Energy, Environment, Security: Can we have it all?

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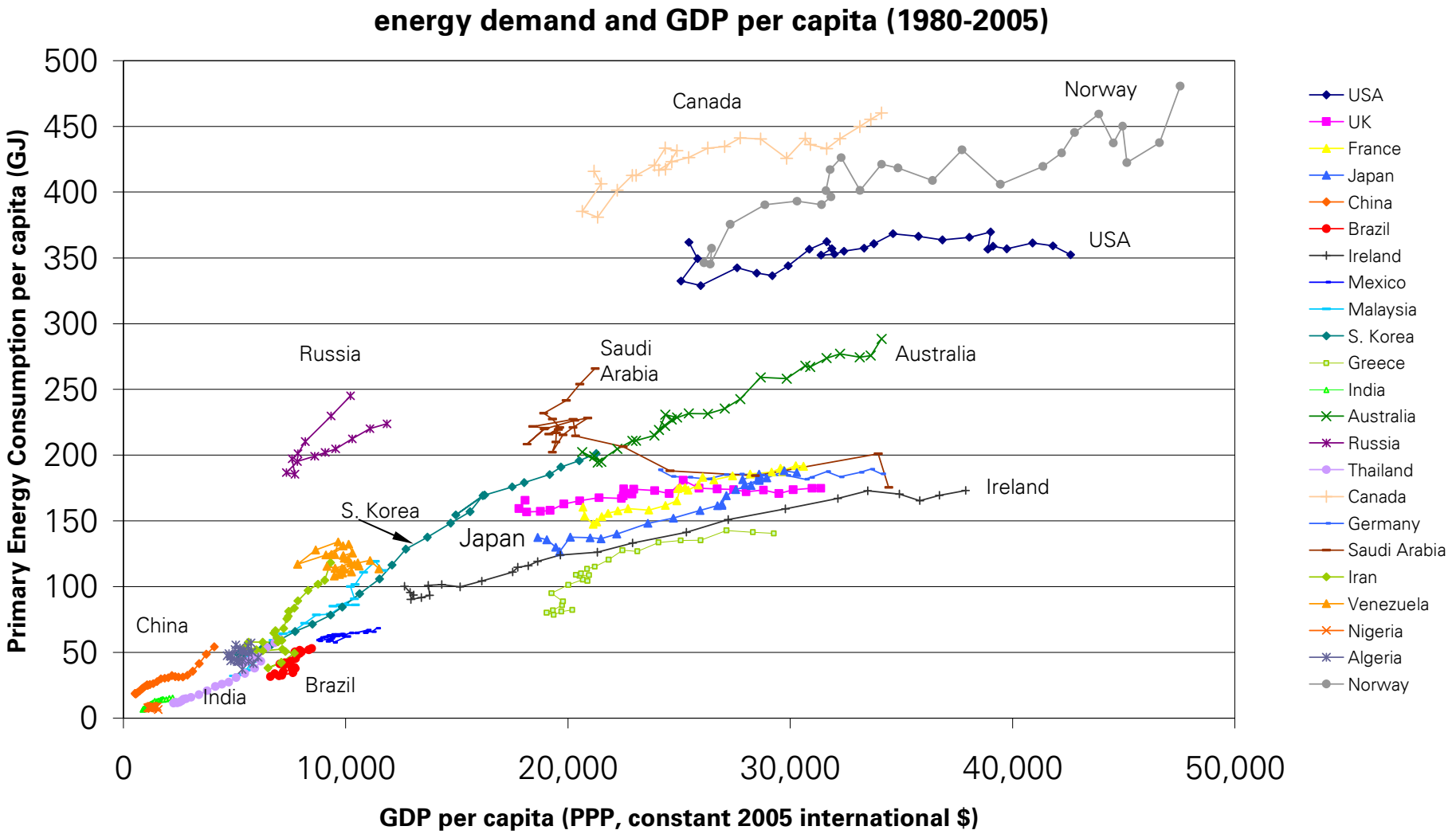
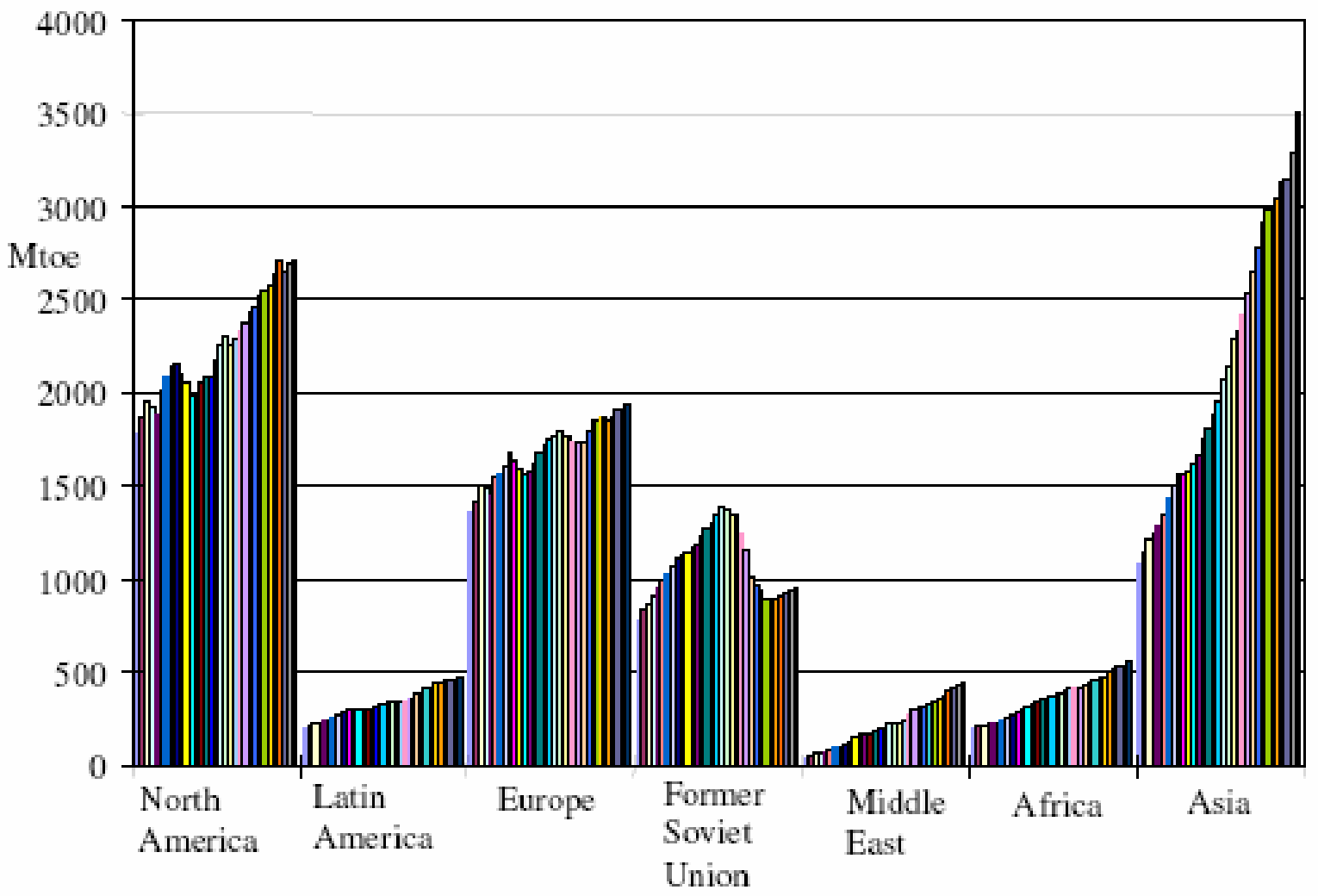
NSF Distinguished Lecture
October 27, 2008

Energy demand grows with economic development



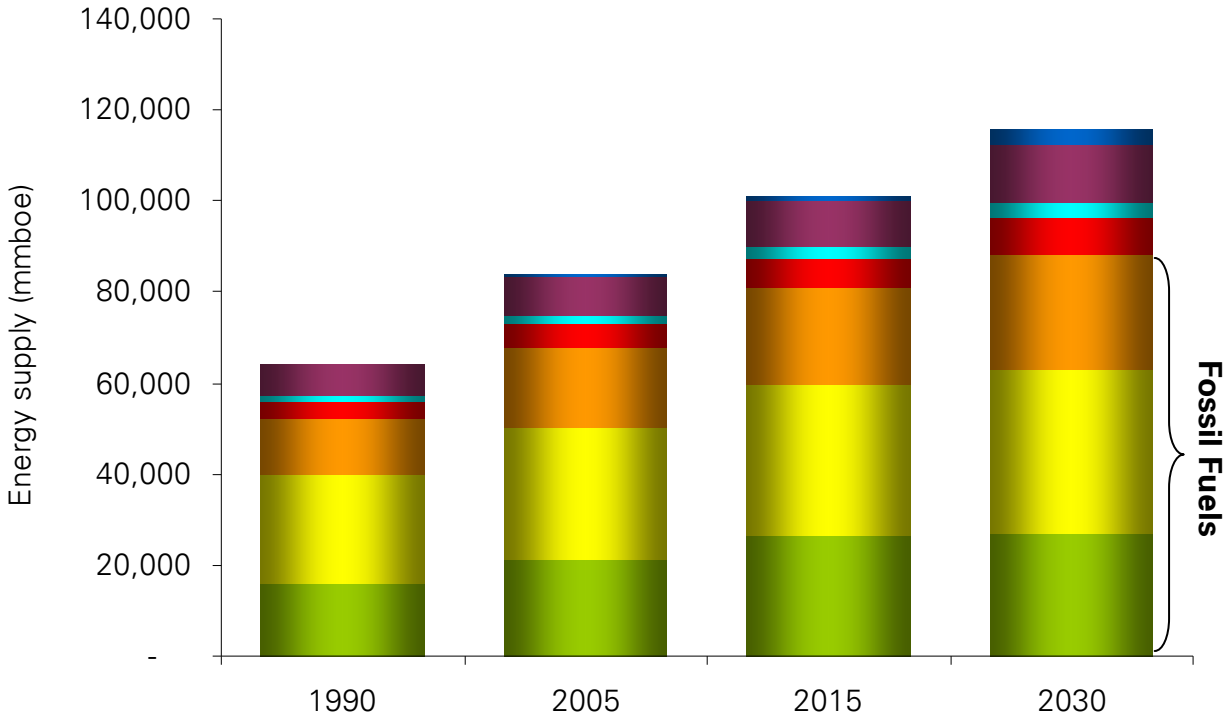
Source: DOE EIA and World Bank WDI databases (2008). Russia data 1992-2005, Germany data 1991-2005

annual primary energy demand 1971-2003



Source IEA, 2004 (Excludes biomass)

