Technologies for secure and sustainable energy

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Future Energy: Chemical Solutions
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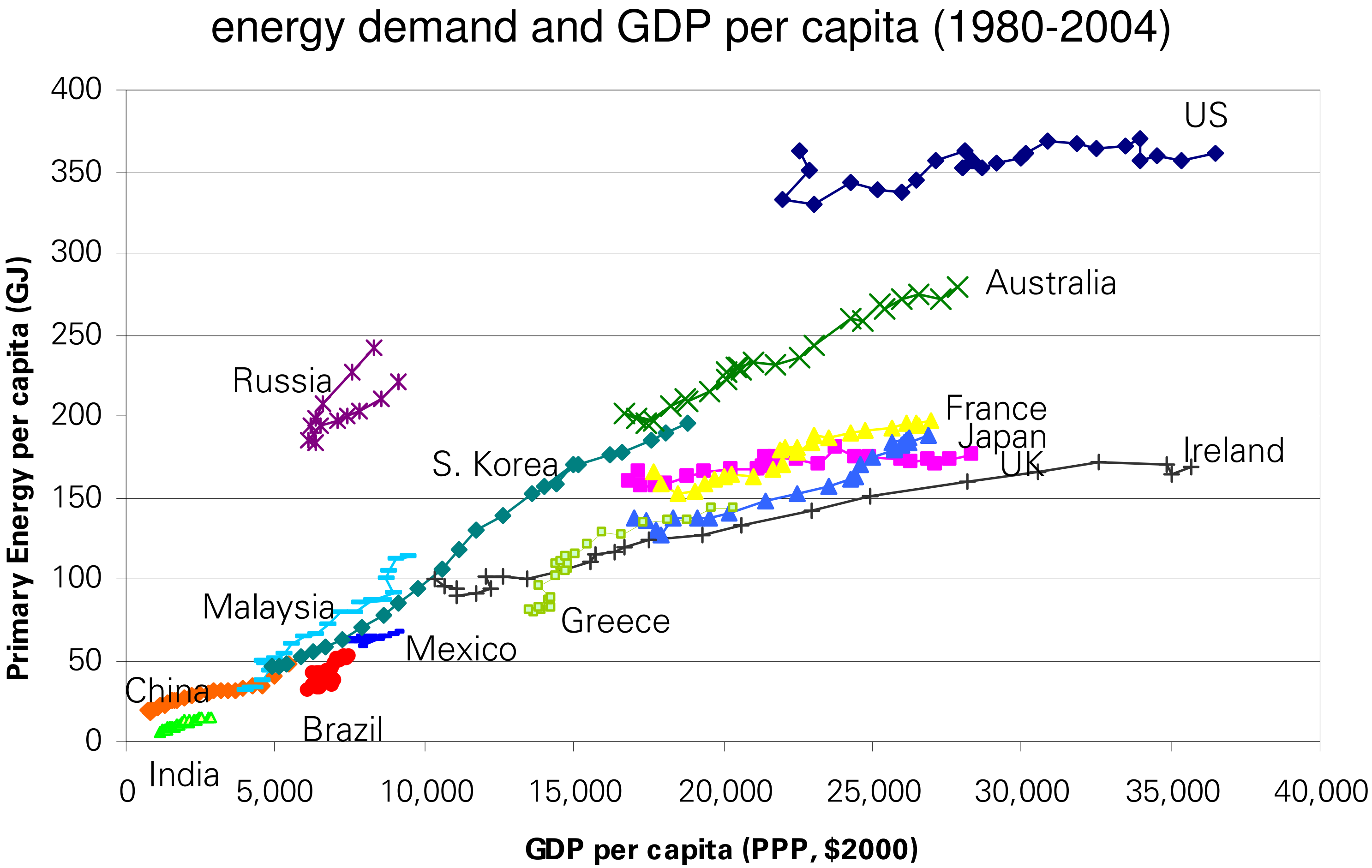
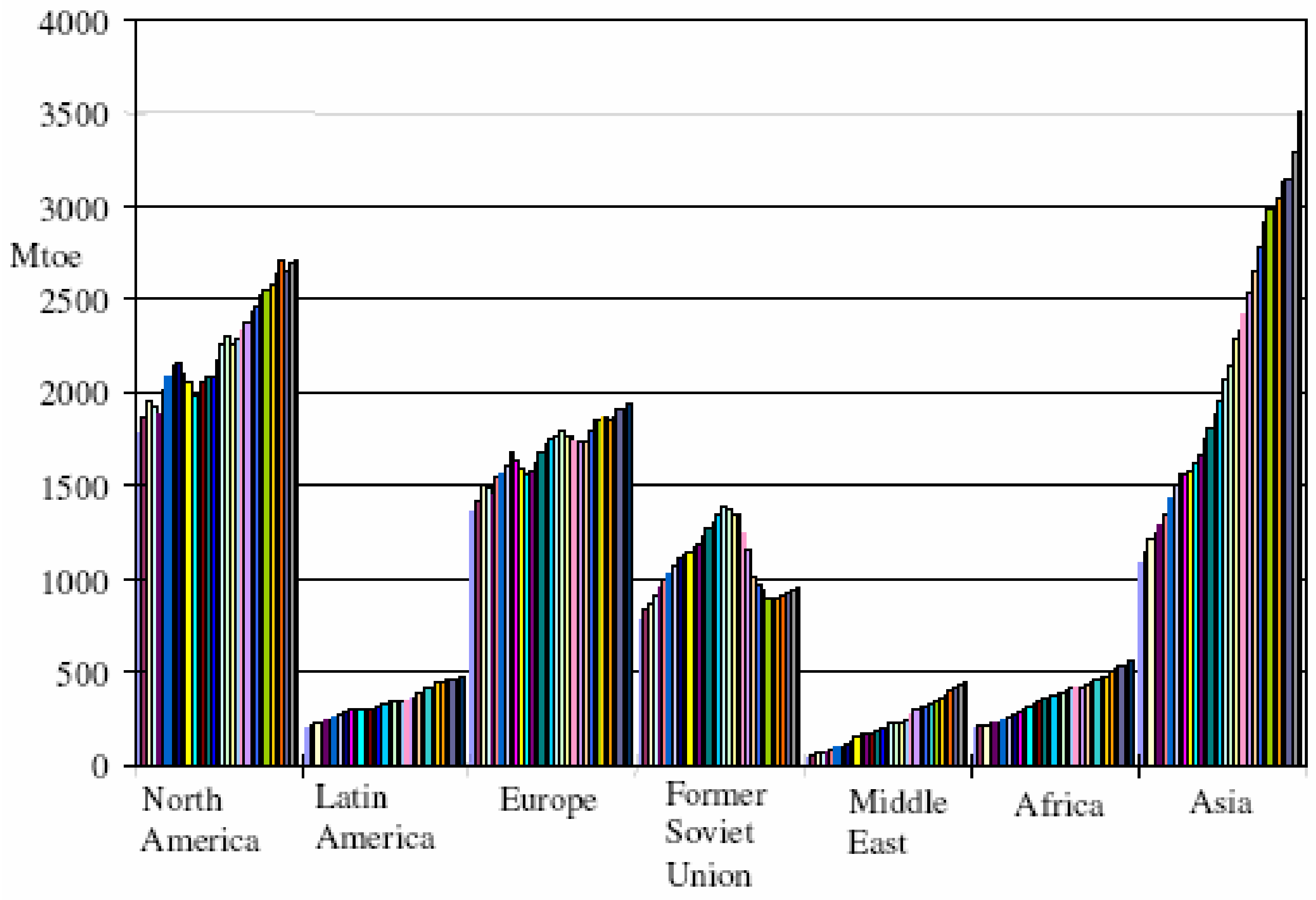
energy use grows with economic development



