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ENERGY

Addressing America's Energy Challenges

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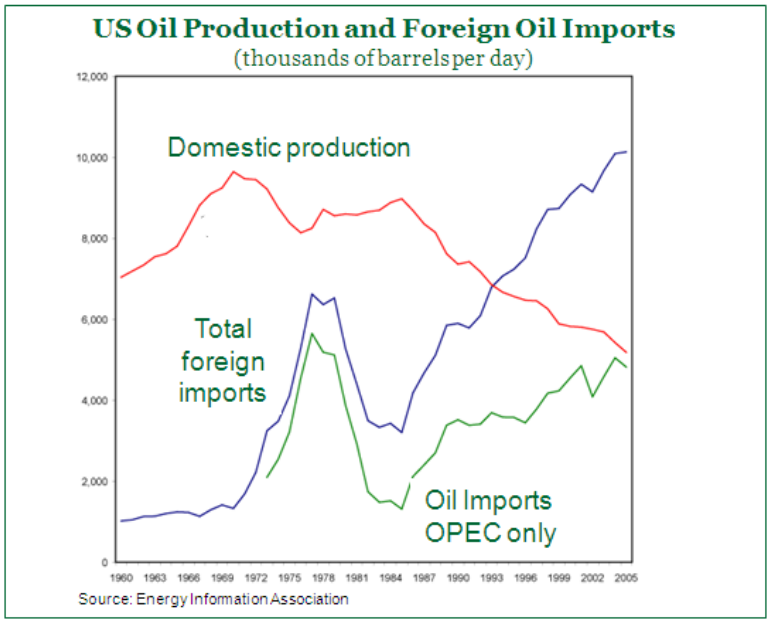
Excused Absence

America's energy challenges (I)

- Energy security
  - Mostly about reliable and economic supply of liquid hydrocarbons for transport
  - Urgency in geopolitics, ~$1B/day import costs
  - Goal: 3.5 M bbl/day reduction in crude use (~25% of daily transport use)



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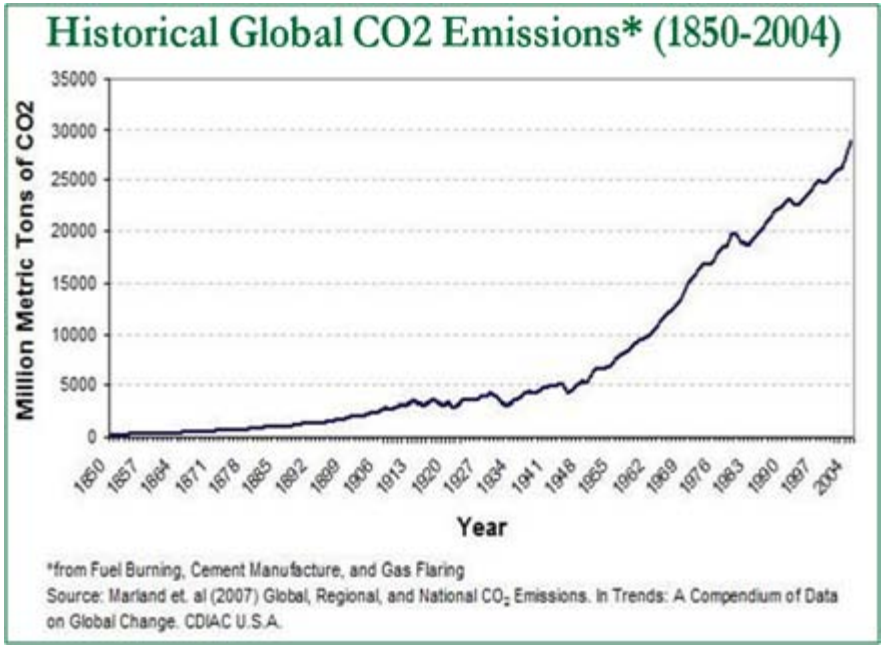
America's energy challenges (II)

- Greenhouse gas emissions
  - Mostly about CO_2 from power and heat
  - Urgency to avoid "lock in", demonstrate leadership, capture low-carbon markets
  - **Goal**: ~17% reduction by 2020, 83% by 2050



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America's energy challenges (III)

- These goals require significant changes in energy sources, transmission, storage, use

Identify, develop, demonstrate, and deploy cost-effective, material, and timely solutions
and
create jobs in the process

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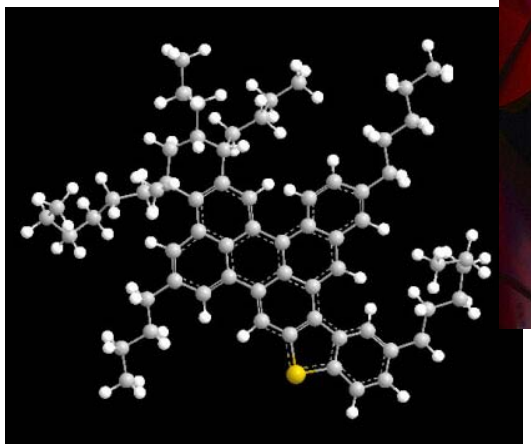
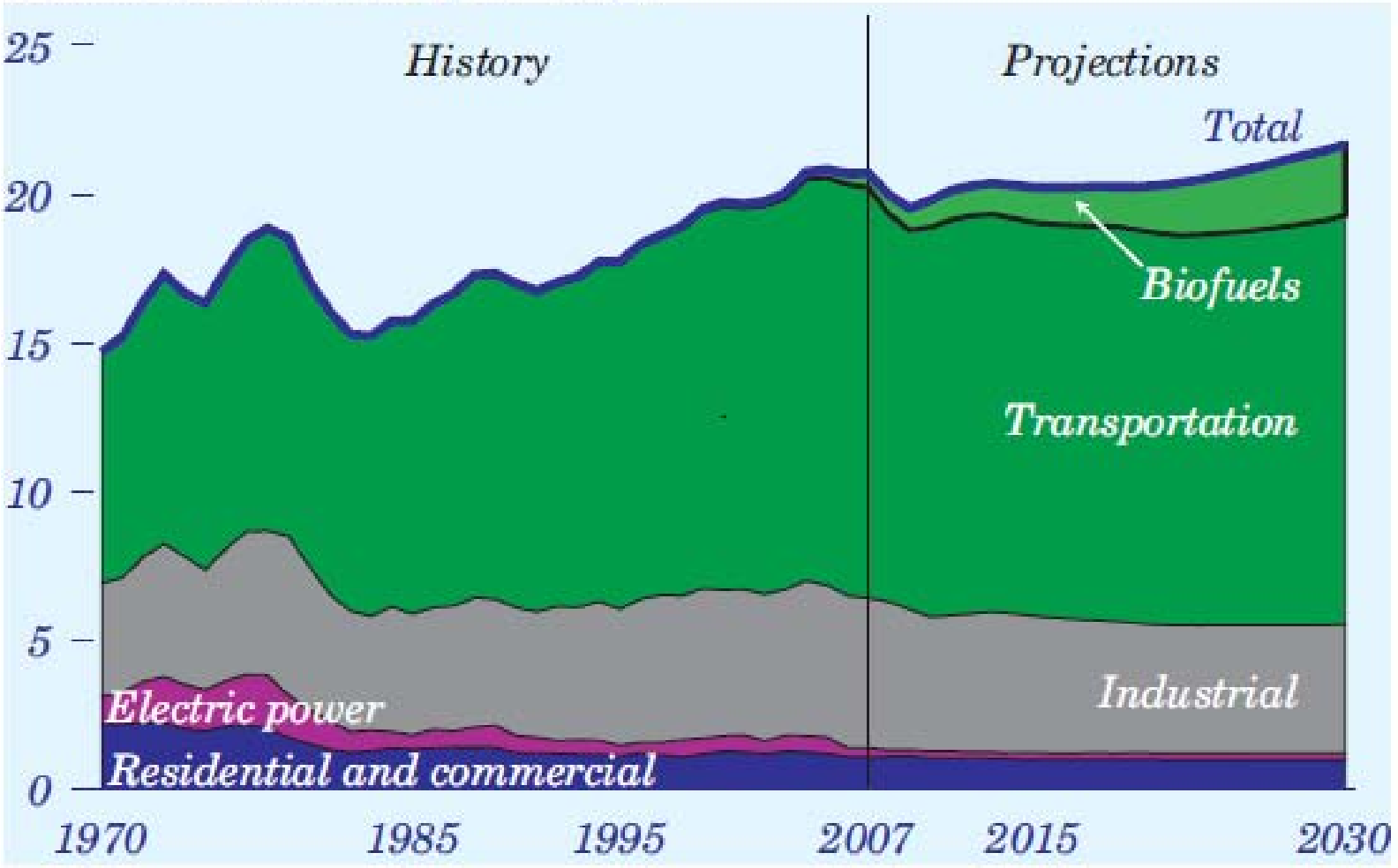
The energy security problem

- Transportation is powered almost exclusively by crude-derived liquid hydrocarbons
  - Energy density (50 times better than the best battery), ease and economy of use, existing infrastructure, availability



US liquid fuel use



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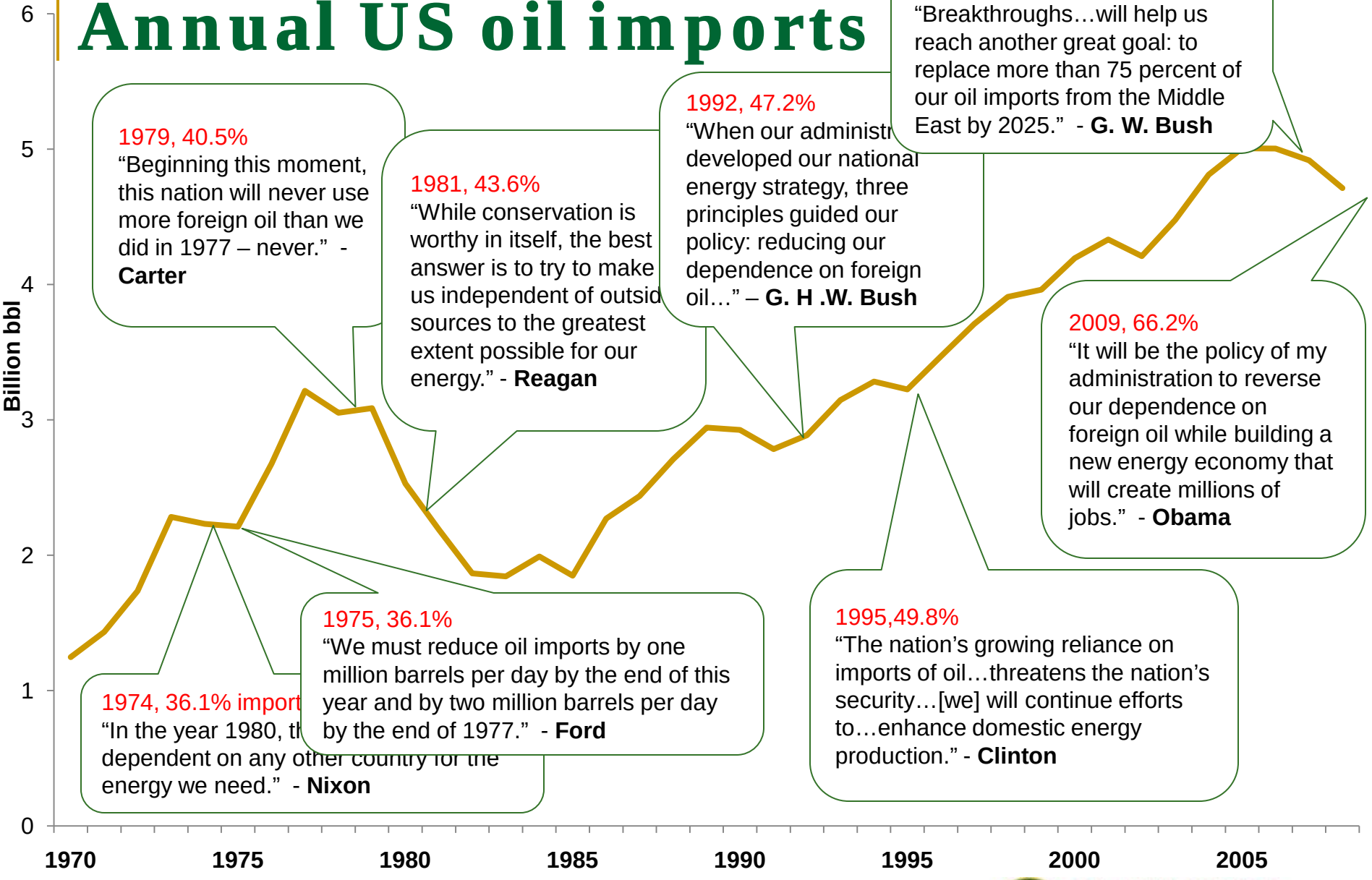
The energy security problem

- Transportation is powered almost exclusively by crude-derived liquid hydrocarbons
- The US imports a large fraction (~60%) of its crude supply