Substantial growth in energy demand is projected

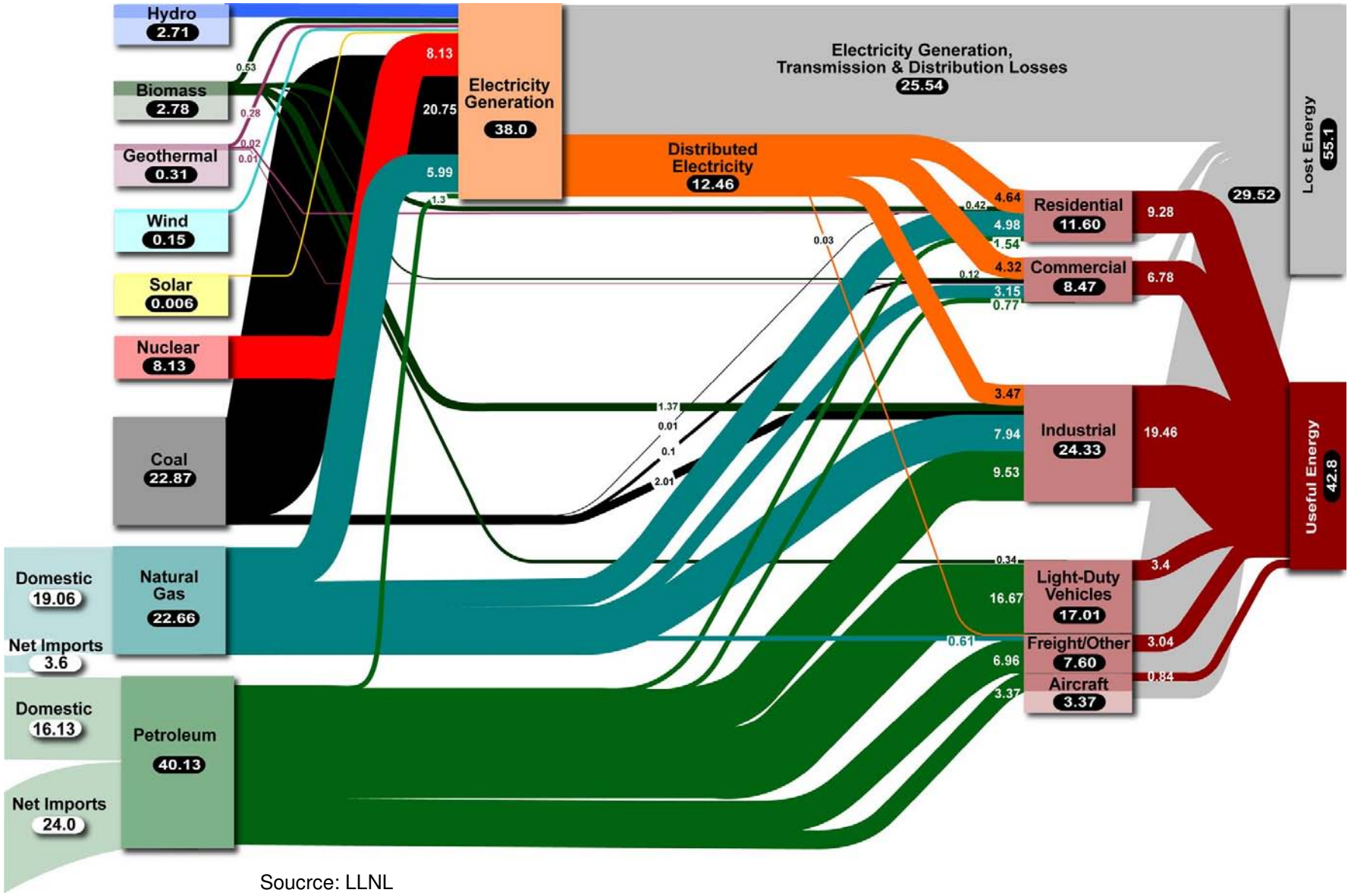


	'05 – '30 Annual Growth Rate (%)
Other Renewables	8.3
Biomass & waste	1.7
Hydro	2.5
Nuclear	1.6
Gas	1.5
Oil	0.8
Coal	1.0
Total	**1.3**

Note: 'Other renewables' include geothermal, solar, wind, tide and wave energy for electricity generation

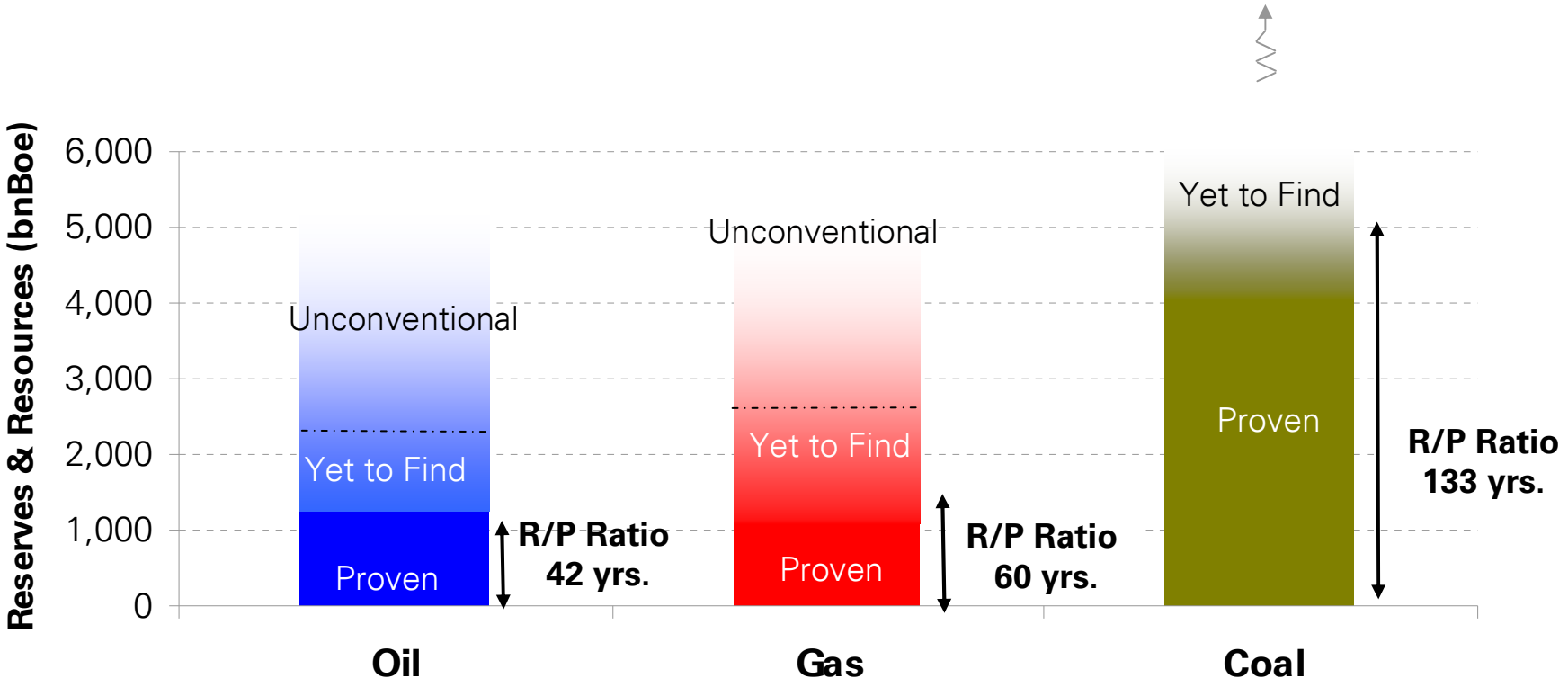
Source: IEA World Energy Outlook 2007 (Alternate Policy Scenario)

US Energy flows illustrate different fuels for different needs (Annual total ~ 100 Ej)



Soucrce: LLNL

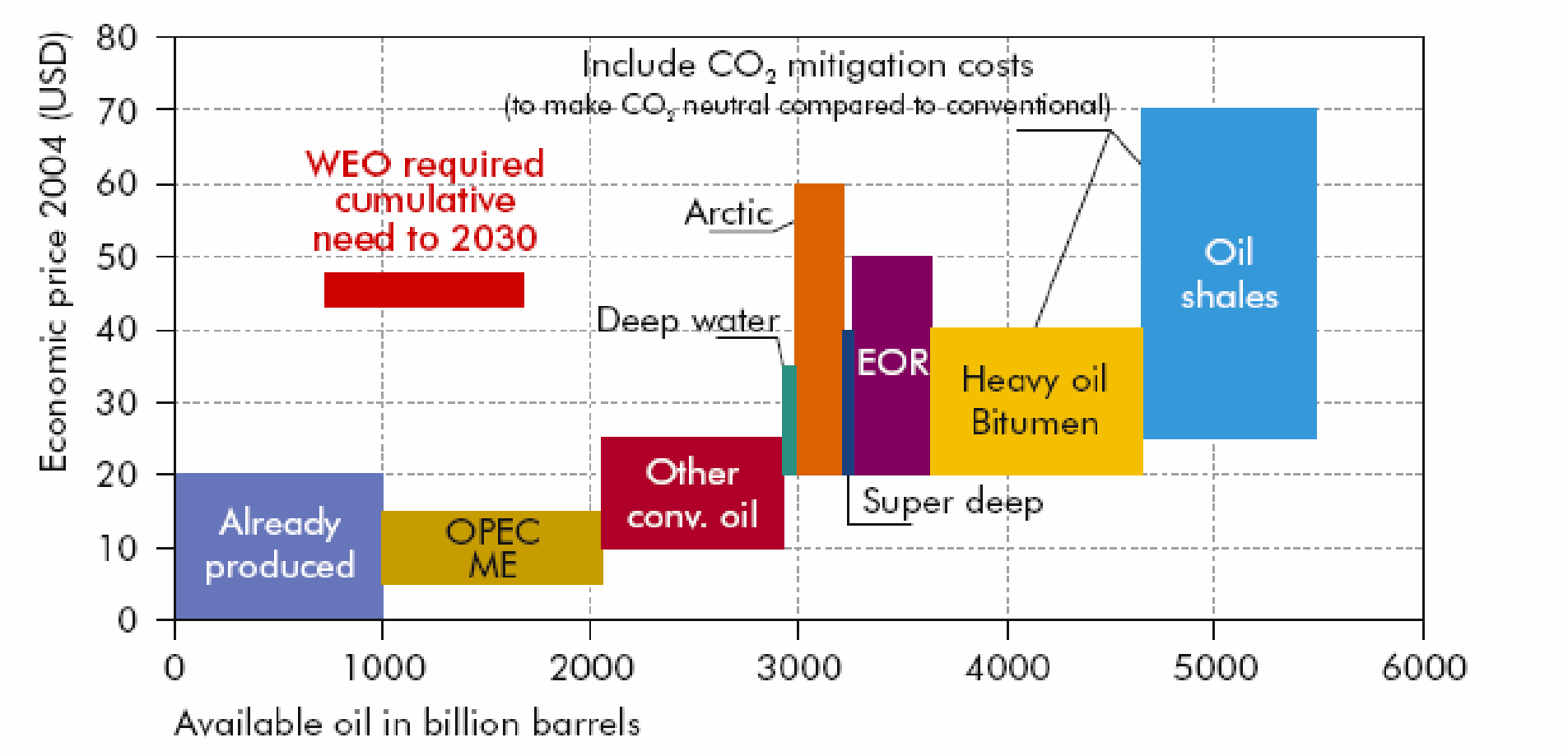
There are substantial global fossil fuel resources; the world will not run out anytime soon…



Source:, BP Statistical Review (2008); Survey of Energy Resources - World Energy Council (2007) ; World Energy Assessment 2001, HIS, Wood Mackenzie