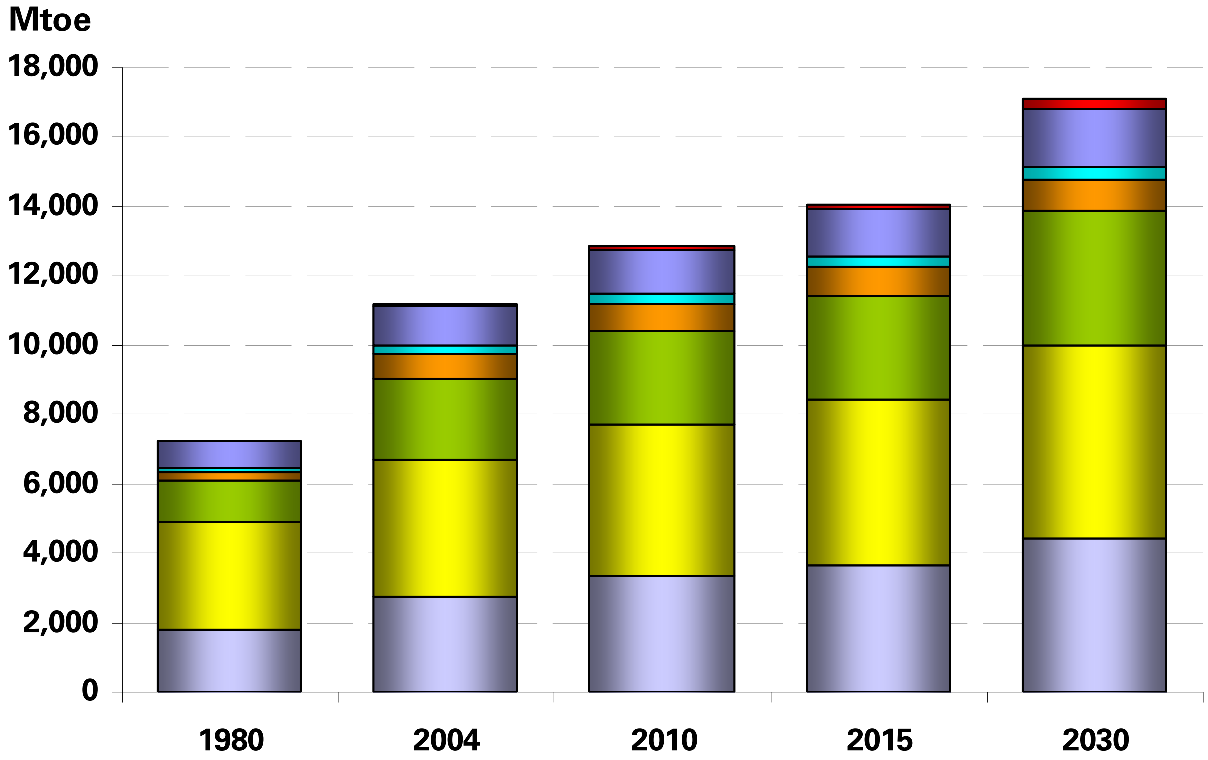
Source: UN and DOE EIA
Russia data 1992-2004 only

annual primary energy demand 1971-2003



Source IEA, 2004   (Excludes biomass)

BAU projection of primary energy sources

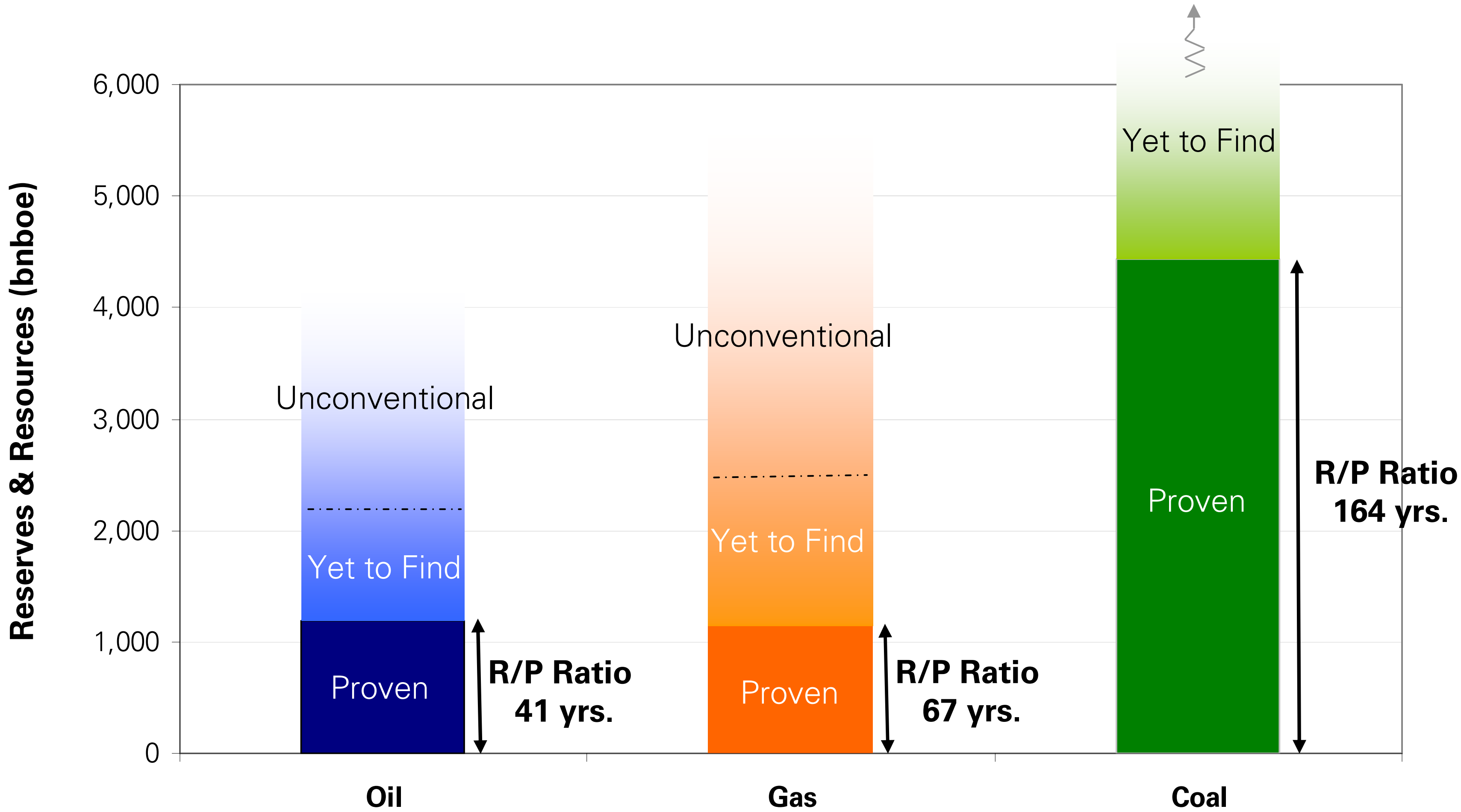


	'04 – '30 Annual Growth Rate (%)
Other Renewables	6.5
Biomass & waste	1.3
Hydro	2.0
Nuclear	0.7
Gas	2.0
Oil	1.3
Coal	1.8
Total	**1.6**

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

Source: IEA World Energy Outlook 2006 (Reference Case)

