Recent Trends in Sustainable Energy Development in the United States

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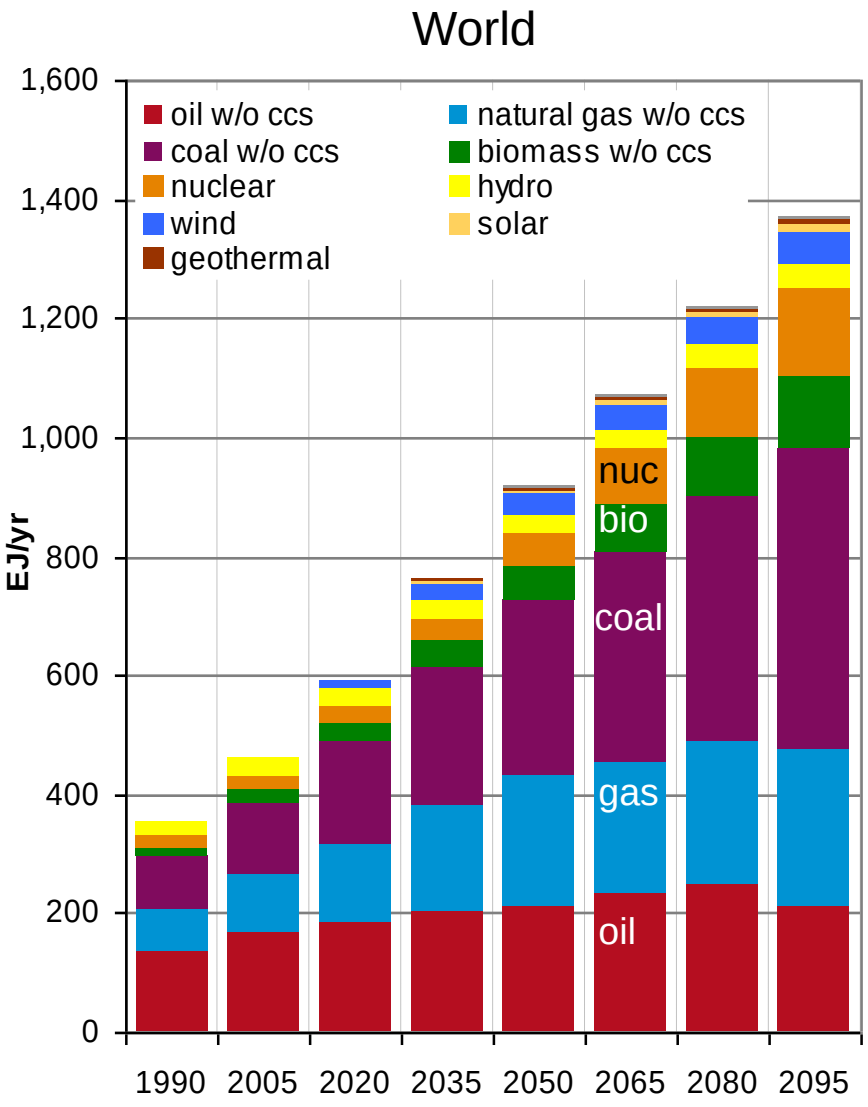
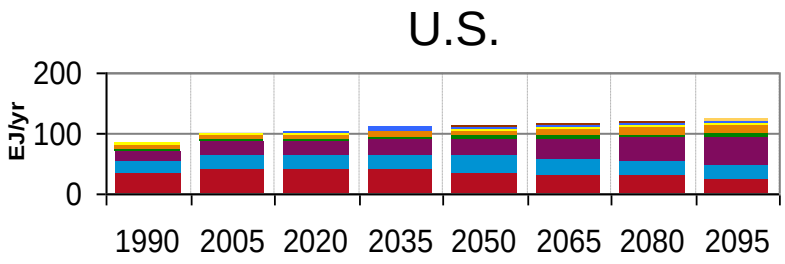
Georgia Institute of Technology

Global Trends: Where the Action Is

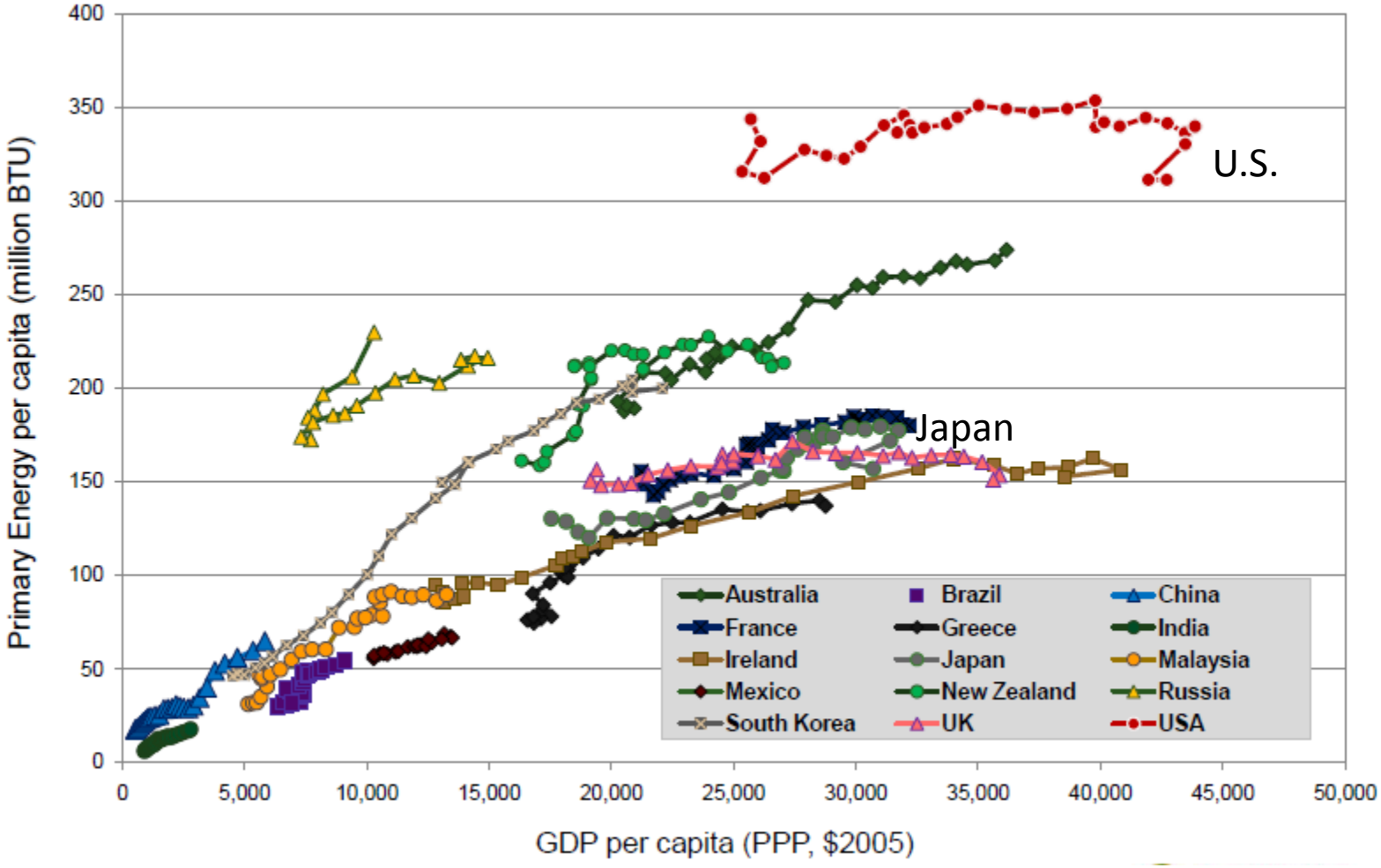


- U.S. energy demand is growing much more slowly than the rest of the world
- Today we consume almost 25% of the world's energy production; in 2100 the U.S. will consume less than 10%



Source: Brown and Sovacool. 2011. Climate Change and Global Energy Security (MIT Press)

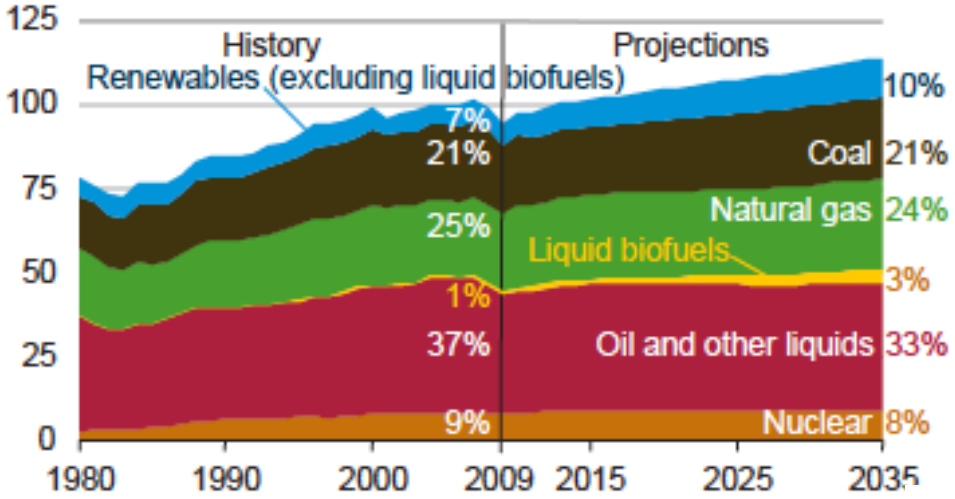
Per Capita Energy Use and GDP (1980-2010)



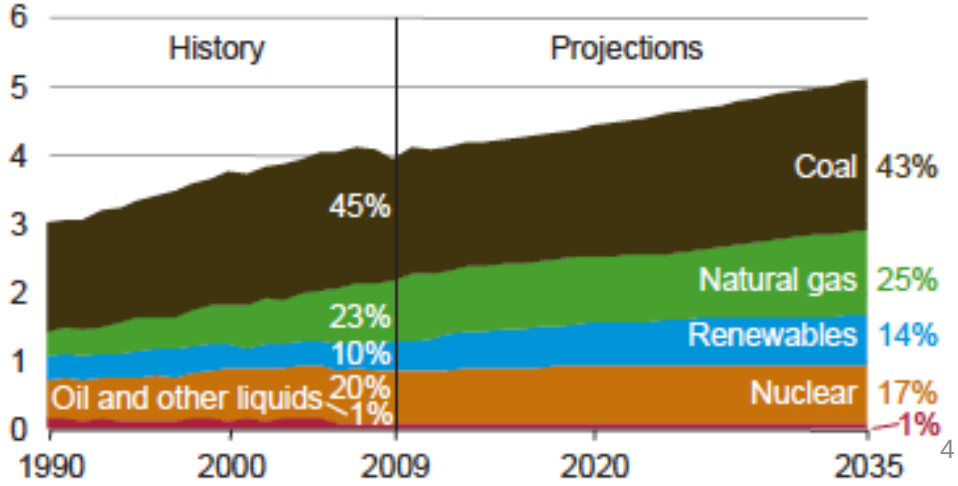
Source: Energy Information Administration (EIA)