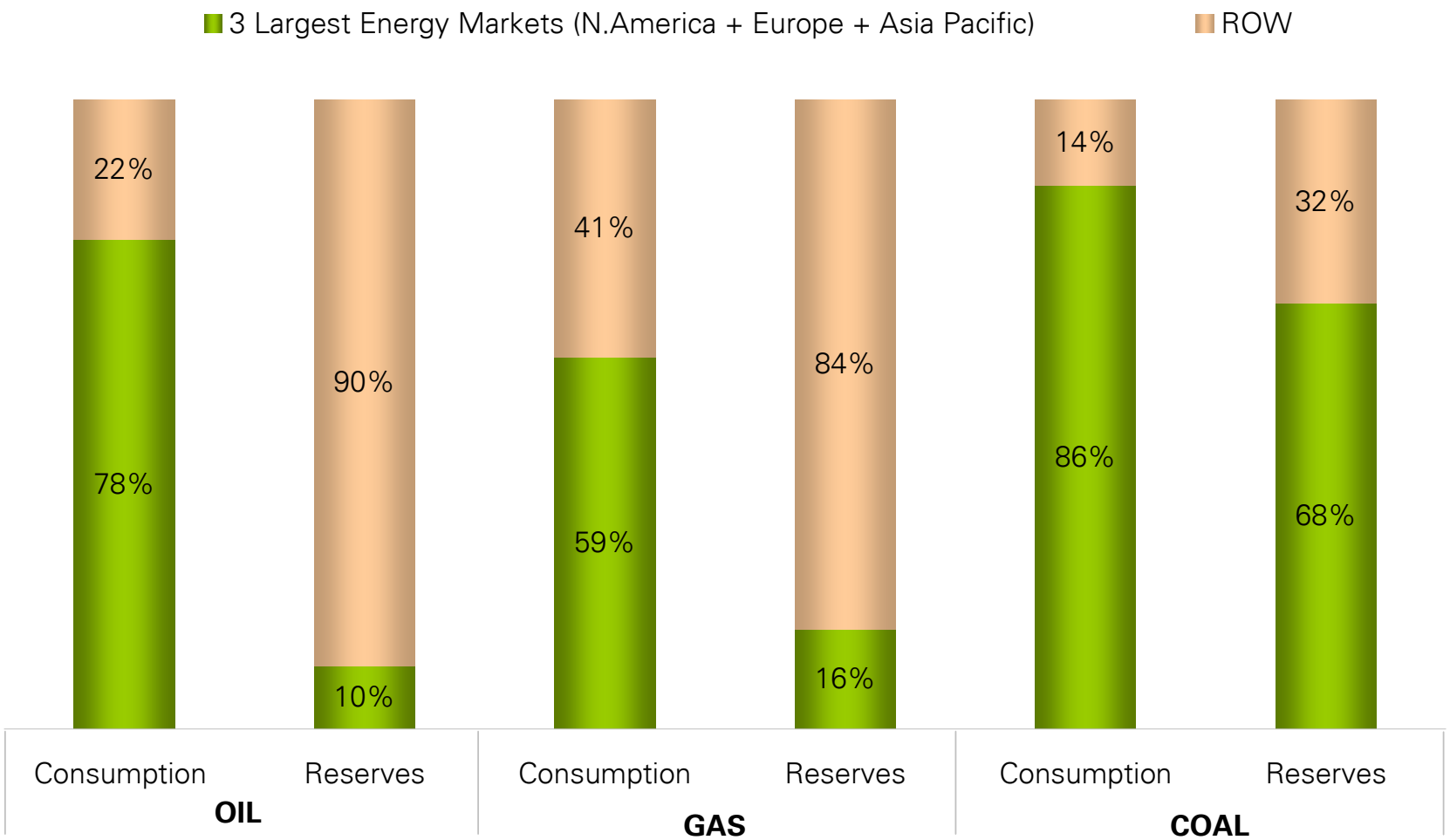
oil supply and cost curve

Availability of oil resources as a function of economic price



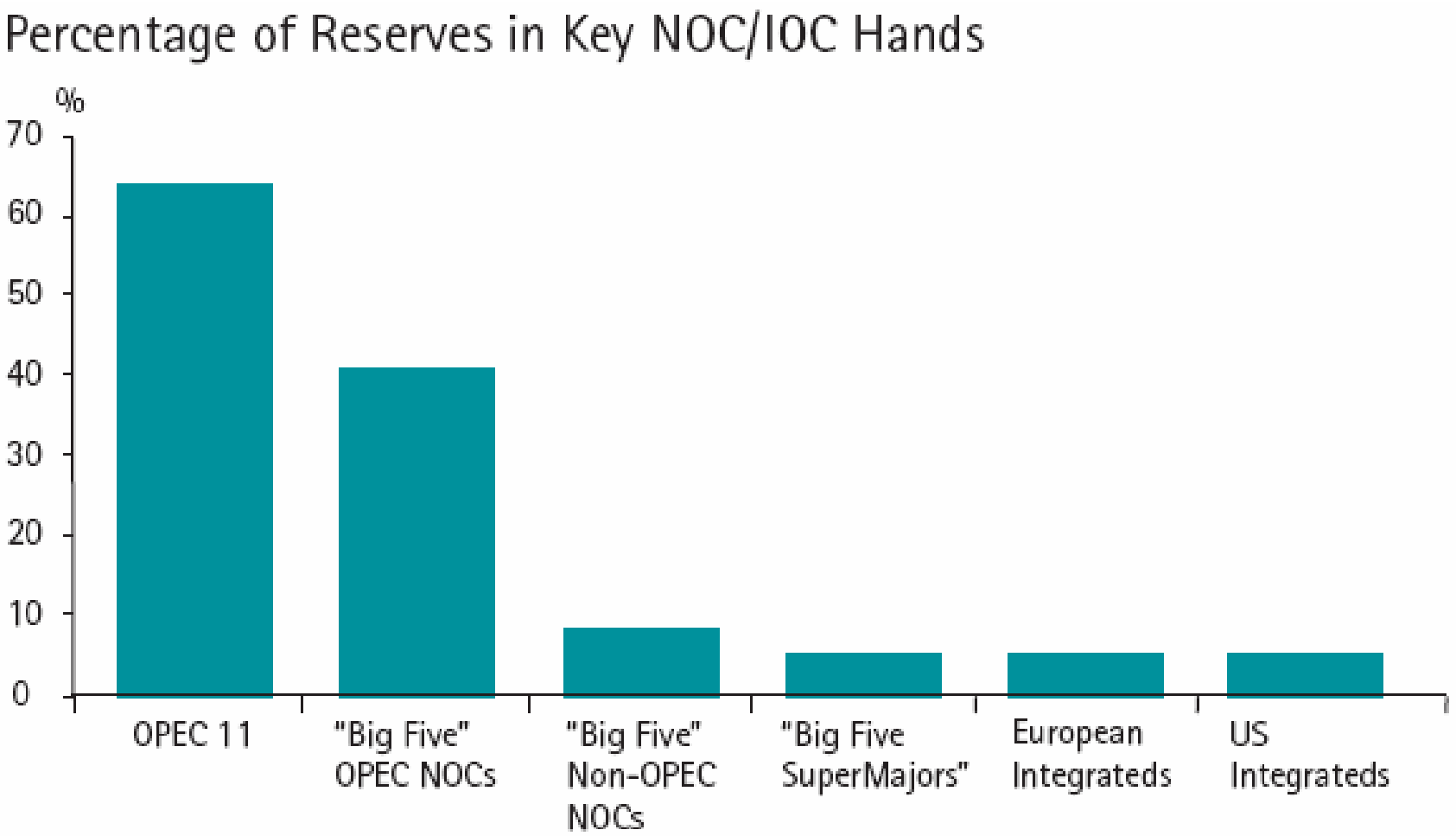
Source: IEA (2005)

Fossil fuel reserves are not uniformly distributed



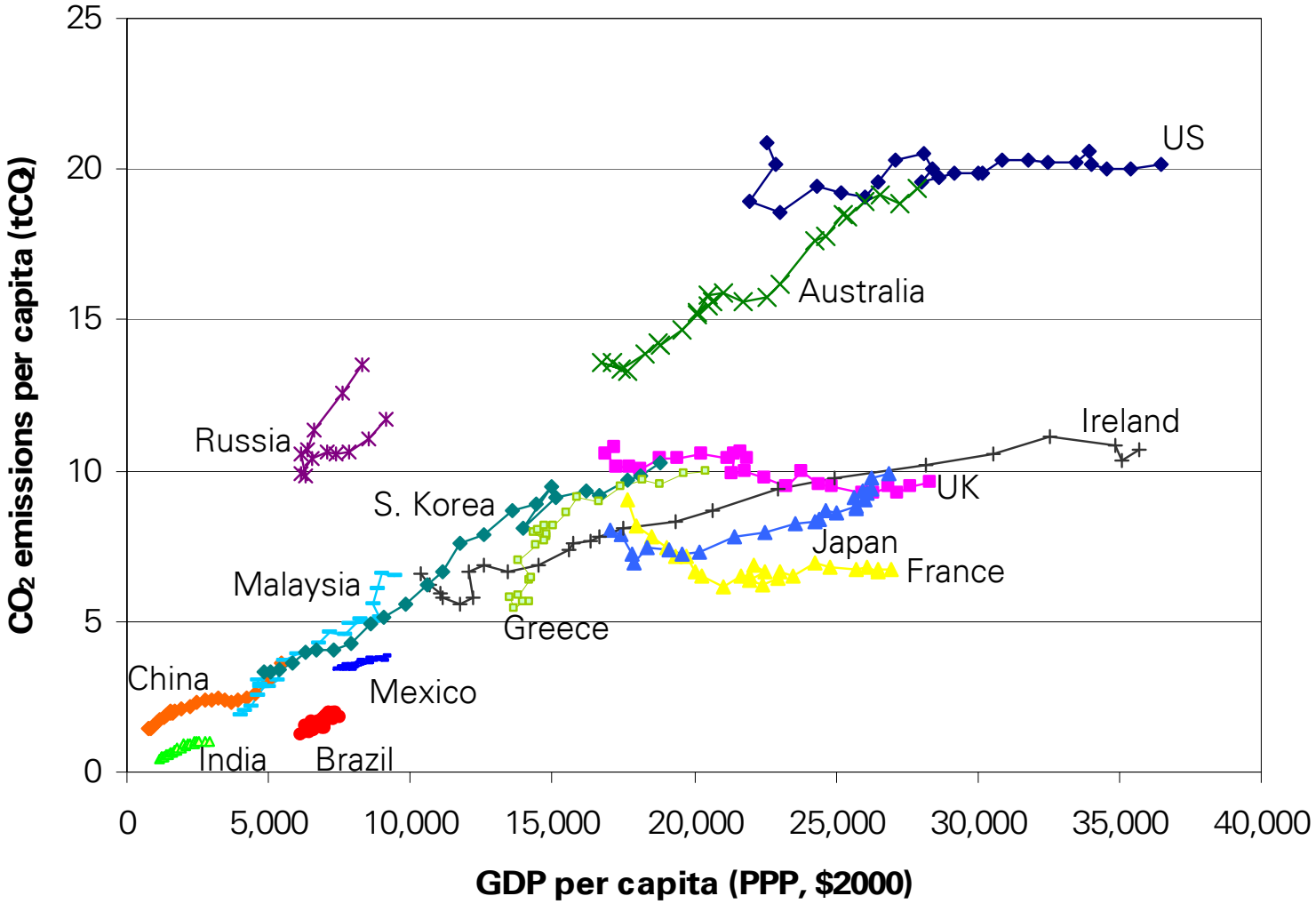
Source: BP Statistical Review 2008

NOCs hold majority of oil and gas reserves; OPEC < 40% of daily production



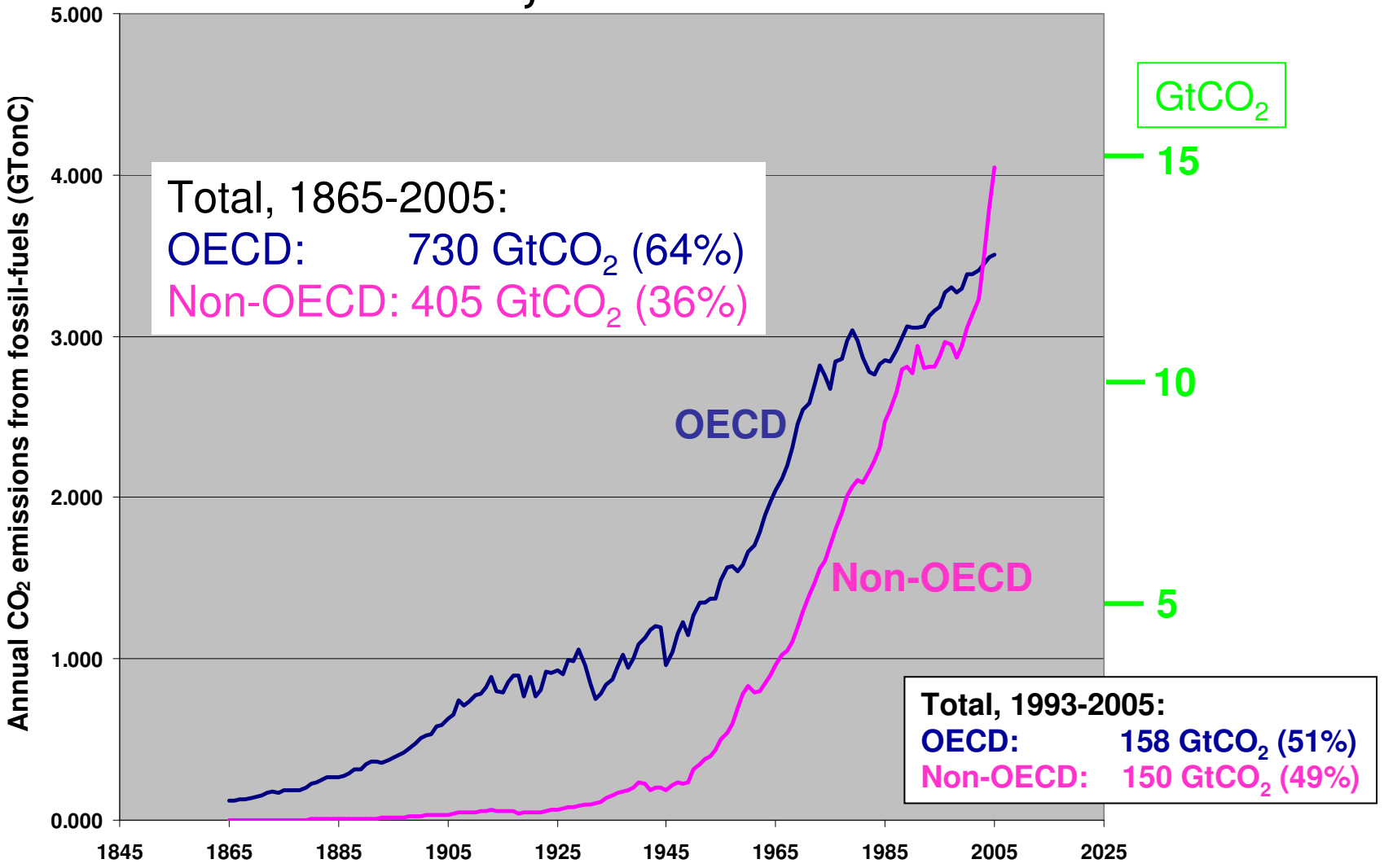
Source: Morgan Stanley Presentation

CO_2 emissions and GDP per capita (1980-2004)