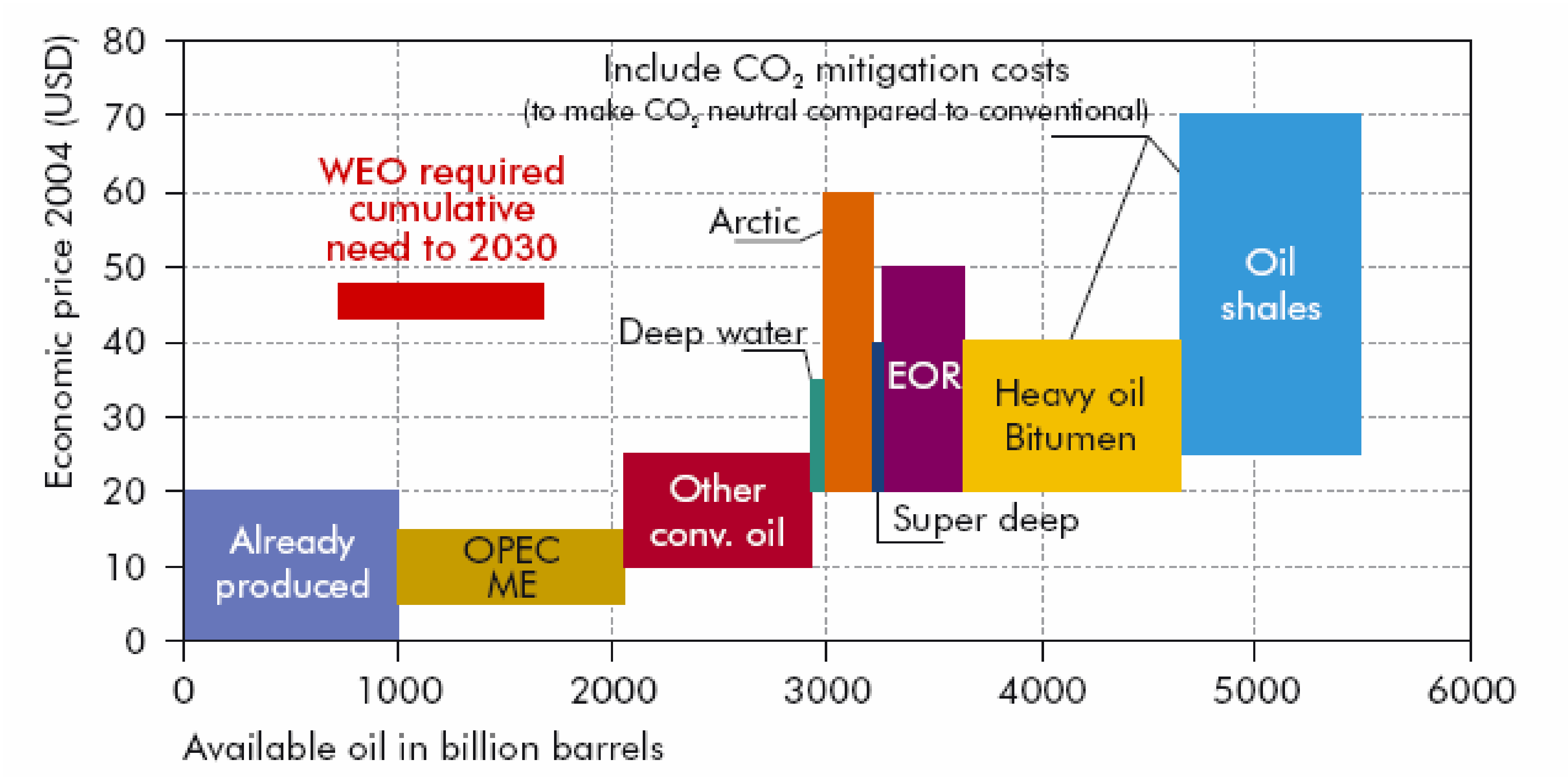
substantial global fossil resources



Source: World Energy Assessment 2001, HIS, WoodMackenzie, BP Stat Review 2005, BP estimates

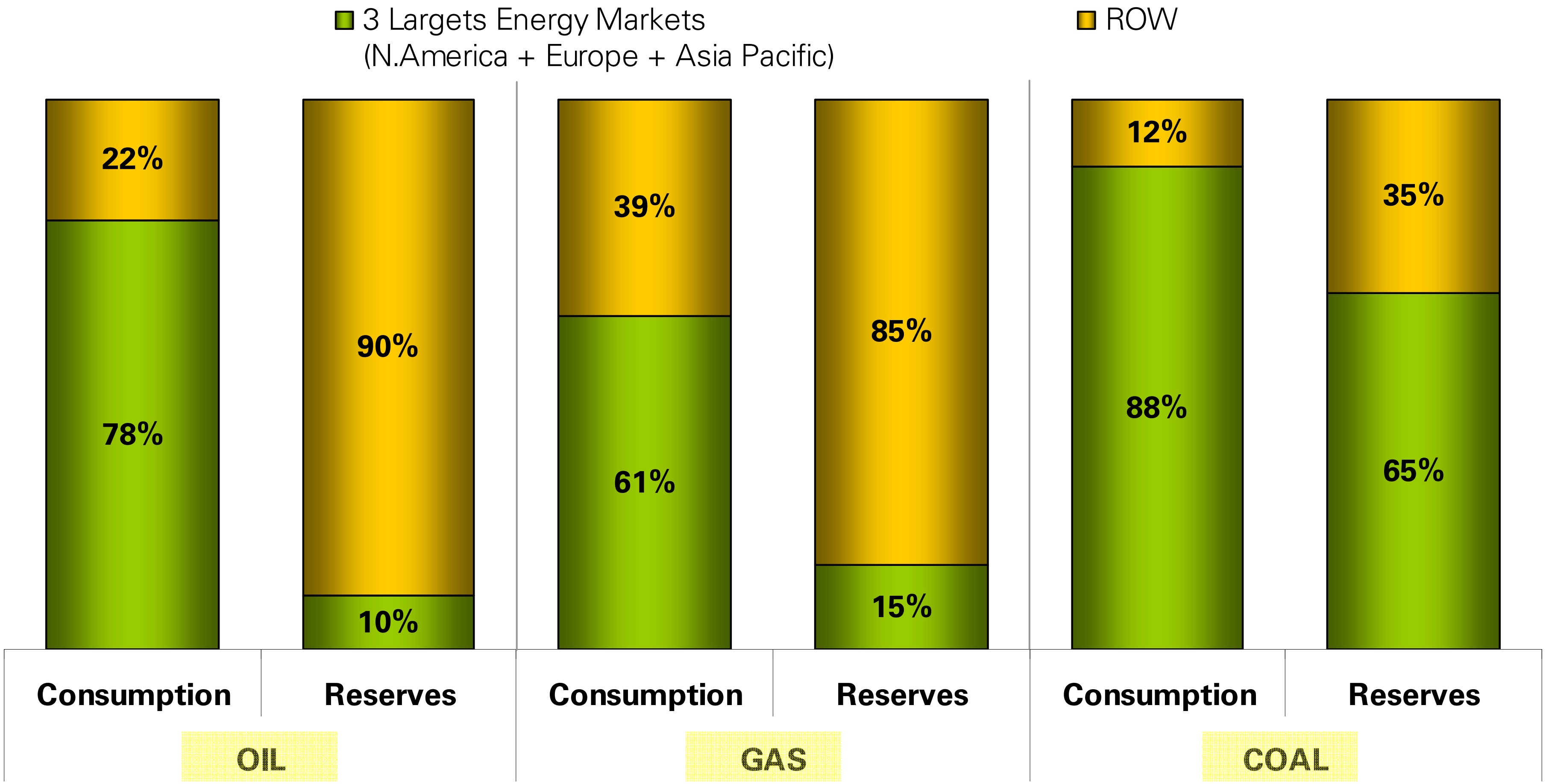
oil supply and cost curve

Availability of oil resources as a function of economic price



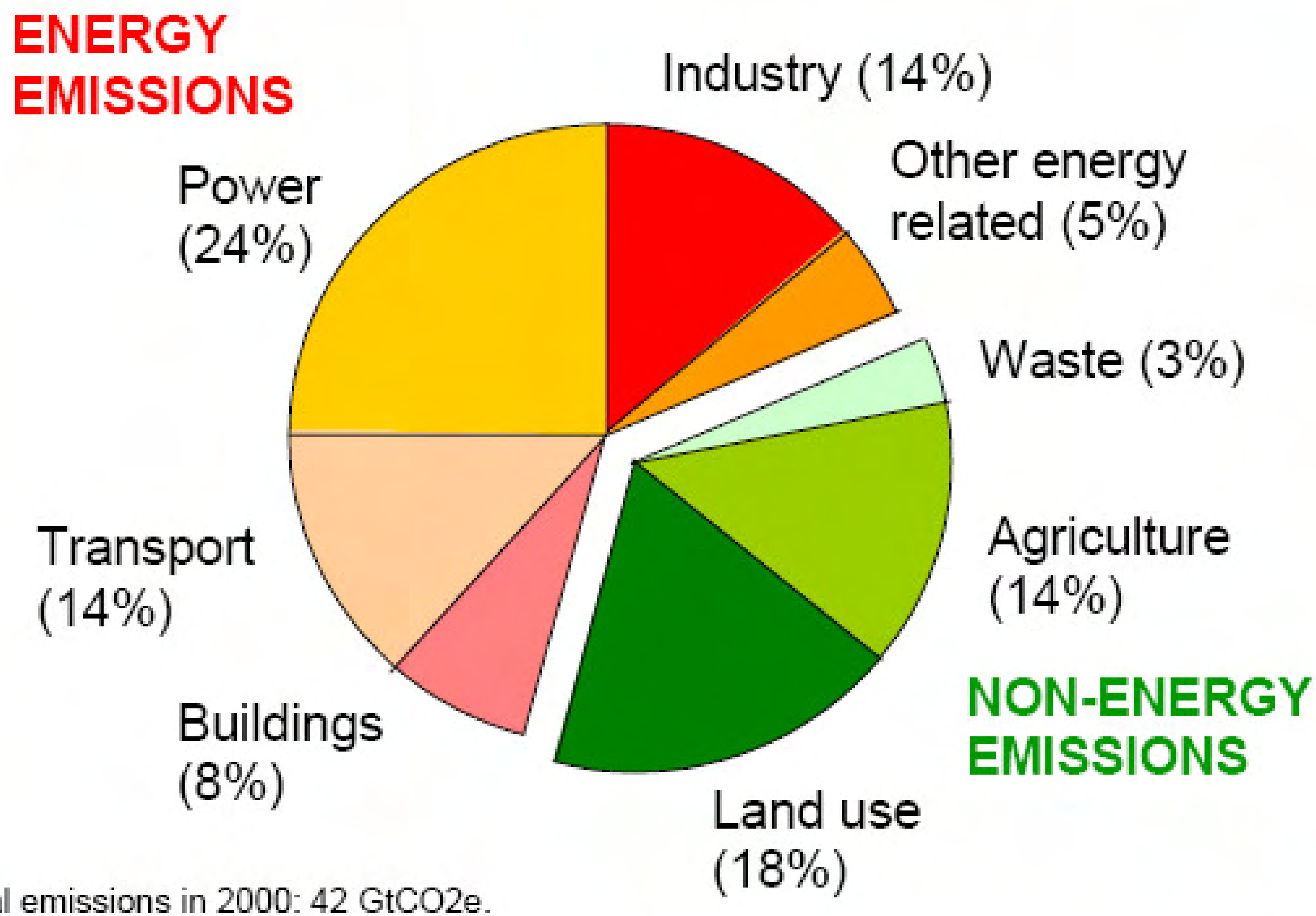
Source: IEA (2005)

