Energy Storage