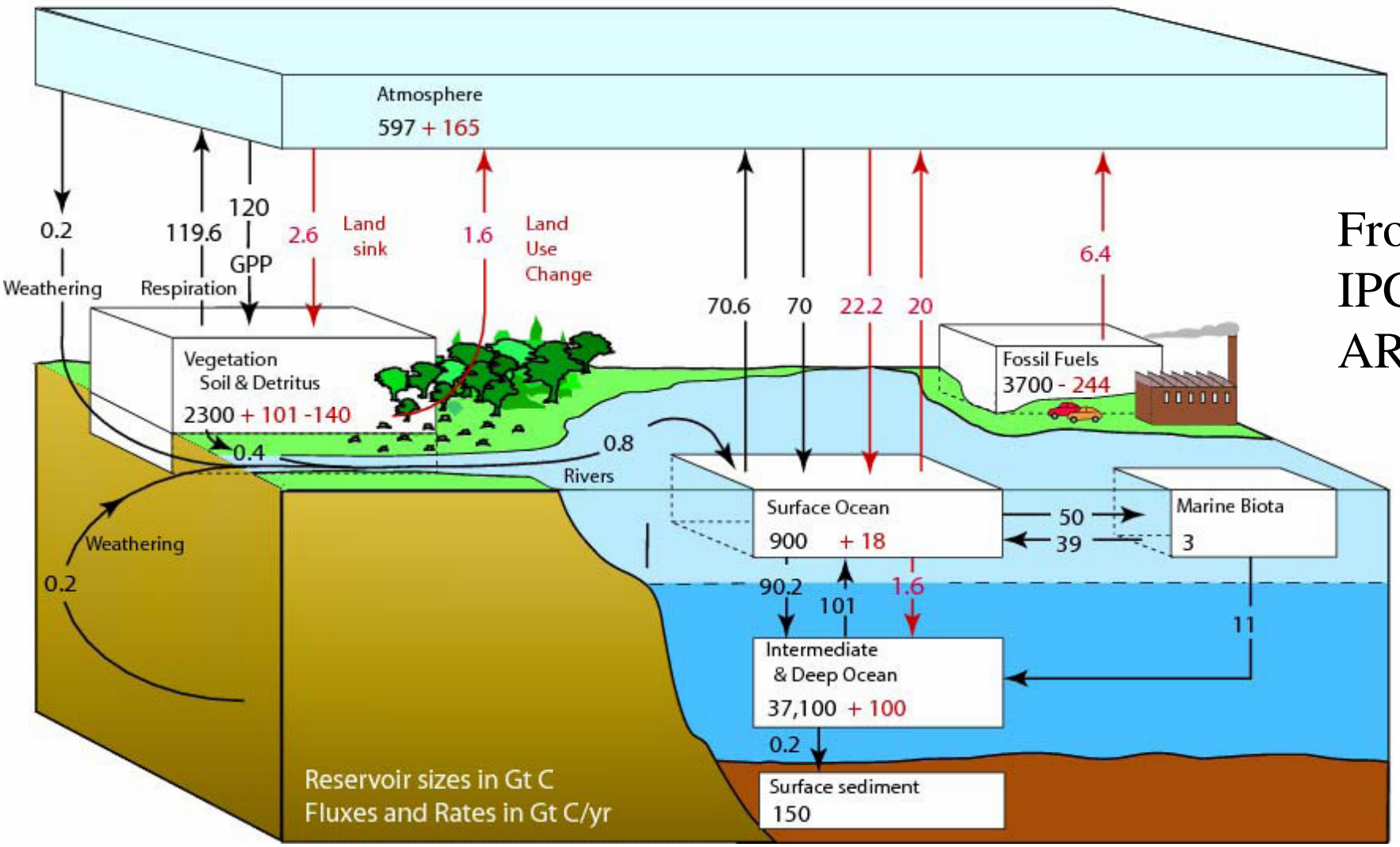
Source: UN and DOE EIA
Russia data 1992-2004 only

CO_2 emissions, OECD and non-OECD, 1865-2005



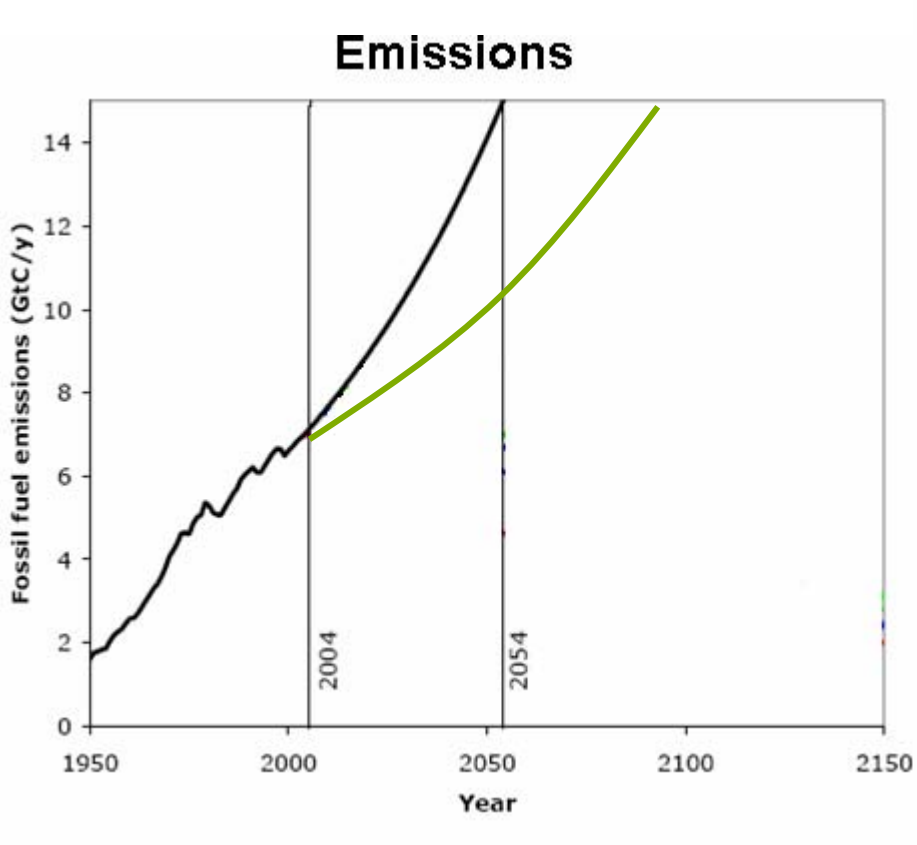
Source: Adrian Ross, 10-06-08

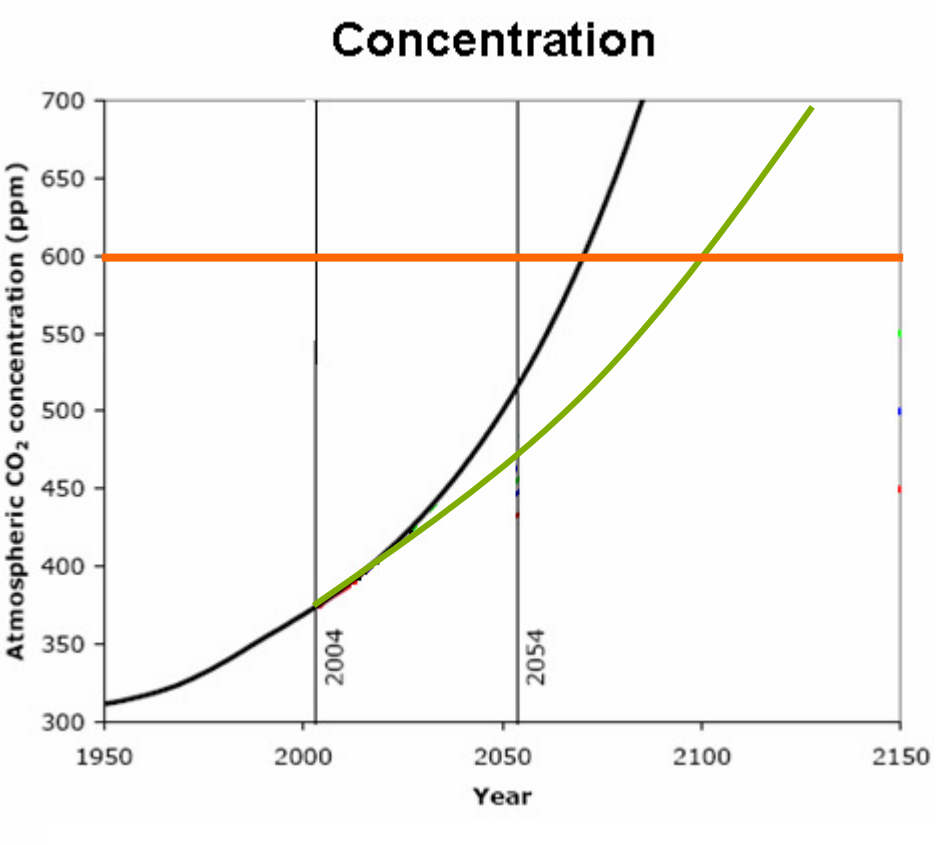
anthropogenic perturbations to the carbon cycle are small, but secular



From IPCC AR4

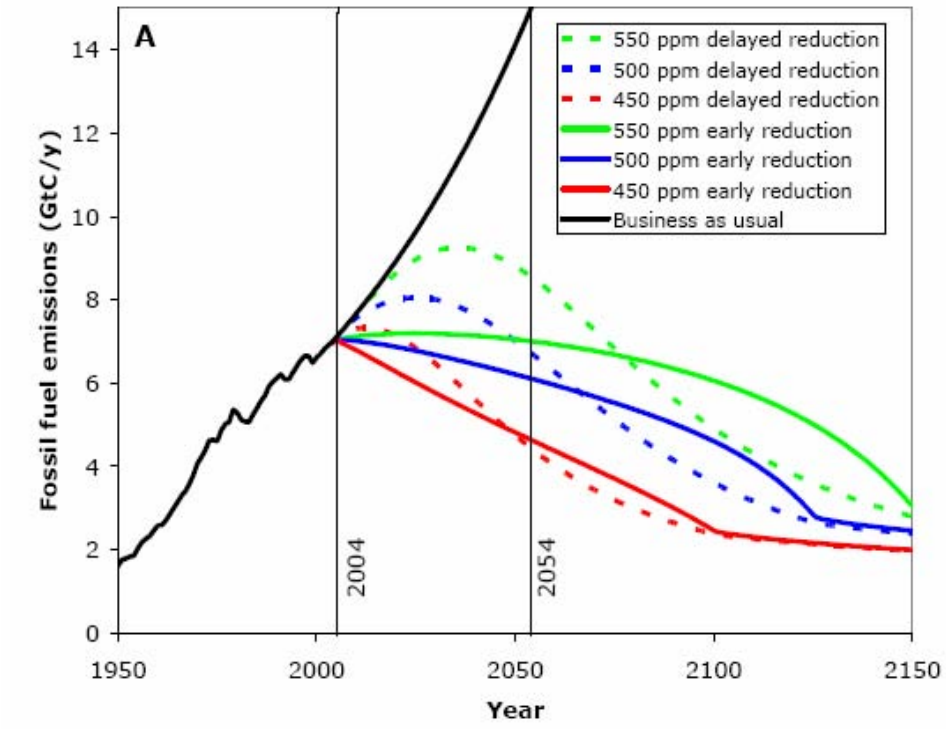
The long CO_2 lifetime is highly problematic