Annual US oil imports

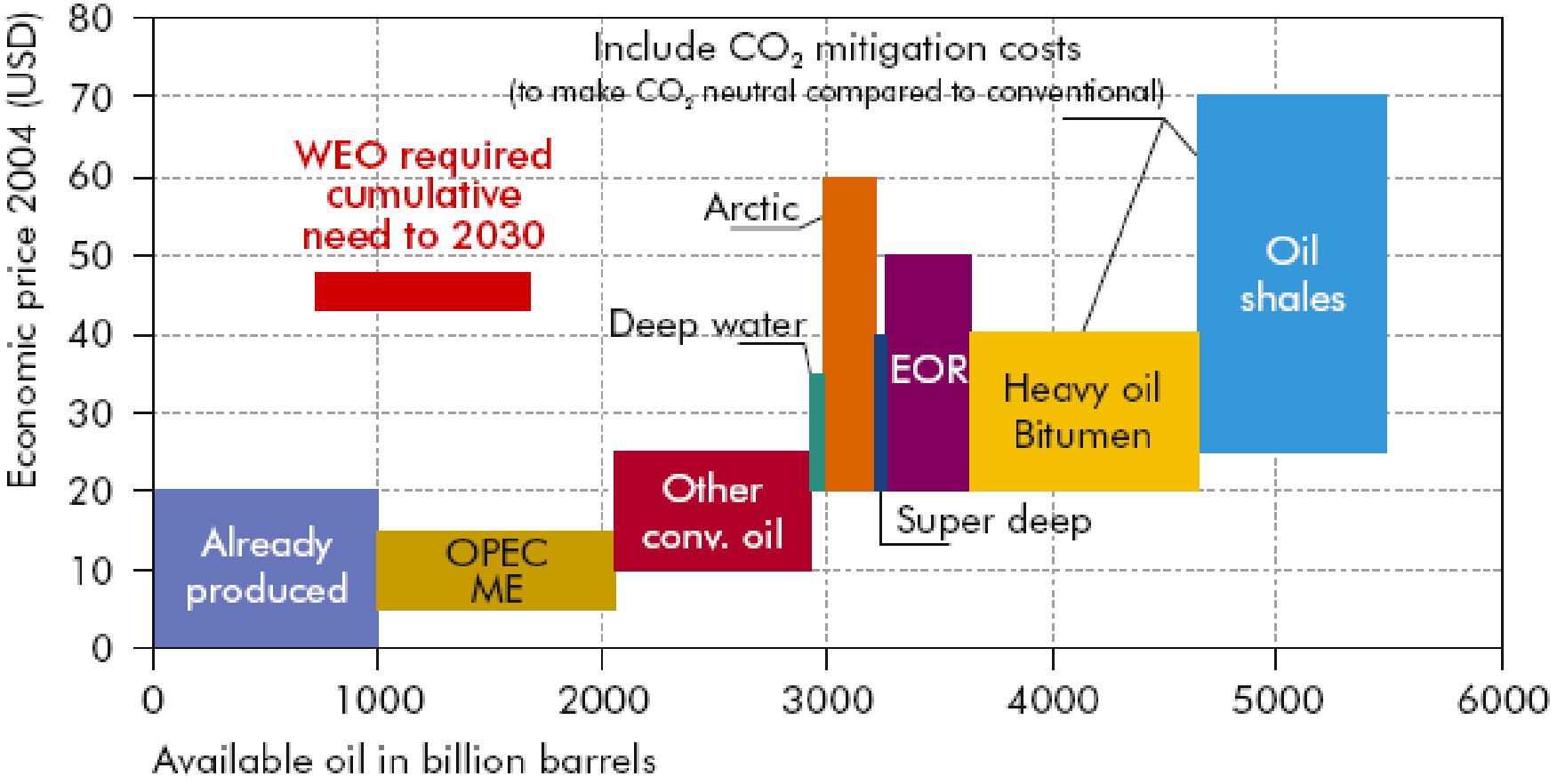


The energy security problem

- Transportation is powered almost exclusively by crude-derived liquid hydrocarbons
- The US imports a large fraction (~60%) of its crude supply
- Crude demand rising with global development
- “Easy” crude resources are increasingly concentrated geographically and politically

oil supply curve

Availability of oil as a function of economic price



Source: IEA (2005)

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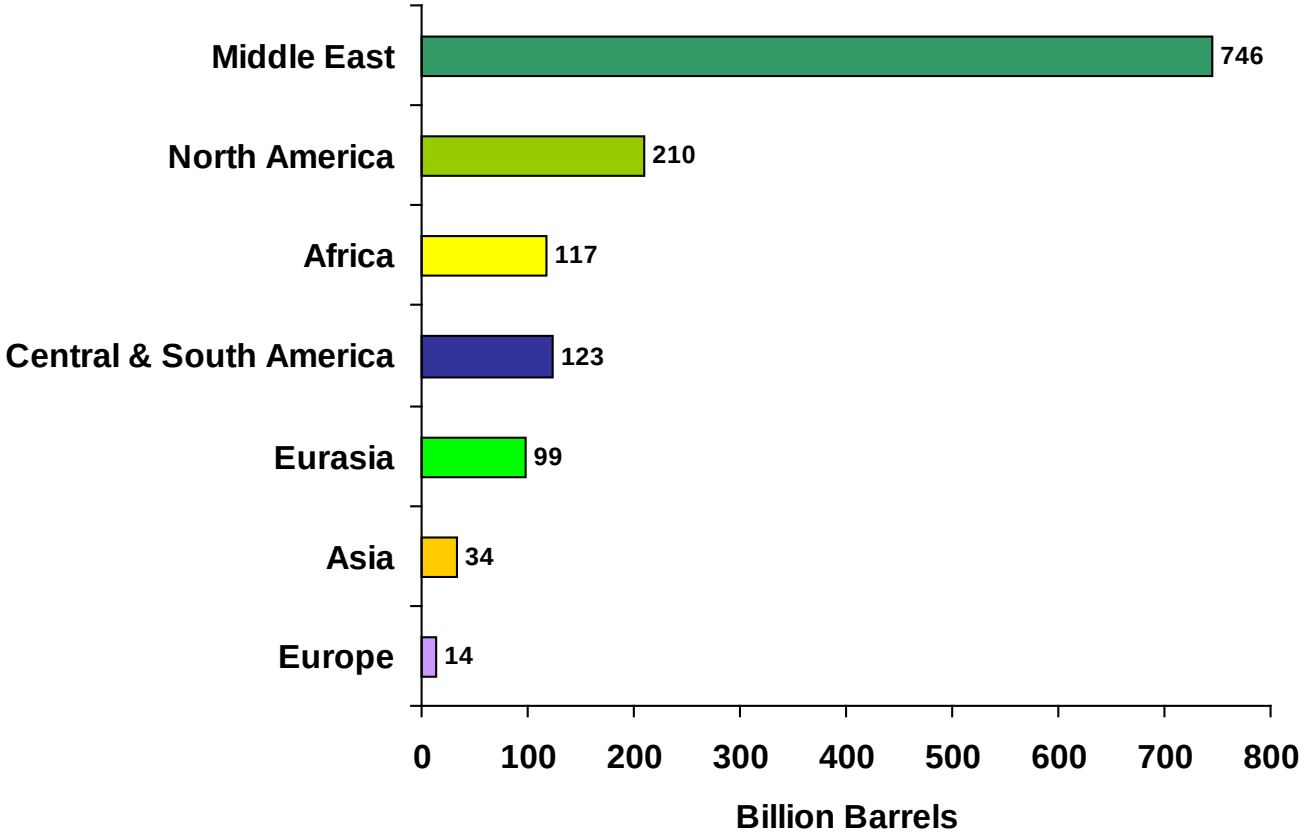
Distribution of crude reserves

Oil is a global market, OPEC is 40% of global supply, and reserves are geographically concentrated

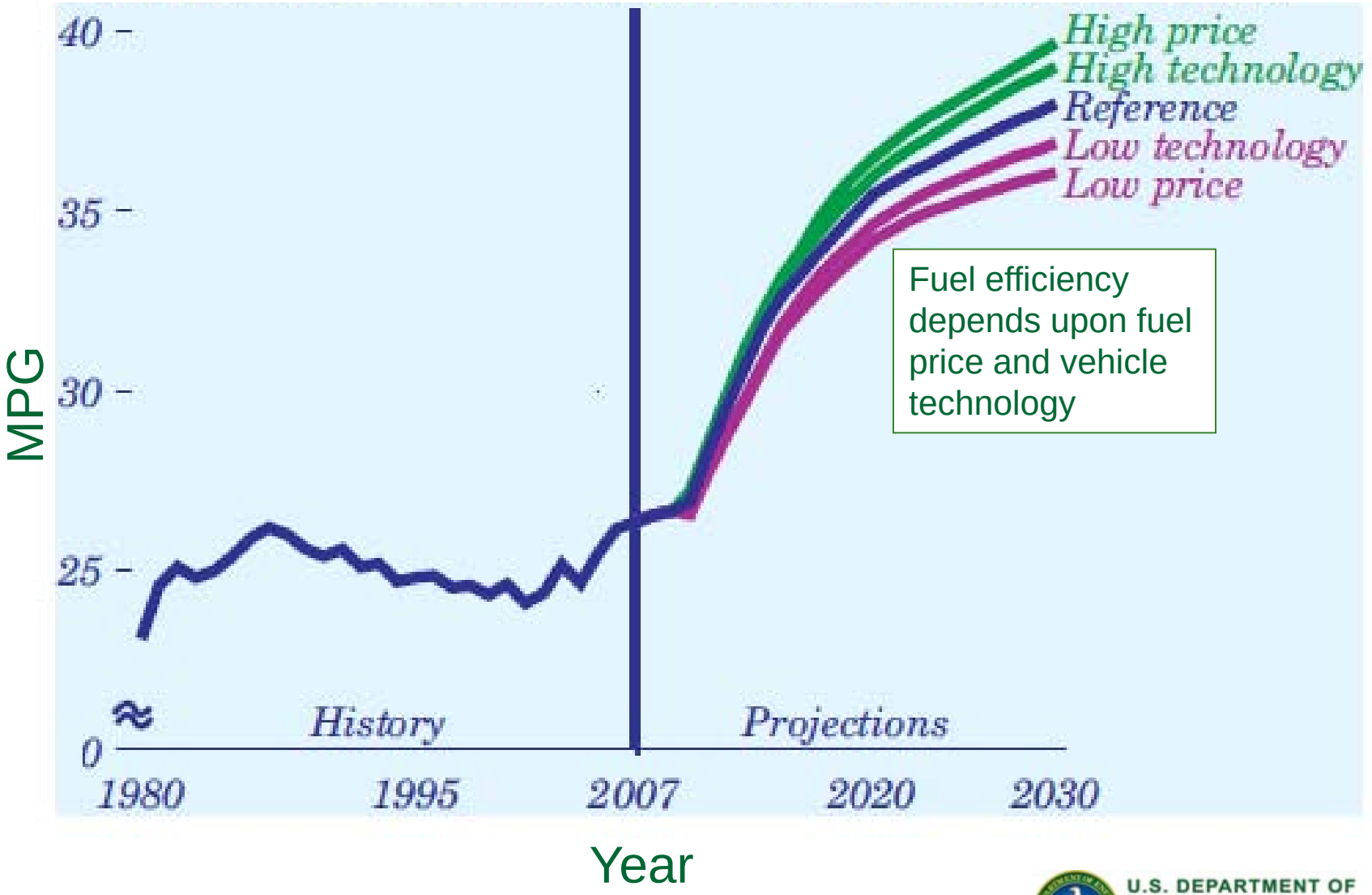


Source: Worldwide Look at Reserves and Production, Oil & Gas Journal, Vol. 105, No. 48 (December 22, 2008), pp. 20-23.

What can we do about transport?

- **Encourage vehicle efficiency and conservation**
  - CAFE standards
  - Vehicle downsizing, lightweighting, behavior
  - Make the cost of driving evident?
    (full amortization, fuel/road tax, insurance, …)

Average fuel economy of <u>new</u> light-duty vehicles



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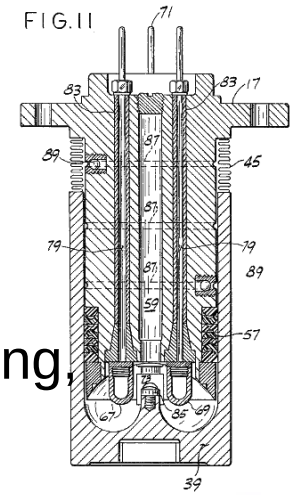
What can we do about transport?