The U.S.: Green Tech – Clean Tech Economy is Progressing, But Slowly

Primary Energy Consumption by Fuel: 1980-2035 (quadrillion Btu per year)



Projected Fuel Mix for Electricity Generation (Trillion kWh per year)

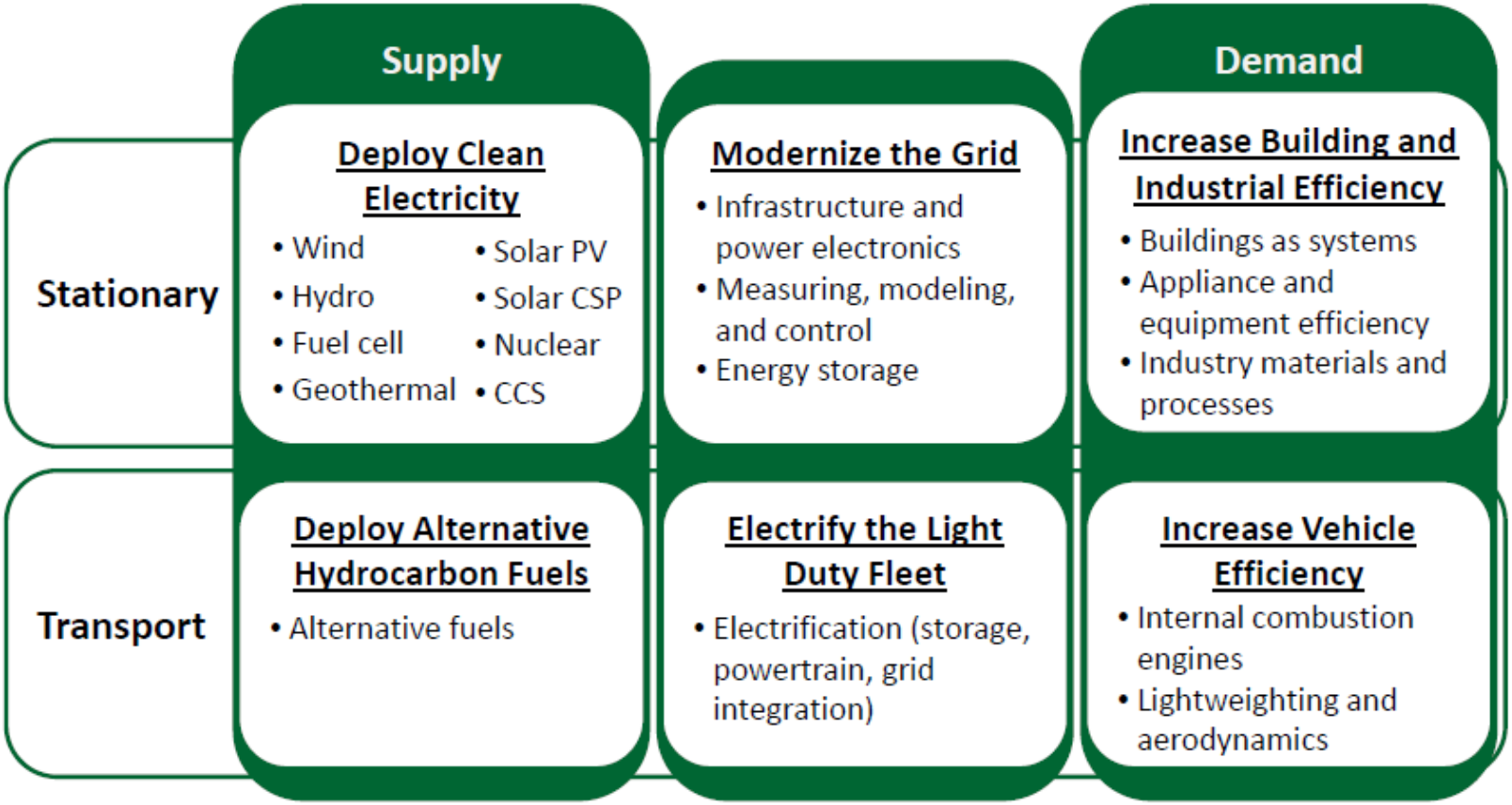


U.S. Energy & Climate Goals

- By 2020, reduce energy-related GHG emissions by 17% (83% by 2050)
- By 2035, 80% of America's electricity will come from clean energy sources
- By 2020, 20% improvement in the energy efficiency of commercial buildings relative to 2010
- By 2030, reduce home energy use by 30-50% (compared to 2009 energy codes for new homes & pre-retrofit for existing homes)
- By 2022, improve the energy intensity of U.S. manufacturers by 25%
- By 2015, put 1 million electric vehicles on the road
- By 2025, require passenger cars and light-duty trucks to average 54.5 miles-per-gallon
- Decrease the price of electricity from solar power 75% by 2020, making it cost competitive with coal

- **How Can these Goals be Achieved?**

18 Technology Assessments mapped to Six Strategies



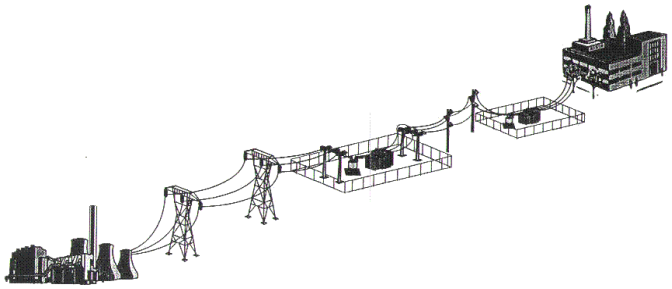
•Stationary and transport power are increasingly linked by energy, climate, health, and air quality issues and goals

Source: U.S. Department of Energy Quadrennial Technology Review

Stationary Power: Technology Headroom

Building and Industrial Efficiency:

- Data Collection and usage
- Integrated systems analyses
- Next-gen processes and products

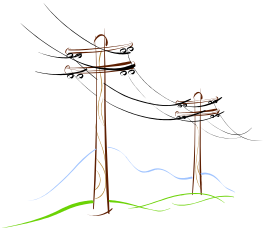


Grid Modernization:

- Communication and data
- Management and control
- Energy storage

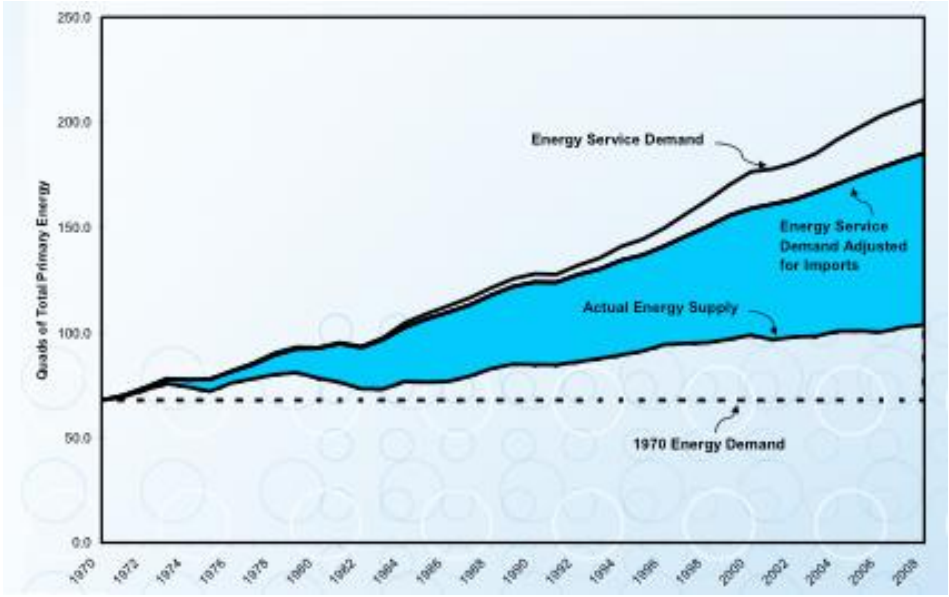
Clean Electricity:

- Drive down costs
- Coupling between energy and water use
- Increase modularity and scalability
- Infrastructure compatibility



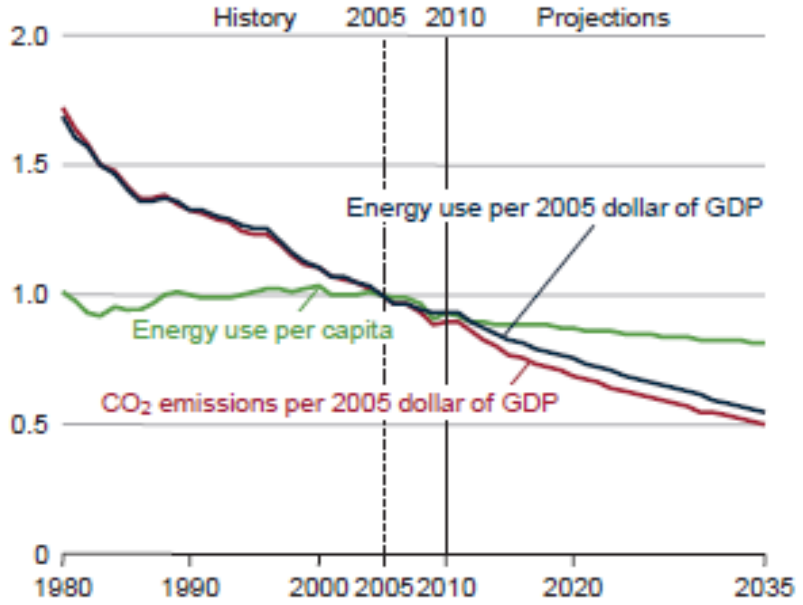
Source: U.S. Department of Energy Quadrennial Technology Review

Energy Efficiency: The Largest Energy Resource, But More is Needed



Source: Steven Nadel, ACEEE, 2011.

