RENEWABLE ENERGY OUTLOOK IN THE US AND THE WORLD

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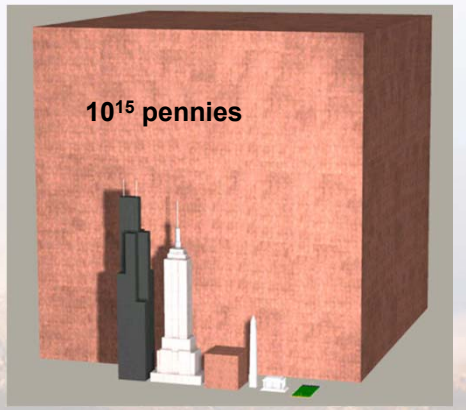
Outline and Goals

- How do we measuring energy use for a country or the world?
- Who measures energy for the U.S.
- Where does our energy originate and how is it used?
- How are states and governments influencing a switch to renewables?
- How reliable are future energy forecasts?
- What are the main barriers to renewable energy?
- What is happening in Europe?

Energy Units and Conventions

- **How do we measure energy?**
  - Joule (J) – 1 newton/meter *or* 1 Watt/sec (very small amount of energy)
    - Gigajoule (GJ) = 1 billion (10^9) Joules (~6 GJ per barrel of oil)
    - Zettajoule (ZJ) = 10^{21} Joules (Annual global energy consumption is about 0.5 ZJ)
  - BTU (British Thermal Units) = 1,055 J = Energy required to heat 1 pound of water from 39 to 40 deg F.
    - **Quad** = quadrillion BTUs (10^{15}) is the standard unit for measuring energy use by world economies.
    - U.S. used about 100 Quads of energy in 2005
      - **1 Q = 8 million gallons of gas**
      - **100 Q = PV energy potential**
        - ~13,000 mi^2
        - Land required = 25 years of coal mining
- The U.S. defines "quadrillion" differently from the rest of the world
  - The "British" quadrillion = 10^{24}



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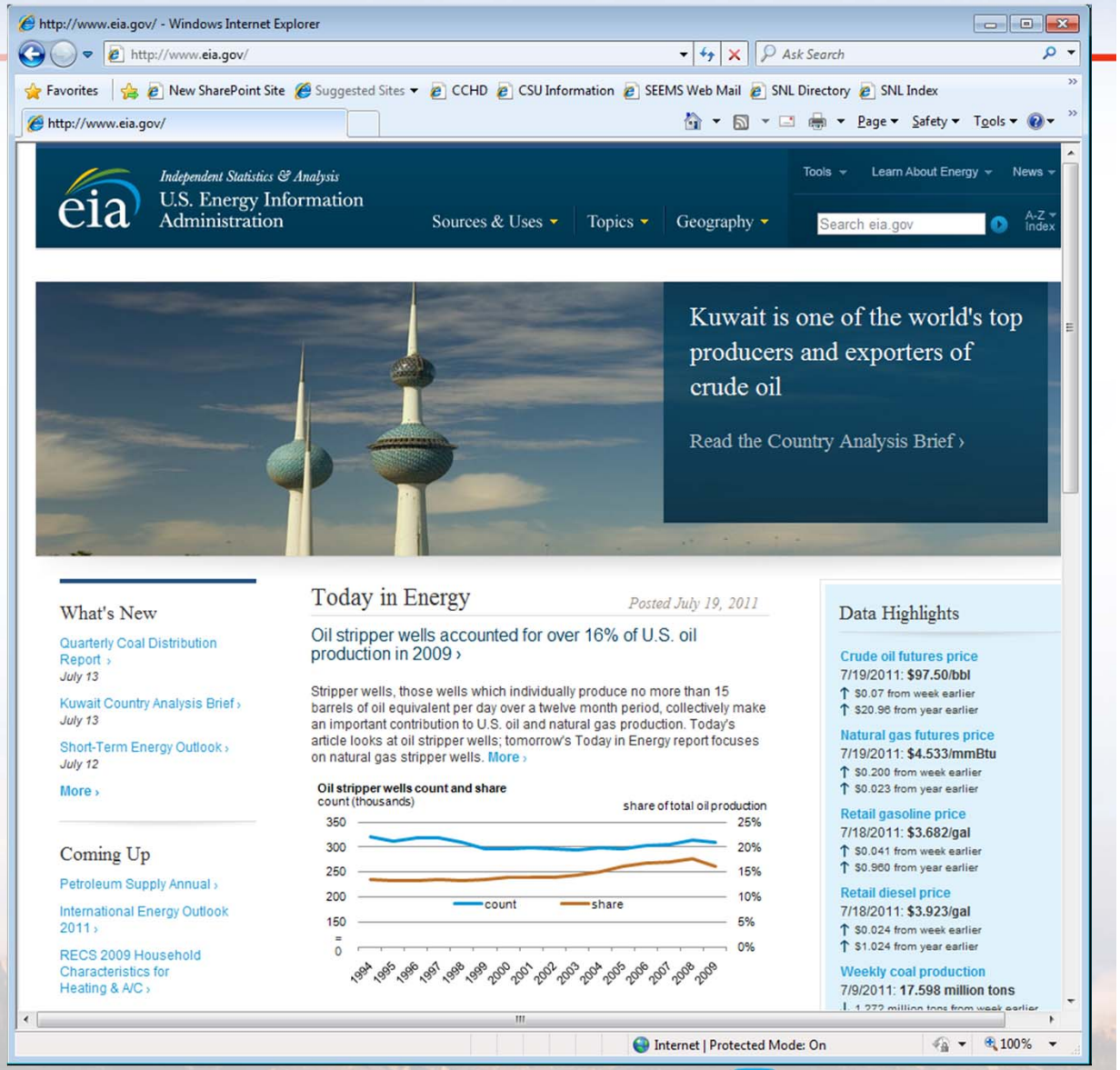
Who Measures Energy for the U.S. and World?

- **U.S. Energy Information Administration**
  - Statistical and analytical agency within DOE
  - Weekly, monthly, quarterly, and annual assessments and forecasts
  - Annual energy outlooks
  - Systems modeling (National Energy Modeling System (NEMS)
- **International Energy Agency**
  - 28 member countries



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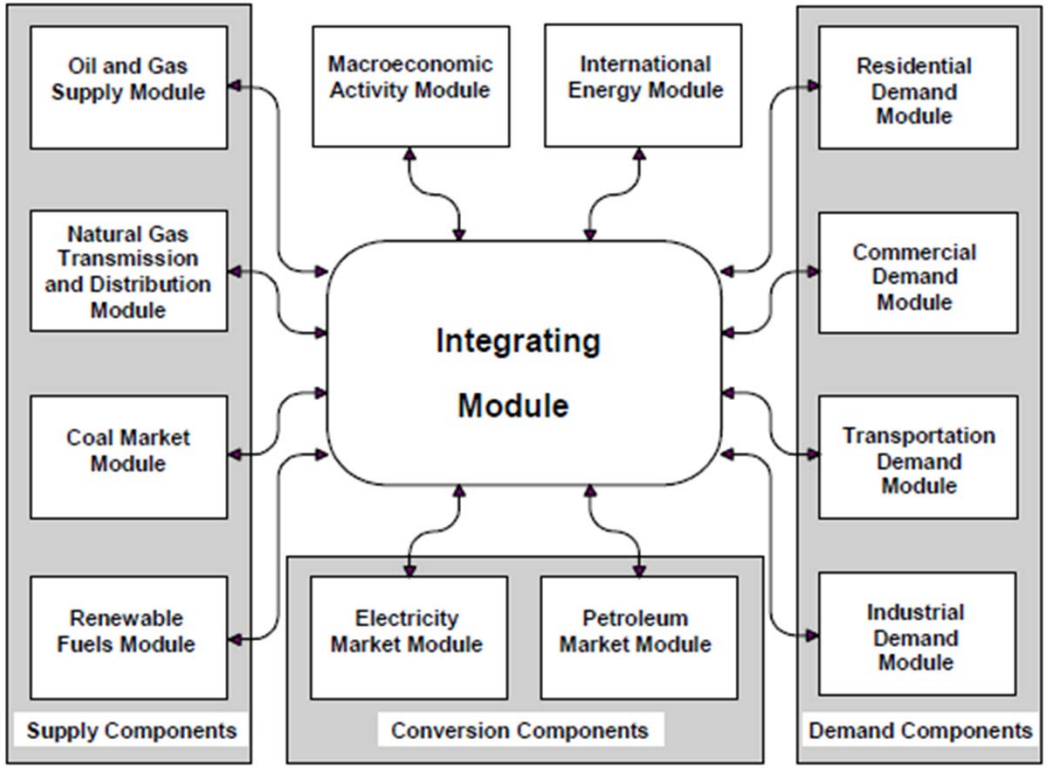
National Energy Modeling System