- Encourage vehicle efficiency and conservation
- **Encourage novel/alternative vehicle technologies at cost**
  - Improved internal combustion engines
    - HCCI, Exhaust Gas Recycling, Variable Valve Timing, selective cylinder deactivation, …
  - Gradual electrification paced by battery development
    - Hybrids, plug-in hybrids, battery vehicles
  - DOE AVT and battery loan programs



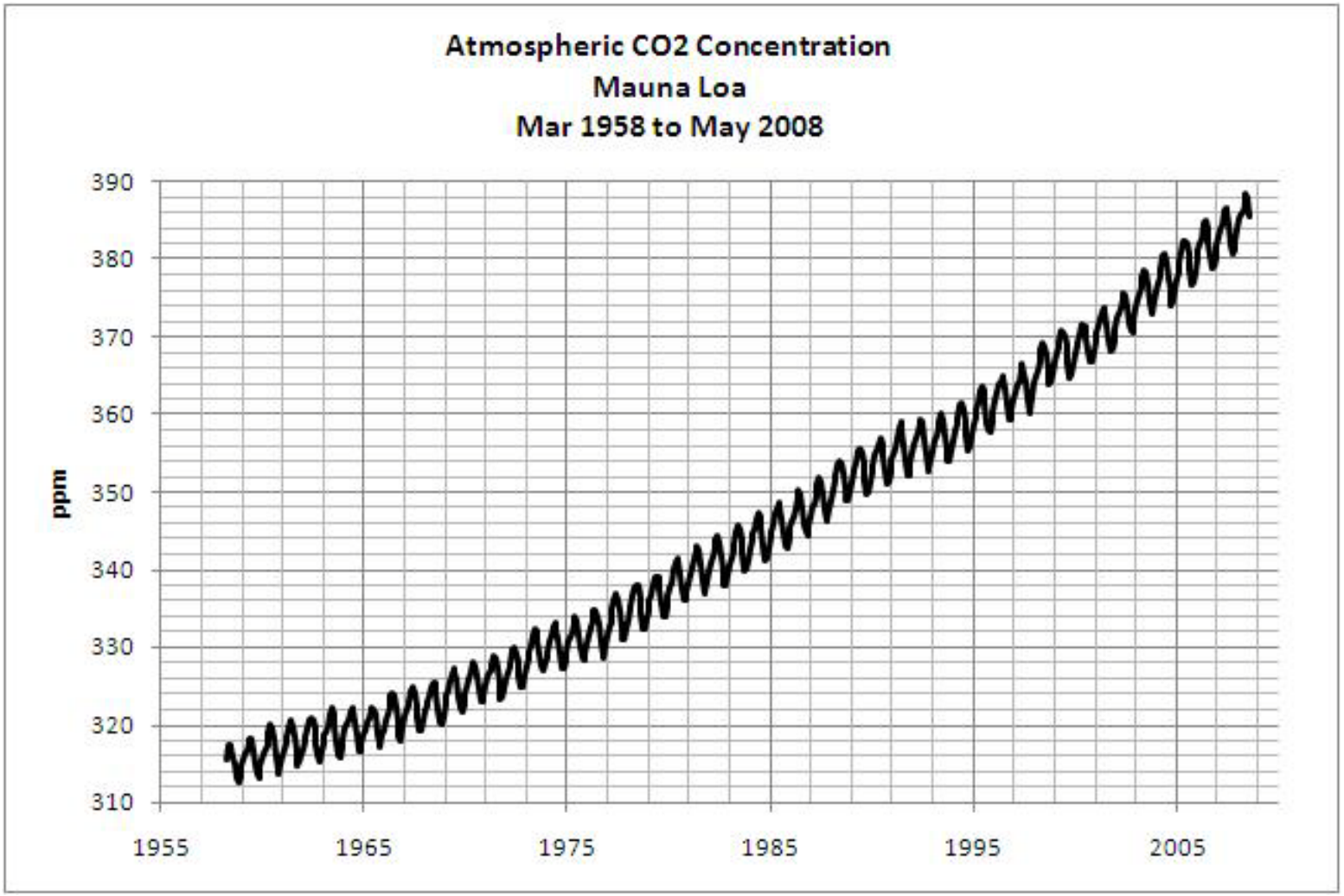
What can we do about transport?

- Encourage vehicle efficiency and conservation
- Encourage novel/alternative vehicle technologies at cost
- **Encourage (with consistency) a diverse portfolio of unconventional fuels**
  - Biofuels
    - Lignocellulose, feedstocks, better molecules, algae?
  - CTL with CCS/biomass
  - What is the government doing?
    - Renewable fuel standards
    - Bioenergy centers, integrated biorefineries

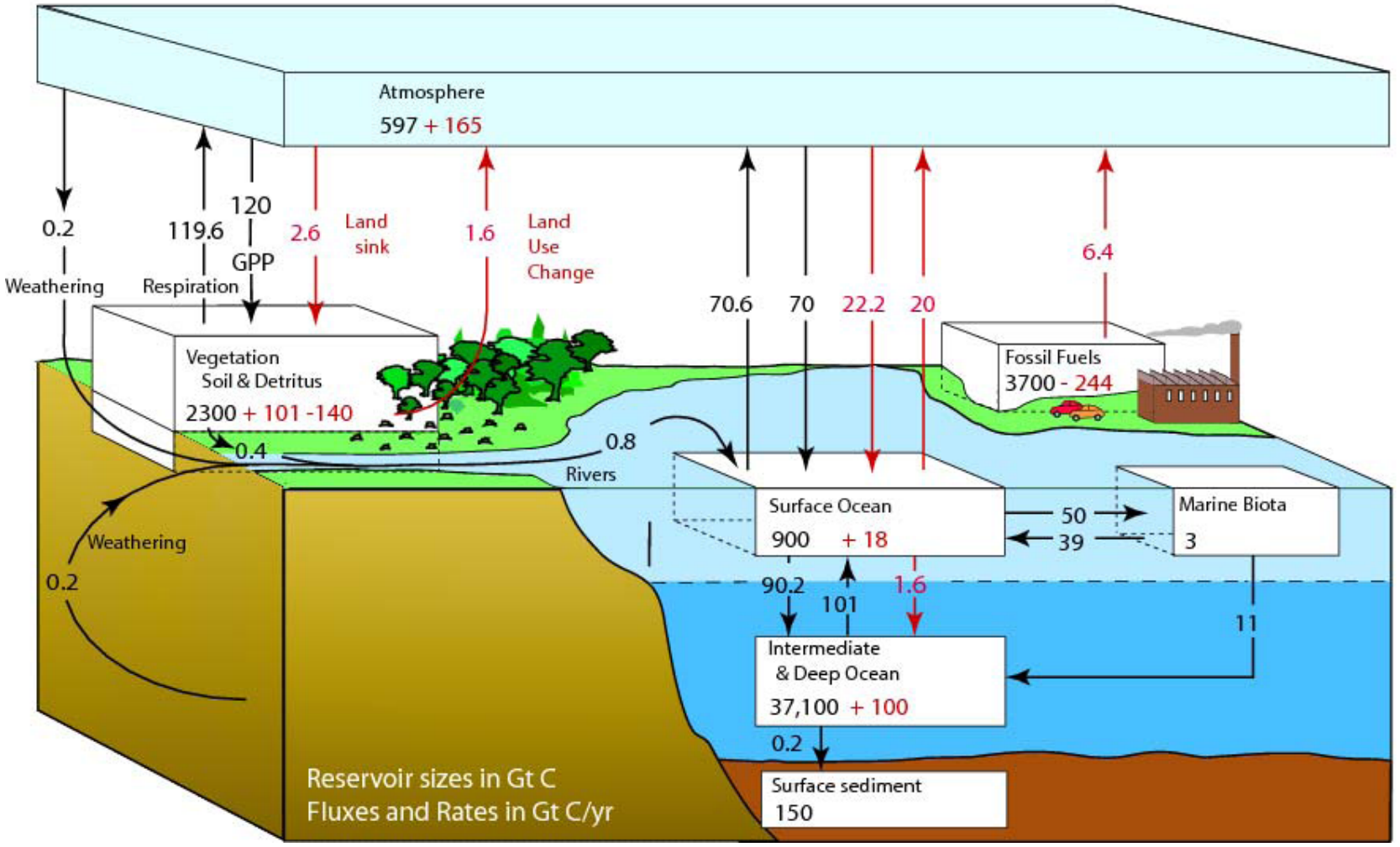
Challenges in stabilizing atmospheric CO_2

- The CO_2 concentration is rising at an accelerating rate; 550 ppm reached by 2050

Atmospheric CO_2 concentration



Anthropogenic perturbations to the carbon cycle are small, but secular



From IPCC AR4

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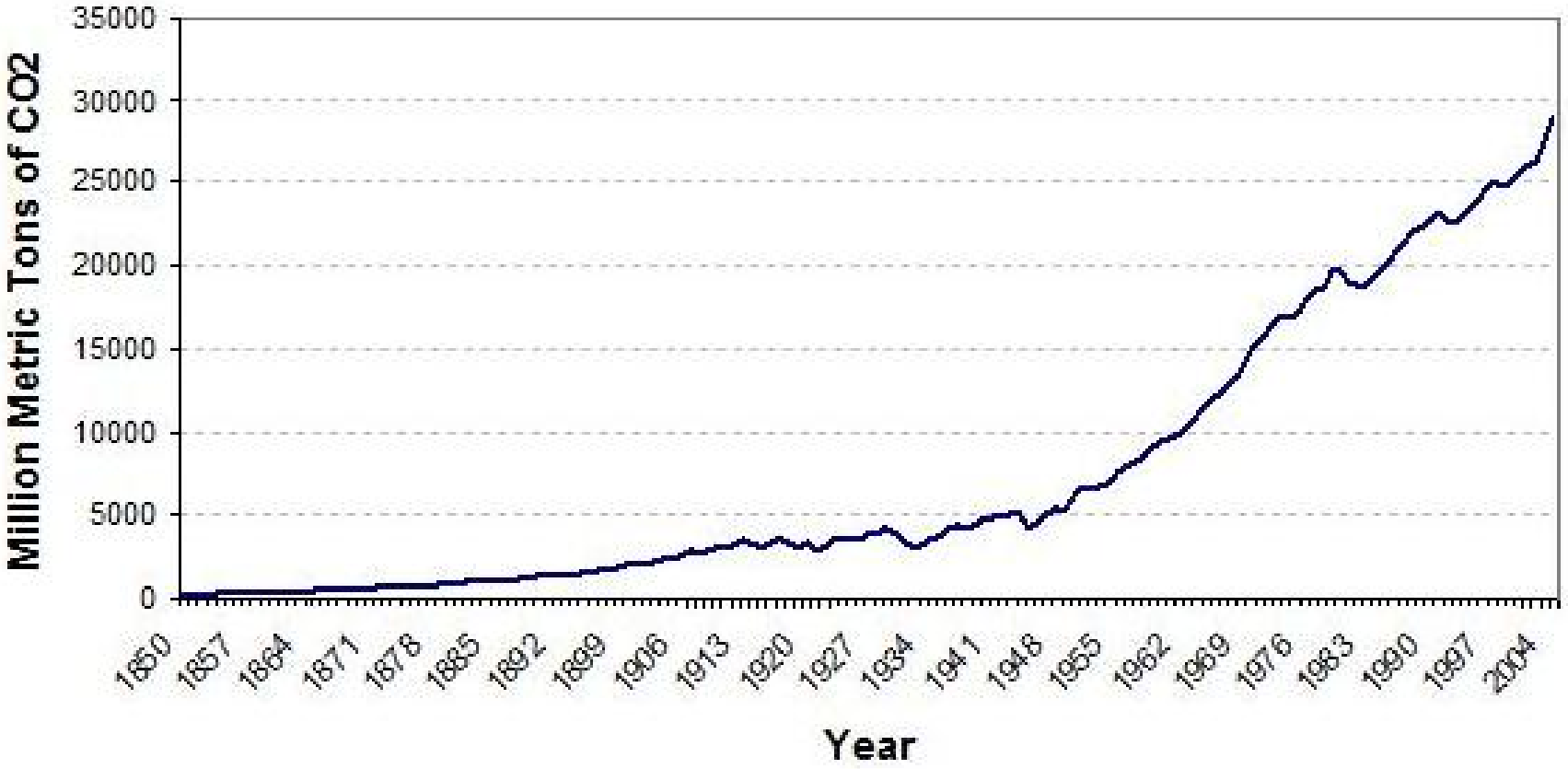
Challenges in stabilizing atmospheric CO_2

- The CO_2 concentration is rising at an accelerating rate; 550 ppm reached by 2050
- Global emissions are growing at ~2-3% per year

Growing Global CO_2 Emissions (1850-2004)