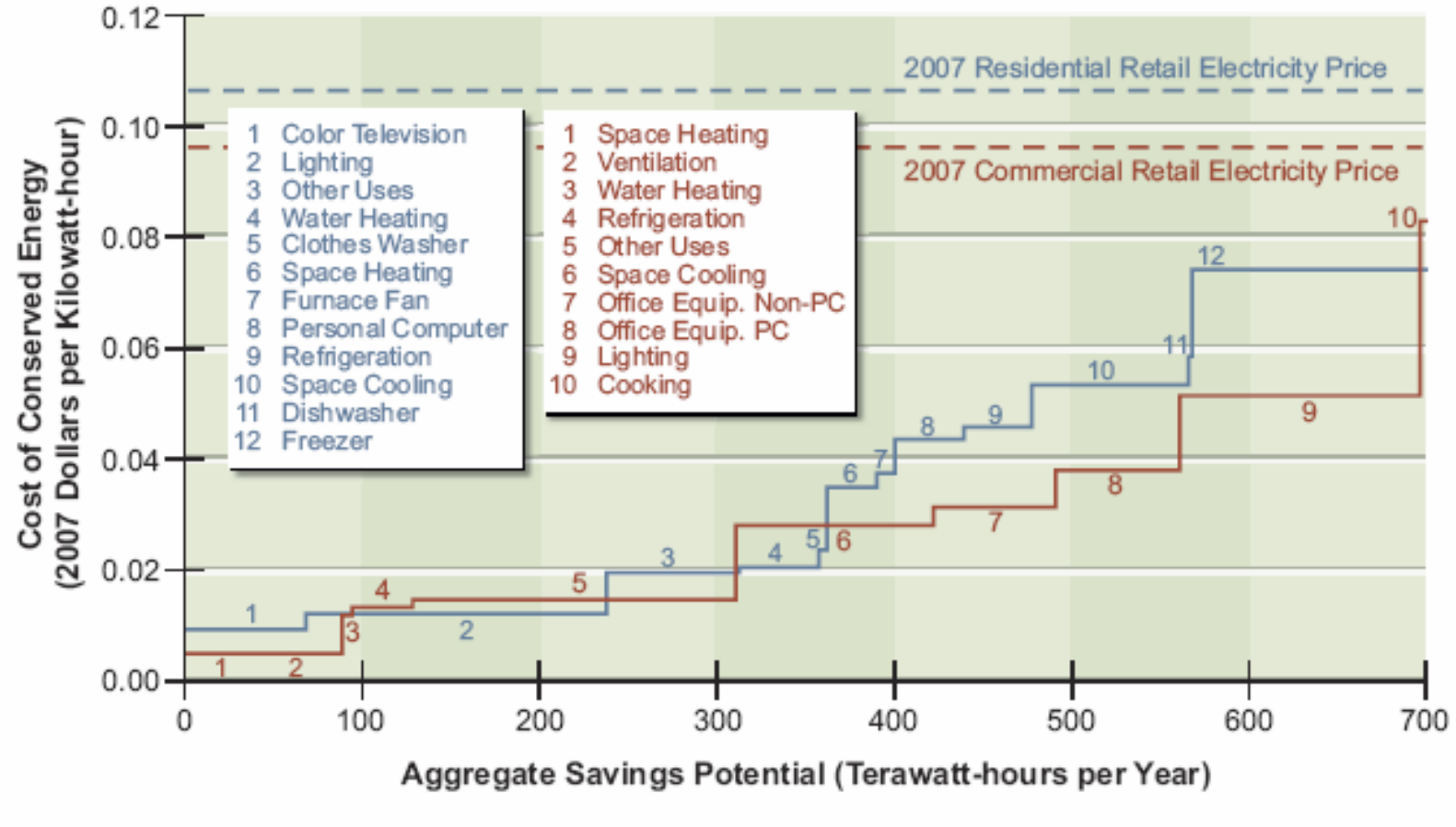
Energy use per capita and per dollar of gross domestic product and emissions per dollar of gross domestic product, 1980-2035 (index, 2005=1)



Source: AEO2012 Early Release Overview, EIA.

Cost of Conserved Energy: Residential and Commercial Electricity

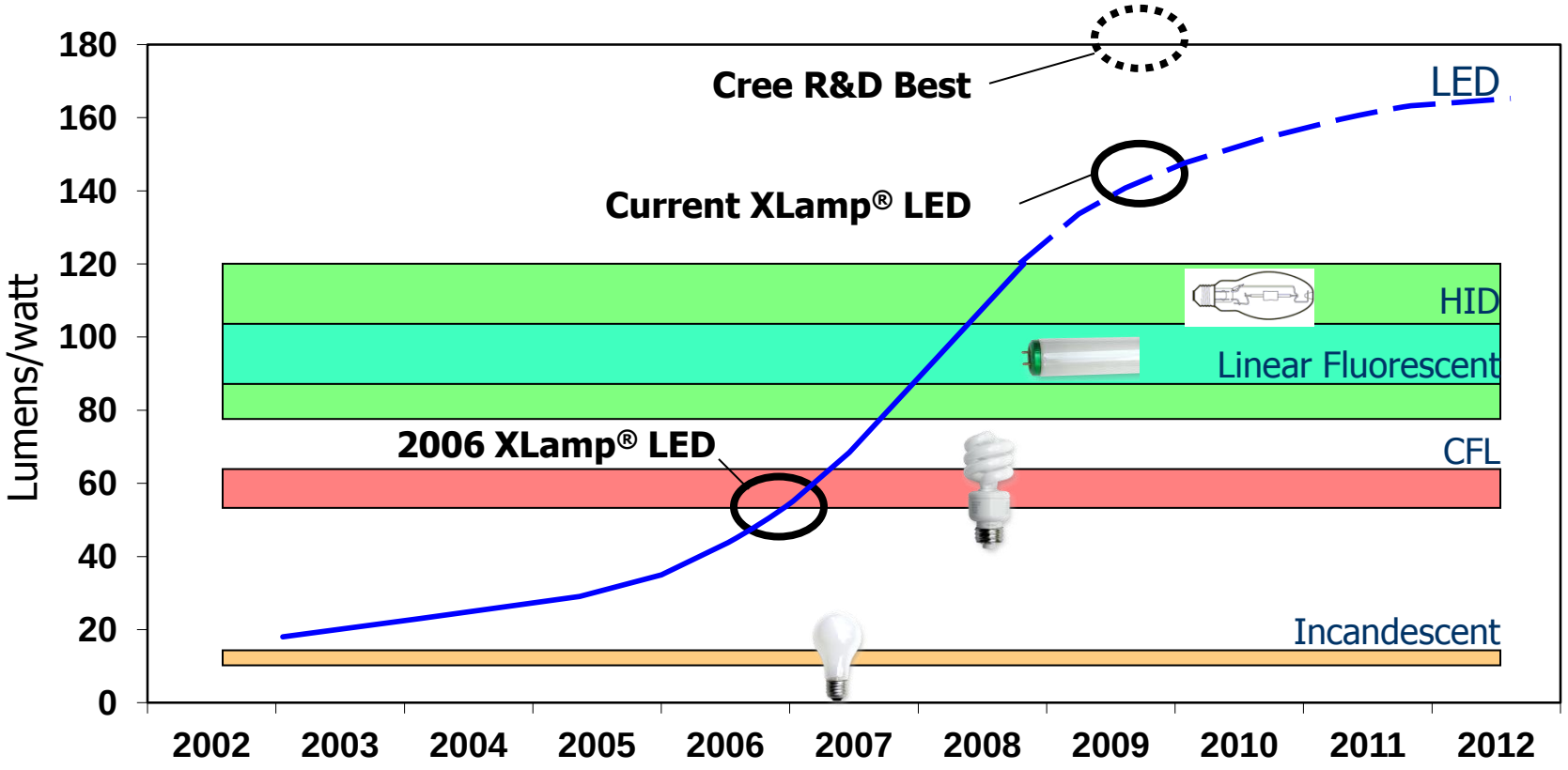
- **Cost of Conserved Energy= the additional cost that must be invested in order to implement a long-term energy-saving strategy or feature**



Source: National Academy of Sciences. 2009. Real Prospects for Energy Efficiency in the United States (Washington, DC: National Academies Press)

Light Source Efficiency Trends

- **Better LED performance increases energy savings and reduces cost**



Source: Cree. December 1, 2009. "LED Lighting Overview"

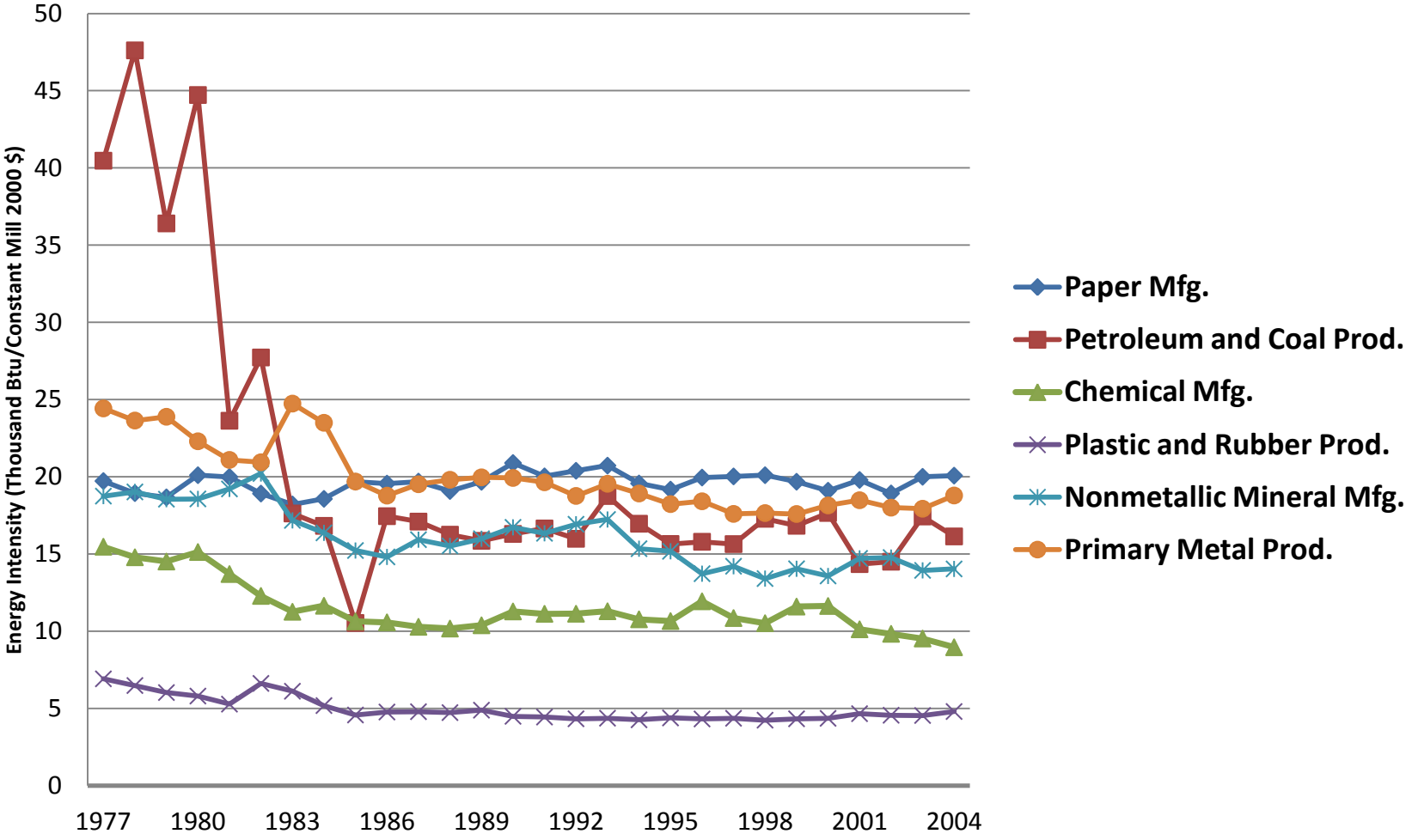
Systems Integration Offers Future Savings (e.g., Climate Master Launches Trilogy™)