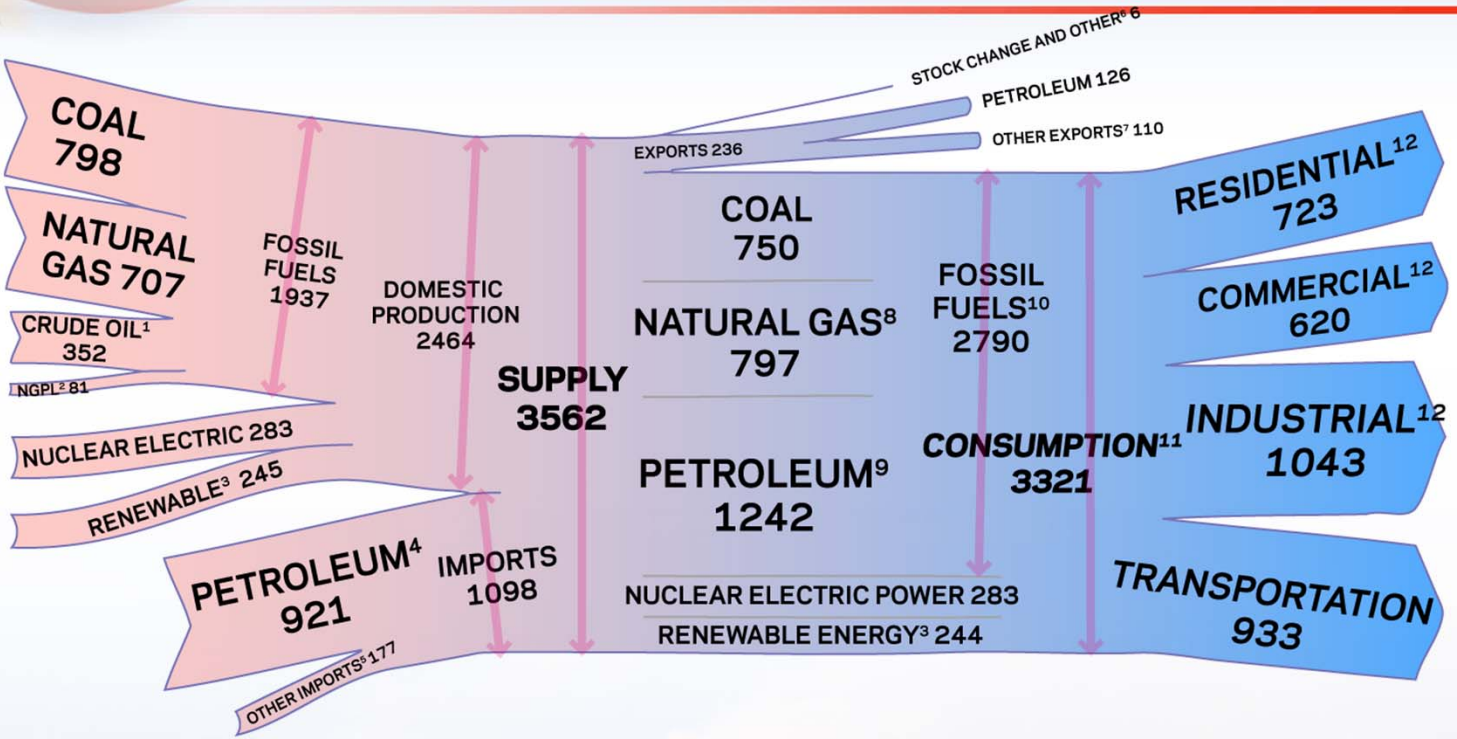
- **Global optimization problem with multiple constraints**
  - Supply and demand are balanced for the minimum price
  - Capital expenditures, international prices, and economic activity are also considered
  - Regional divisions are considered
  - Current incentives included

Figure 1. Basic NEMS Structure and Information Flow



U.S. Energy Flow by Source and Sector

US TOTAL Energy Flow, 2008
(Gigawatts)



[1] Includes lease condensate.
[2] Natural gas plant liquids.
[3] Conventional hydroelectric power, biomass, geothermal, solar/photovoltaic, and wind.
[4] Crude oil and petroleum products. Includes imports into the Strategic Petroleum Reserve.
[5] Natural gas, coal, coal coke, fuel ethanol, and electricity.
[6] Adjustments, losses, and unaccounted for.
[7] Coal, natural gas, coal coke, and electricity.
[8] Natural gas only; excludes supplemental gaseous fuels.
[9] Petroleum products, including natural gas plant liquids, and crude oil burned as fuel.
[10] Includes 0.04 quadrillion Btu of coal coke net imports.
[11] Includes 0.11 quadrillion Btu of electricity net imports.
[12] Primary consumption, electricity retail sales, and electrical system energy losses, which are allocated to the end-use sectors in proportion to each sector's share of total electricity retail sales. See Note, "Electrical Systems Energy Losses," at end of Section 2.

Notes: • Data are preliminary. • Values are derived from source data prior to rounding for publication. • Totals may not equal sum of components due to independent rounding.
Sources: Tables 1.1, 1.2, 1.3, 1.4, and 2.1a.

MODIFIED FROM: Energy Information Administration / Annual Energy Review 2008

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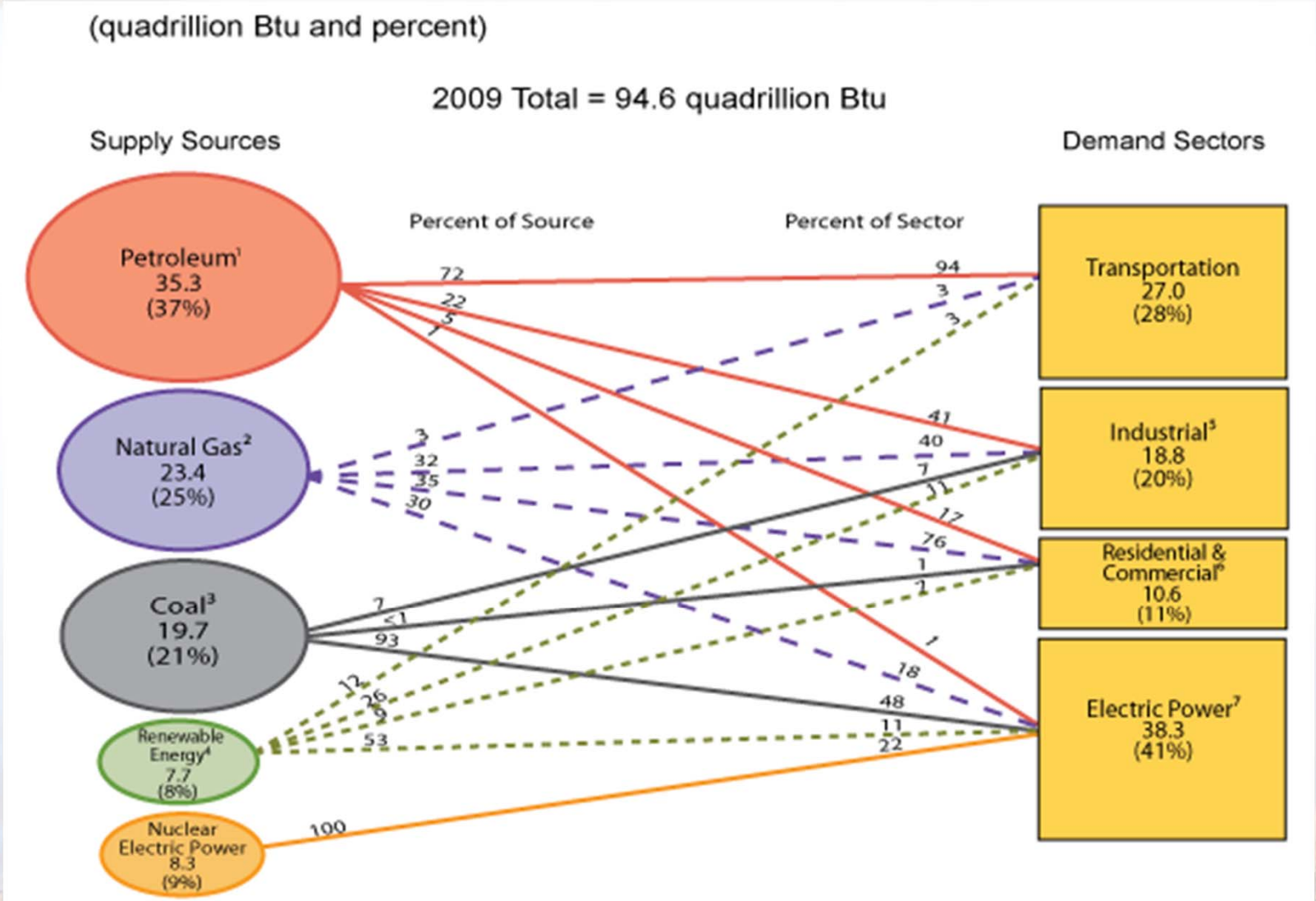
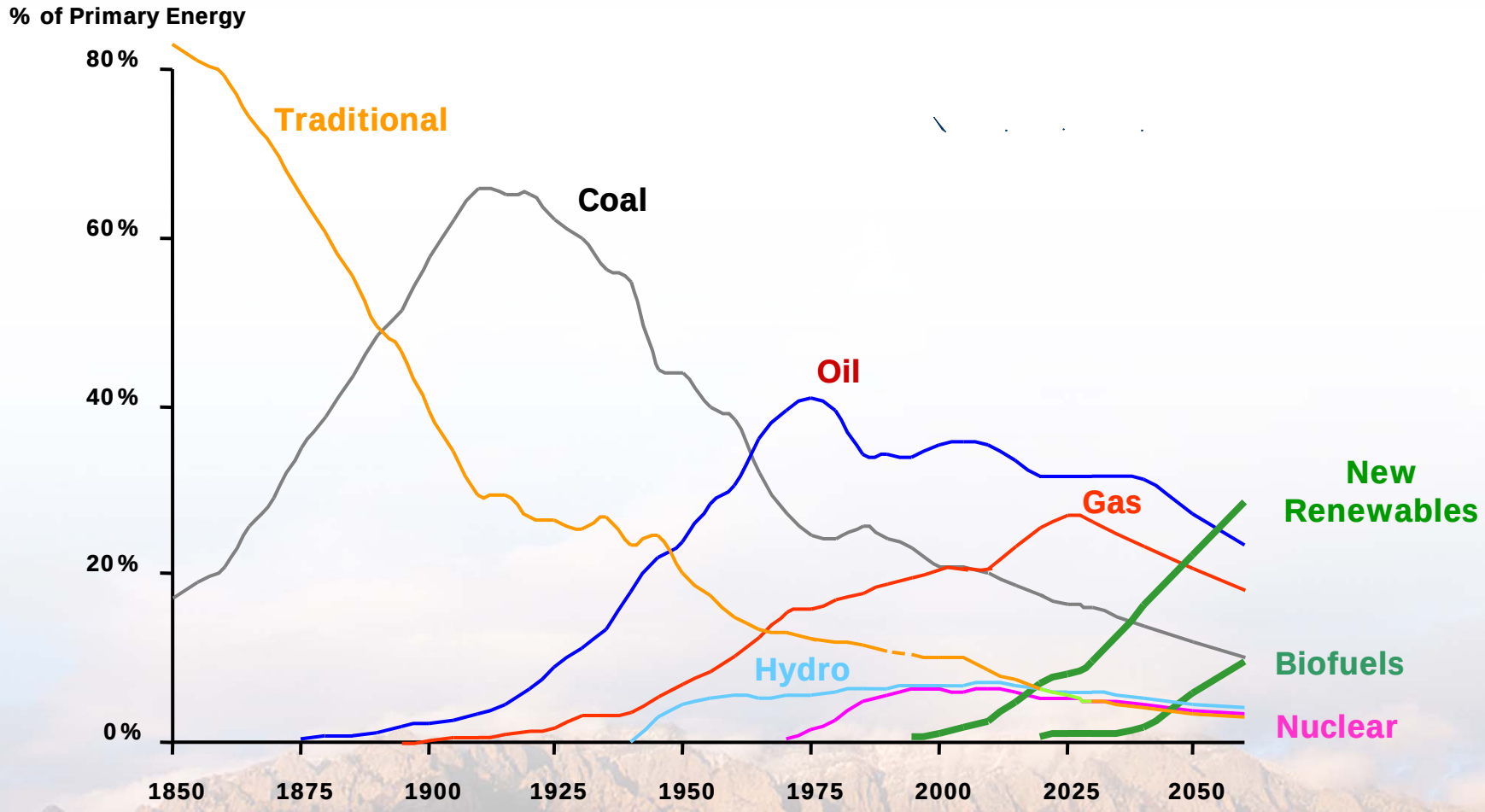
U.S. Primary Energy Flow by Source