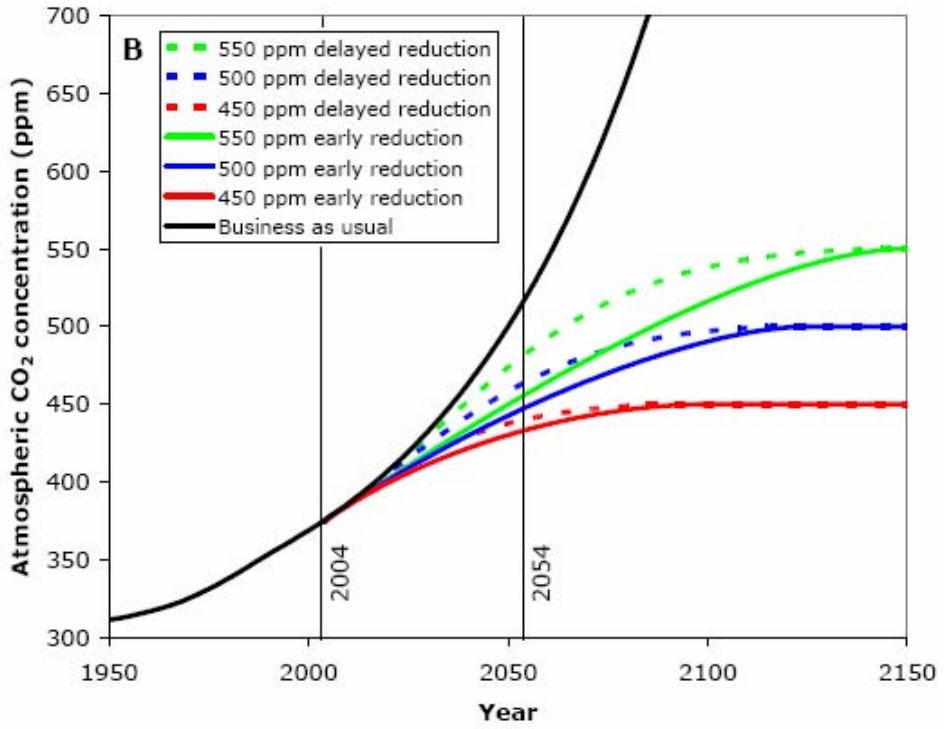


Drastic emissions reductions are required to stabilize concentrations

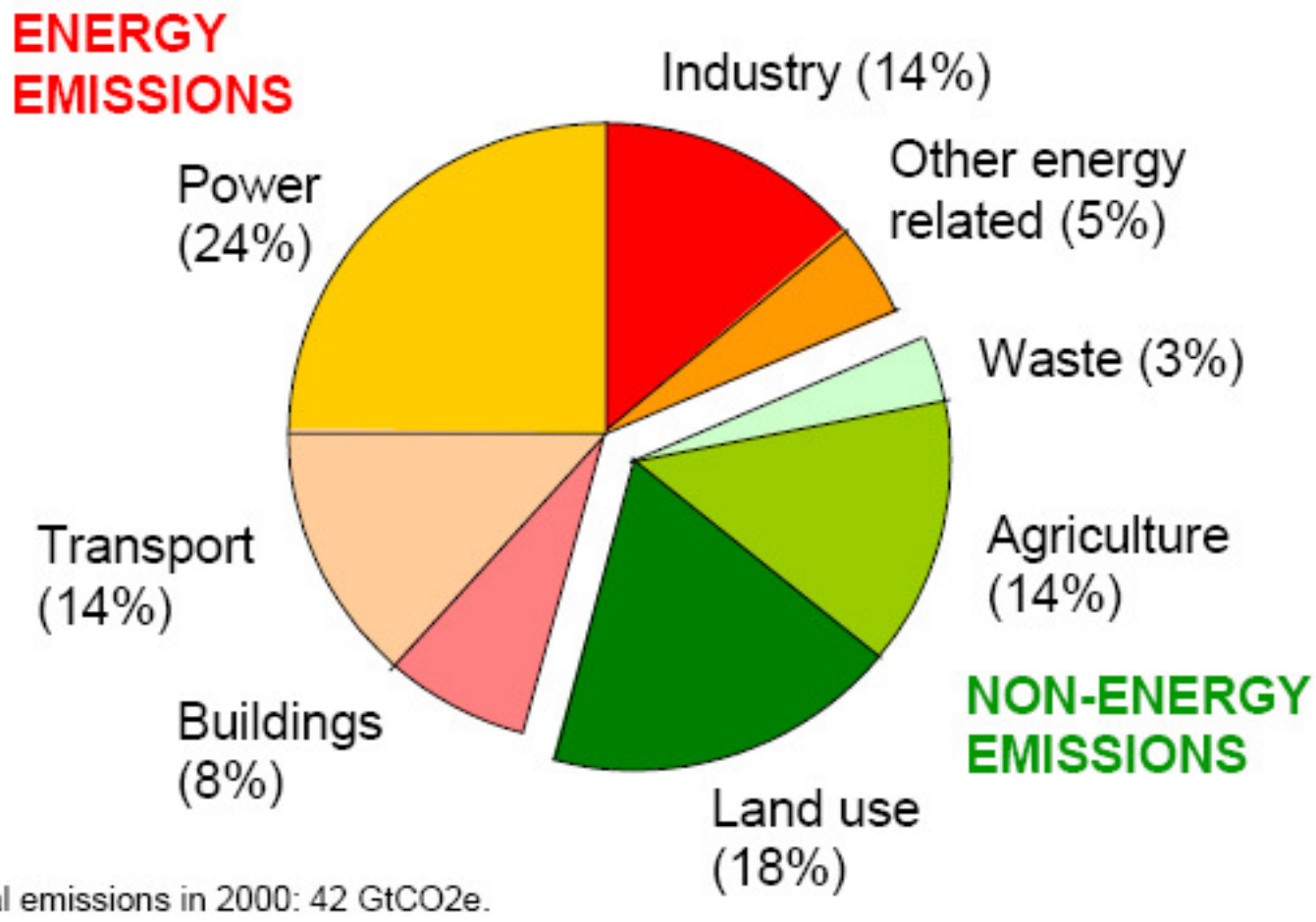
Emissions



Concentration



greenhouse gas emissions in 2000 by source



Total emissions in 2000: 42 GtCO2e.

Energy emissions are mostly CO_2 (some non-CO_2 in industry and other energy related).
Non-energy emissions are CO_2 (land use) and non-CO_2 (agriculture and waste).

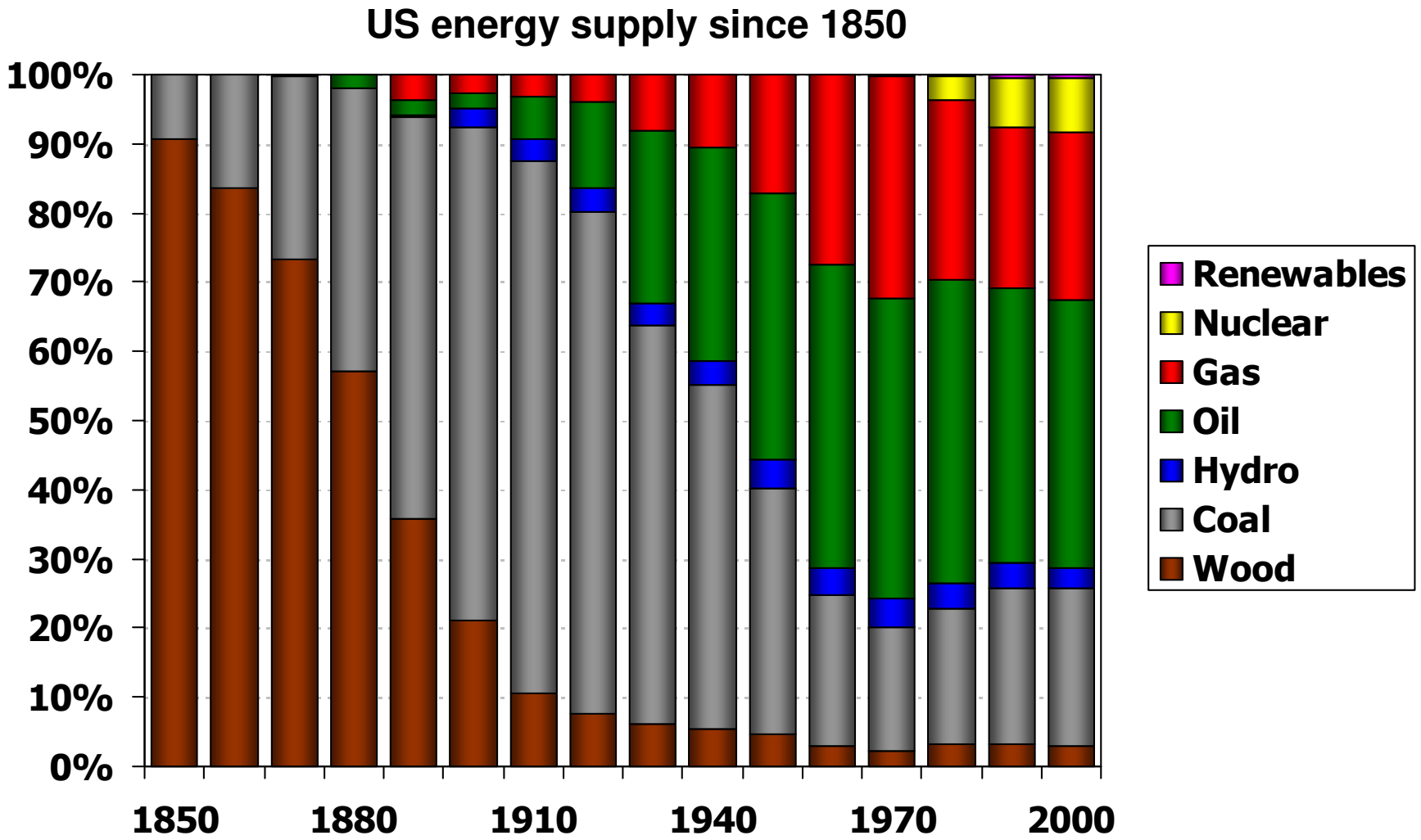
Source: Stern Review, from data drawn from World Resources Institute Climate Analysis Indicators Tool (CAIT) on-line database version 3.0

The three great energy problems

- **Energy poverty of ca 2B people**
  - **Fuel for cooking/heating**
  - **Electricity for lighting**
- **Security of supply**
  - **Reliable and economic energy supply**
  - **Mostly about liquid hydrocarbons for transport**
- **Greenhouse gas emissions**
  - **Mostly about CO_2 from stationary sources**
  - **Power and heat**

We must identify, develop, and implement the most cost-effective and material solutions