- ~ 65% energy savings vs. minimum efficiency (SEER 13) equipment
- ~ 33% savings vs. state-of-the-art two-stage GHP with the super heater

Integrated Unit: Water Heating and Heating/Cooling

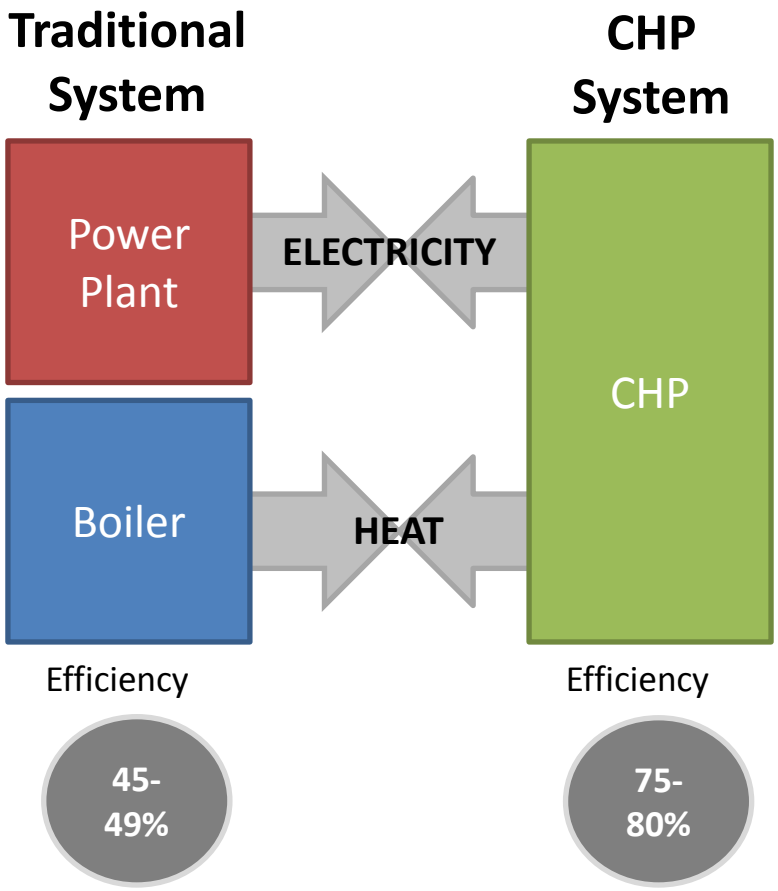
Separate Units: Water Heating and Heating/Cooling

Changes in Energy Intensity in Six Key US Industries



Source: Brown, M. A., Cortes, R., & Cox, M. (2010). Reinventing Industrial Energy Use in a Resource-Constrained World in Fereidoon Sioshansi (ed.) *Smart Living in the Coming Age of Scarcity*. Maryland Heights, MO: Elsevier Press: Chapter 8.

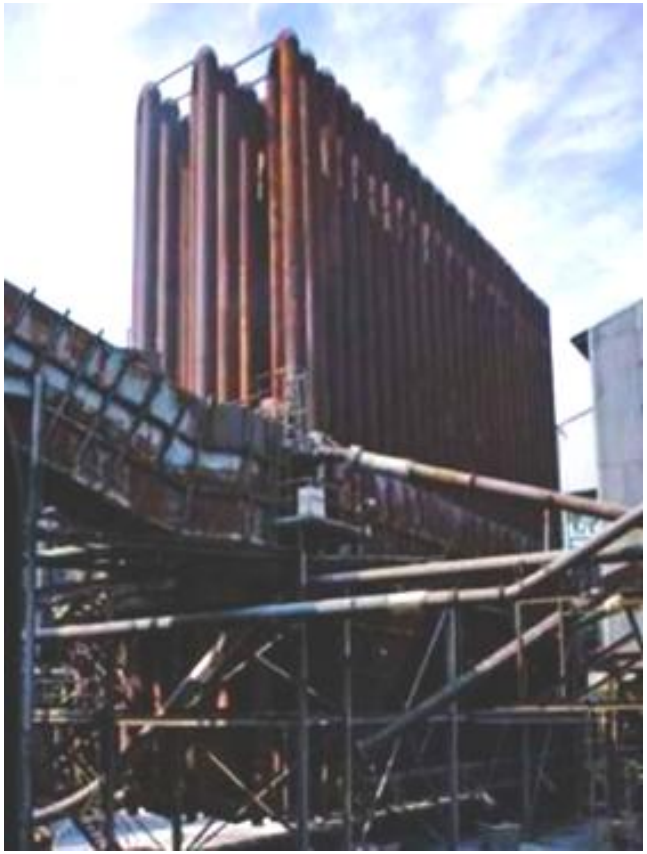
Combined Heat and Power can improve System Efficiencies by 30%



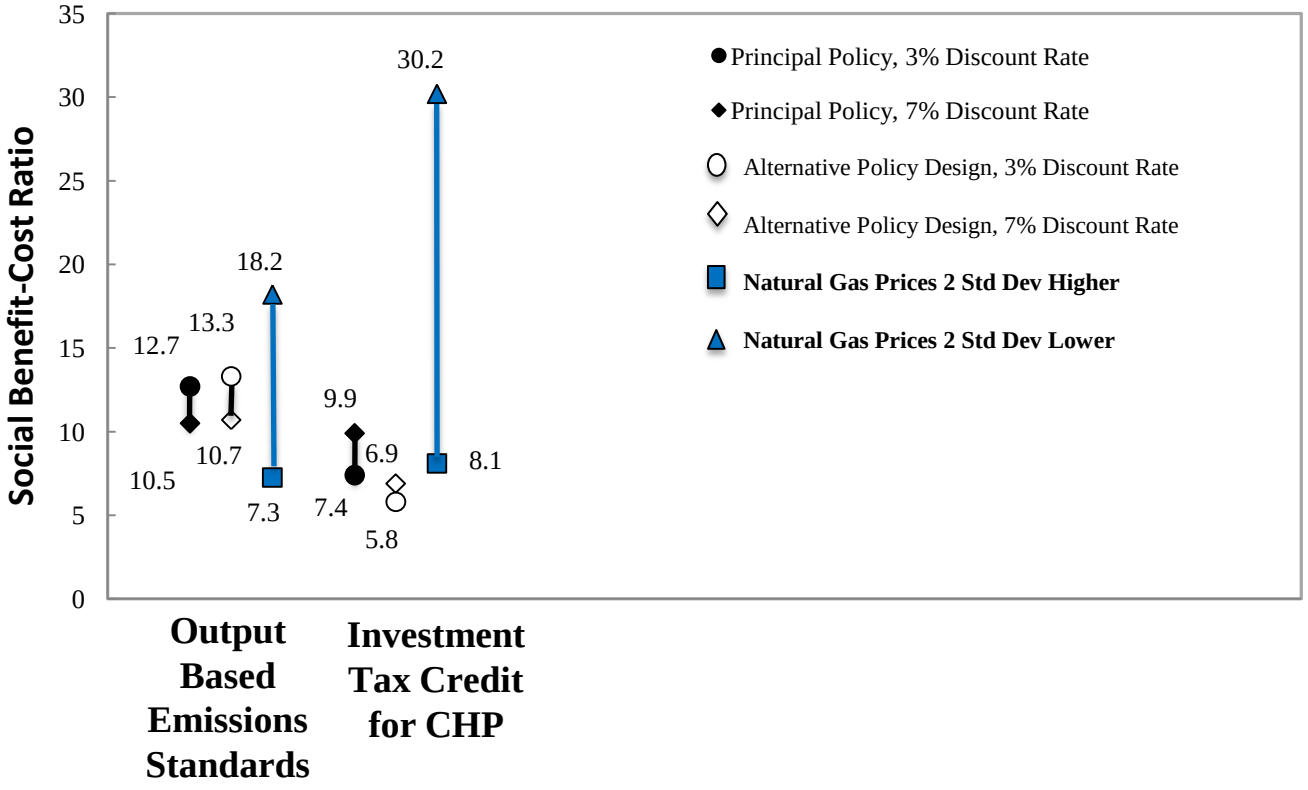
Source: Brown, M. A., Jackson, R., Cox, M., Cortes, R., Deitchman, B., & Lapsa, M. V. (2011). Making Industry Part of the Climate Solution: Policy Options to Promote Energy Efficiency. Oak Ridge National Laboratory, ORNL/TM-2010/78, May.

Lots of Opportunities for CHP in Industry: Proposed CHP Plant in Alloy, WV

- Waste heat from silicon manufacturing could generate 60 MW of electricity



Social Benefit-Cost Ratios of Two CHP Policy Options



Source: Brown, M. A., Baer, P., Cox, M., and Kim, Y. Working Paper. "Evaluating the Risks of Alternative Energy Policies: A Case Study of Industrial Energy Efficiency" Retrieved from http://www.spp.gatech.edu/faculty/workingpapers/wp68.pdf