The Evolving Energy Mix



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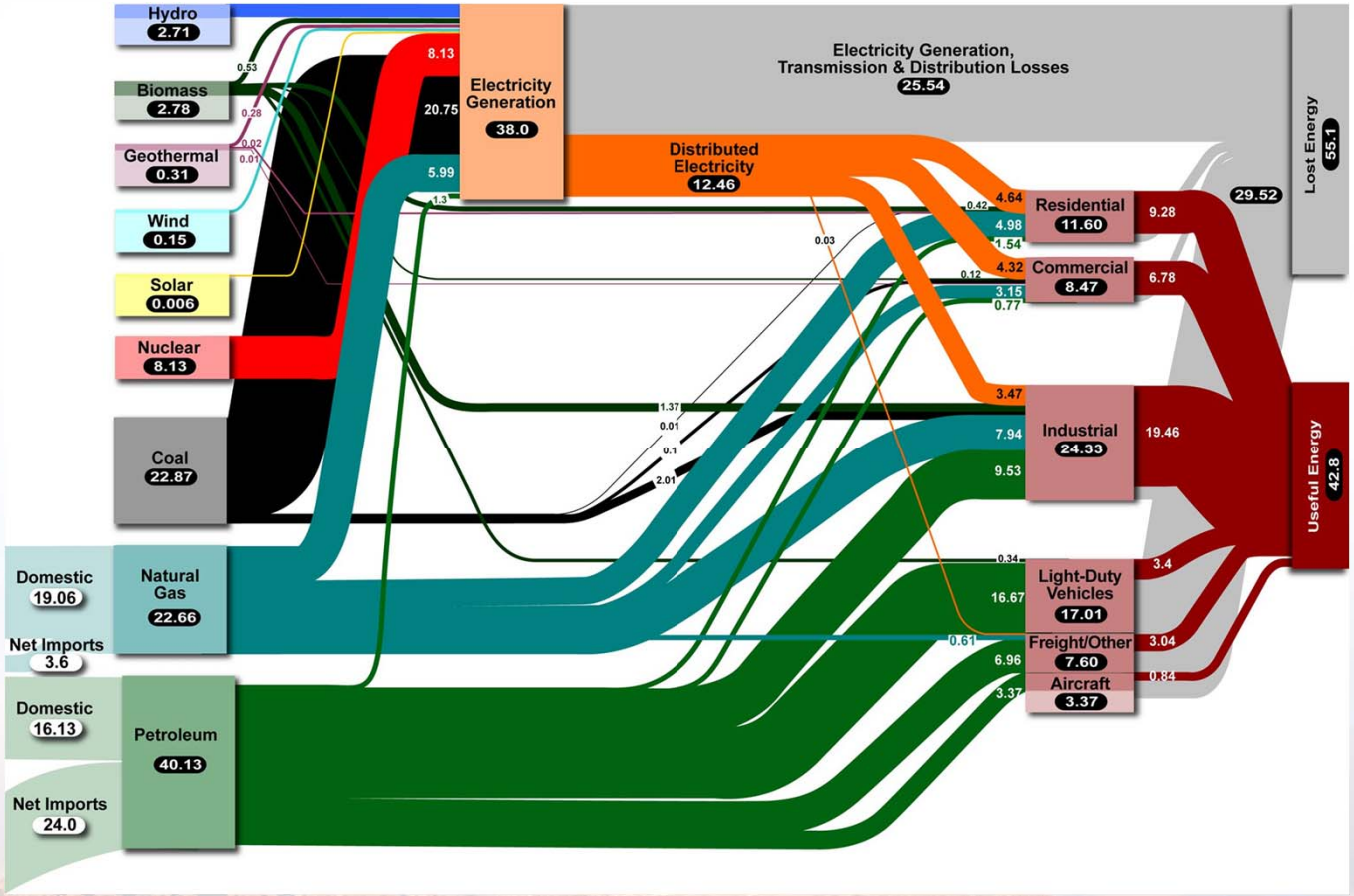
U.S. Electricity Flow

- Increasing efficiency is important
- Conversion losses (technology)
- Transmission and distribution losses (system design)

- Does not include wasted energy
  - E.g., consumer electronics on standby, lighting, A/C, …



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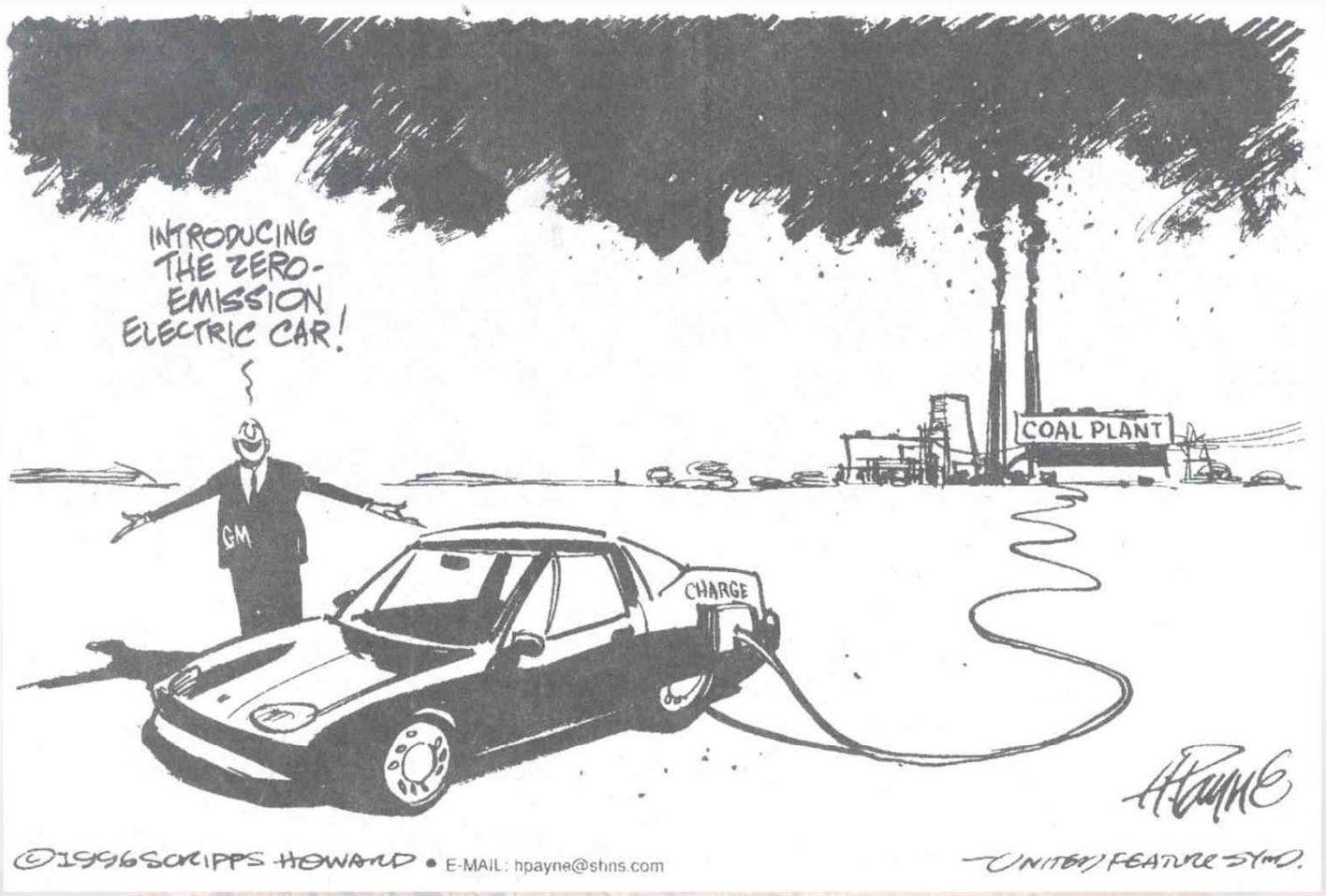
Using the "Spaghetti Chart" to Understand Energy Issues