Energy technologies change slowly

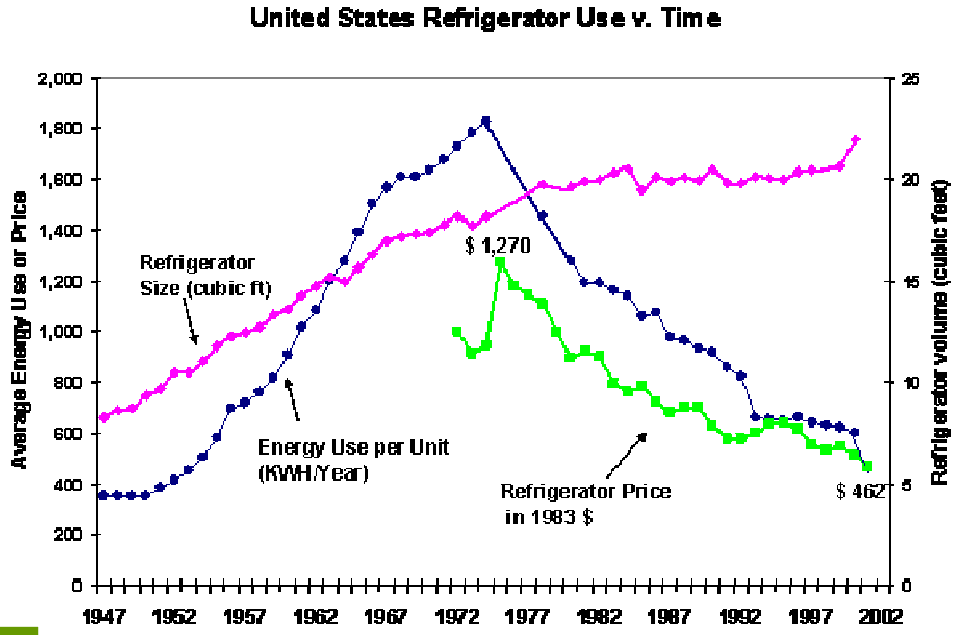


Source: EIA

efficiency is not the same as conservation

It is wholly a confusion of ideas to suppose that the economical use of fuels is equivalent to a diminished consumption. – W.S. Jevons, 1865

- **Instances**
  - Supply-limited situations
  - US refrigerators
  - US automobile fleet



US Autos (1990-2001)

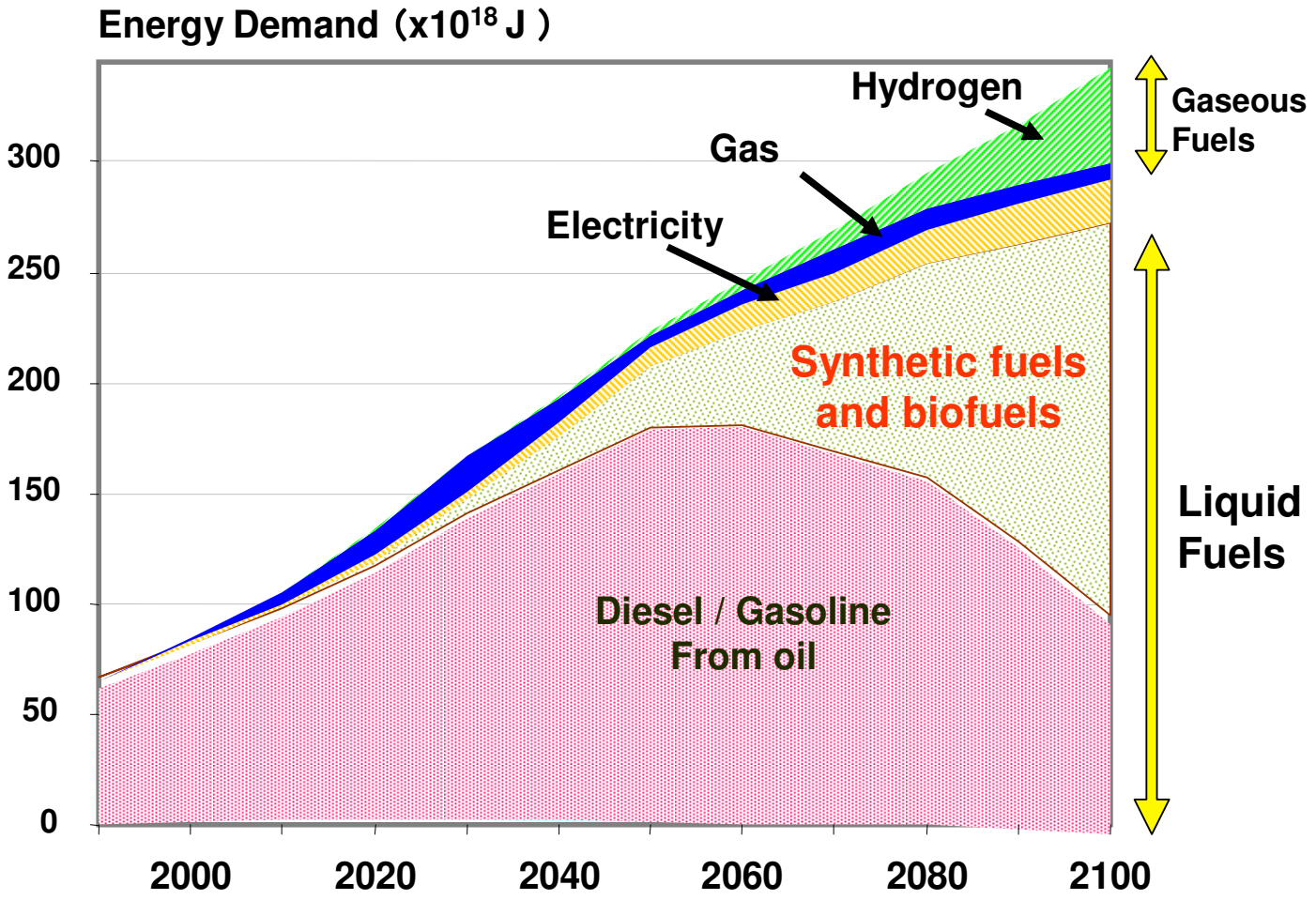
Net Miles per Gallon:	**+4.6%**
- engine efficiency:	***+23.0%***
- weight/performance:	***-18.4%***
Annual Miles Driven:	**+16%**
Annual Fuel Consumption:	**+11%**

- Price and/or policy are the surest ways to induce conservation
  - Make full cost visible at point of use
- This is politically difficult

What can we do about transport?

- **Encourage conservation (not efficiency!)**
  - raise the price of driving
  - Vehicle downsizing and lightweighting, behavior
- **Encourage novel/alternative vehicle technologies at cost (CAFÉ, …)**
  - HCCI, EGR, VVT, cylinder deactivation, …
  - Hybrids, plug-in hybrids
  - "Caution" on full electric,"no" on hydrogen

Transportation Fuel Supply and Demand



Source: IEA

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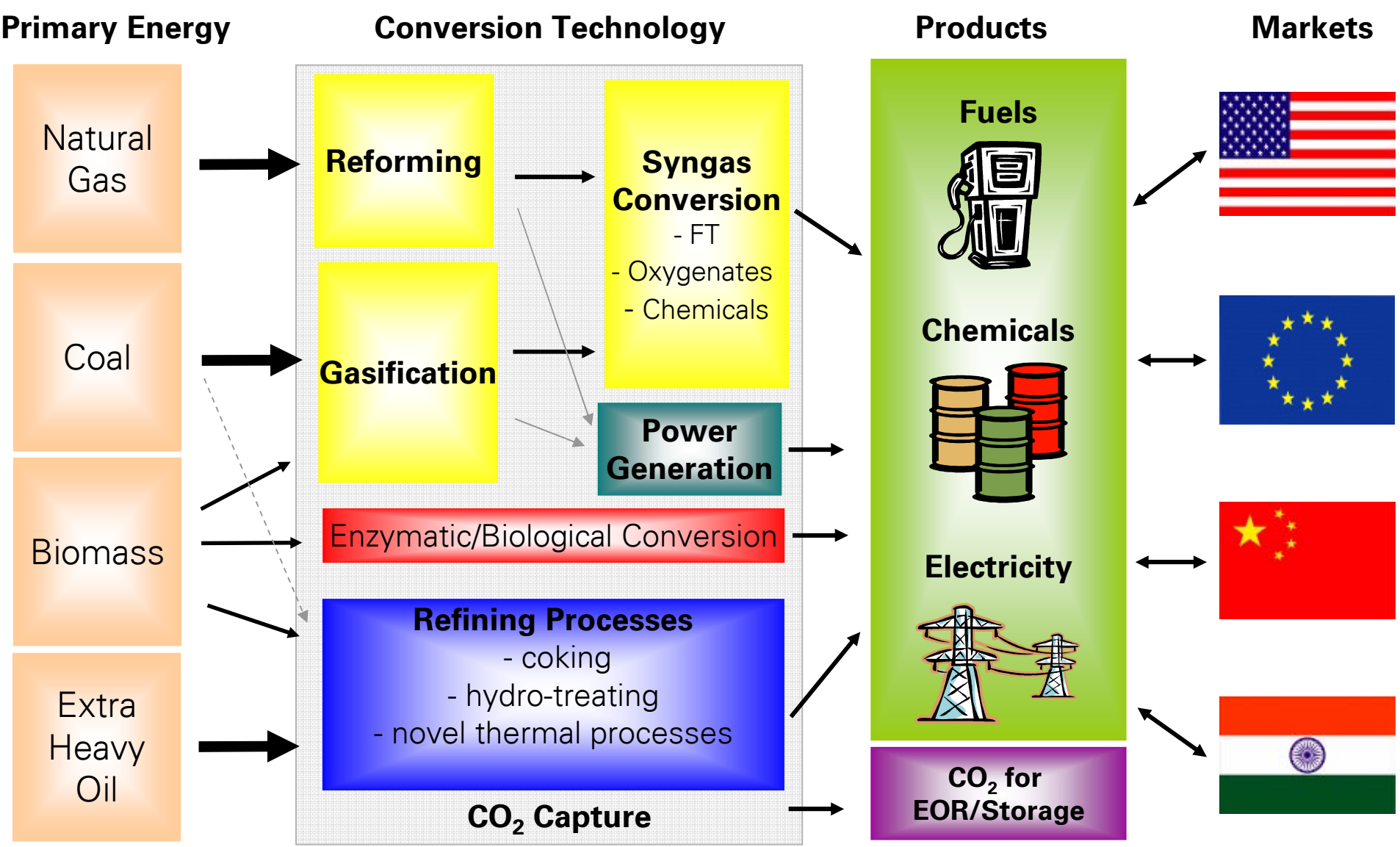
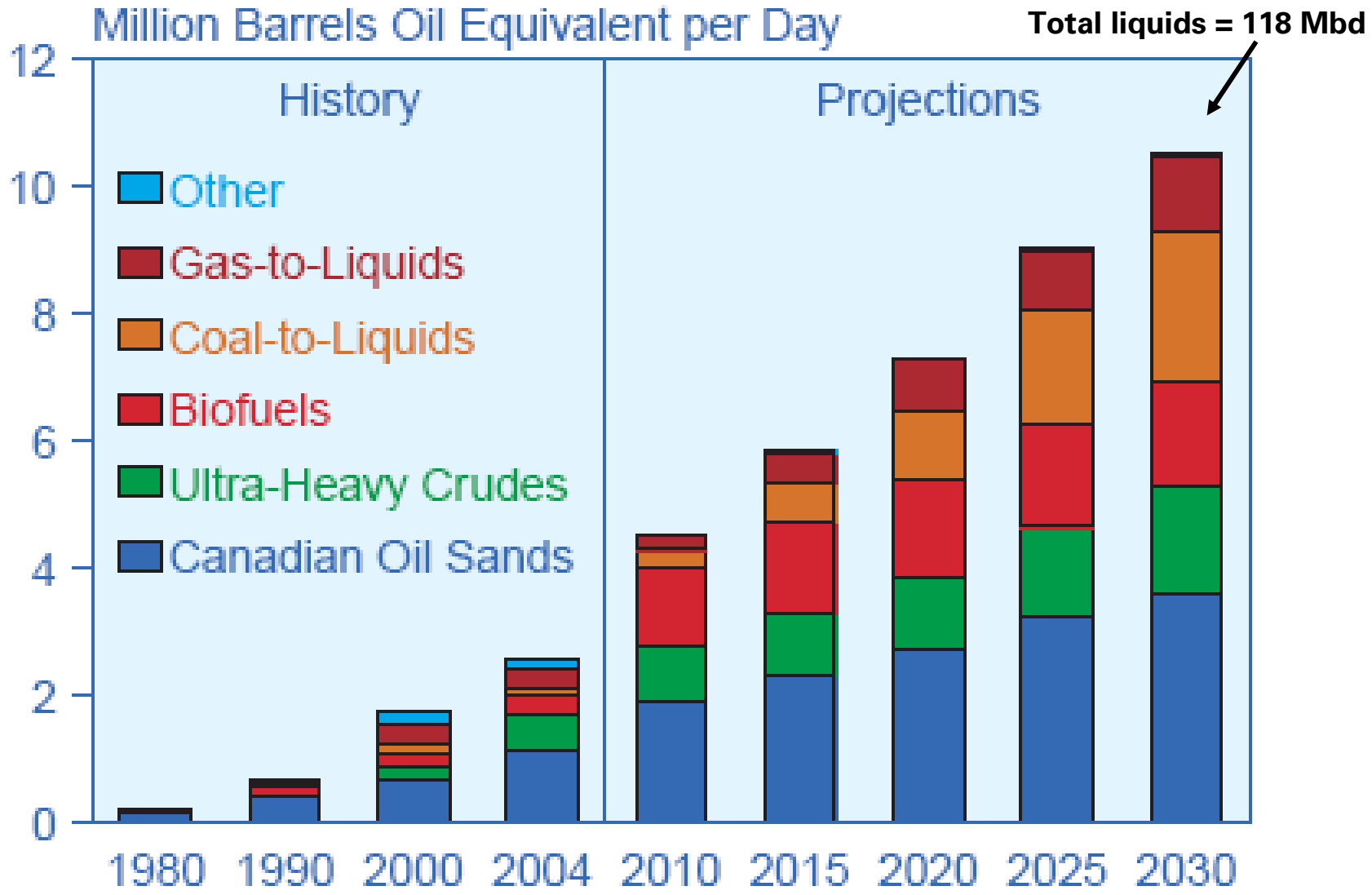
- **Encourage (with consistency) a diverse portfolio of unconventionals and alternatives**
  - Biofuels (relax the ethanol tariff, 2nd and later generations)
  - Coal to liquids, tar sands production (CO_2 mitigation?)