Nano-info-bio Technologies could Make Industry much Leaner

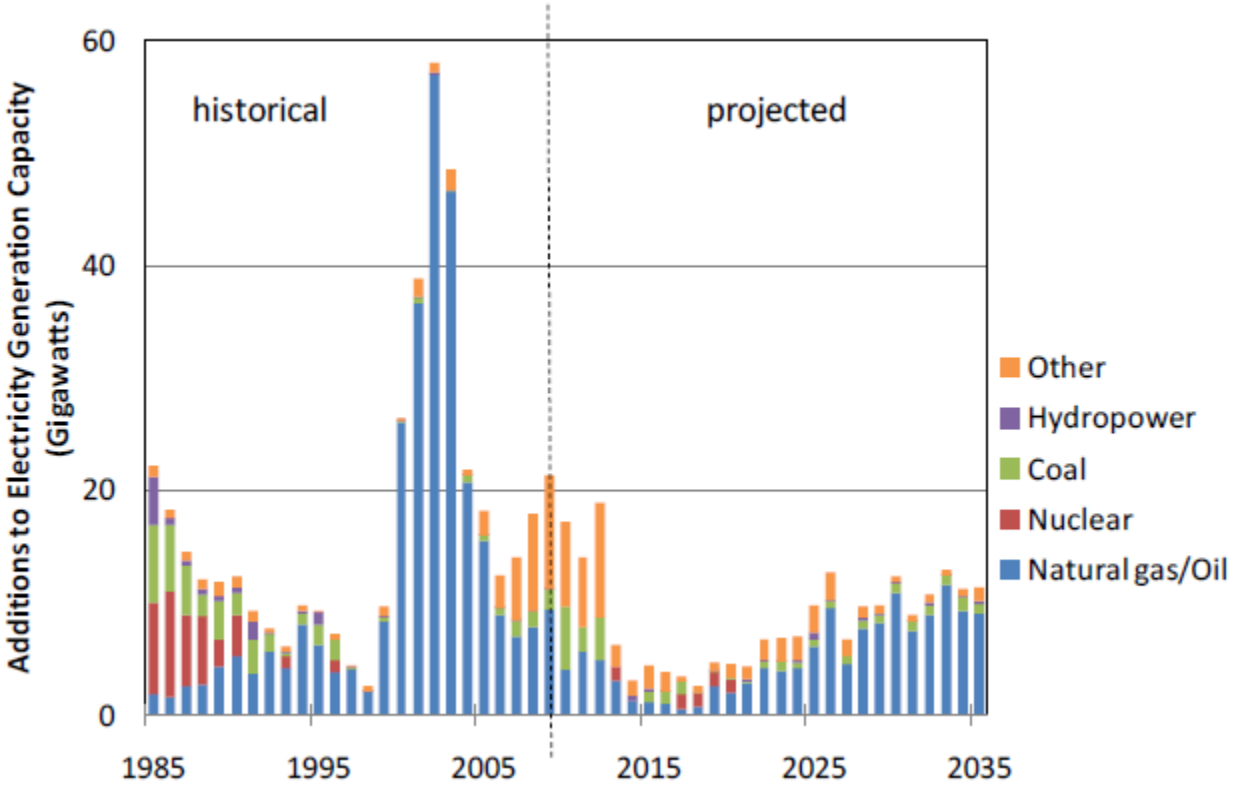
Significant improvements are anticipated in:

- Energy-efficient distillation through supercomputing
- Novel energy-efficient separations
- Super-durable materials for aggressive environments
- Molecular-level control of catalytic materials
- Self-optimizing sensor systems
- Recovery and use of waste heat

Source: Brown, Marilyn. 2005. "Nano-Bio-Info Pathways to Extreme Efficiency," AAAS Annual Meeting, Washington, DC, February 21, 2005

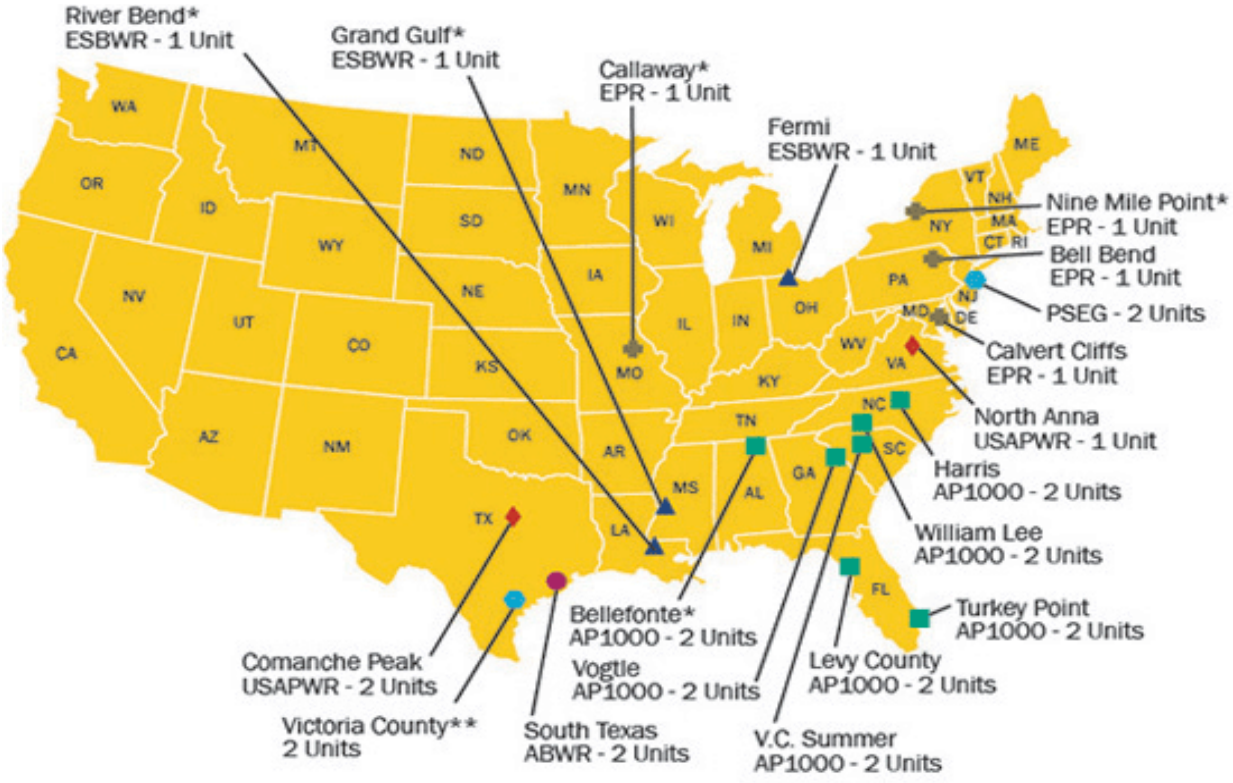
Additions to U.S. Electricity Generation Capacity, 1985-2035

The U.S. is predicted to add less than 10 GW of generating capacity(~1% of total) per year over the next 25 years, most of which will be natural gas



Source: Annual Energy Outlook, EIA.

Location of Projected New Nuclear Power Reactors



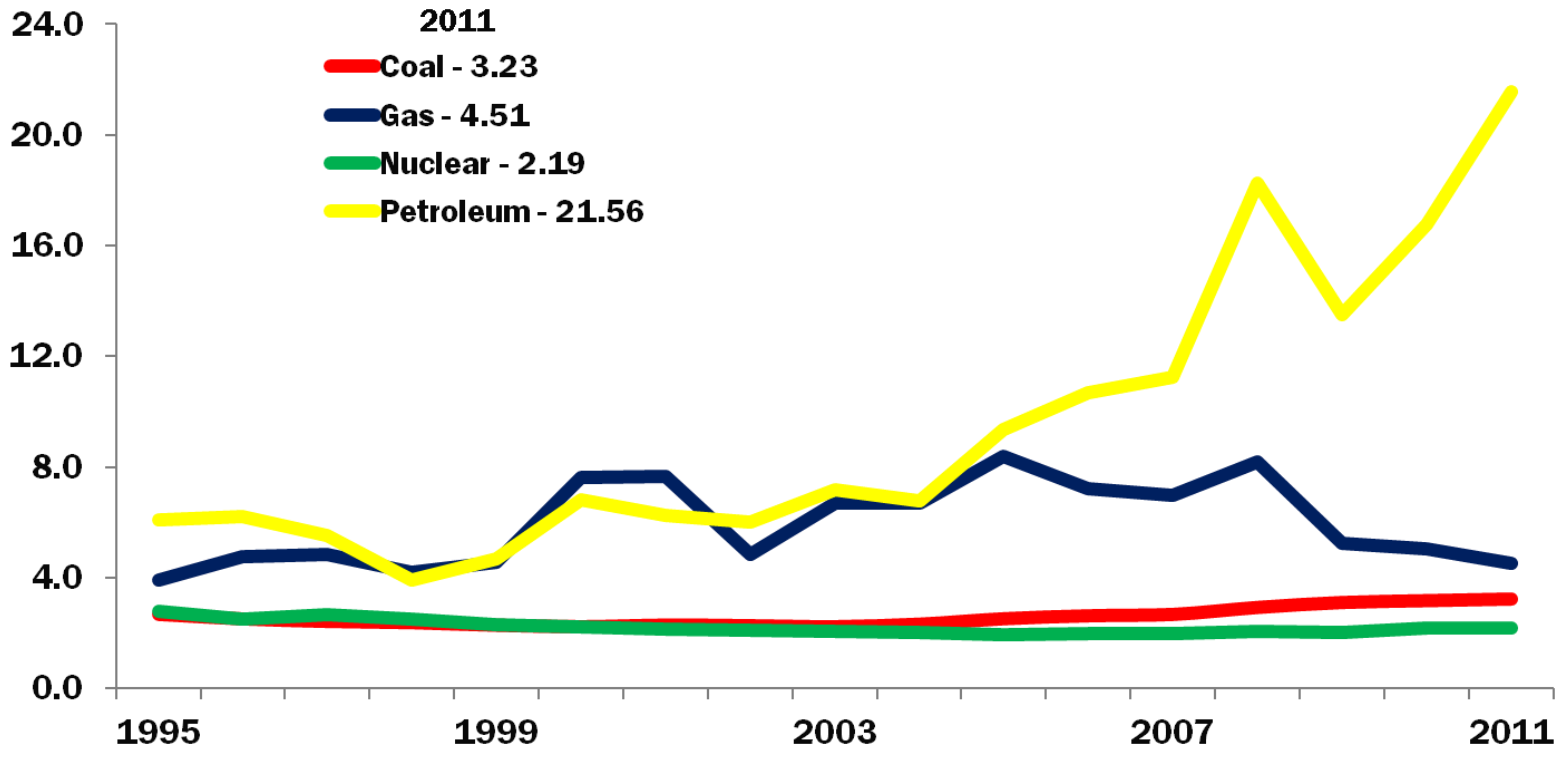
Nuclear Power Reactors Under Construction:

Southern Company	Burke County, GA (Vogtle 3, 4)	AP1000
South Carolina Electric & Gas	Jenkinsville, SC (Summer 2, 3)	AP1000
Tennessee Valley Authority	Rhea County, TN (Watts Bar 2)*	Gen II PWR

Source: U.S. Nuclear Regulatory Commission. Retrieved from http://www.nrc.gov/reactors/new-reactors/col/new-reactor-map.html