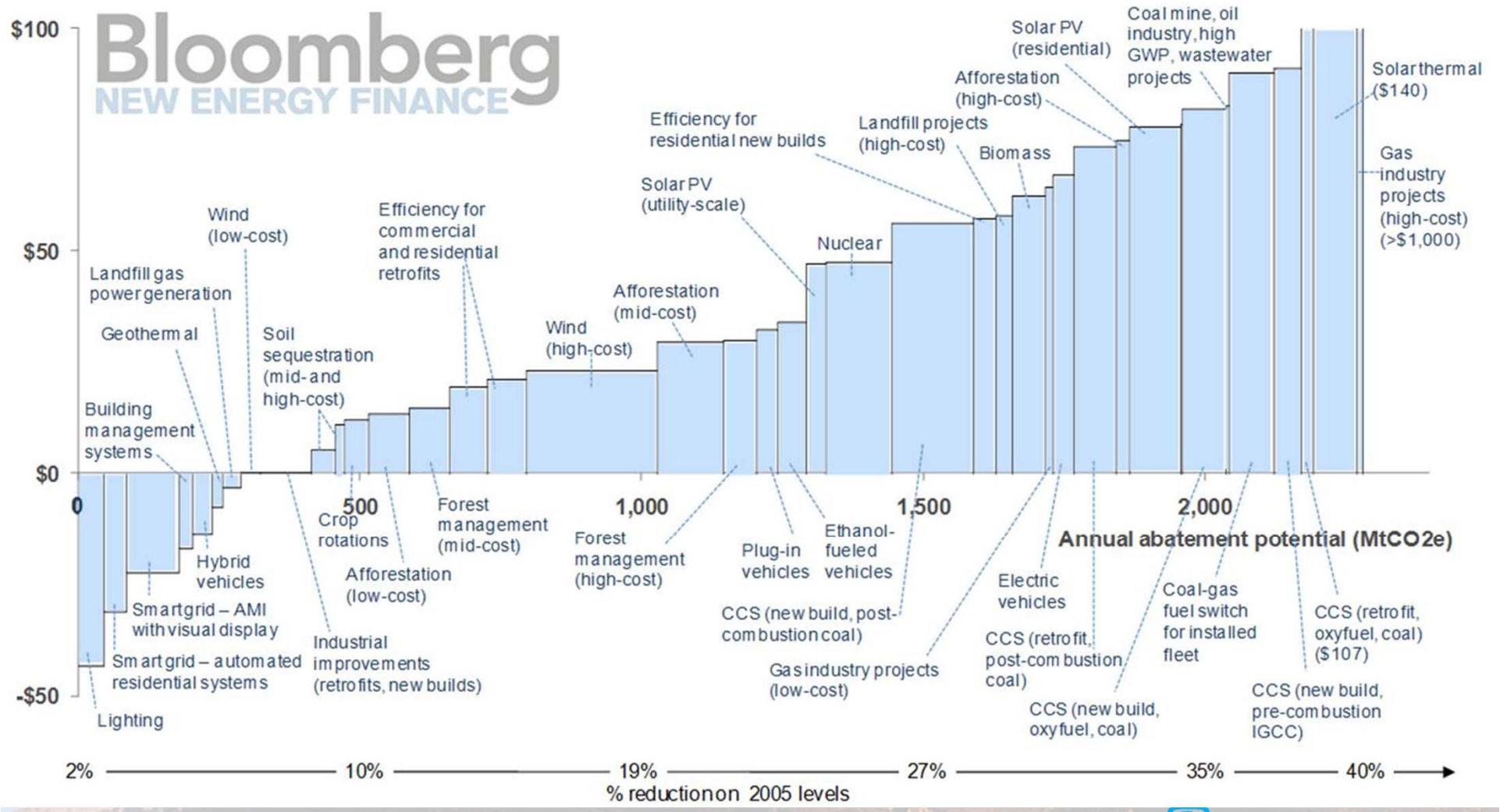
- Nuclear energy role in U.S. energy supply and in electric energy production?
- Is the U.S energy supply vulnerable, how much is imported and for what?
- Benefits of solid-state lighting on oil imports? On energy efficiency and future power plant needs?
- Are there benefits of higher fuel efficiency standards for cars? For cars and trucks?
- Where are energy efficiency technology improvements most productive?

Growing Environmental and Ecological Issues (Carbon Footprint)