dislocation of fossil fuel supply & demand



Source: BP Statistical Review 2006

greenhouse gas emissions in 2000 by source

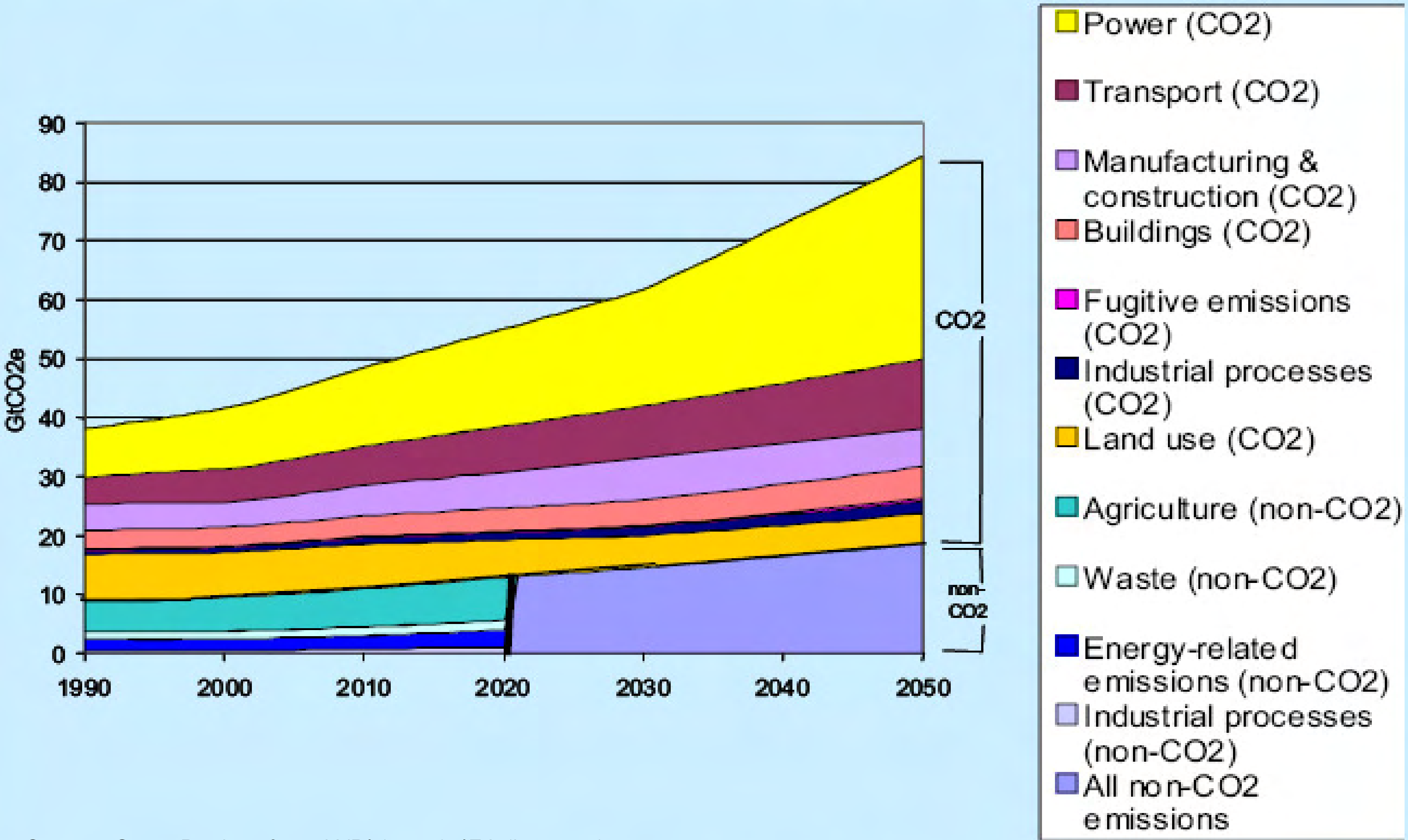


Total emissions in 2000: 42 GtCO2e.

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

historical and projected GHG emissions by sector



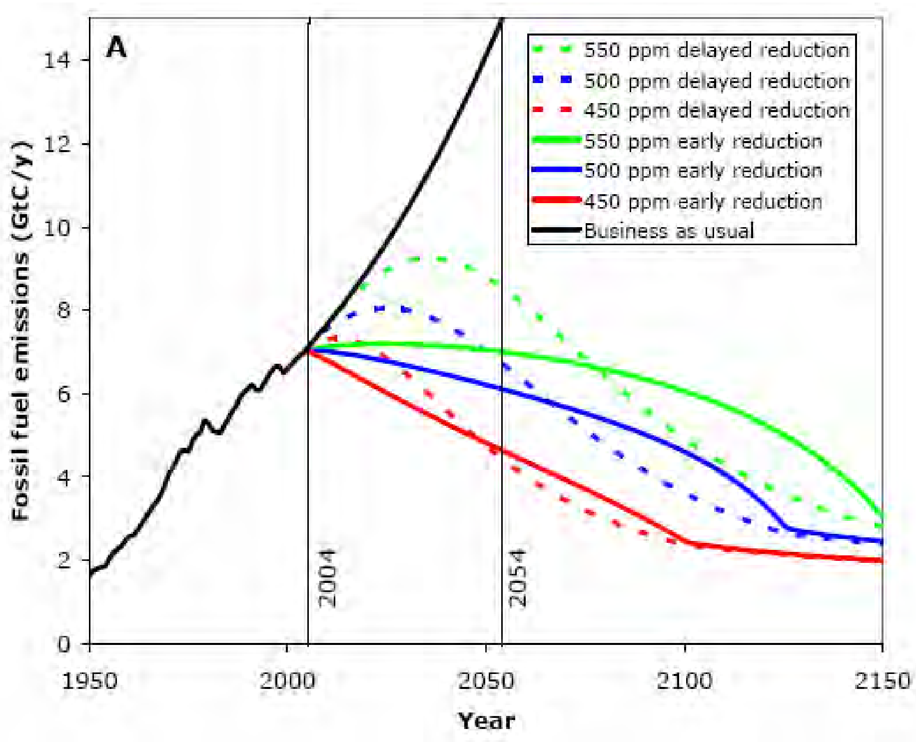
Source: Stern Review from WRI (2006), IEA (in press), IEA (2006), EPA (forthcoming), Houghton (2005).