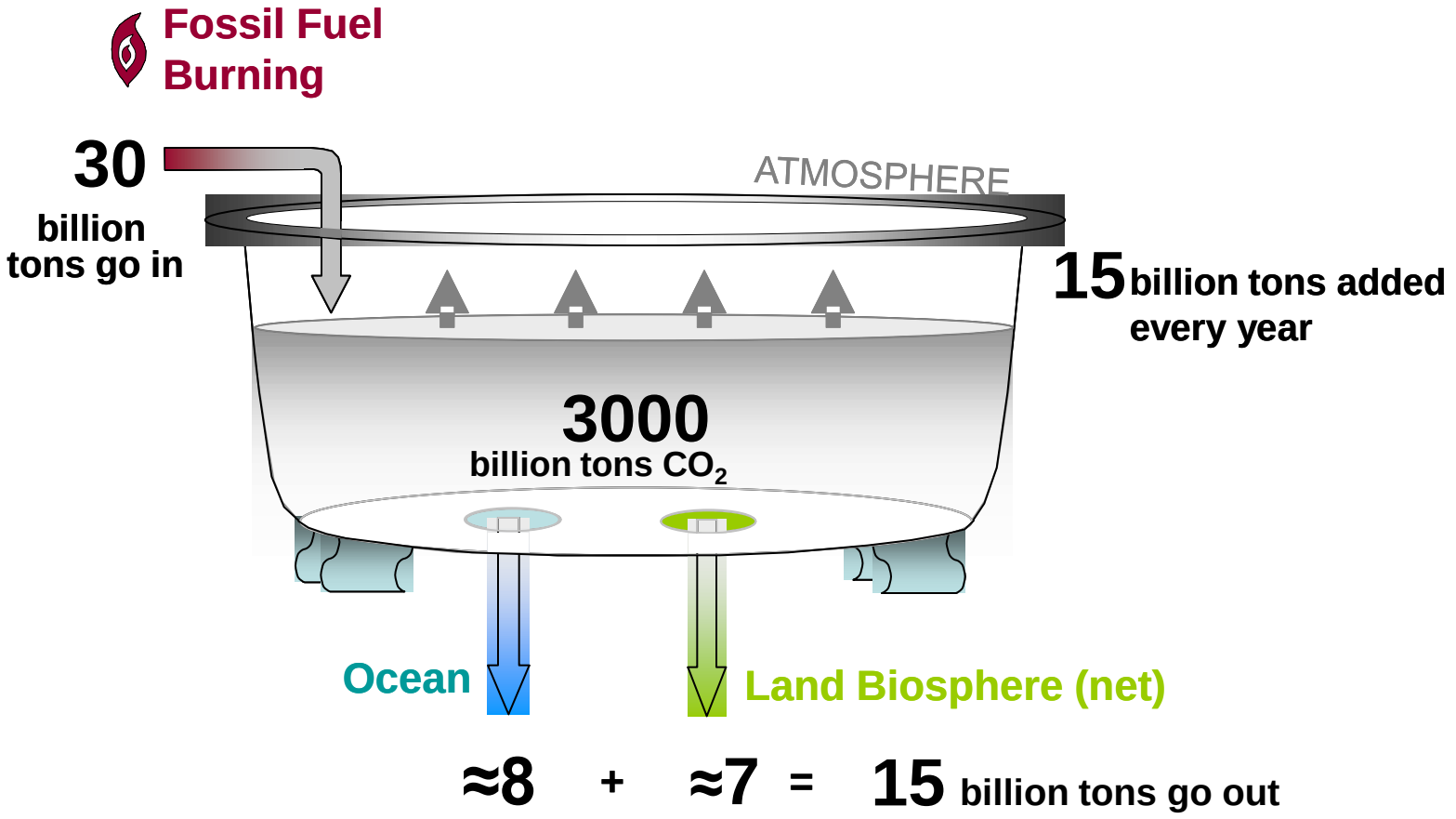
*from Fuel Burning, Cement Manufacture, and Gas Flaring

Source: Marland et. al (2007) Global, Regional, and National CO_2 Emissions. In Trends: A Compendium of Data on Global Change. CDIAC U.S.A.

Challenges in stabilizing atmospheric CO_2

- The CO_2 concentration is rising at an accelerating rate; 550 ppm reached by 2050
- Global emissions are growing at 2-3% per year
- The long CO_2 lifetime means that the atmosphere accumulates the emissions
  - Drastic reductions in emissions are required implying large and major changes in energy production / use

Half of the carbon we emit stays in the atmosphere for centuries



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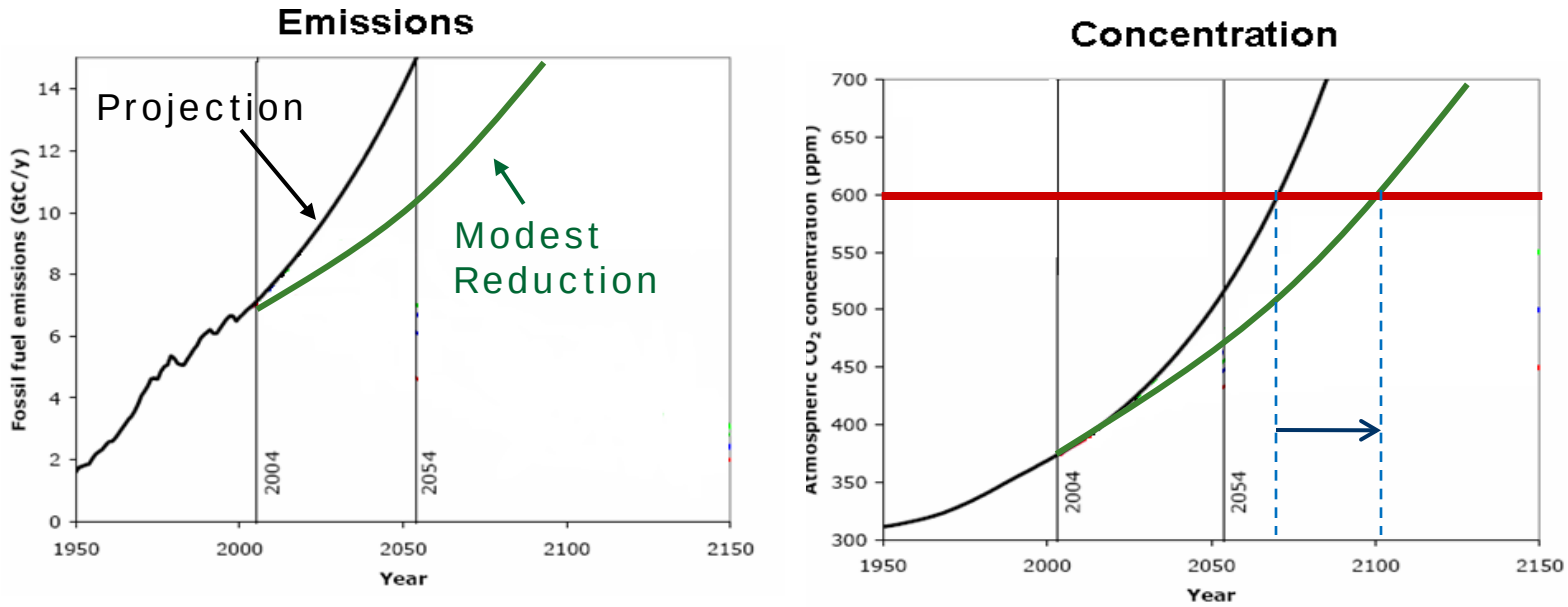
The long CO_2 lifetime is highly problematic



Modest emissions reductions will only delay, but not prevent, high concentrations

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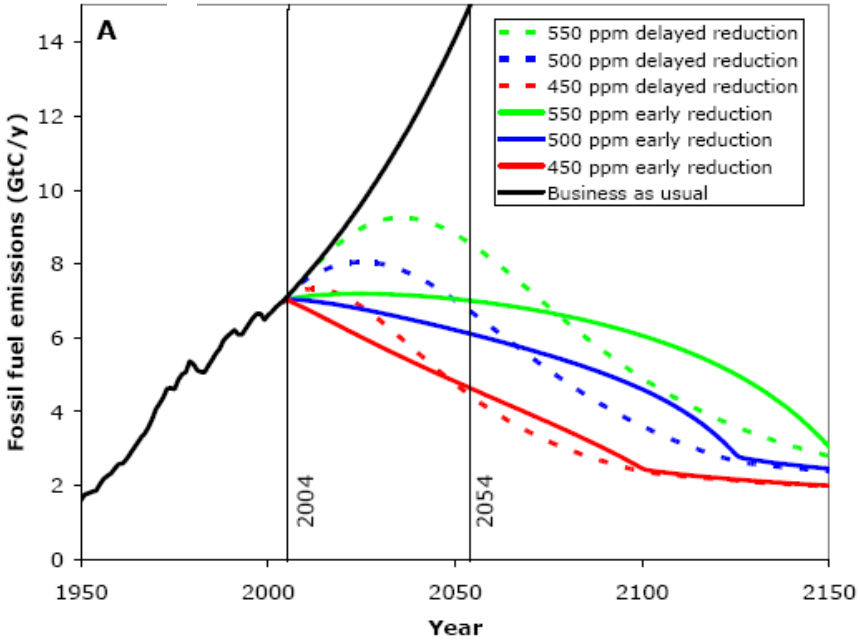
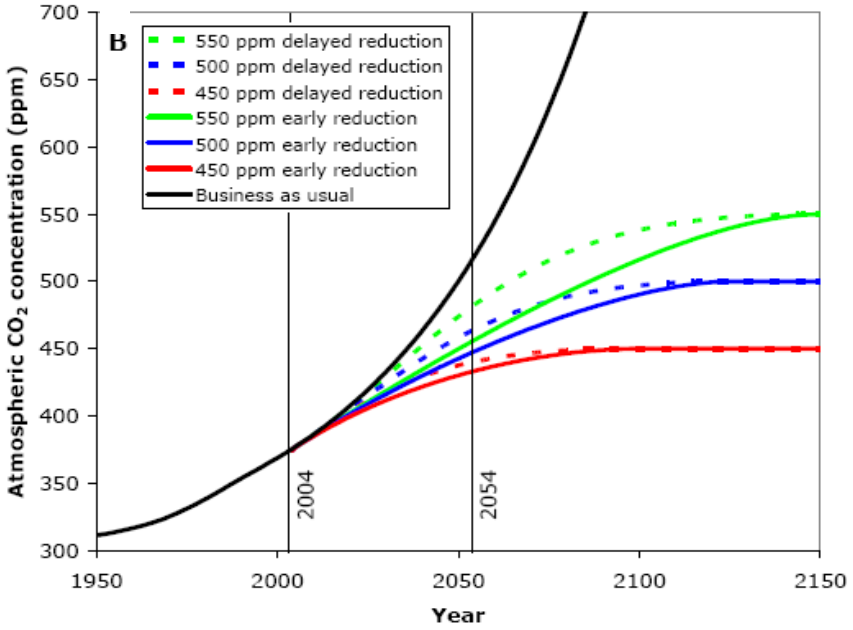
Drastic emissions reductions are required to stabilize concentrations

Emissions



Concentration



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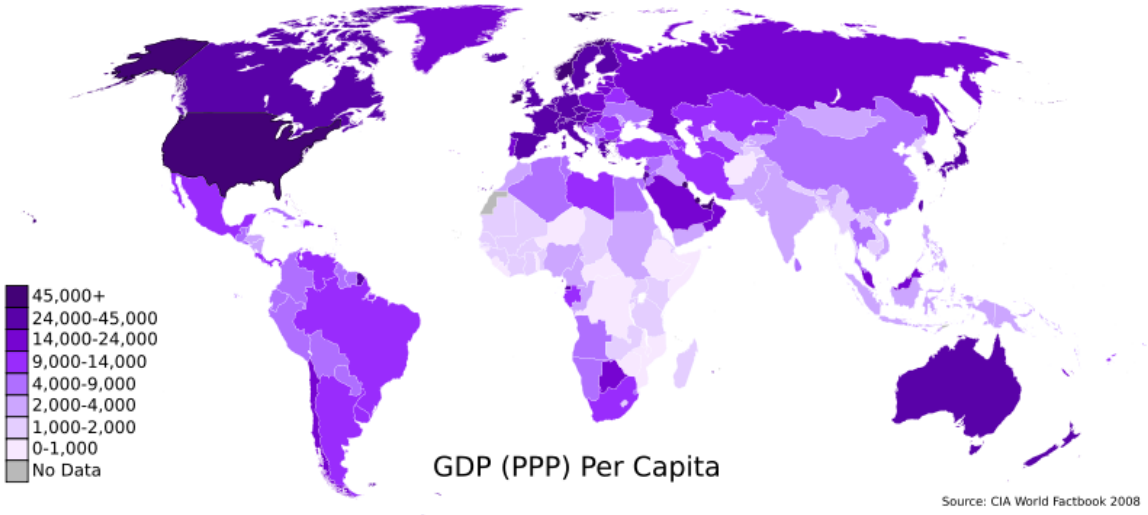
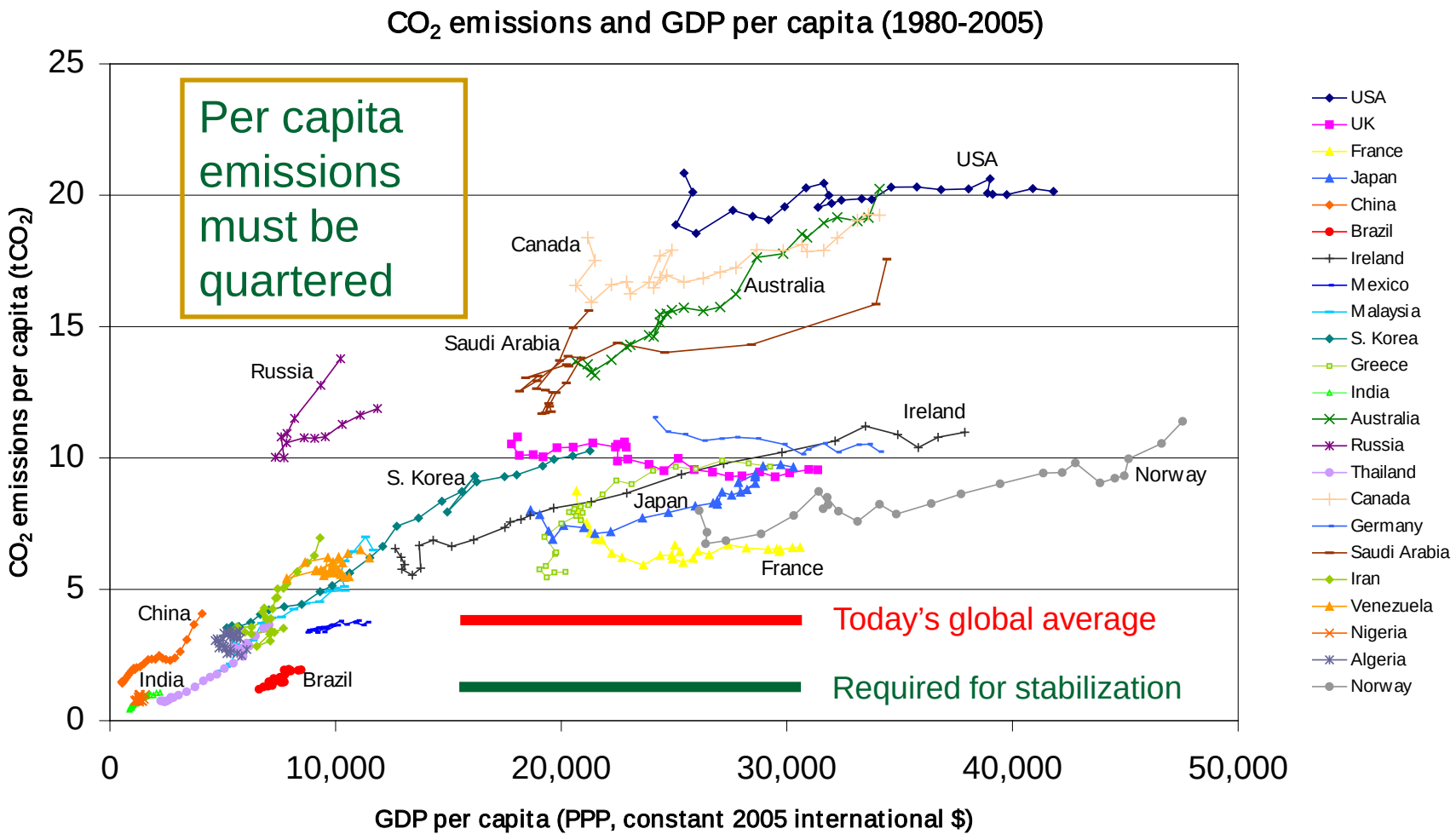
Non-scientific aspects of the problem