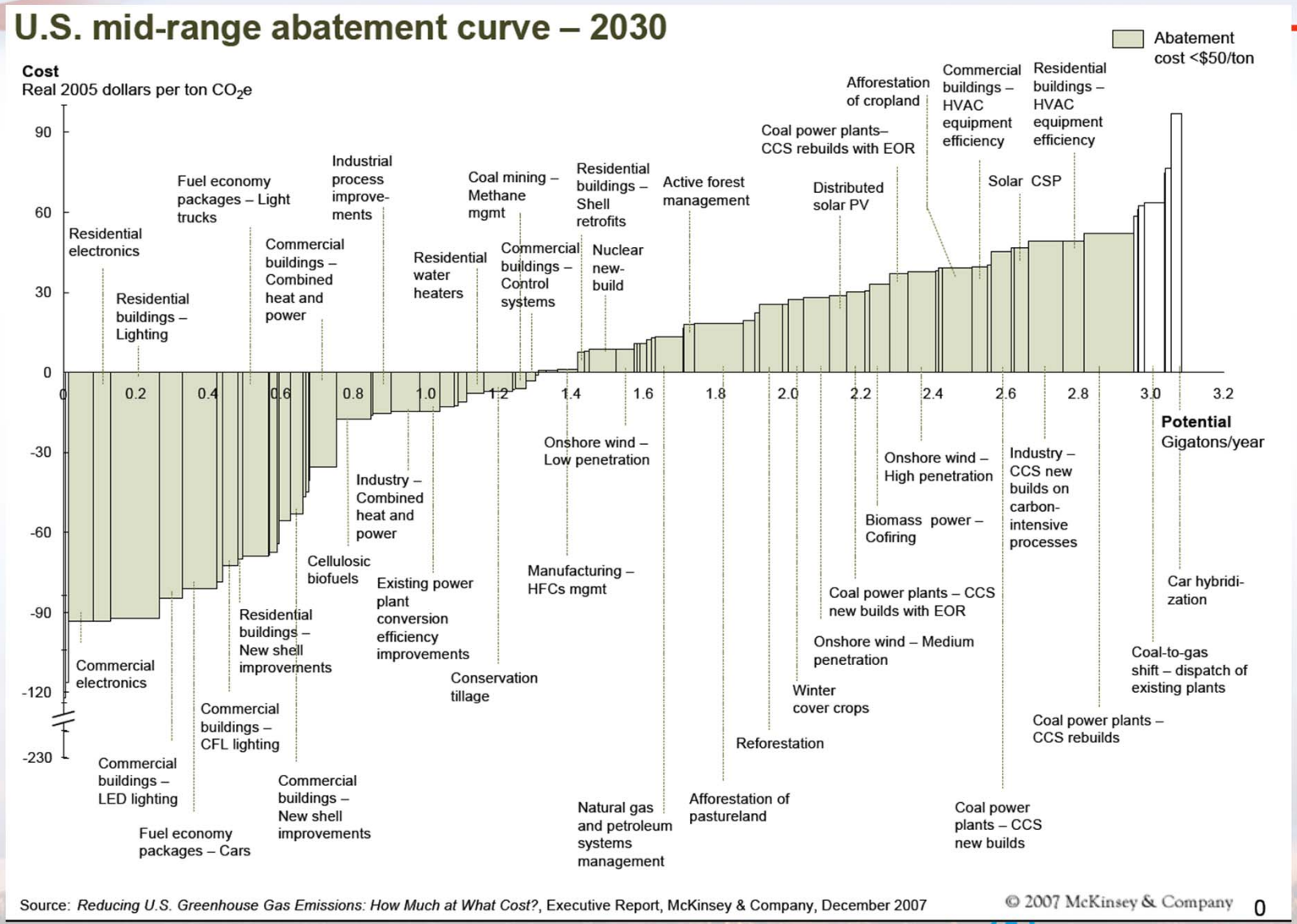


HYDROGEN FUEL CELL – $CH_4 + 2H_2O \rightarrow 4H_2 + CO_2$

Cost of Reducing CO^2



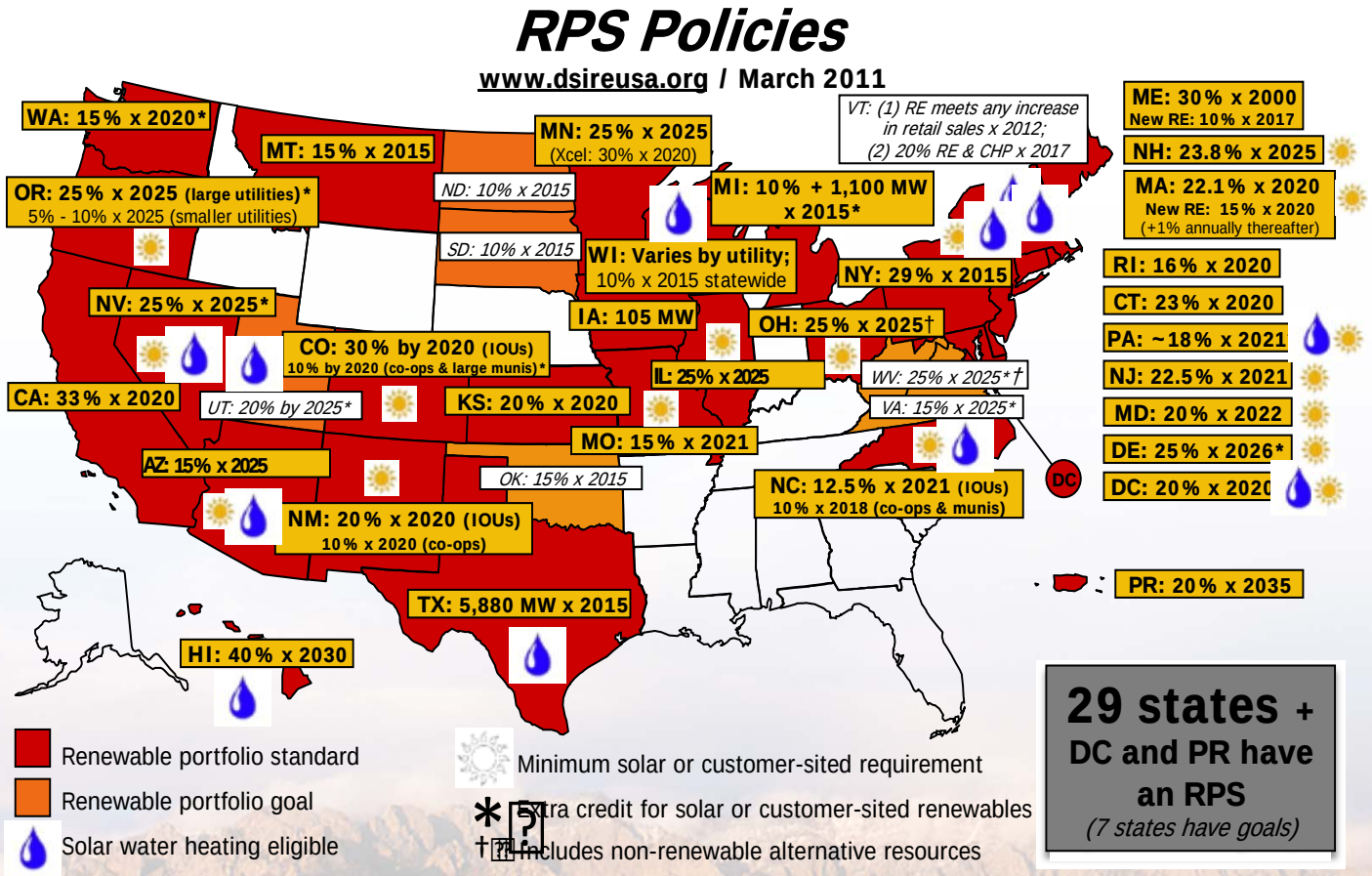
Cost of Reducing CO_2



Source: *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?*, Executive Report, McKinsey & Company, December 2007

Renewable Portfolio Standards Are Gaining Ground Across the US

New Market Scenario: **Climate change concerns, renewable portfolio standards, incentives, and accelerated cost reduction driving steep growth in U.S. renewable energy system installations.**



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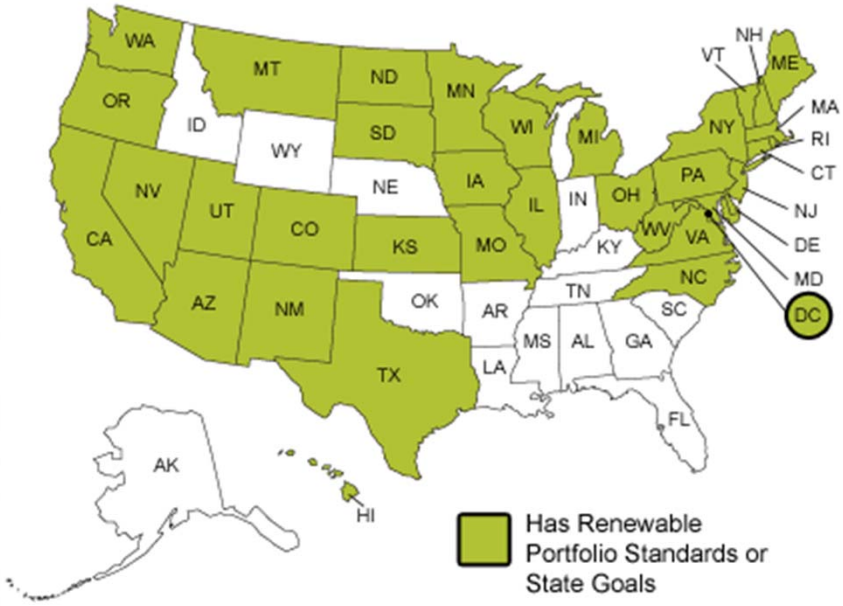
Most States have Renewable Portfolio Standards

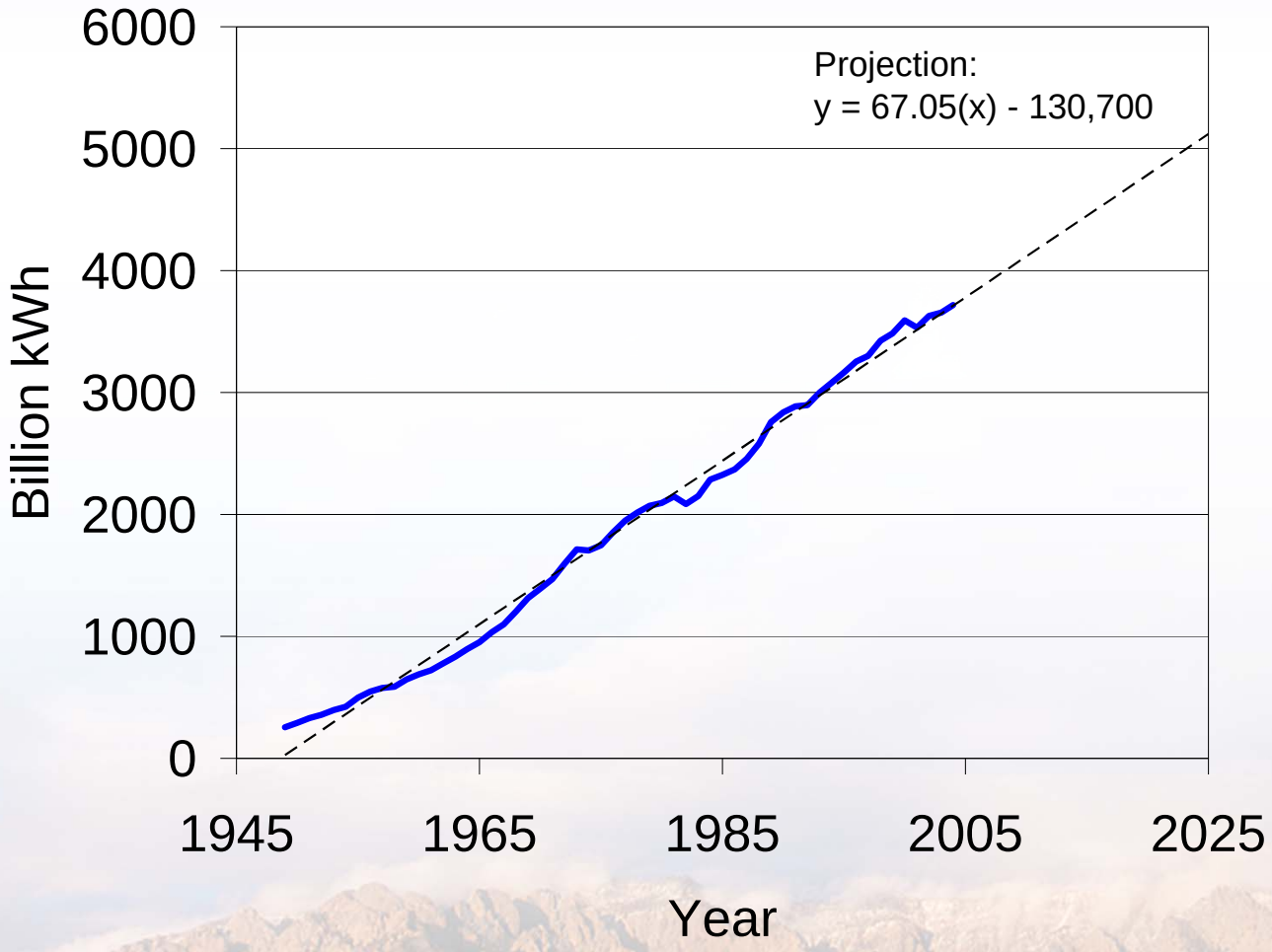
- 2007 EIA examined 15% Federal RPS
- Result was tripling of electricity generated from biomass as well as large increases in wind and solar
- Price for electricity increased by 0.9%
- Natural gas prices fell as a result of decreased demand
- RPS can have significant and sometimes unintentional effects on other economic sectors