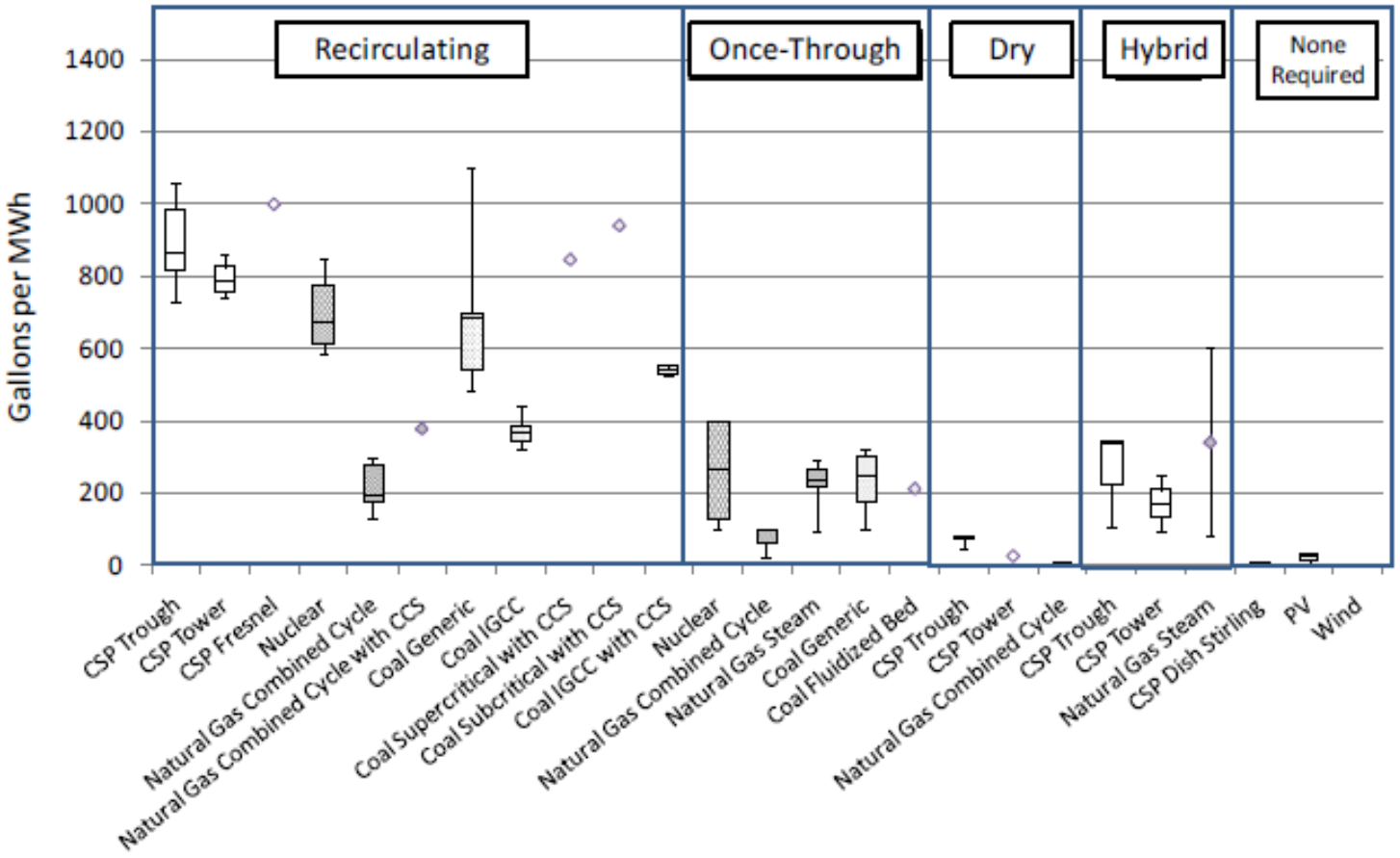
U.S. Electricity Production Costs 1995-2011, In 2011 cents per kilowatt-hour

Production Costs = Operations and Maintenance Costs + Fuel Costs



Source: Ventyx Velocity Suite, Updated: 5/12

Water Consumption for Various Power Generation Technologies



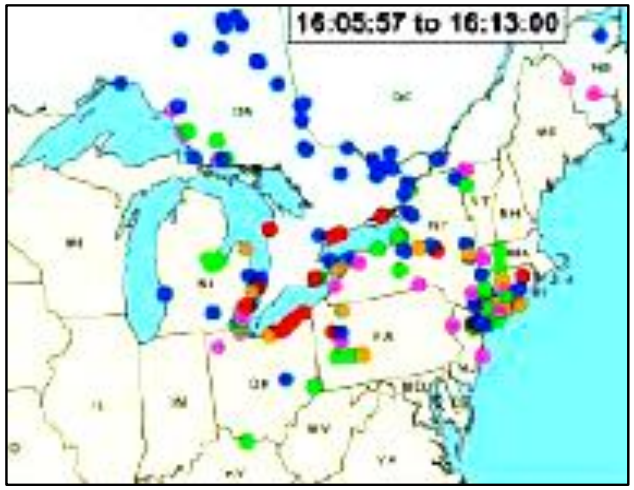
CSP = Concentrating Solar Power, CCS = Carbon Capture and Storage, PV = Solar Photovoltaic

Source: NREL. 2011. A Review of Operational Water Consumption and Withdrawal Factors for Electricity Generating Technologies.

"Why should I worry when the grid is better than 99% reliable?"

2009 U.S. electricity consumption	**3,741 Billion kW-h** *(EIA)*
Estimated annual outage costs	**$ 30 Billion - $ 130 Billion** *(LBNL report to OE, 2004)*

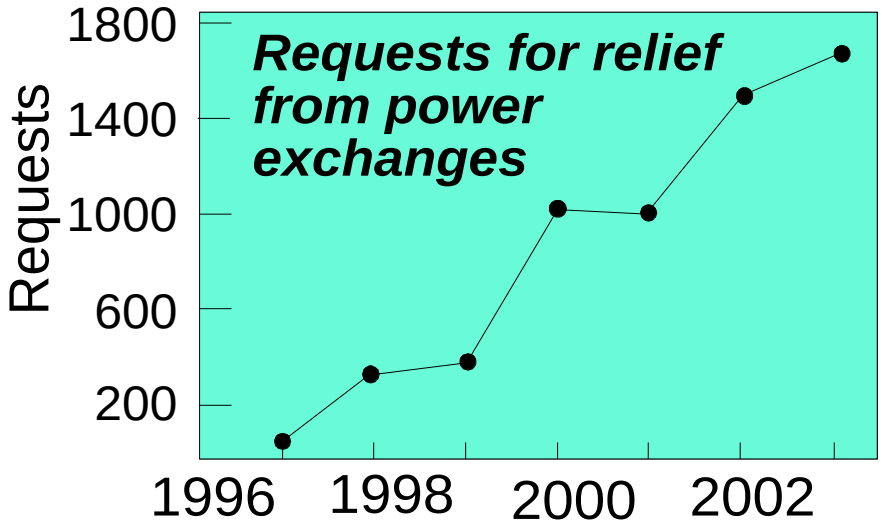
2003 Northeast Blackout



- 508 generators tripped
- Cleveland → Toronto → NYC
- 7 minutes

Report on 2003 North American Blackout,

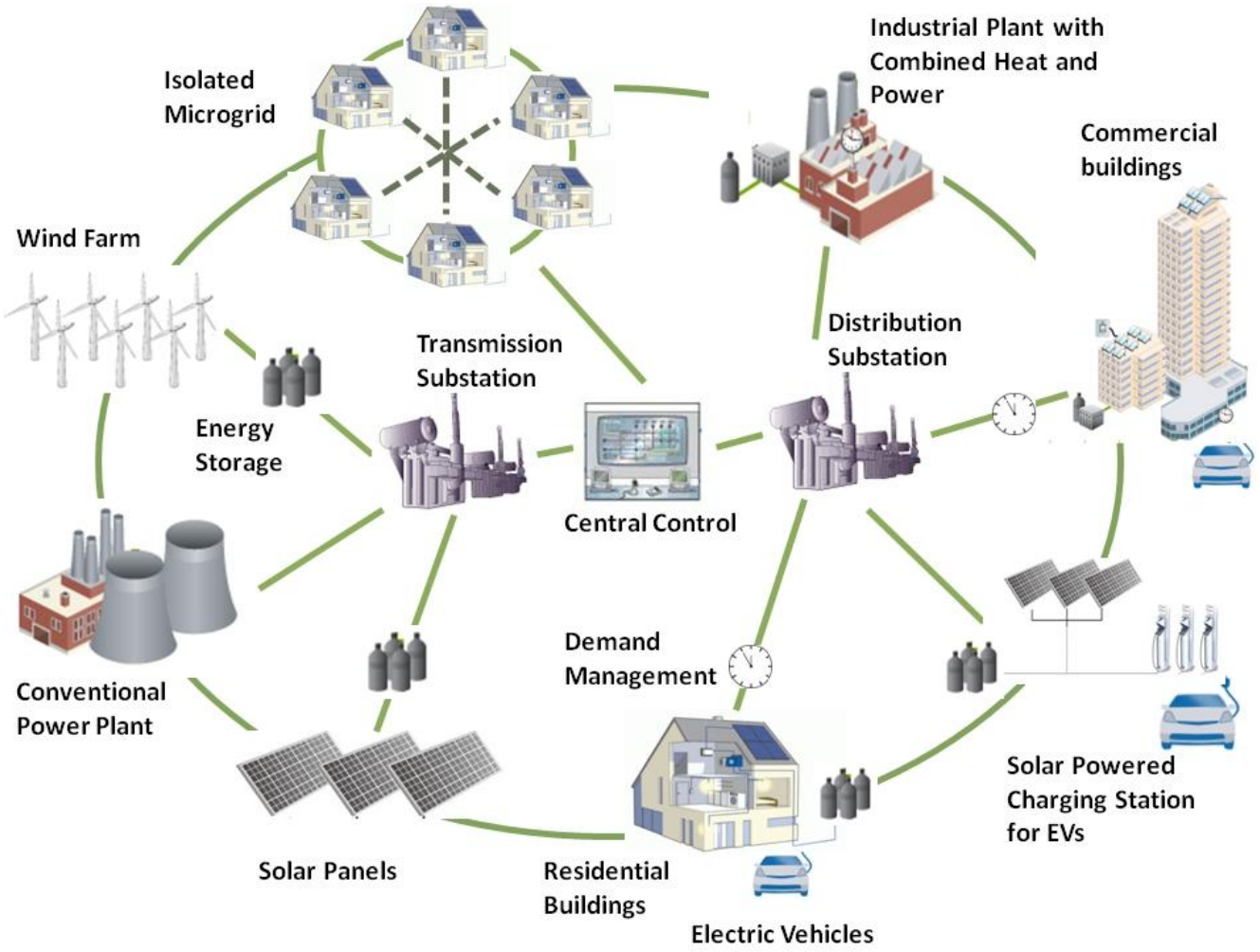
Grid congestion



North American Electric Reliability Council

Source: Modified from Williams Parks. 2011. "Plugging America into Clean Energy" Presentation at the National Academy of Sciences, January 31, 2012.