- Emissions have historically increased with economic activity (especially during development)
- Emissions are heterogeneous around the globe
  - Developed world emissions per capita are high but slowly growing
  - Developing world emissions per capita are much lower and are climbing rapidly



CO_2 emissions and GDP per capita

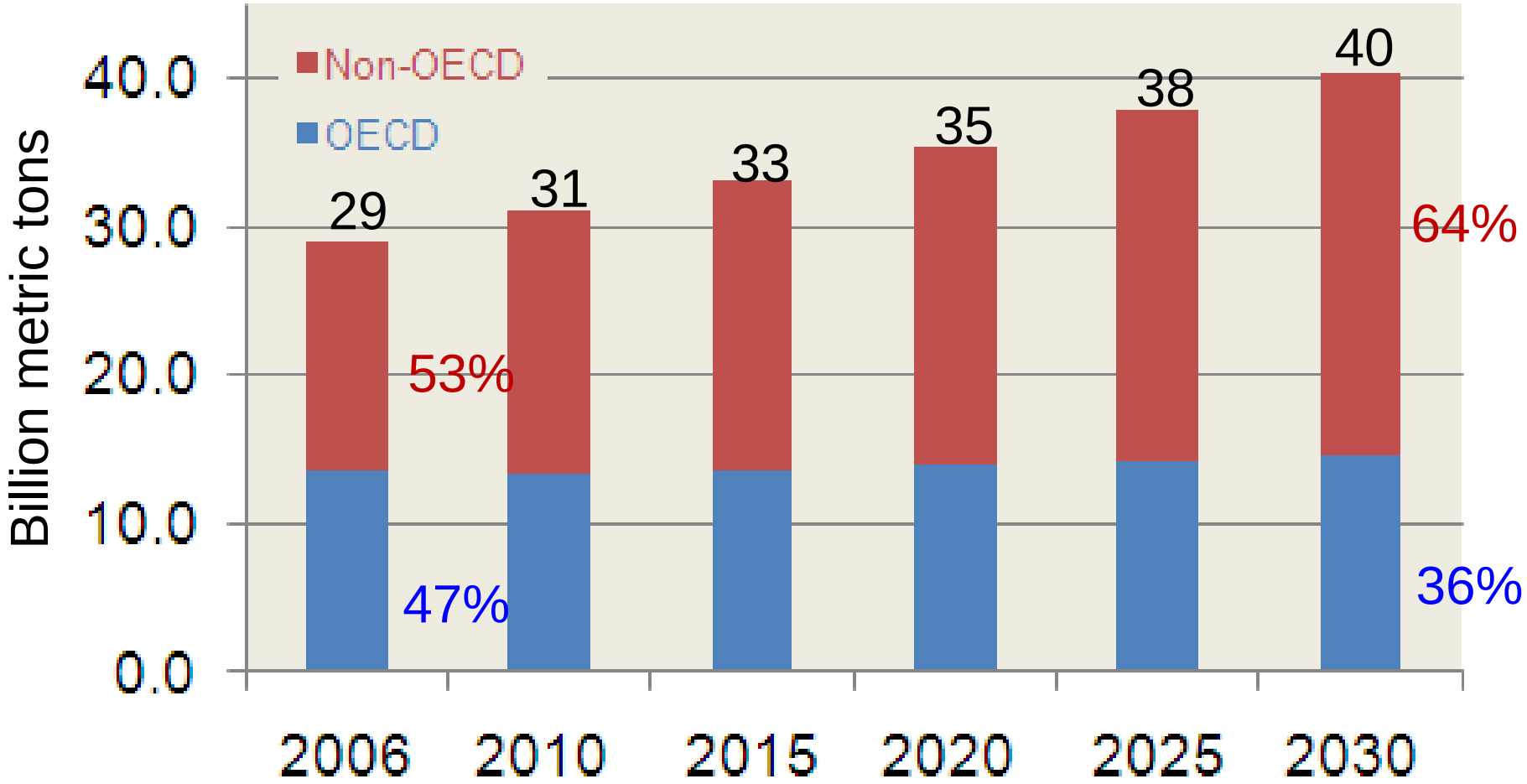


Source: DOE EIA database (2008)

Russia data 1992-2005, Germany data 1991-2005

GHG emissions continue to grow

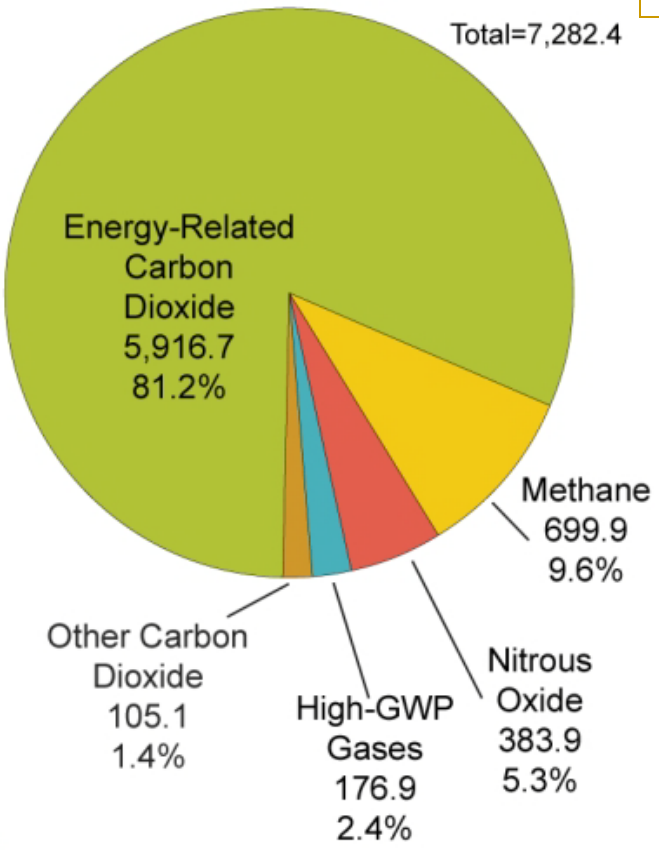
Absent new policies, global energy-related CO2 emissions grow 39% by 2030 in EIA's reference case

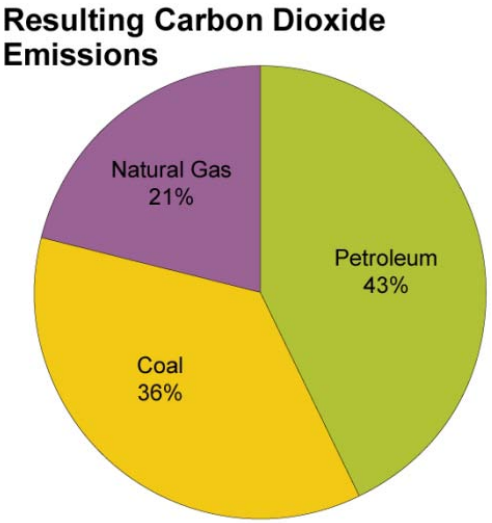


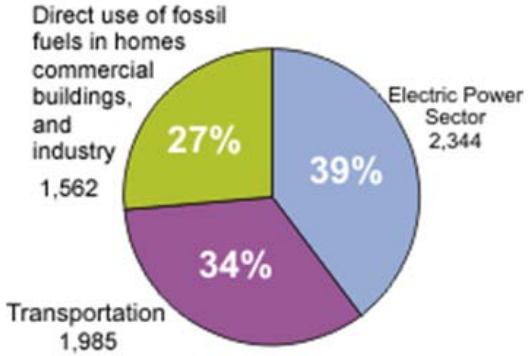
Source: EIA *International Energy Outlook 2009*, Reference Case

US anthropogenic GHG emissions are about energy

Over 80% of US greenhouse gas emissions in 2007 were energy-related







Source: EIA *Emissions of Greenhouse Gases in the United States 2007*

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What do we do about heat and power?

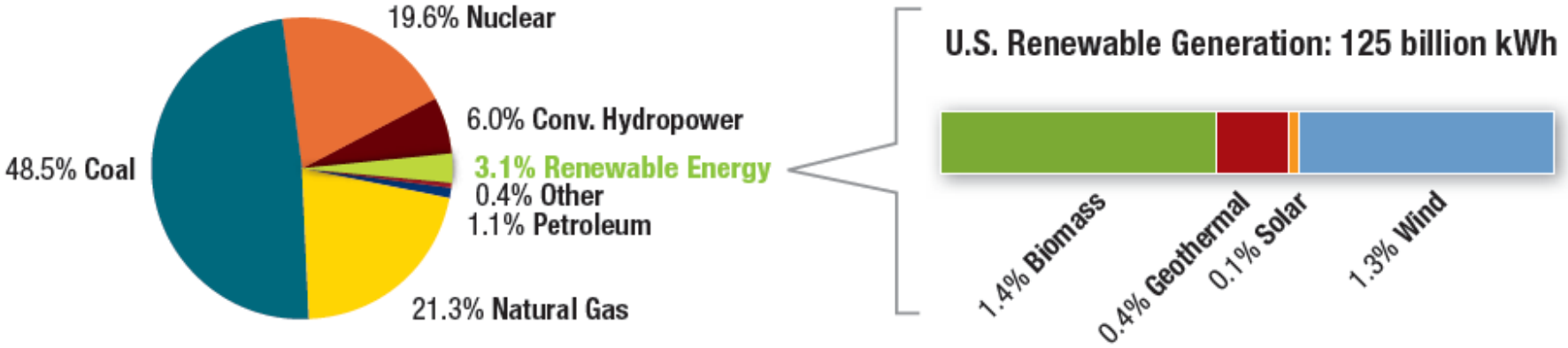
- **Conservation and efficiency**
  - Make the price of electricity evident
  - Efficiency standards (appliances…)
  - Regulatory incentives

    (pay utilities for conservation)
  - Buildings, city design

    (DOE weatherization programs)

  - Smart grid and storage enable renewables, encourage efficiency, provide reliability

US power in 2008 (4,112 billion kWh)



Source: EIA

Other includes: pumped storage, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, tire-derived fuels, and miscellaneous technologies.

* Includes on- and off-grid capacity.