Most States Have Renewable Portfolio Standards, Mandates, or Goals, 2010



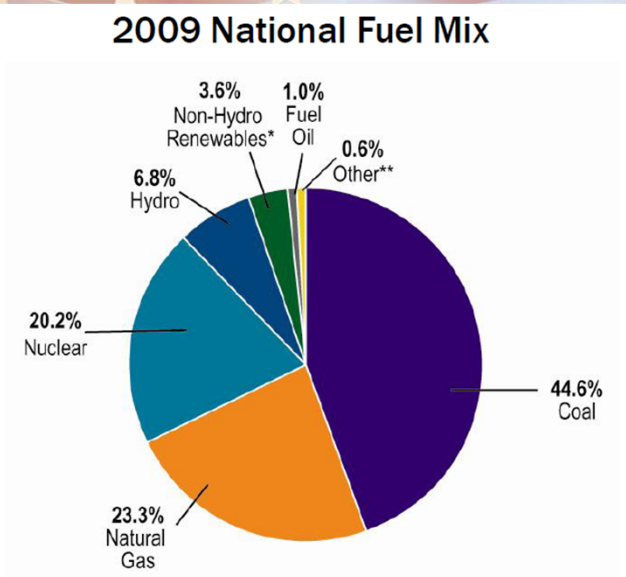
Source: Database of State Incentives for Renewables & Efficiency (accessed January 2010).

Forecasting: The U.S. electrical energy demand only increases

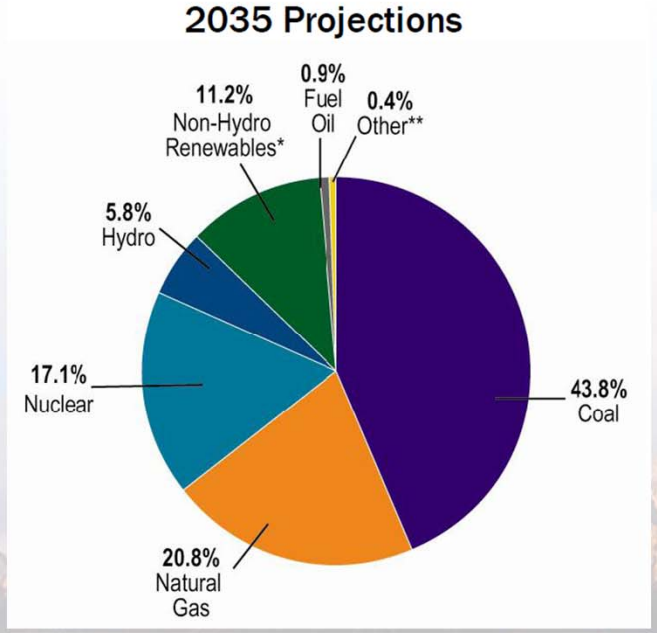


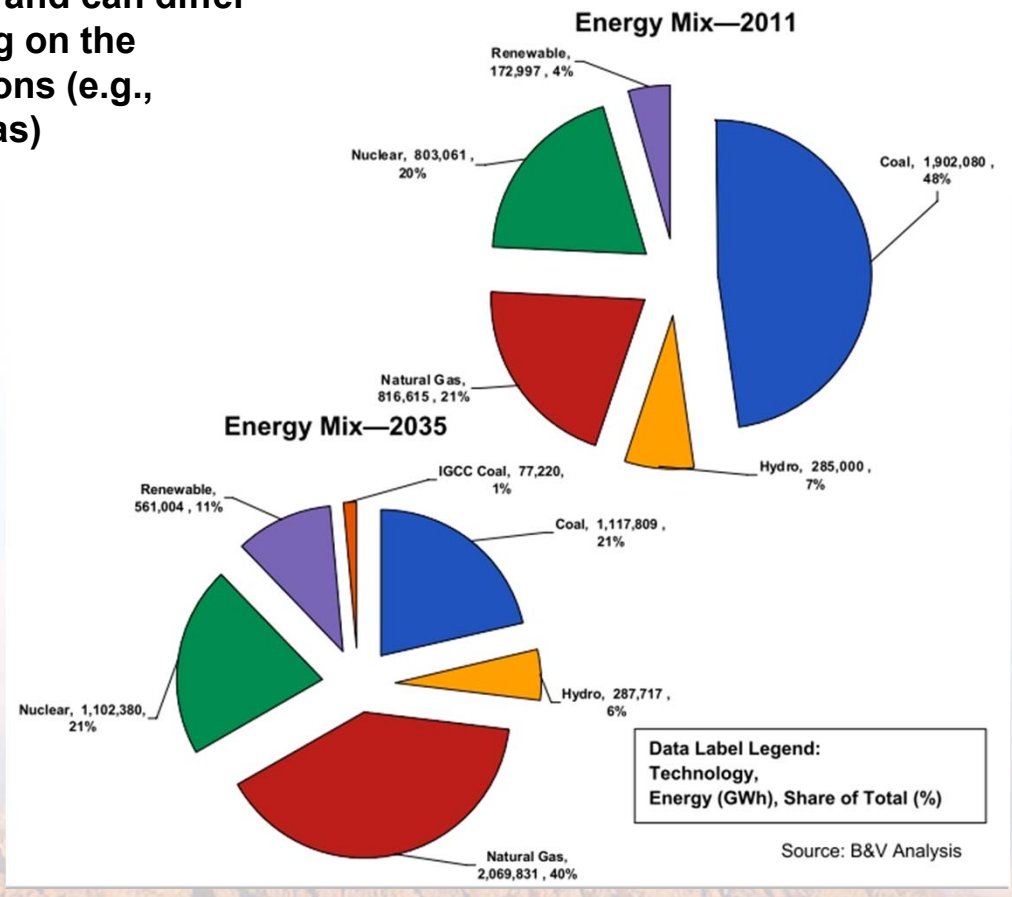
Source: DOE/EIA-0384(2004)

Electrical Energy Forecasts (IEA and B&V)

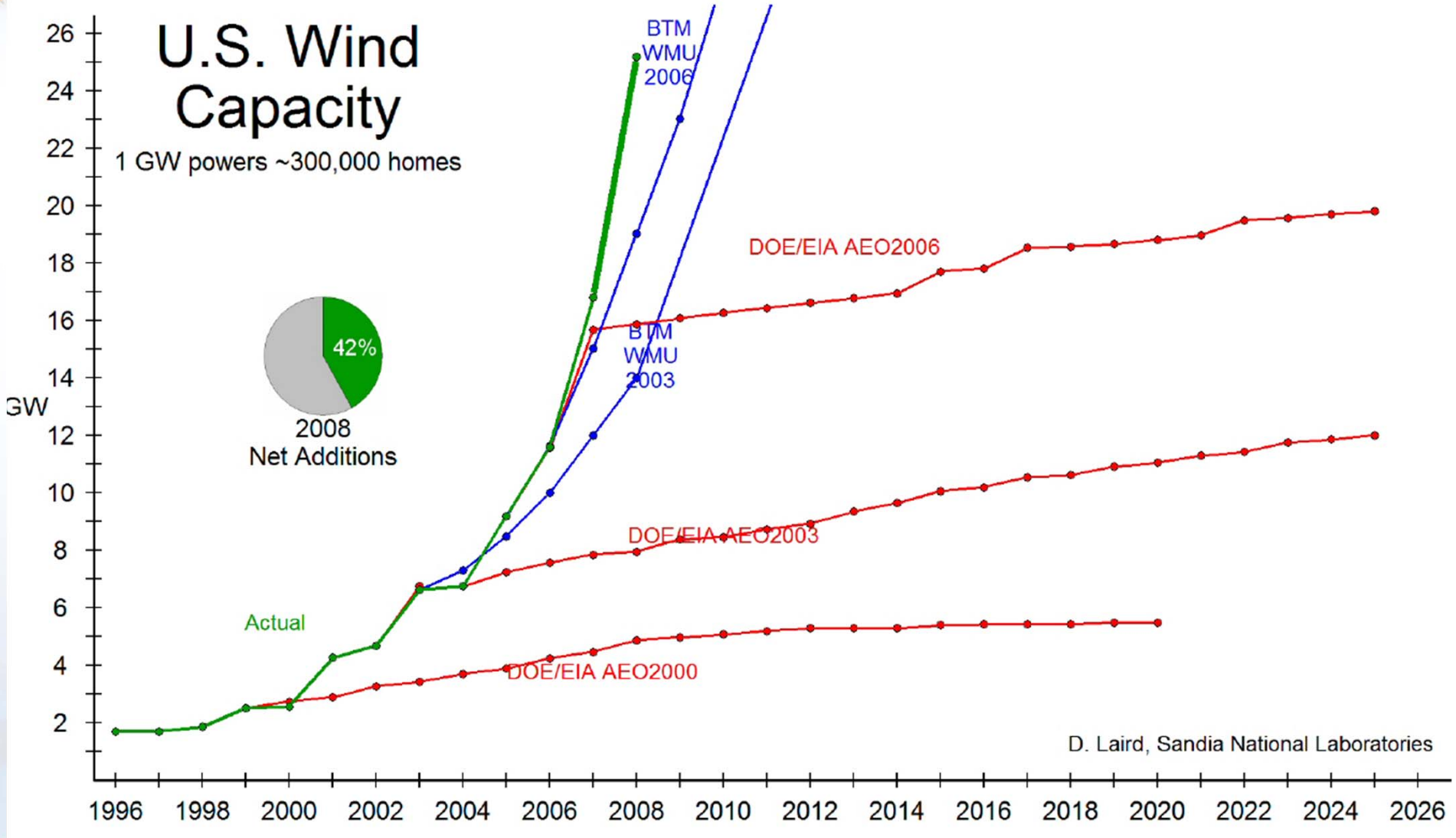


Forecasts are quite uncertain and can differ depending on the assumptions (e.g., Natural gas)