crucial facts about CO_2 science

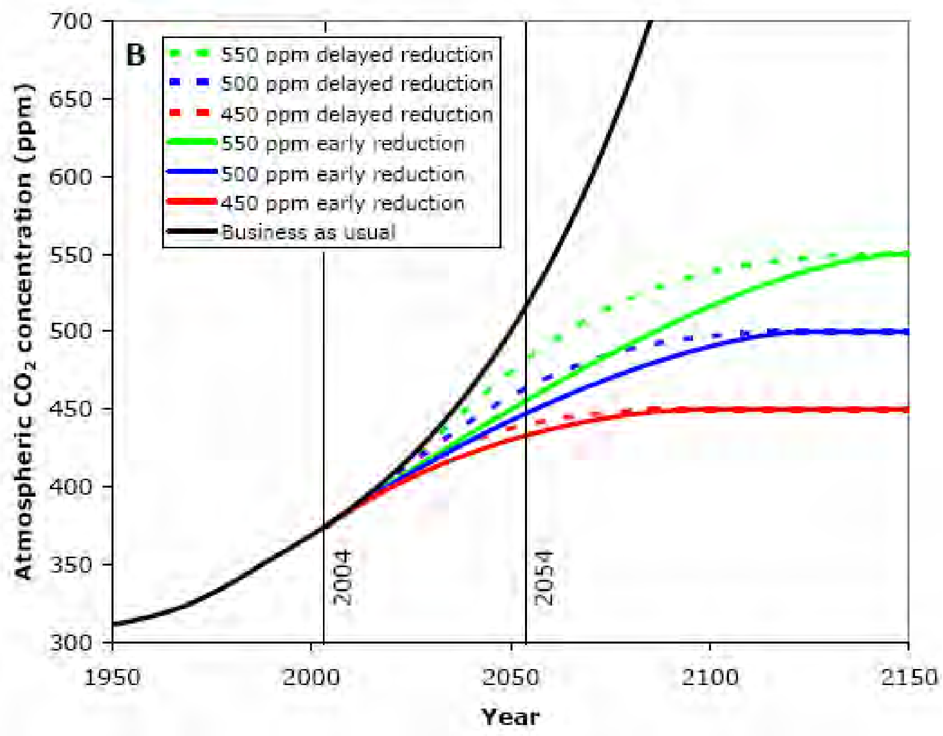
- **The earth absorbs anthropogenic CO_2 at a limited rate**
  - **Emissions would have to drop to about half of their current value by the end of this century to stabilize atmospheric concentration at 550 ppm**
  - **This in the face of a doubling of energy demand in the next 50 years (1.5% per year emissions growth)**
- **The lifetime of CO_2 in the atmosphere is ~ 1000 years**
  - **The atmosphere will accumulate emissions during the 21st Century**
  - **Modest emissions reductions only delay the growth of concentration (20% emissions reduction buys 15 years)**

some stabilization scenarios

Emissions

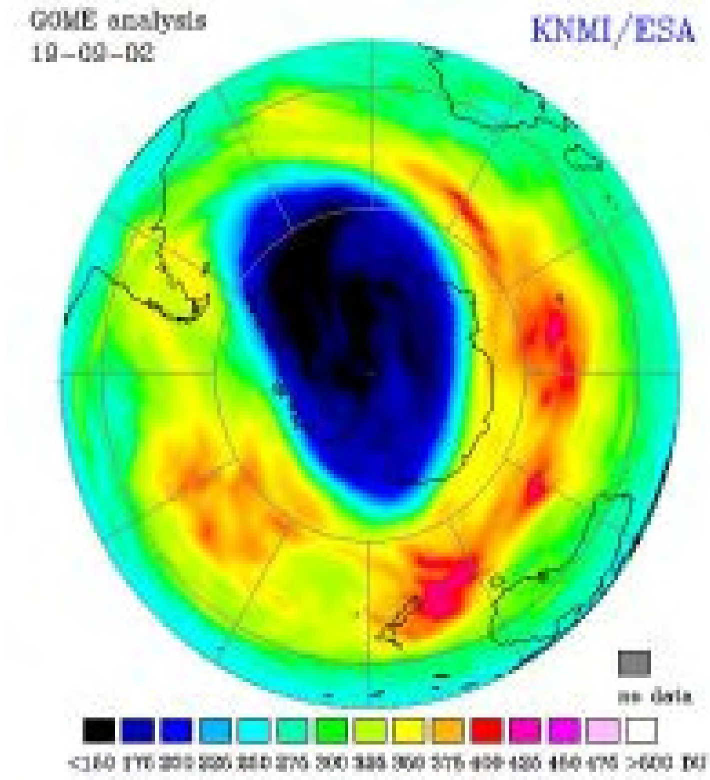


Concentration

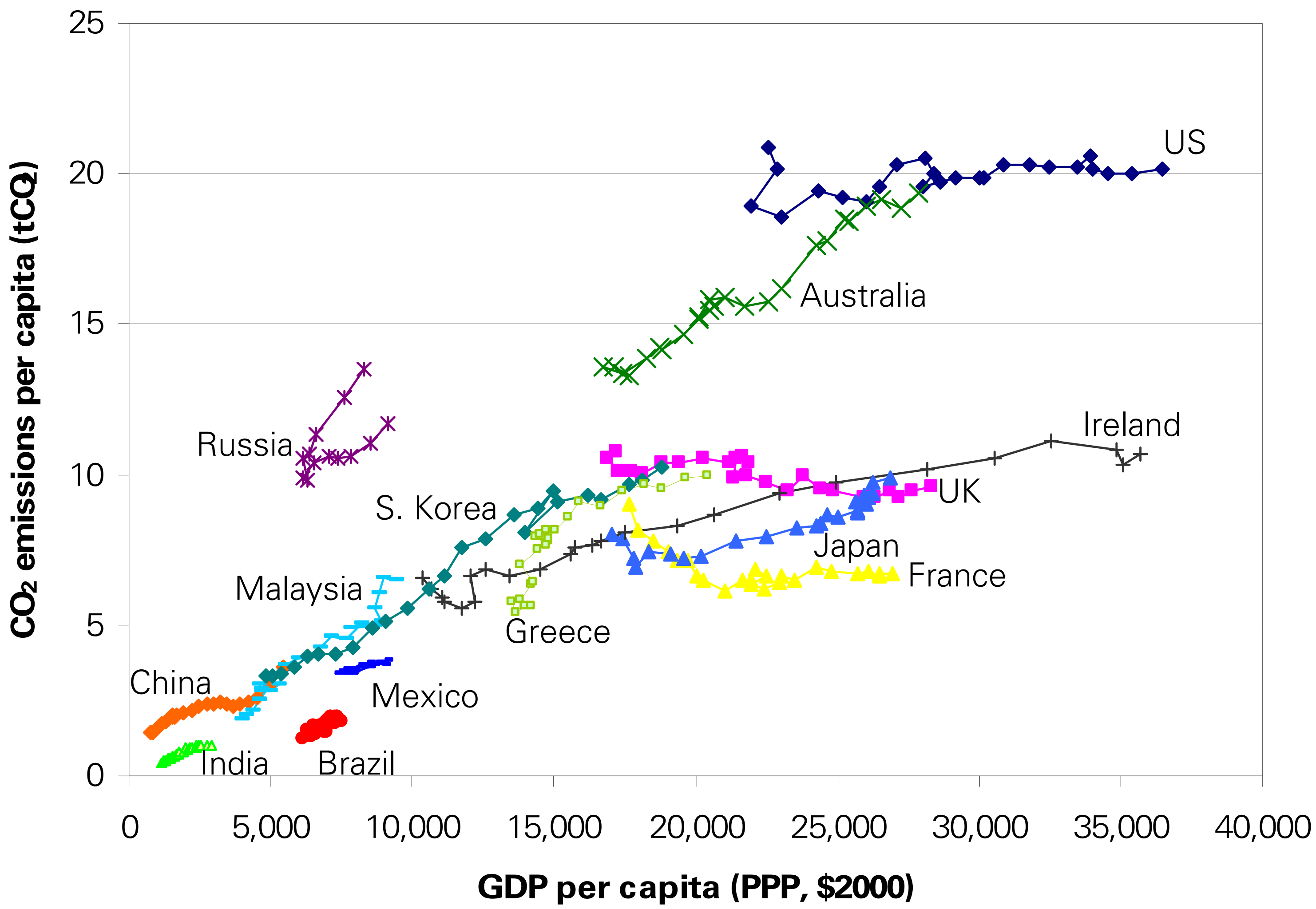


social barriers to meaningful emissions reductions

- **Climate threat is intangible and diffuse; can be obscured by natural variability**
  - contrast ozone, air pollution
- **Energy is at the heart of economic activity**
- **CO_2 timescales are poorly matched to the political process**
  - Buildup and lifetime are centennial scale
  - Energy infrastructure takes decades to replace
    - Power plants being planned now will be emitting in 2050
    - Autos last 20 years; buildings 100 years
  - Political cycle is ~6 years; news cycle ~1 day
- **There will be inevitable distractions**
  - a few years of cooling
  - economic downturns
  - unforeseen expenses (e.g., Iraq, tsunamis, …)
- **Emissions, economics, and the priority of the threat vary greatly around the world**



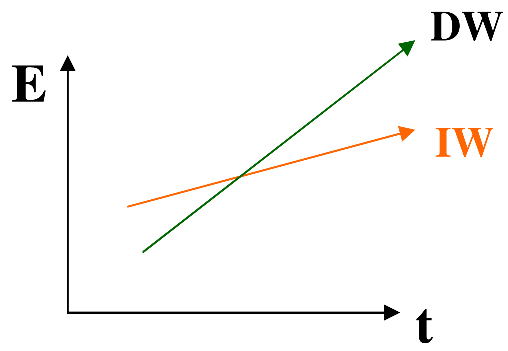
CO_2 emissions and GDP per capita (1980-2004)