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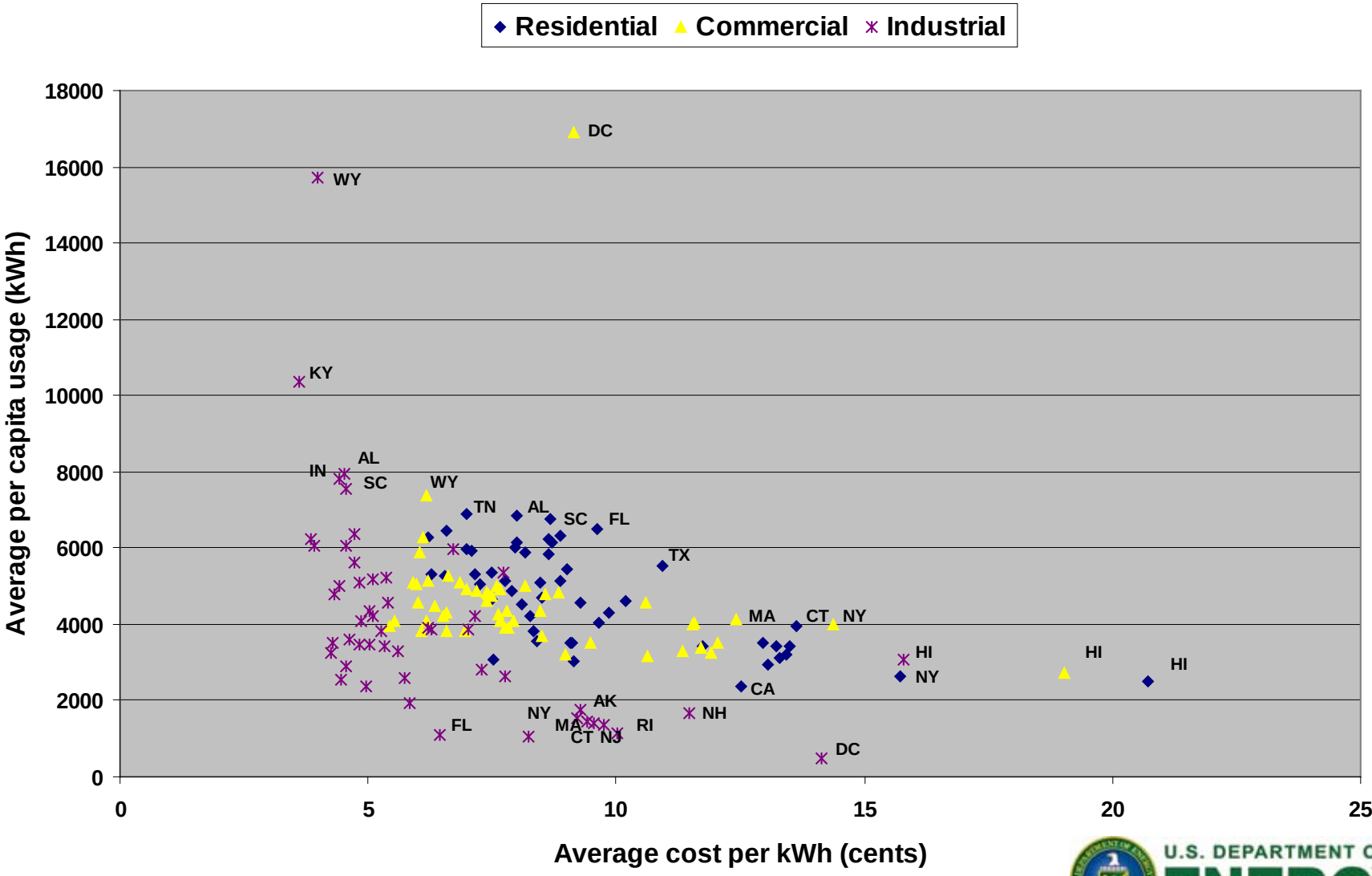
Renewables are <4% of US power

Per capita US electricity by state



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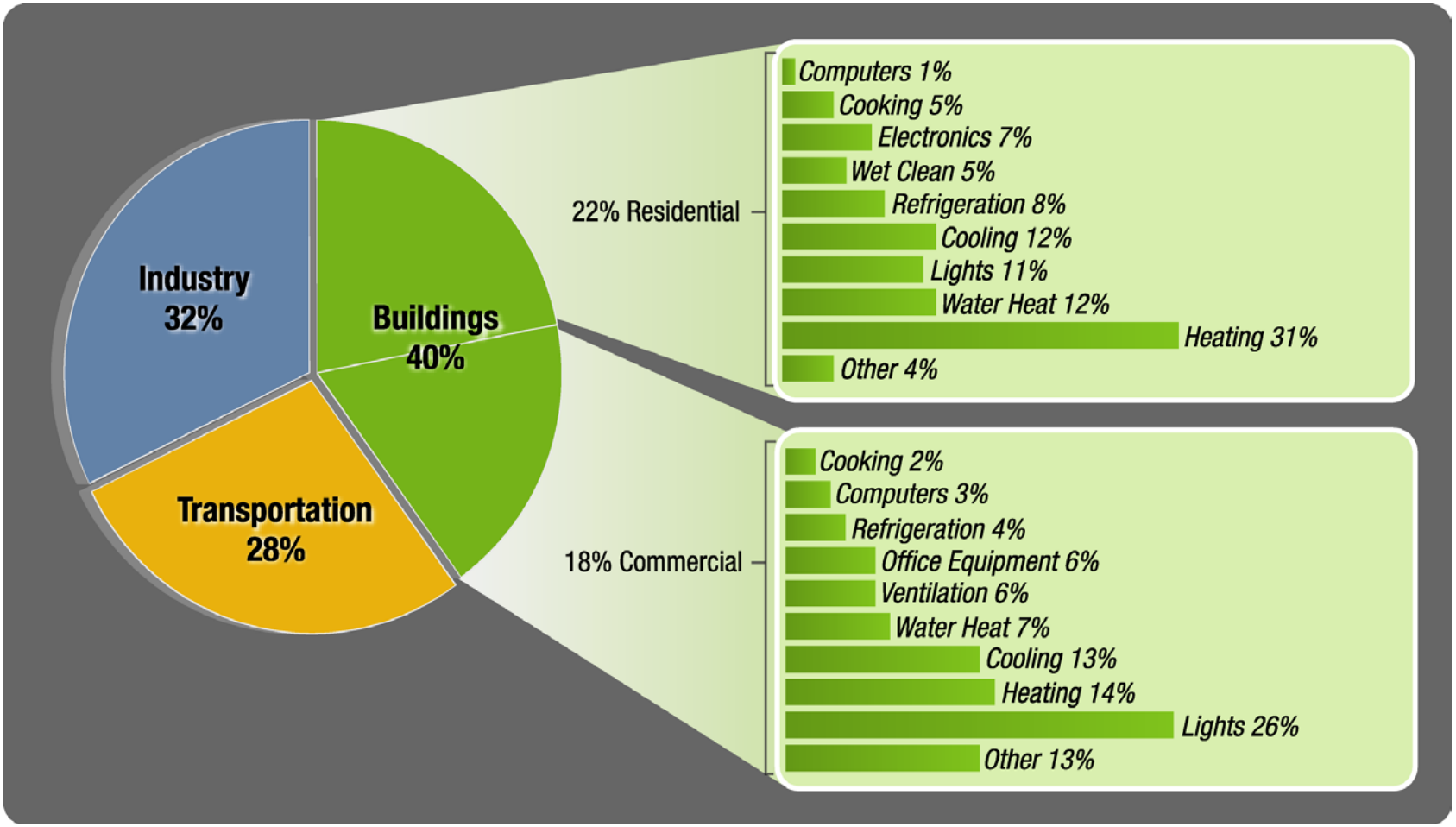
Categories of US energy consumption

Buildings use about 40% of total US energy



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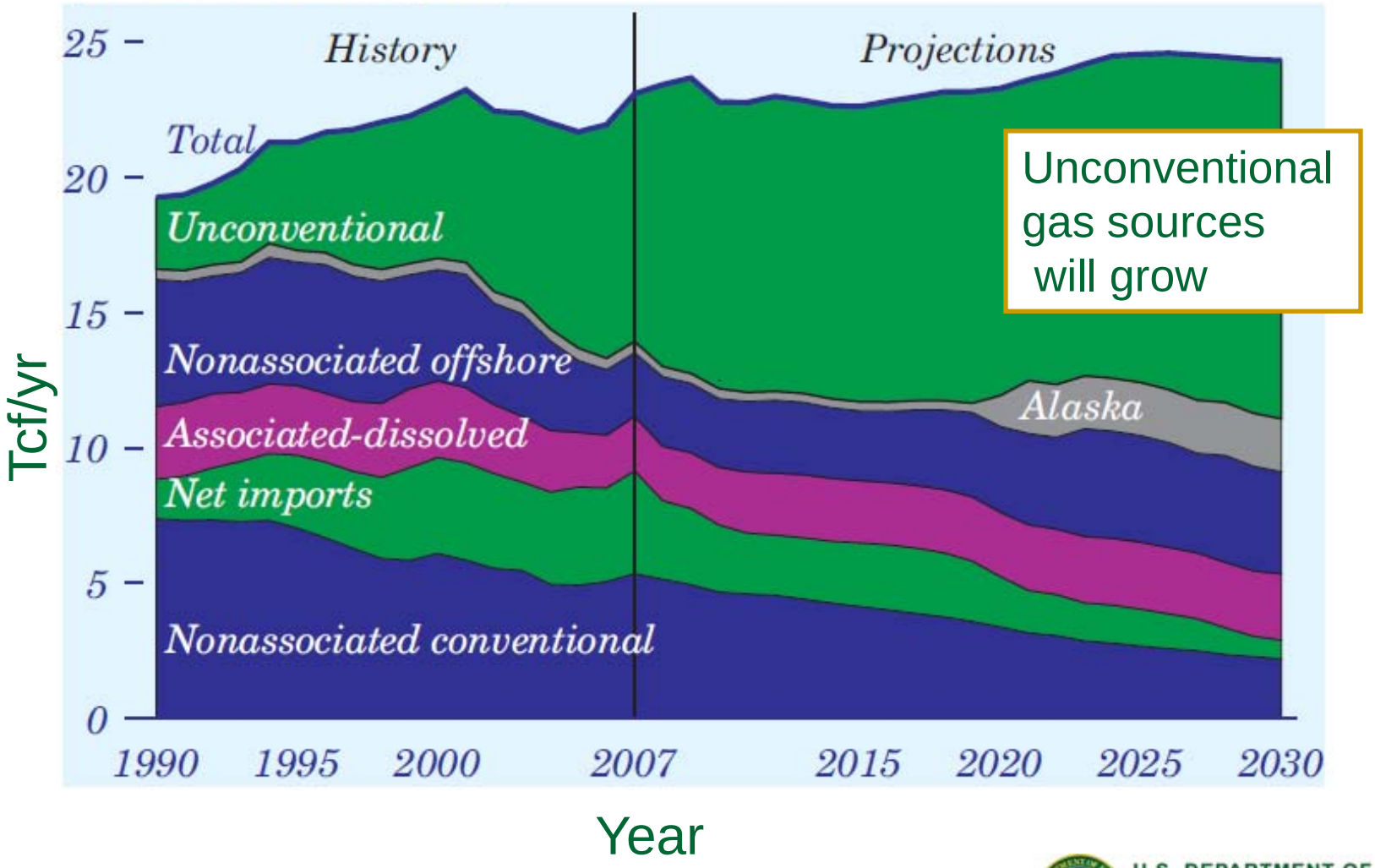
What do we do about heat and power?

- Conservation and efficiency
- **Set a price on carbon emissions**
  - Sources favored by technology and economics are:
    - Natural gas
    - On-shore wind
    - Small and medium hydropower
    - Nuclear fission
    - Carbon capture and storage (in demo soon)