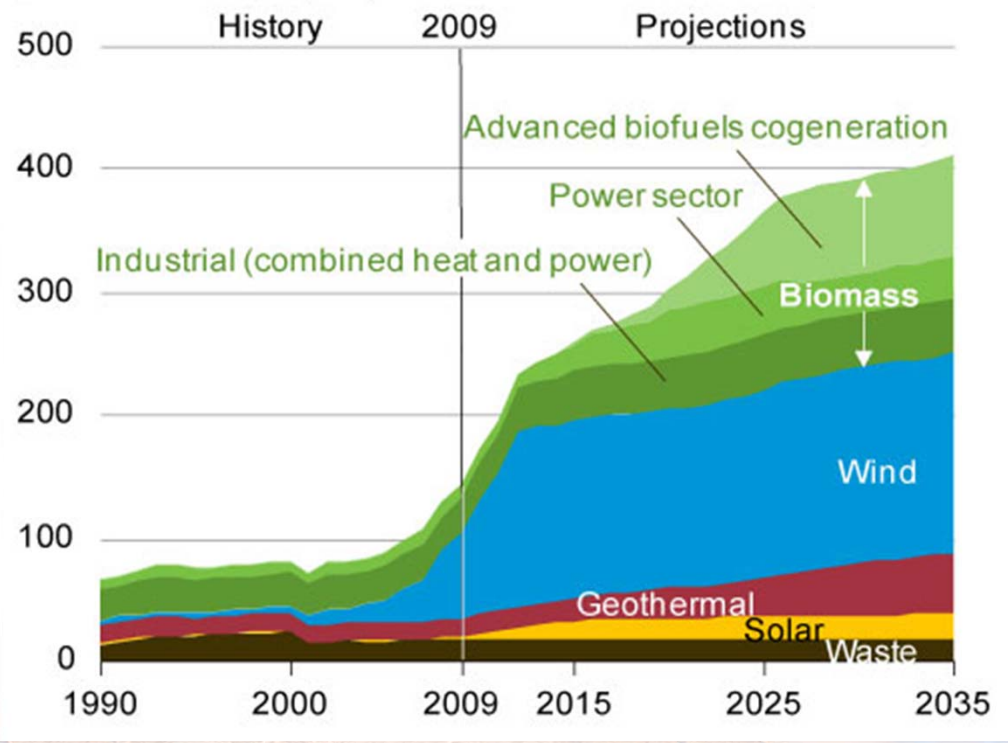
Growth Forecasts for Wind



Projected Growth in Renewable Energy to 2035

- **EIA predicts that biomass and wind will increase the most**
- **These projections assume modest price reductions for solar**
- **DOE SunShot Initiative aims to reduce installed cost of solar to below $1/W (5-6 cents per kWh LCOE)**
  - This would be a major game changer of successful

Figure 3. U.S. nonhydropower renewable electricity generation, 1990-2035
(billion kilowatts per year)



Why is Renewable Energy Such a Minor Component of the Total Mix Going Forward?

- **First, natural gas is cheap (now)**
- **Answer depends on technology**
  - **Wind**: public opposition, transmission, and variability
  - **Solar**: price and variability
  - **Hydro**: environmental

Table 1. Estimated Levelized Cost of New Generation Resources, 2016.

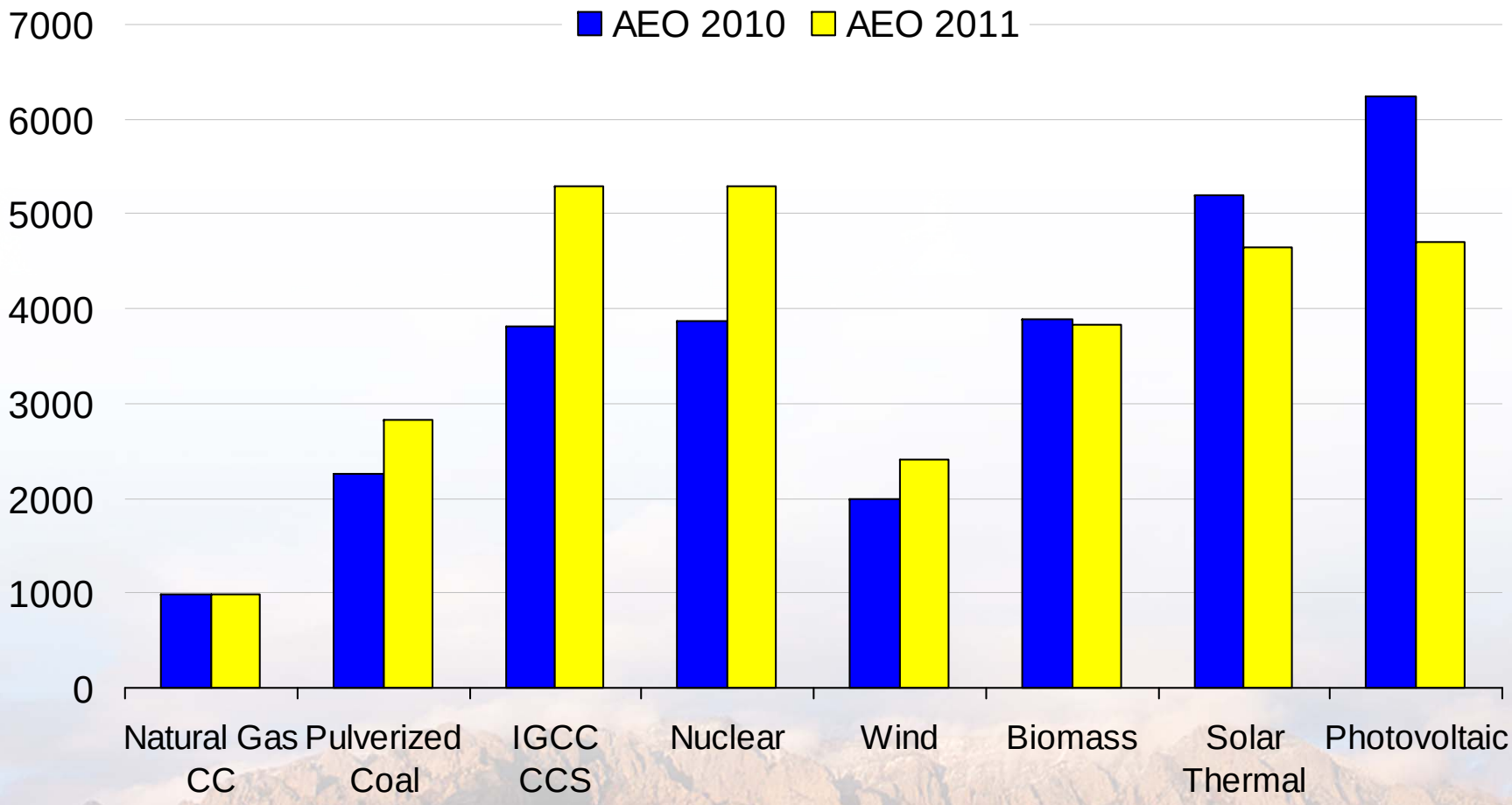
Plant Type	Capacity Factor (%)	U.S. Average Levelized Costs (2009 $/megawatthour) for Plants Entering Service in 2016				
		Levelized Capital Cost	Fixed O&M	Variable O&M (including fuel)	Transmission Investment	Total System Levelized Cost
Conventional Coal	85	65.3	3.9	24.3	1.2	94.8
Advanced Coal	85	74.6	7.9	25.7	1.2	109.4
Advanced Coal with CCS	85	92.7	9.2	33.1	1.2	136.2
Natural Gas-fired						
Conventional Combined Cycle	87	17.5	1.9	45.6	1.2	66.1
Advanced Combined Cycle	87	17.9	1.9	42.1	1.2	63.1
Advanced CC with CCS	87	34.6	3.9	49.6	1.2	89.3
Conventional Combustion Turbine	30	45.8	3.7	71.5	3.5	124.5
Advanced Combustion Turbine	30	31.6	5.5	62.9	3.5	103.5
Advanced Nuclear	90	90.1	11.1	11.7	1.0	113.9
Wind	34	83.9	9.6	0.0	3.5	97.0
Wind – Offshore	34	209.3	28.1	0.0	5.9	243.2
Solar PV[1]	25	194.6	12.1	0.0	4.0	210.7
Solar Thermal	18	259.4	46.6	0.0	5.8	311.8
Geothermal	92	79.3	11.9	9.5	1.0	101.7
Biomass	83	55.3	13.7	42.3	1.3	112.5
Hydro	52	74.5	3.8	6.3	1.9	86.4

[1] Costs are expressed in terms of net AC power available to the grid for the installed capacity.