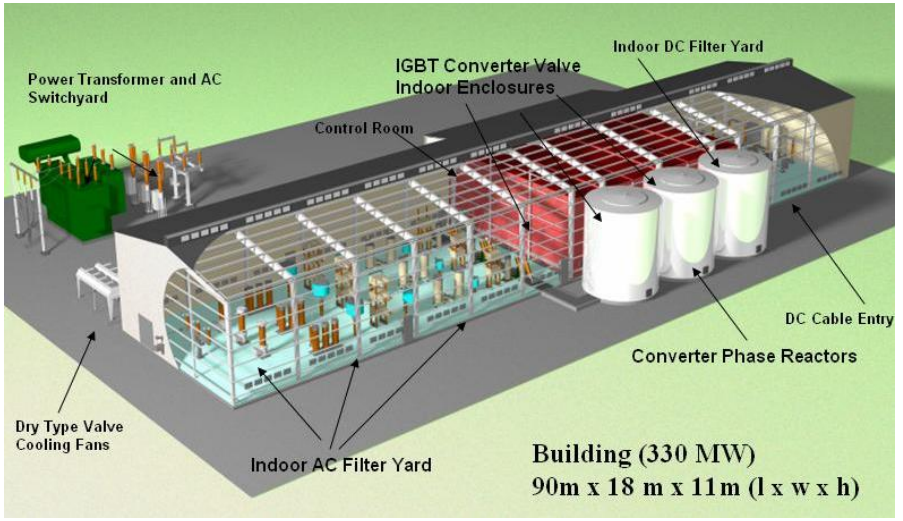
Smart Grid: A Vision for the Future



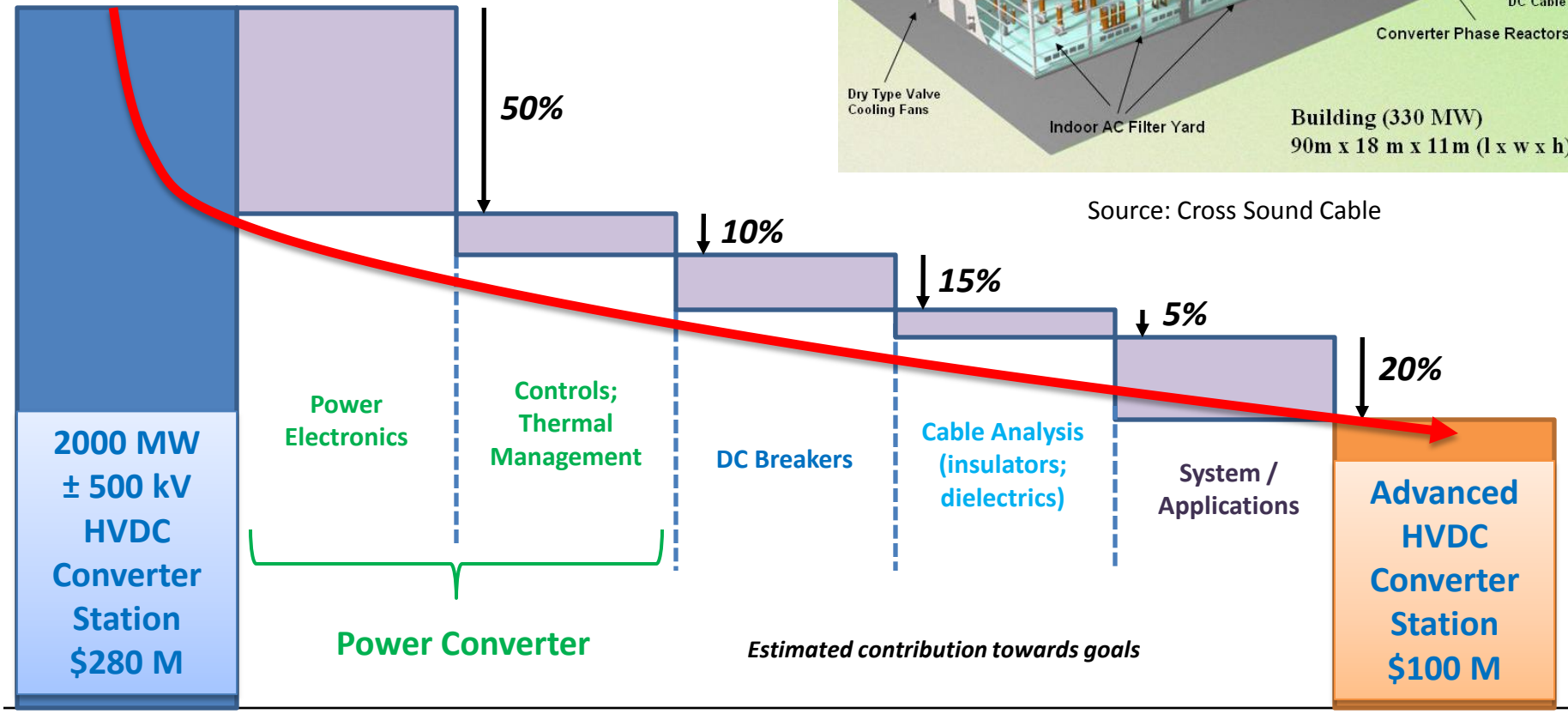
Source: Brown, M.A., Shan, Z. 2012. "The Emergence of Policies to Promote Sustainable Smart Grids, " Encyclopedia of Sustainability Science and Technology (Robert A. Meyers, ed.), Springer Science+Business media, LLC.

Technologies:
High Voltage DC Converter Stations

Converter stations are the most expensive part of HVDC and limits the cost-effectiveness of systems to > 300-500 miles



Source: Cross Sound Cable

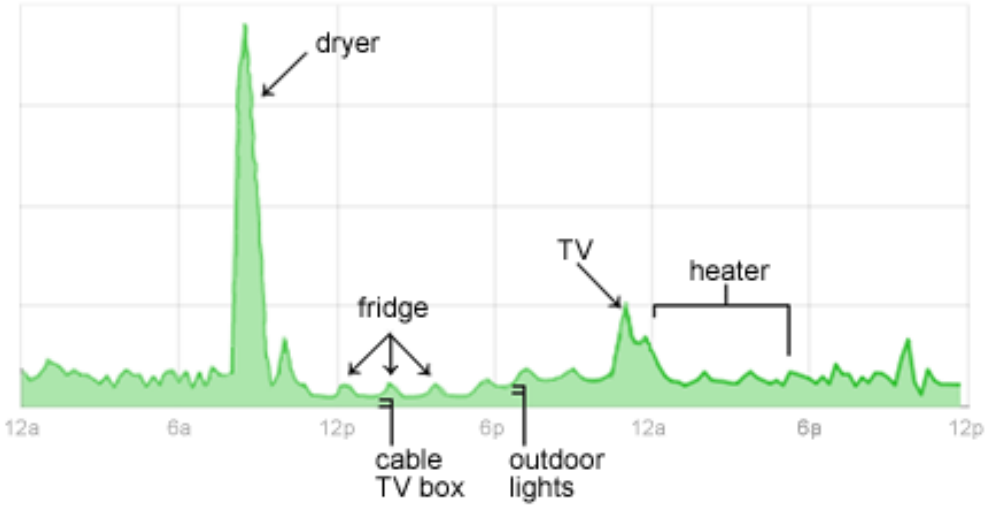


Technologies: Smart Meters & Displays

- Meter that allows frequent data collection
- Enables alternative pricing
- Can interface with in-home or in-office displays of online consumption information
- NOT just an automatic meter reader

ZigBee Rate saver

Energy Orbs that signal expensive & inexpensive times to use energy



Google Power Meter

Transport Power: Technology Headroom

Vehicle Efficiency:

- Increase internal combustion engine efficiency
- Light weighting and aerodynamics

Electrification:

- Batteries
- Electric motors and power electronics

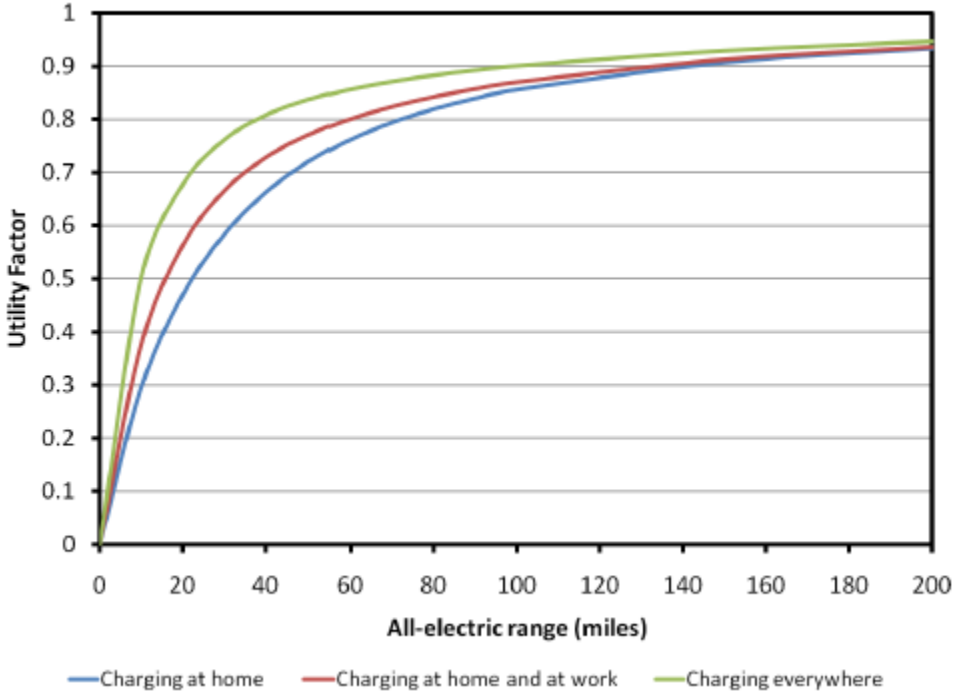
Alternative hydrocarbon Fuels (for HDVs):

- Biofuels
- Alternative fossil fuels (only if less carbon than gasoline/diesel

Source: U.S. Department of Energy Quadrennial Technology Review

Impact of plug-in electric range and charging infrastructure

• The benefit of ubiquitous charging becomes smaller as the all-electric range increases; for most applications, home charging is sufficient. Source: forthcoming EPRI report, “Understanding the Effects and Infrastructure Needs of Plug-In Electric Vehicle (PEV) Charging”