- **Portfolio standards**
  - Renewable or low-carbon

US gas supply by source



Unconventional gas sources will grow

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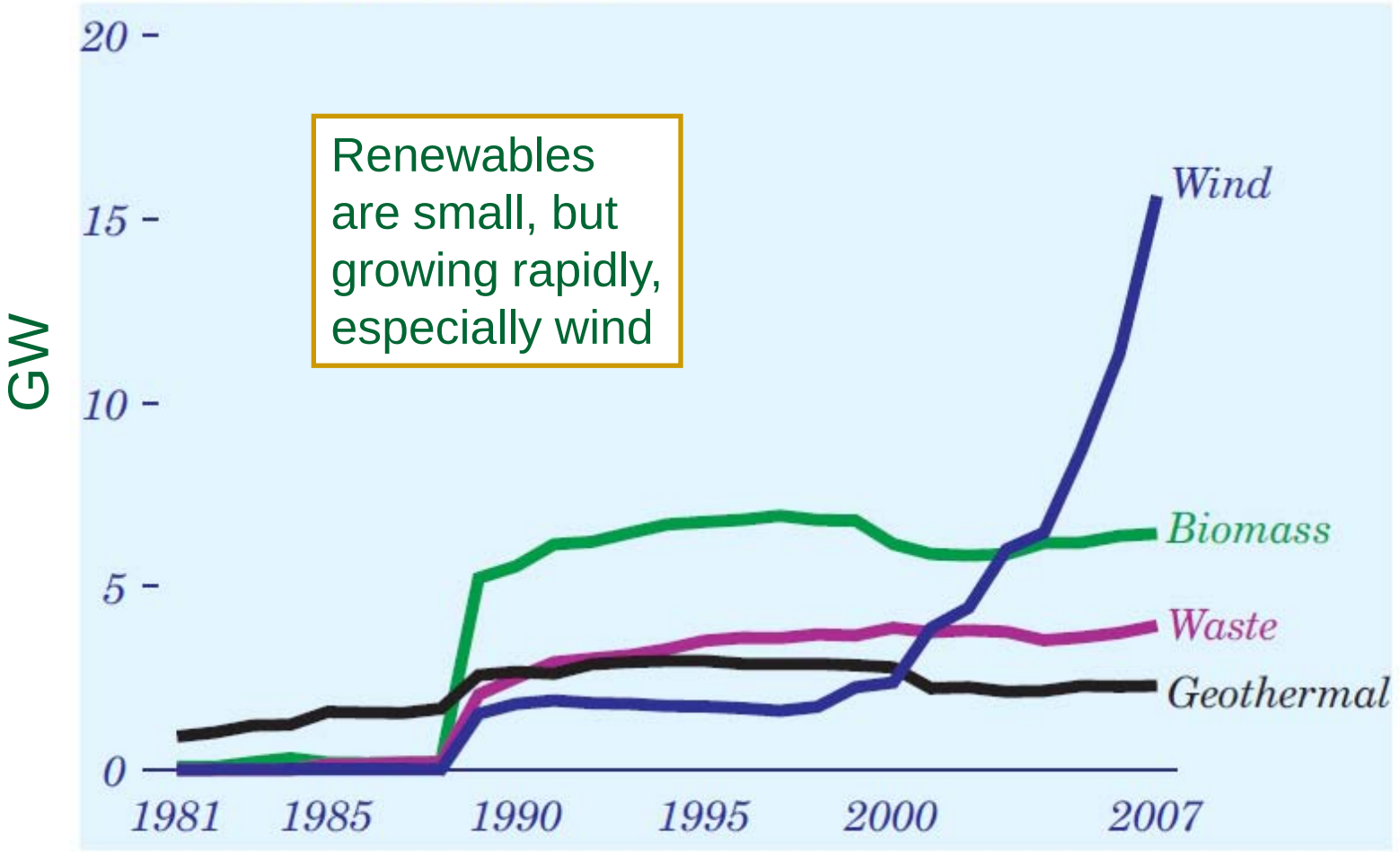
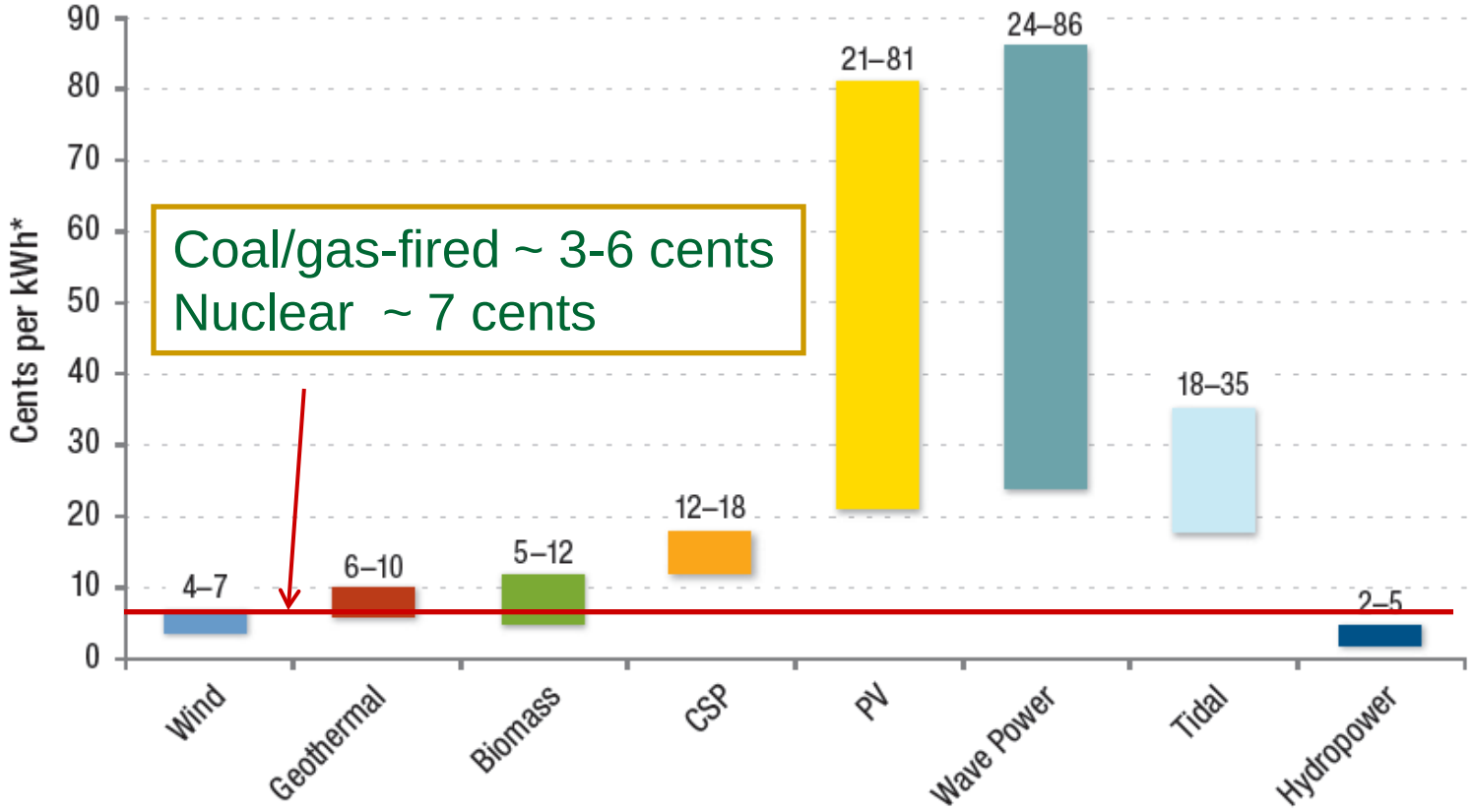
US renewable generation capacity (GW)



Renewable electricity costs (2008)



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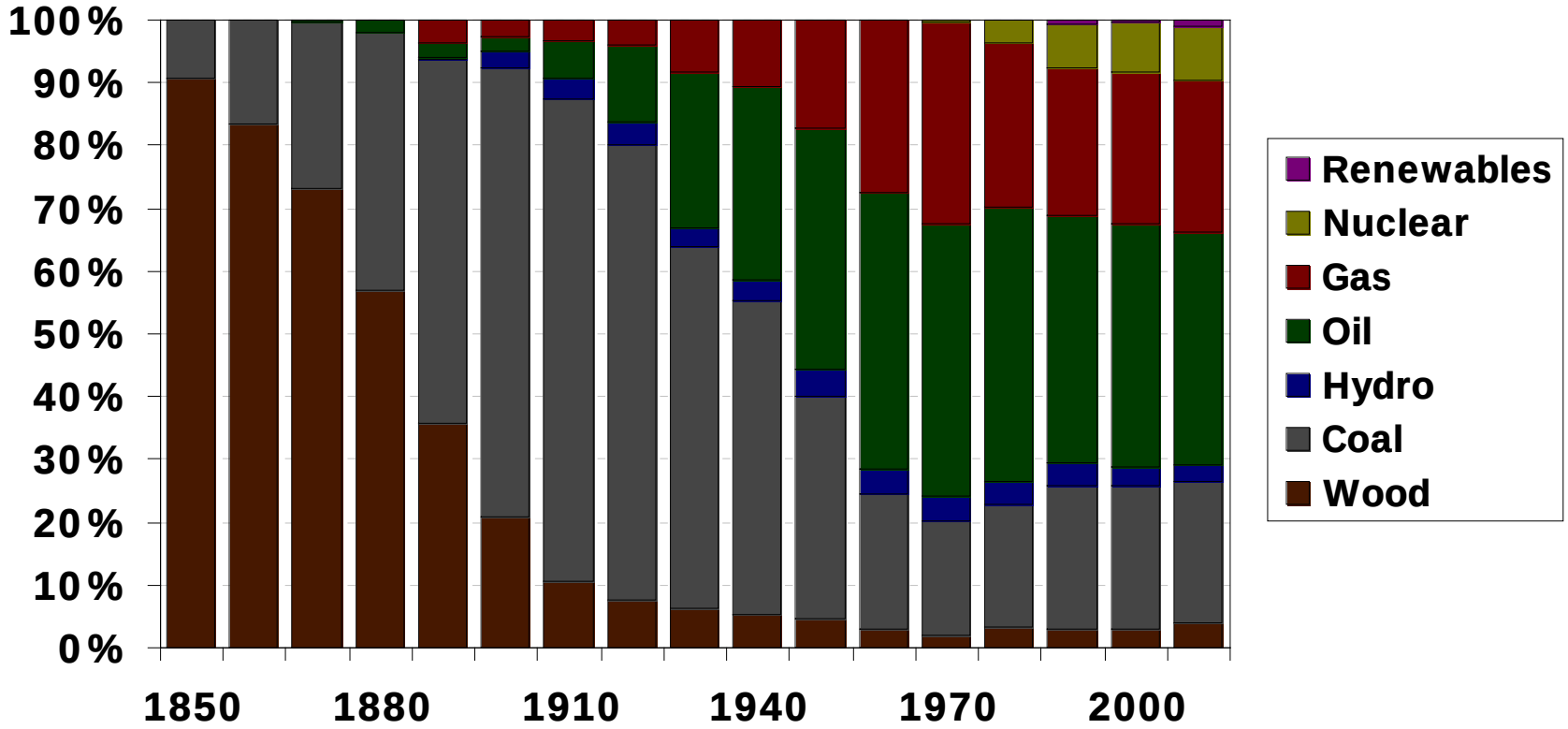
Energy change is slow without deliberate acceleration

US energy supply since 1850



Source: EIA

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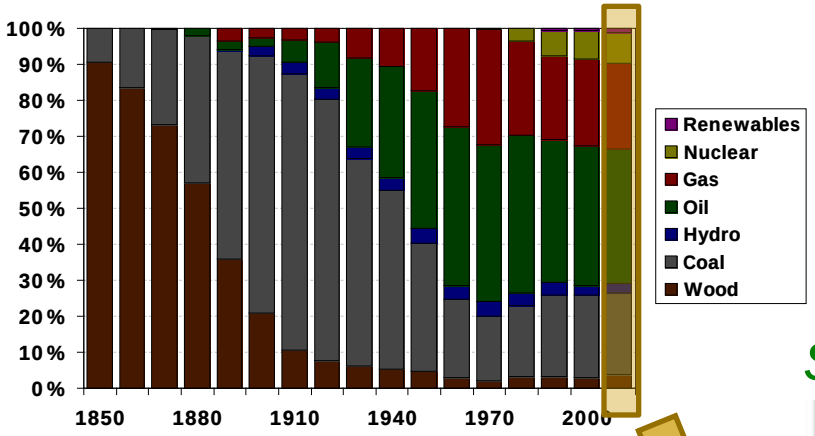
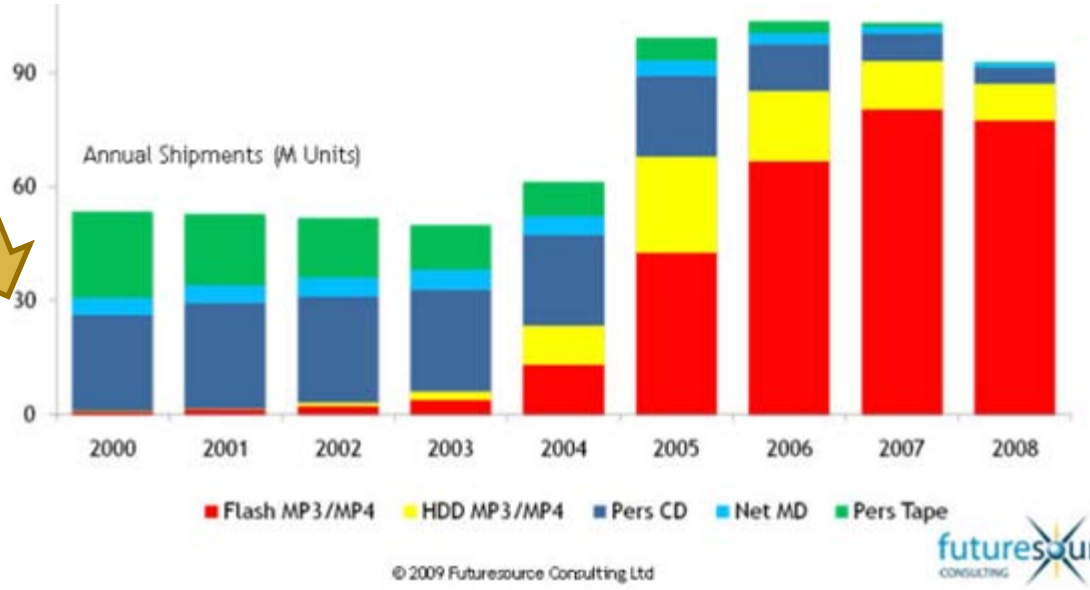
IT moves much faster than energy