Source: Energy Information Administration, Annual Energy Outlook 2011, December 2010, DOE/EIA-0383(2010)

Recent Price Trends for Generation Sources

overnight capital cost
2009 dollars per kilowatt



Source: EIA, *Annual Energy Outlook 2011*

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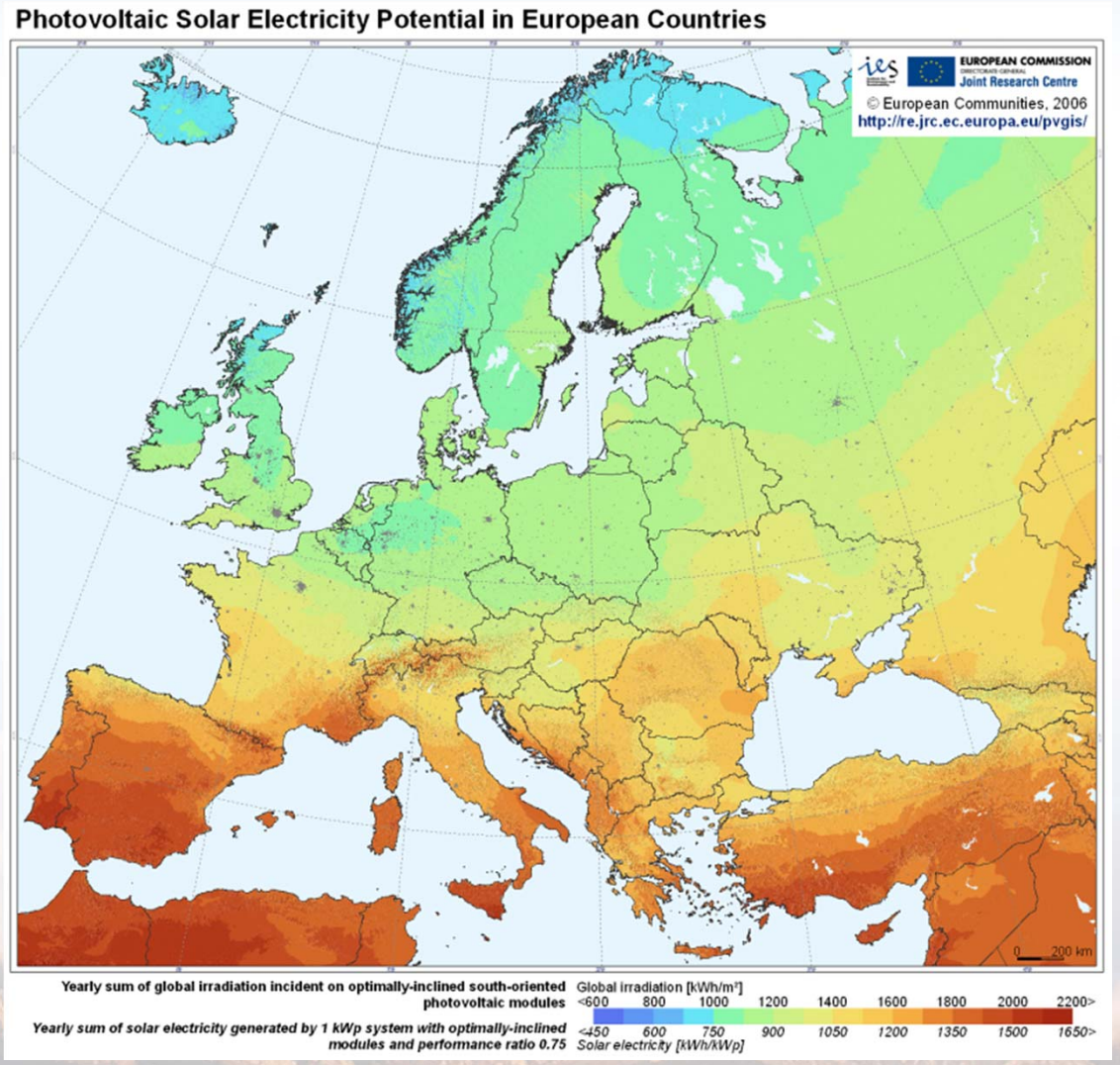
European Solar Experience

- Northern Europe is at a very high latitude
- Significant portion of Europe has solar resource lower than anywhere in the U.S.
- Vermont has a better solar resource than Germany!
- Germany is the world leader in solar power



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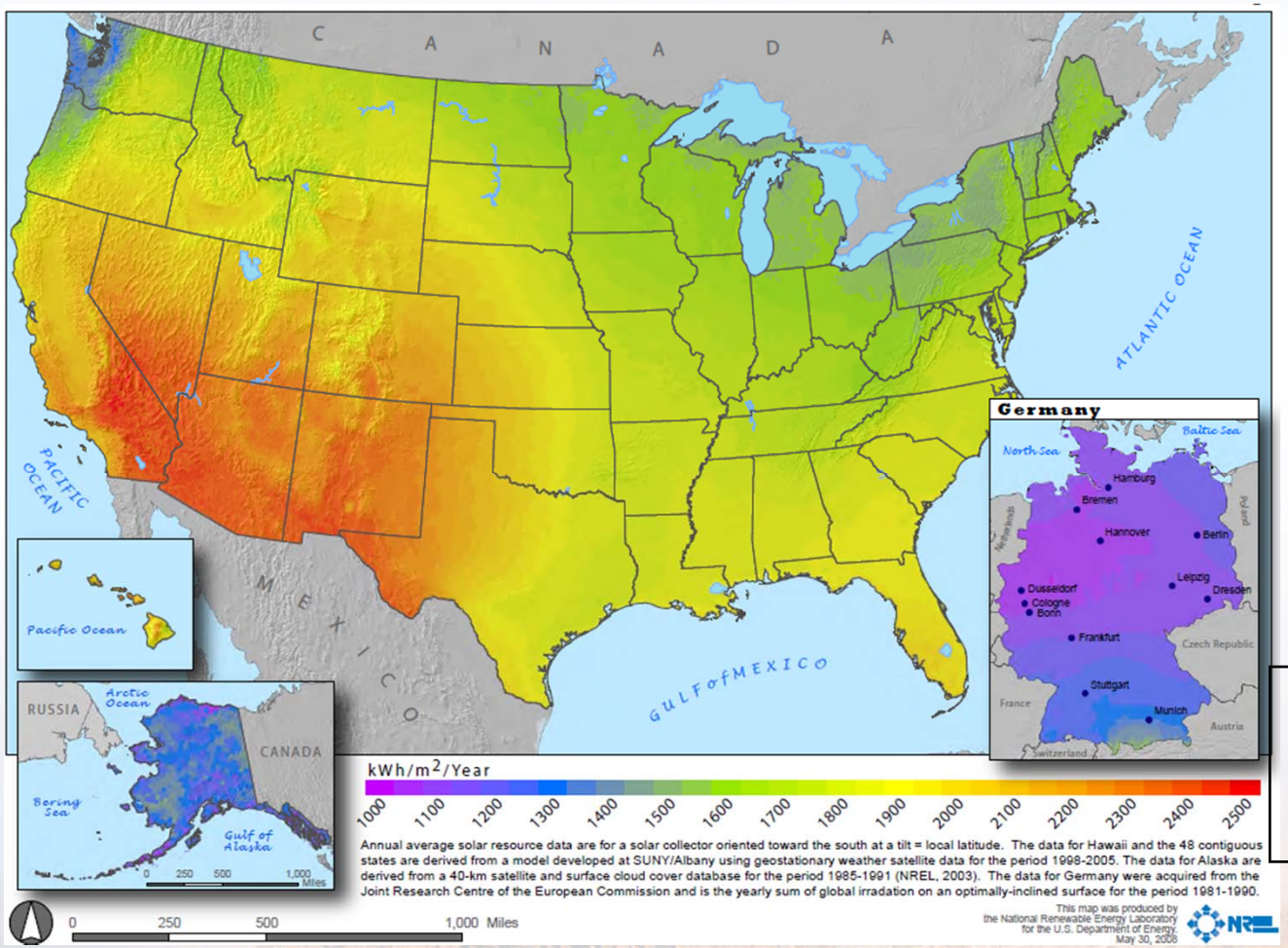
U.S. Has Great Opportunities for Increased Solar Energy Applications



All of the electricity in the U.S. could be provided using:

- **Less than 2% of the land dedicated to cropland and grazing.**
- **Less than the current amount of land used for corn ethanol production.**

2009 PV Installs

Germany: 3.87GW

US: 485MW

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Germany Facts

- **Target: Renewable electricity 35% by 2020 and 80% by 2050**
- **Renewable energy has increased from 6.3% in 2000 to 17% in 2010**
- **Solar: as of 2010, Germany has 17 GW solar installed**
  - 7.4 GW (250,000 systems) installed in 2010 (U.S. installed 956 MW)
  - Market analysts predict this could reach 25% by 2050.
  - Growth driven by feed-in-tarif
    - July 2011: subsidies being cut
      - **Rooftop solar cut by 16%, Ground mount solar cut by 15%, Brown field PV cut by 11%, Large PV on arable land cut by 100% (eliminated)**
- **Wind: as of 2010, Germany has 27.2 GW wind capacity**
- **Electricity price = $0.31 /kWh (compared with $0.11 /kWh for U.S.)**
- **2010: Total RE = 101.7 TWh (36.5 TWh wind, 33.5 TWh biomass, 19.7 TWh hydro, and 12 TWhr solar PV)**
- **2009 study concluded that electricity rates increased 3%, utility profits reduced by 8%, PV market going to Asia**

Summary

- **Energy flows are measured in very large quantities**
  - Hard to measure accurately (need lots of information)
  - DOE has entire agency devoted to keeping track of this information
- **Energy flows need to be considered when making policy decisions**
  - CO_2 Emissions and pollution reduction policies
  - Regional differences are very significant
- **Renewable Energy Incentives**
- **Renewable Energy Forecasts**
- **Renewable Energy Costs**
- **Why so much Renewable Energy in Europe?**

- **Next… What is the renewable energy situation in Vermont?**

Questions and Discussion

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