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

implications of emissions heterogeneities

- **21st Century emissions from the Developing World (DW) will be more important than those from the Industrialized World (IW)**
  - DW emissions growing at 2.8% vs IW growing at 1.2%
  - DW will surpass IW during 2015 - 2025



- **Sobering facts**
  - When DW ~ IW, each 10% reduction in IW emissions is compensated by *< 4 years* of DW growth
  - If China's (or India's) per capita emissions were those of Japan, global emissions would be 40% higher
- **Reducing emissions is an enormous, complex challenge; technology development will play a central role**

Distinguishing aspects of energy technologies

- **Scale**
  - Large infrastructure, amounts of material, numbers of units
  - Requires large capital, leverage of existing infrastructure
- **Ubiquity**
  - There are many players with sometimes divergent interests
  - Consumers, suppliers, governments, NGOs, …
- **Longevity**
  - Lifetimes of large equipment and/or interoperability imply slow changes
- **Incumbency**
  - New energy technologies must compete on cost
  - May not provide any qualitatively new service to the end-user

some energy technologies

Primary Energy Sources:

- Light Crude
- Heavy Oil
- Tar Sands
- Wet gas
- CBM
- Tight gas
- Nuclear
- Coal
- Solar
- Wind
- Biomass
- Hydro
- Geothermal

Extraction & Conversion Technologies:

- Exploration
- Deeper water
- Arctic
- LNG
- Refining
- Differentiated fuels
- Advantaged chemicals
- Gasification
- Syngas conversion
- Power generation
- Photovoltaics
- Bio-enzyimatics
- H_2 production & distribution
- CO_2 capture & storage

End Use Technologies:

- ICEs
- Adv. Batteries
- Hybridisation
- Fuel cells
- Hydrogen storage
- Gas turbines
- Building efficiency
- Urban infrastructure
- Systems design
- Other efficiency technologies
- Appliances
- Retail technologies

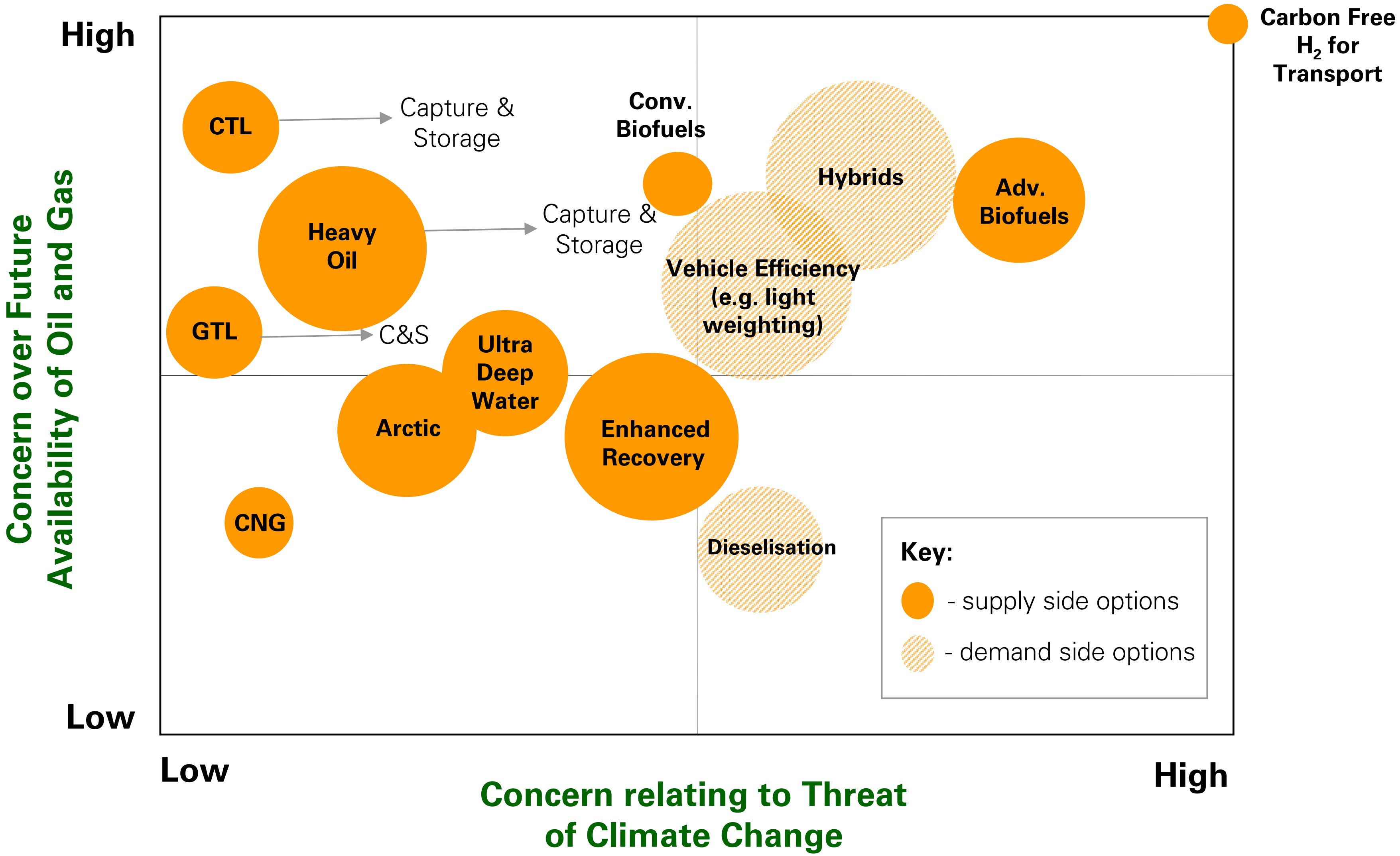
There are no "silver bullets"
But some have a larger calibre than others !

evaluating energy technology options

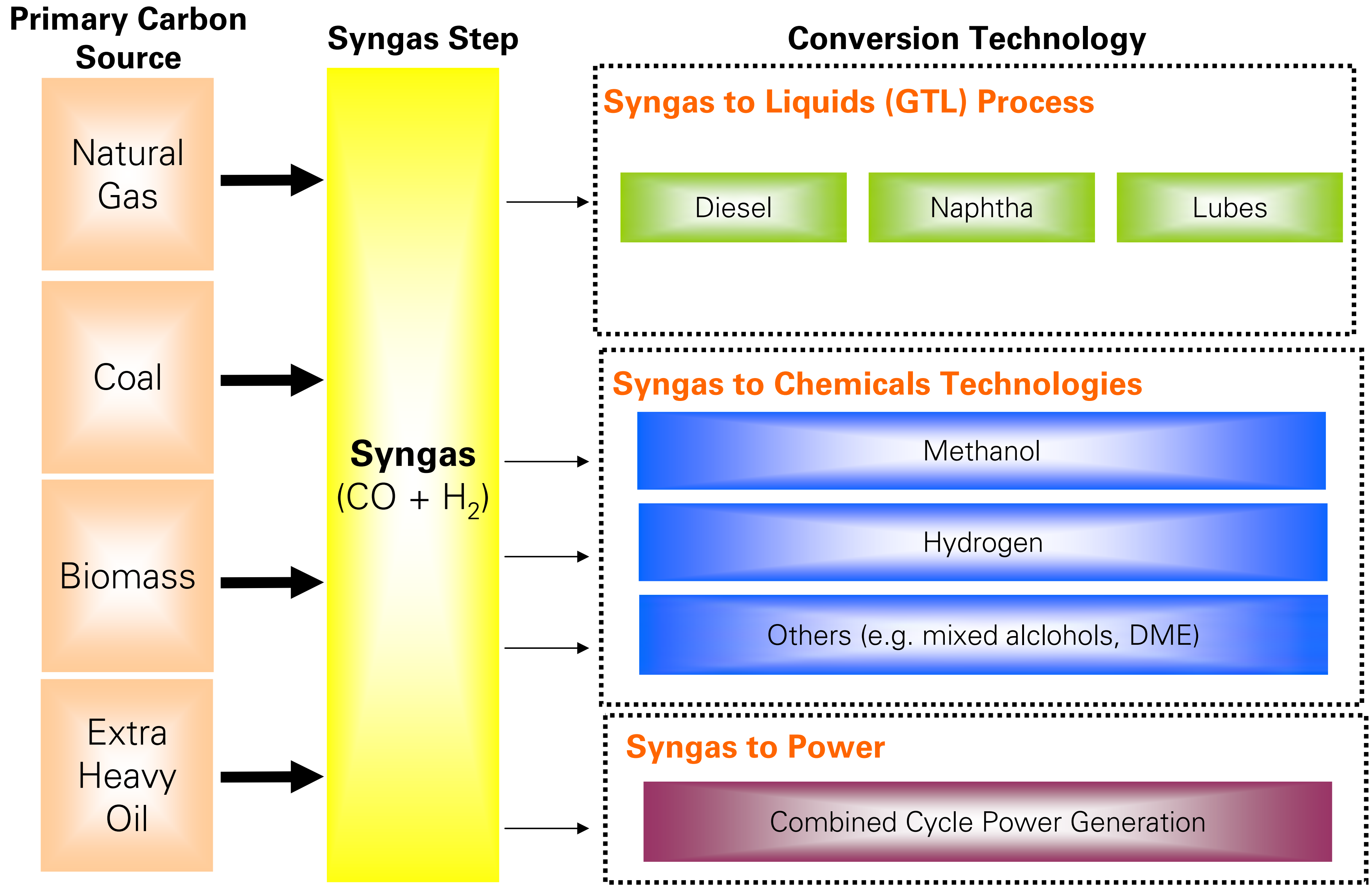
- Current **technology status** and plausible **technical headroom**
- **Budgets** for the three E's:
  - **Economic** (cost relative to other options)
  - **Energy** (output how many times greater than input)
  - **Emissions** (pollution and CO_2; operations and capital)
- **Materiality** (at least 1TW = 5% of 2050 BAU energy demand)
- **Other costs** - reliability, intermittency etc.
- Social and political **acceptability**