Sales of Personal Audio/Video since 2000



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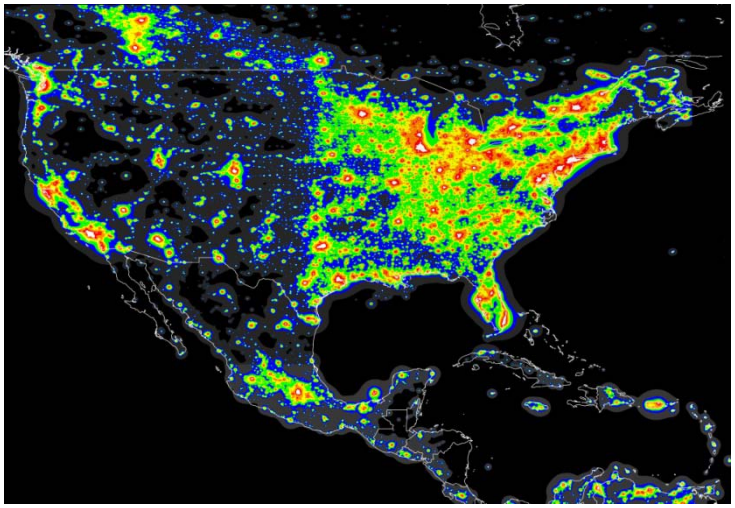
Energy innovation is different

Ubiquity *Consider economic, political, and social dimensions*



Longevity *Stock of existing assets*

Incumbency

New technologies compete on cost

Scale

Large capital and access to existing infrastructure are required

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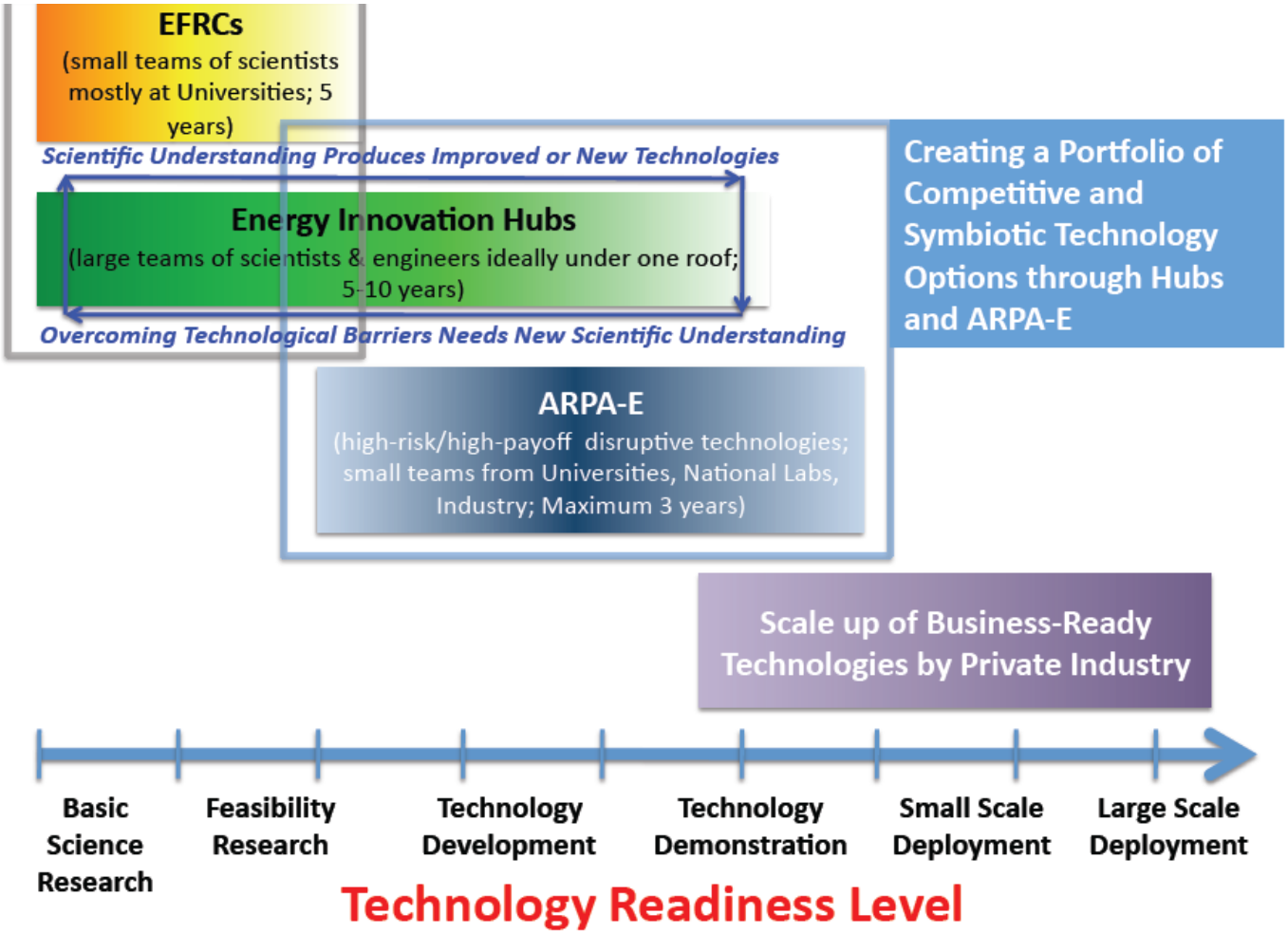
New research structures to catalyze innovation at scale



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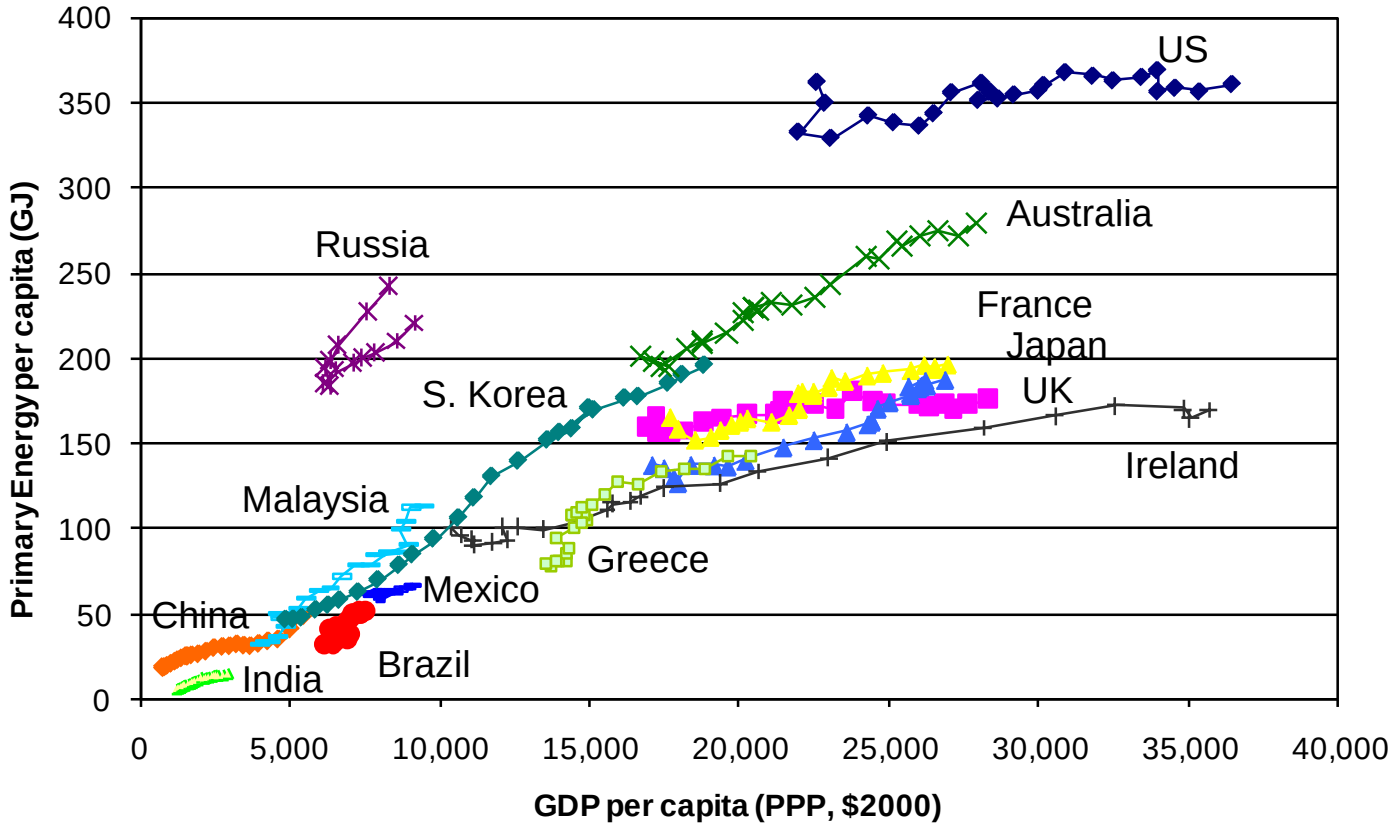
We must integrate diverse players with diverse roles

- Universities
  - Knowledge, people, education, credible voices
- National labs
  - Large facilities and programs, multidisciplinary RD&D
- For-profit sector
  - High-risk innovation, take technology to scale
  - Optimize under economics and regulation
- Government
  - Policies, precompetitive R&D

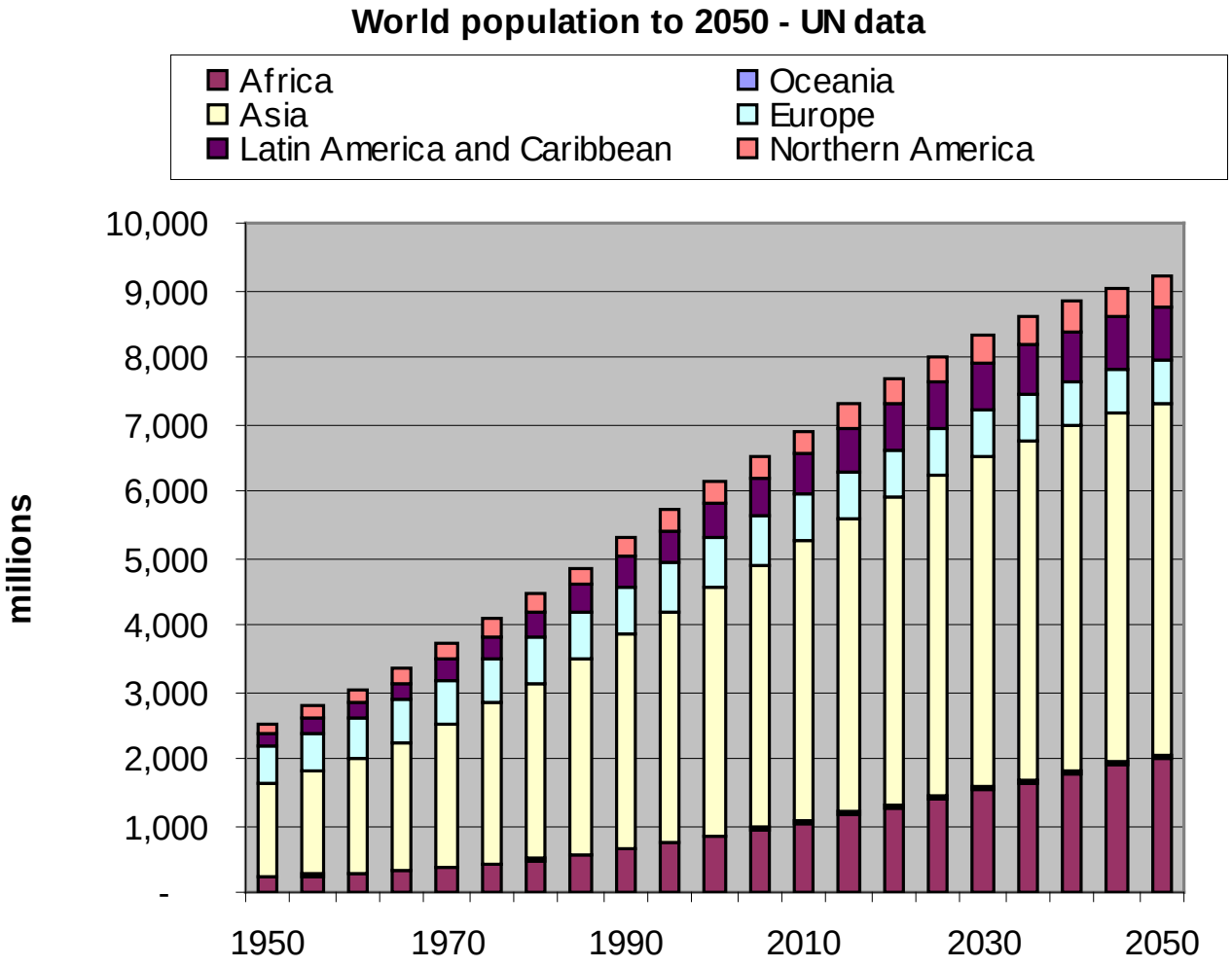
Energy consumption has increased with development

Energy demand and GDP per capita (1980-2004)



Source: UN and DOE EIA, Russia data 1992-2004 only

Global population growing 4X in a century



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Questions/Comments?