carbon is fungible



Growth in unconventional liquids



Source: IEA IEO 2007

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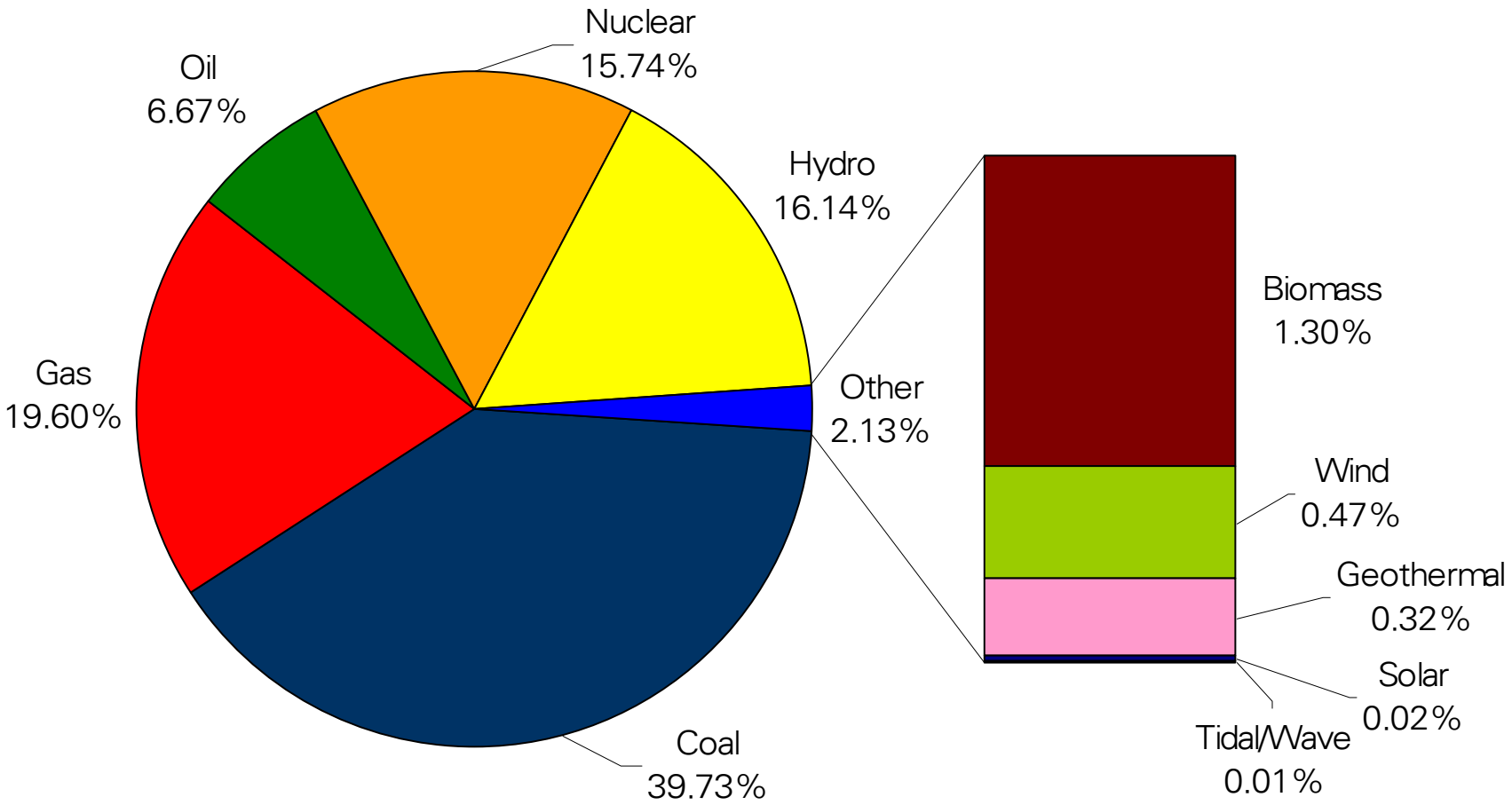
  - Biofuels (relax the ethanol tariff, 2nd and later generations)
  - Coal to liquids, tar sands (CO_2 mitigation?)
- **Expand conventional production**
  - Increased investment in producing known reserves
  - EOR for existing fields
  - US OCS (80 B bbl reserves?)

electricity generation shares by fuel - 2004

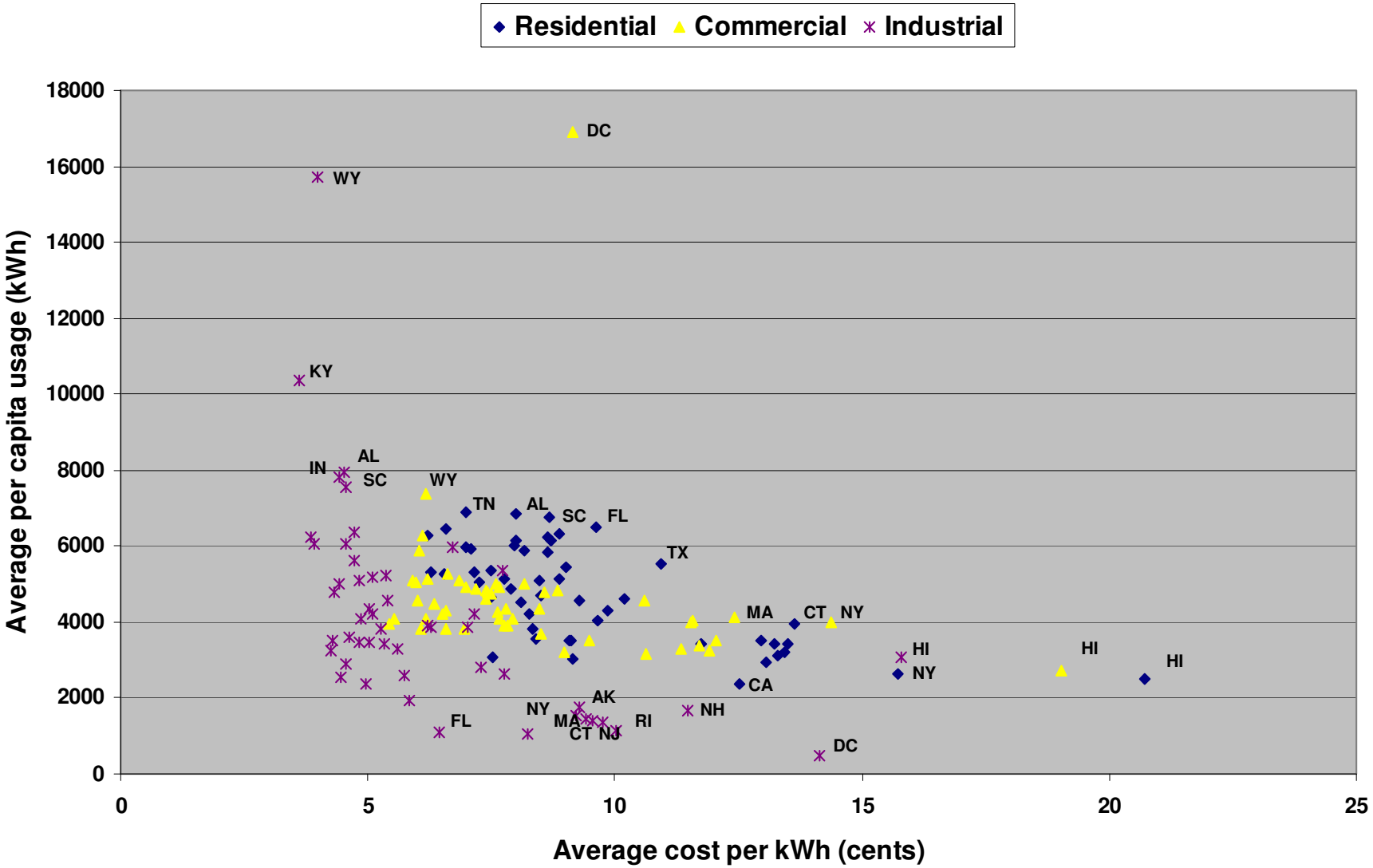


Source: IEA WEO 2006

What do we do about heat and power?

- **Conservation and efficiency**
  - raise the price of electricity and make it evident
  - efficiency standards
  - regulatory incentives
  - Building design, city design

per capita US electricity by state



potential of demand side reduction

Low Energy Buildings

- Buildings represent 40-50% of final energy consumption
- Technology exists to reduce energy demand by at least 50%
- Challenges are consumer behaviour, policy and business models