we also must know what problem we are trying to solve

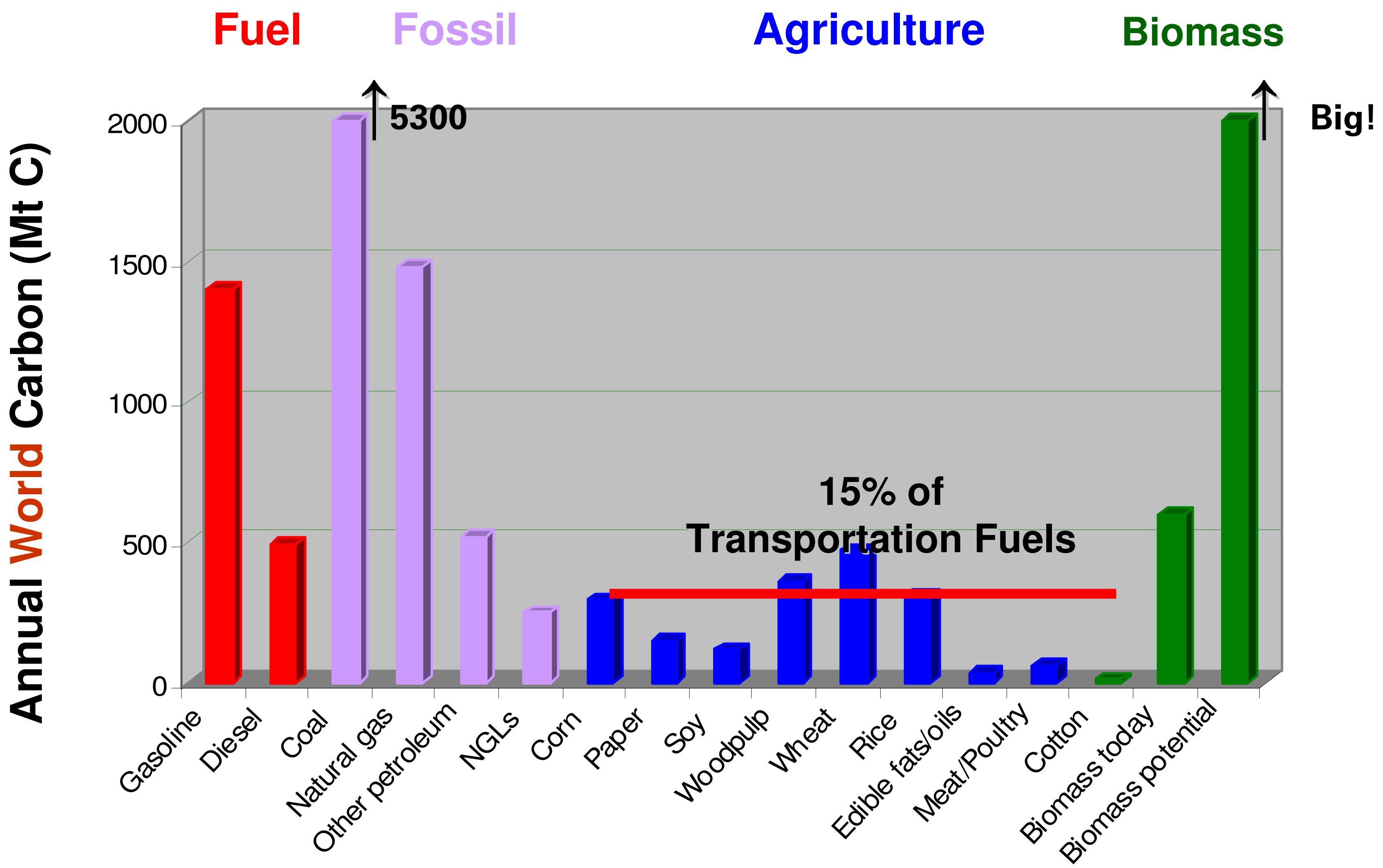
two key energy considerations – security & climate



the fungibility of carbon

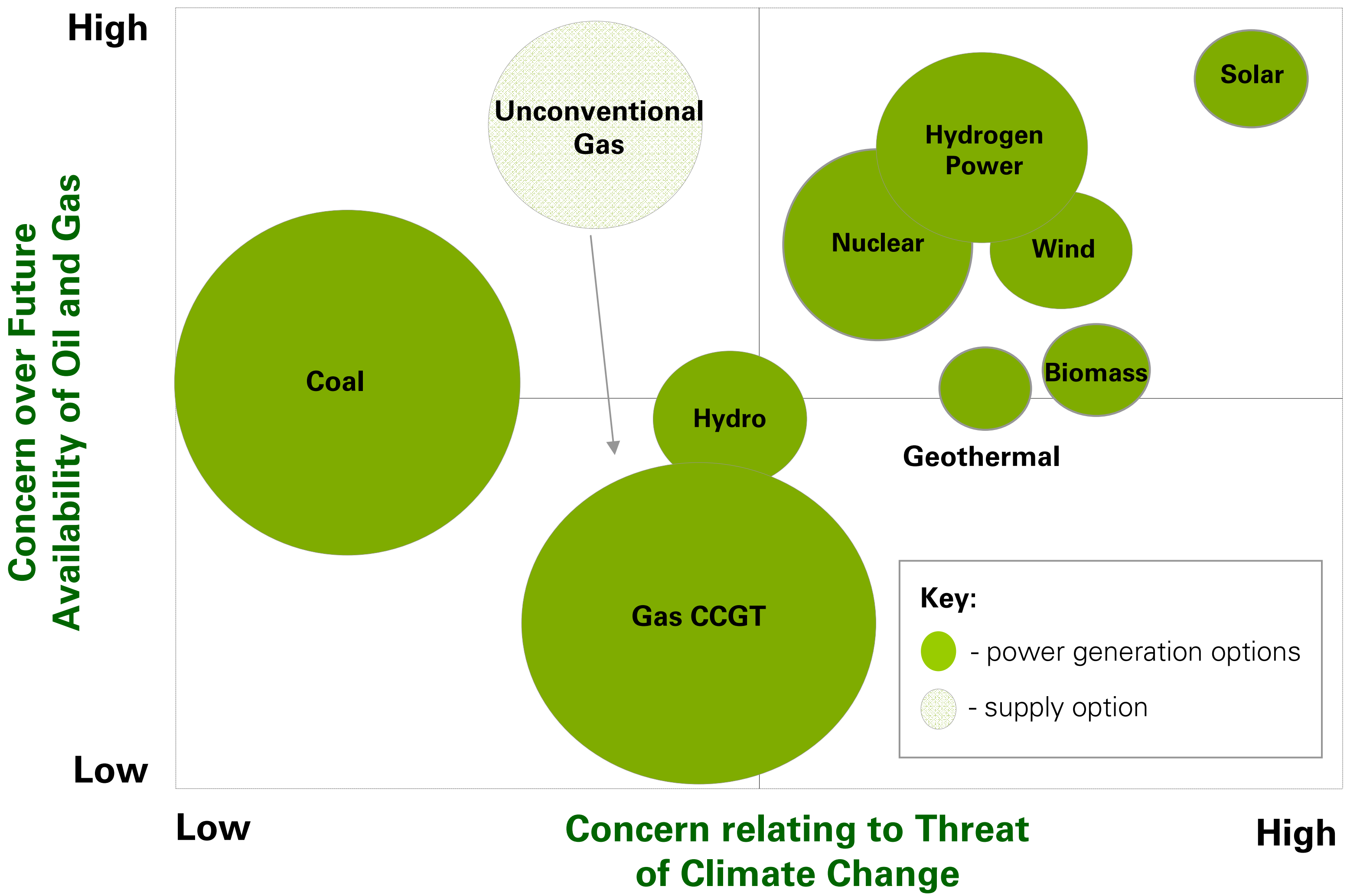


what carbon "beyond petroleum"?