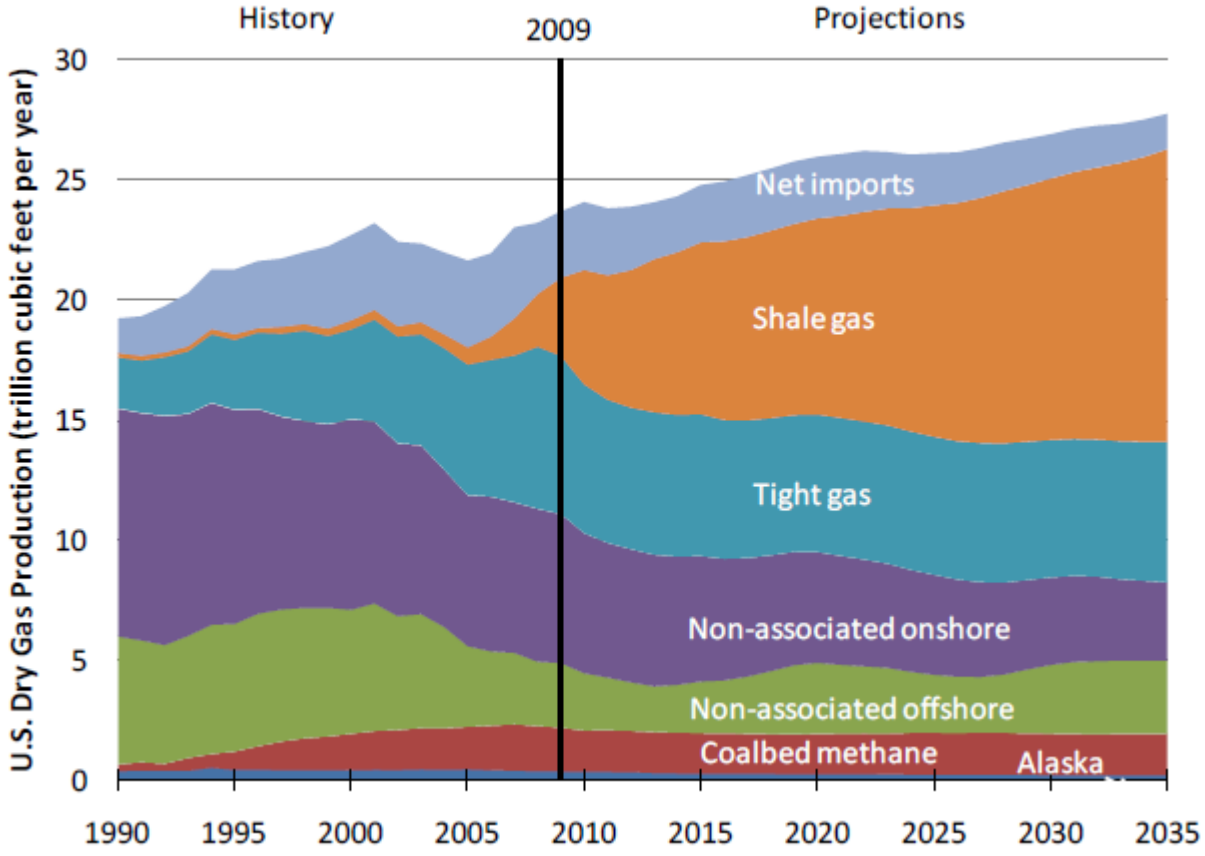


•Utility factor is the fraction of vehicle miles that could be driven on electric power without recharging

Source: U.S. Department of Energy Quadrennial Technology Review

U.S. Natural Gas Supply, 1990-2035

• Shale gas is expected to grow in the next several decades, reducing net imports and challenging the development of renewables and energy efficiency



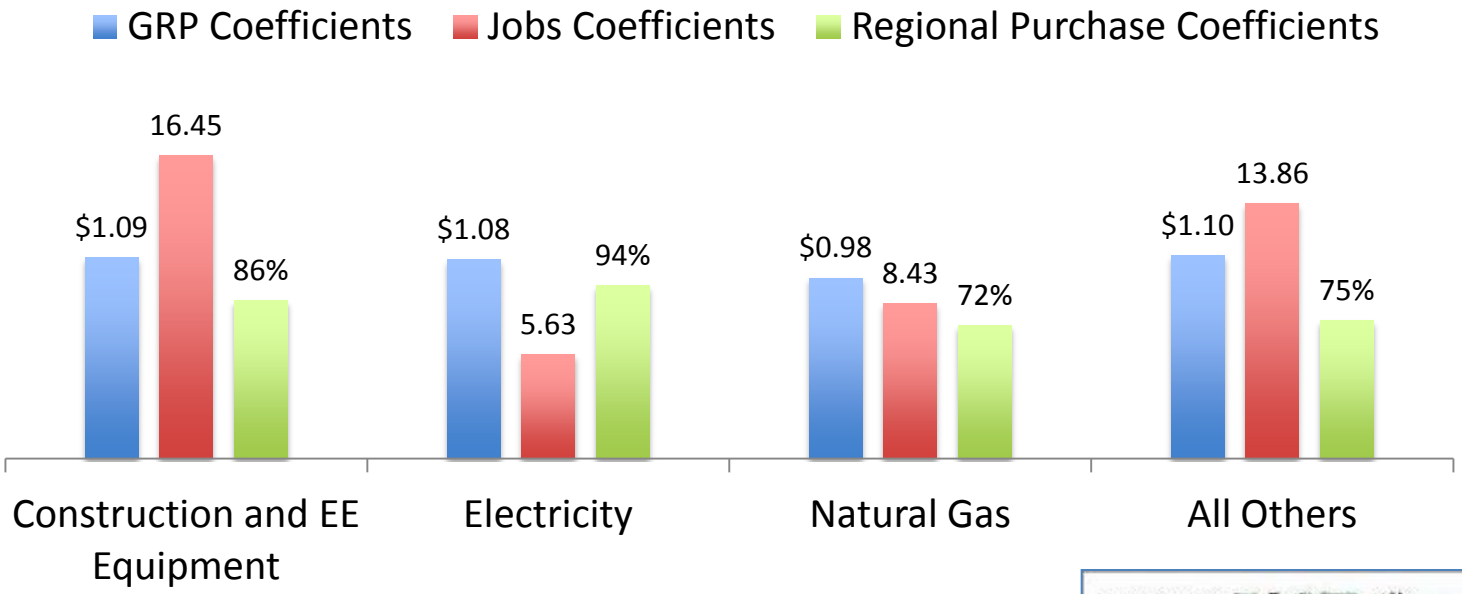
Source: Annual Energy Outlook 2011, EIA.

Manufacturing the Next Generation of Lean and Green Technologies

- **Product line choices are important**
  - A new generation of fuel cells and batteries for motor vehicles
  - Biorefinery innovations for a next generation of biofuels
  - New plastics that double as integrated photovoltaic systems
- **Corporate sustainability**
  - Industry is adopting a much broader view of its energy and environmental responsibilities

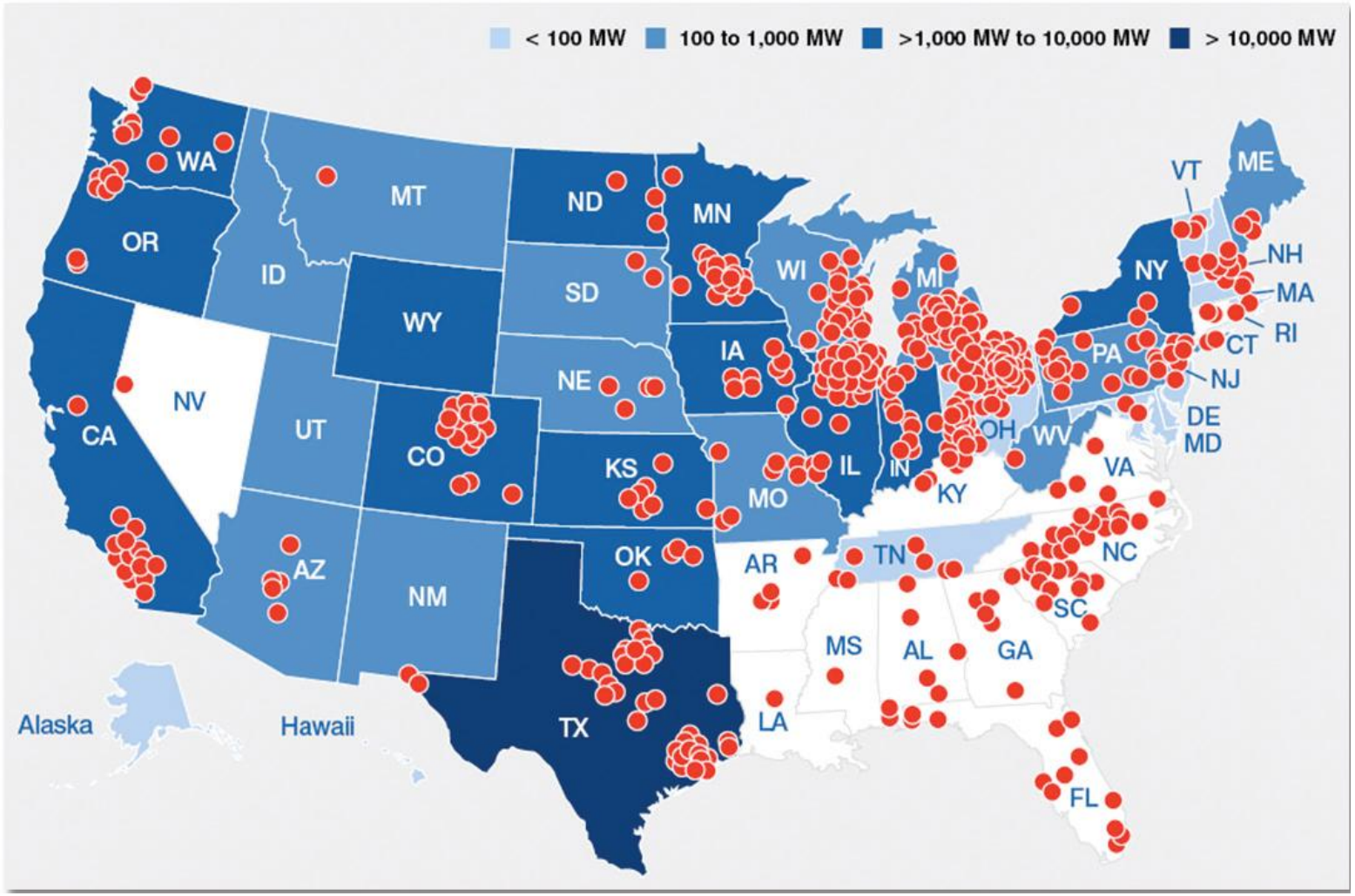
Source: Delamaide, Darrell. 2011. "Green Trade Wars Heat Up, *energybiz*, 8(2) pp. 12-14

Input/Output Coefficients Confirm the Labor Intensity of Energy Efficiency Investments



Source: Deitchman, B., Brown, M., & Baer, P. (2011). Green Jobs from Industrial Energy Efficiency. Energy Productivity in Industry: Partners and Opportunities, *2011 American Council for an Energy Efficient Economy (ACEEE) Summer Study on Energy Efficiency in Industry*. Washington, DC: ACEEE.

Over 400 U.S. Manufacturing Plants Serve the Wind Industry Today



Source: AWEA U.S. Wind Industry Annual Market Report, 2009
Manufacturing data updated through November 2010, includes wind-related facilities

Recommended Policy Directions to Promote U.S. Energy Sustainability

- A policy framework is needed that attracts diverse funding sources
- Policies could help motivate businesses to focus more of their resources on green and lean energy systems – preserving jobs in existing industries
- Advancing product innovation can enable next-generation green and clean technologies – creating new jobs in new industries
- Policy making needs to take into account societal cost s & benefits and consumer behavior

FOR MORE INFORMATION

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