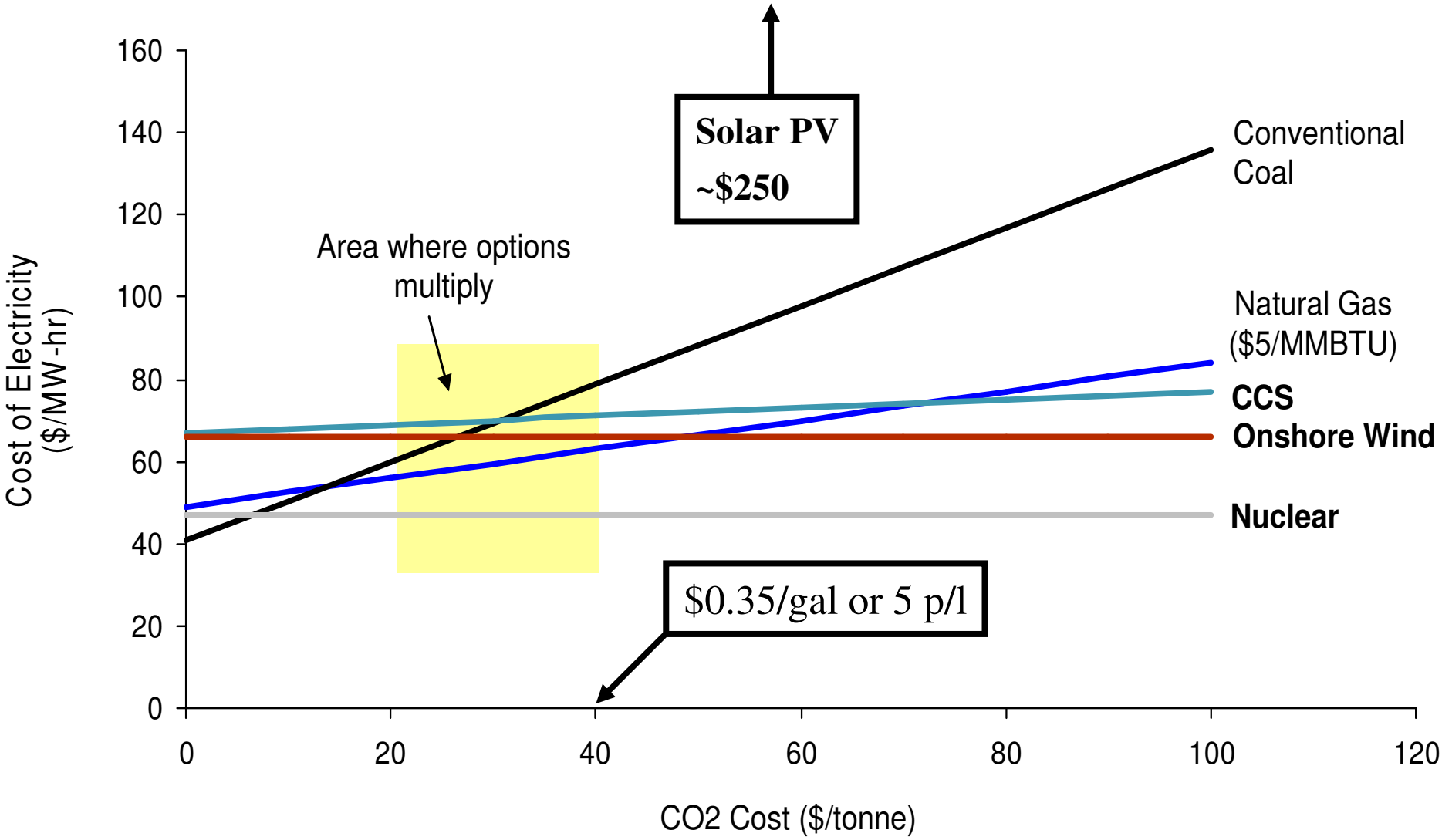
Urban Energy Systems

- 75% of the world's population will be urbanised by 2030
- Are there opportunities to integrate and optimise energy use on a city wide basis?

What do we do about heat and power?

- **Conservation and efficiency**
  - raise the price of electricity and make it evident
  - efficiency standards
  - regulatory incentives
  - Building design, city design
- **Set a price on carbon emissions**
  - A level playing field for all technologies
  - Likely "winners" will be
    - Natural gas
    - On-shore wind
    - Nuclear fission
    - Carbon capture and storage

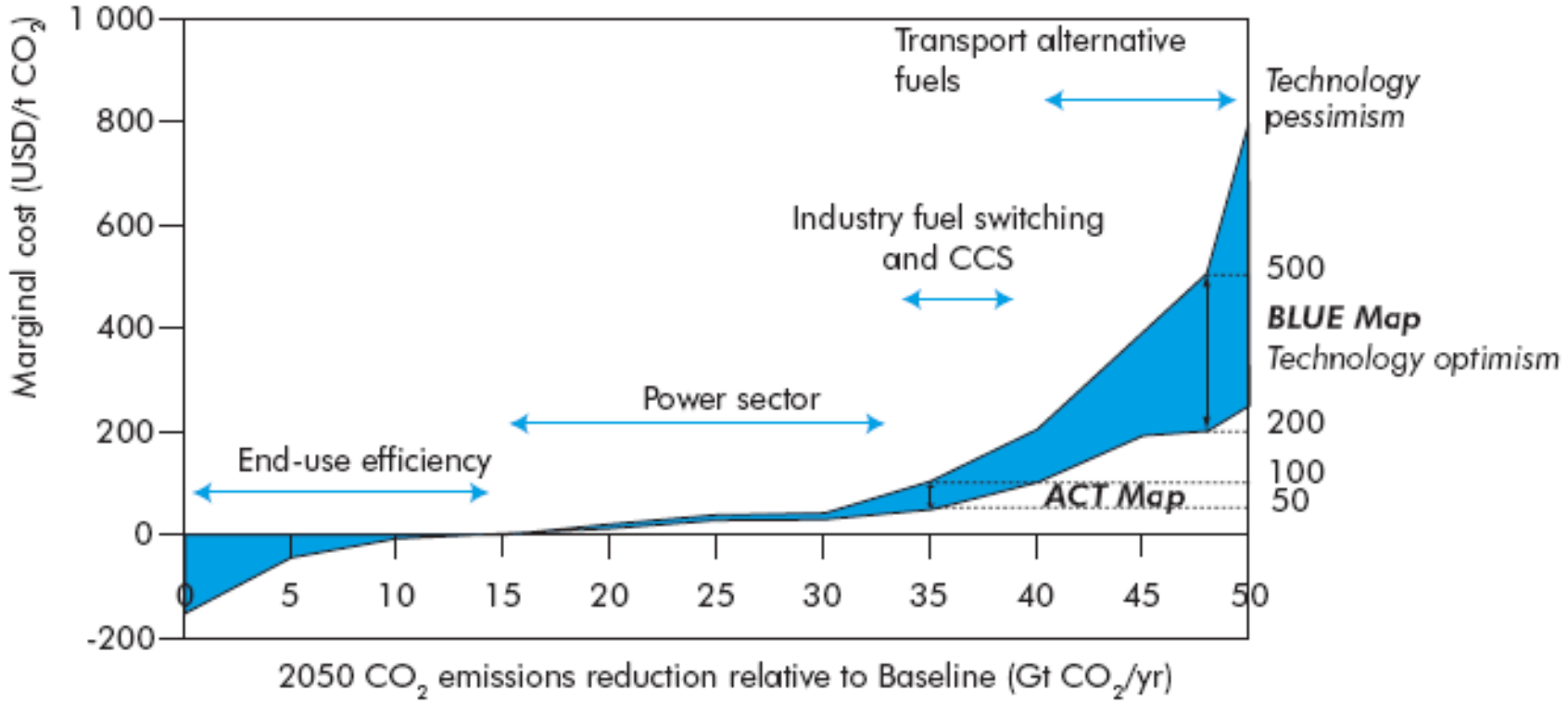
impact of CO_2 cost on levelised Cost of Electricity



Source: IEA Technology Perspectives 2006, IEA WEO 2006 and BAH analysis

IEA carbon cost curve shows similar conclusion

Figure ES.1 ▶ *Marginal emission reduction costs for the global energy system, 2050*



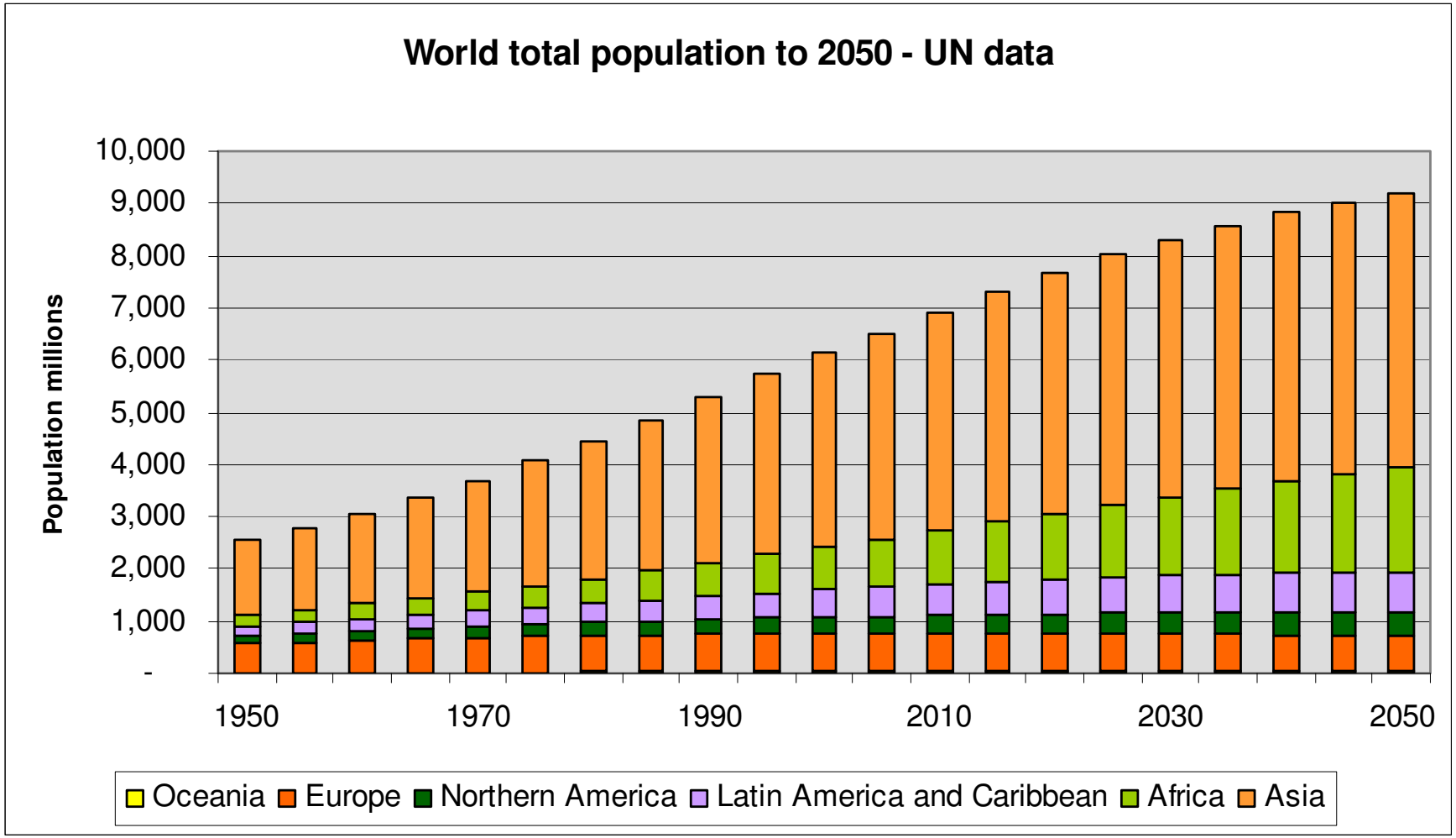
How do we get started on the solutions

- **Technically informed, coherent, stable government policies**
  - Educated decision-makers and public
  - Focus on the most material/lowest-cost measures
  - For short/mid-term technologies
    - Avoid picking winners/losers
    - Level playing field for all applicable technologies
  - For longer-term technologies
    - Support for pre-competitive research
      - Hydrates, fusion, advanced [fission, PV, biofuels, …]
- **Business needs reasonable expectation of "price of carbon"**
  - The "right" price applied universally with long-term consistency
  - Transparent and ring-fenced use of carbon revenues
  - Mitigation of impacts on the poor
- **Universities/labs must recognize and act on importance of energy research**
  - Technology, economics, and policy

What is Plan B for climate change?

- **The world should make its best effort to stabilize GHG concentrations through conservation, decarbonization of the energy supply, and reducing non-energy emissions**
- **But it is possible that levels deemed "safe" will be exceeded**
- **The CO_2 will remain in the atmosphere for many centuries**
- **The response beyond continued conservation and decarbonization would depend upon how severe the impacts are**
- **Adaptation (will be happening anyway)**
  - Hardening of infrastructure (insulation, dams, seawalls, aqueducts, …)
  - Shifts in agricultural patterns, population
  - Proportional, local, immediate
  - Costs? The ability to pay?
- **Climate engineering is a last resort for "climate emergencies"**
  - Albedo modification (need only to go from 0.30 to 0.31)
    - In space, in the atmosphere, at the surface
    - At best a palliative response (rebound, continued ocean acidification)
  - Removal of GHGs from the atmosphere (probably biological)
    - Annual carbon exchange with the atmosphere is ~200 Gt vs fossil fuels increment of ~8 Gt

Energy is only one aspect of "The Problem"



Energy Trends and Technologies Video at

http://clients.mediaondemand.net/BP/#

Questions/Comments/Discussion