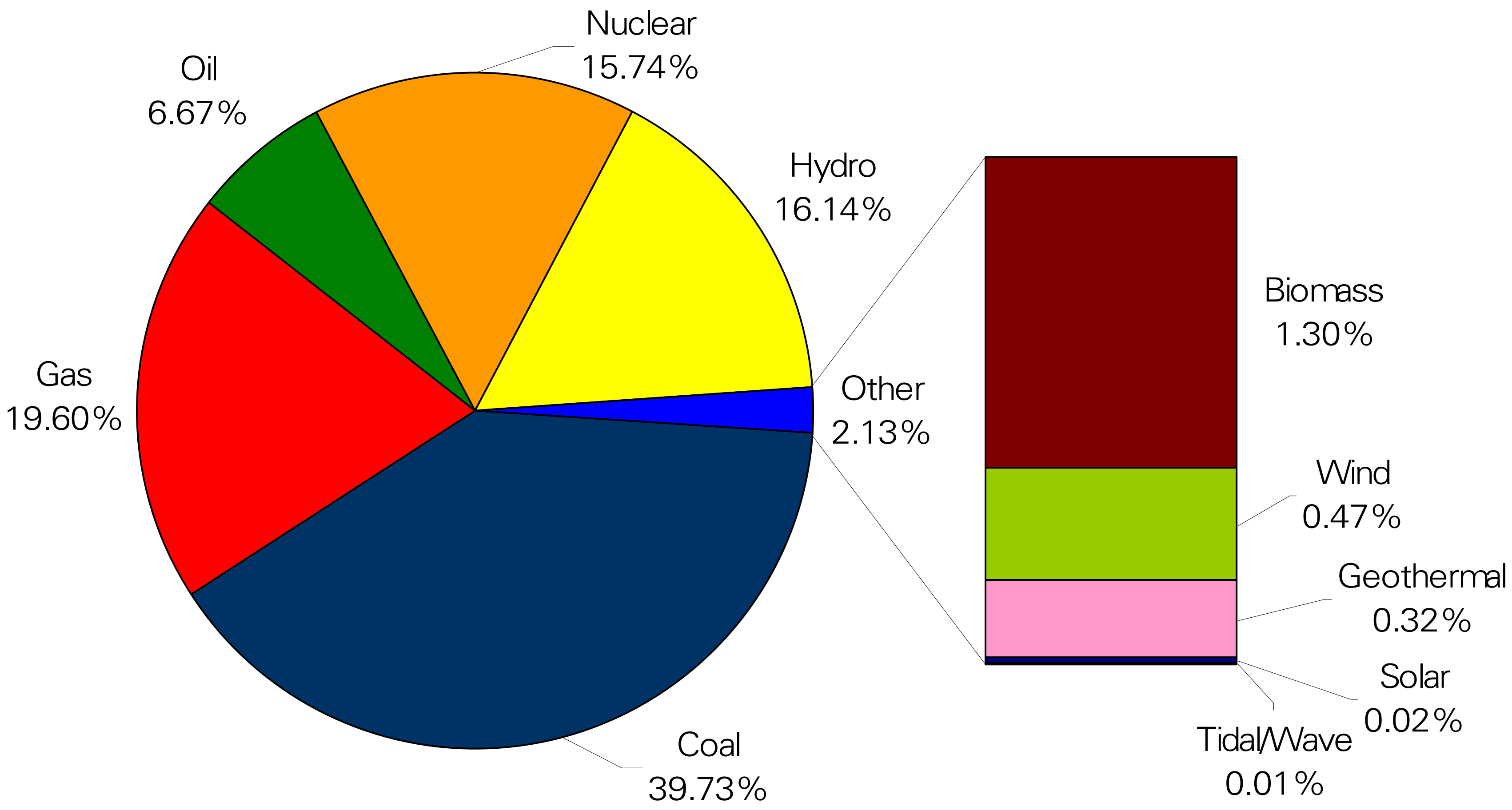


evaluating power options

power sector

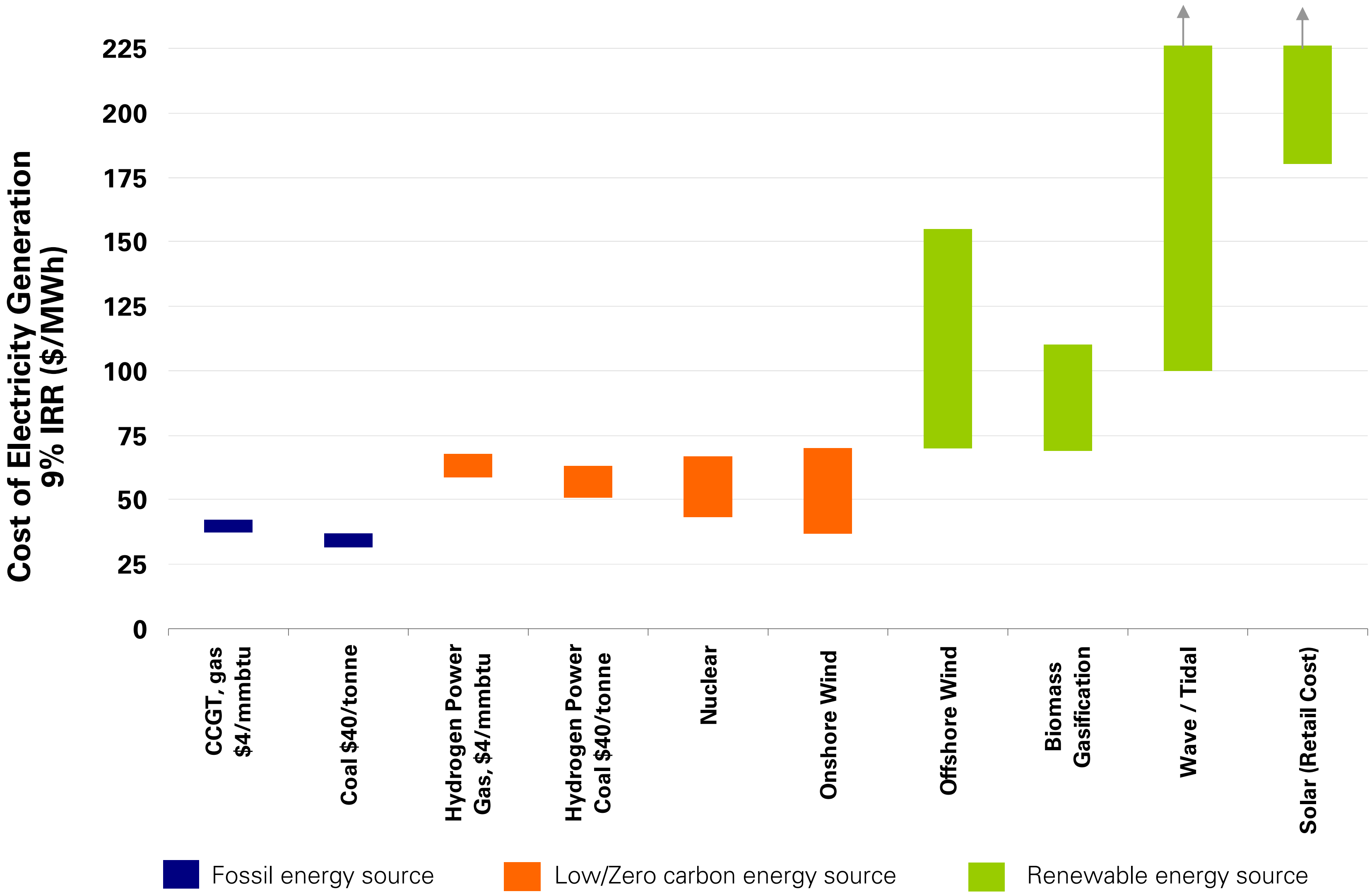


electricity generation shares by fuel - 2004



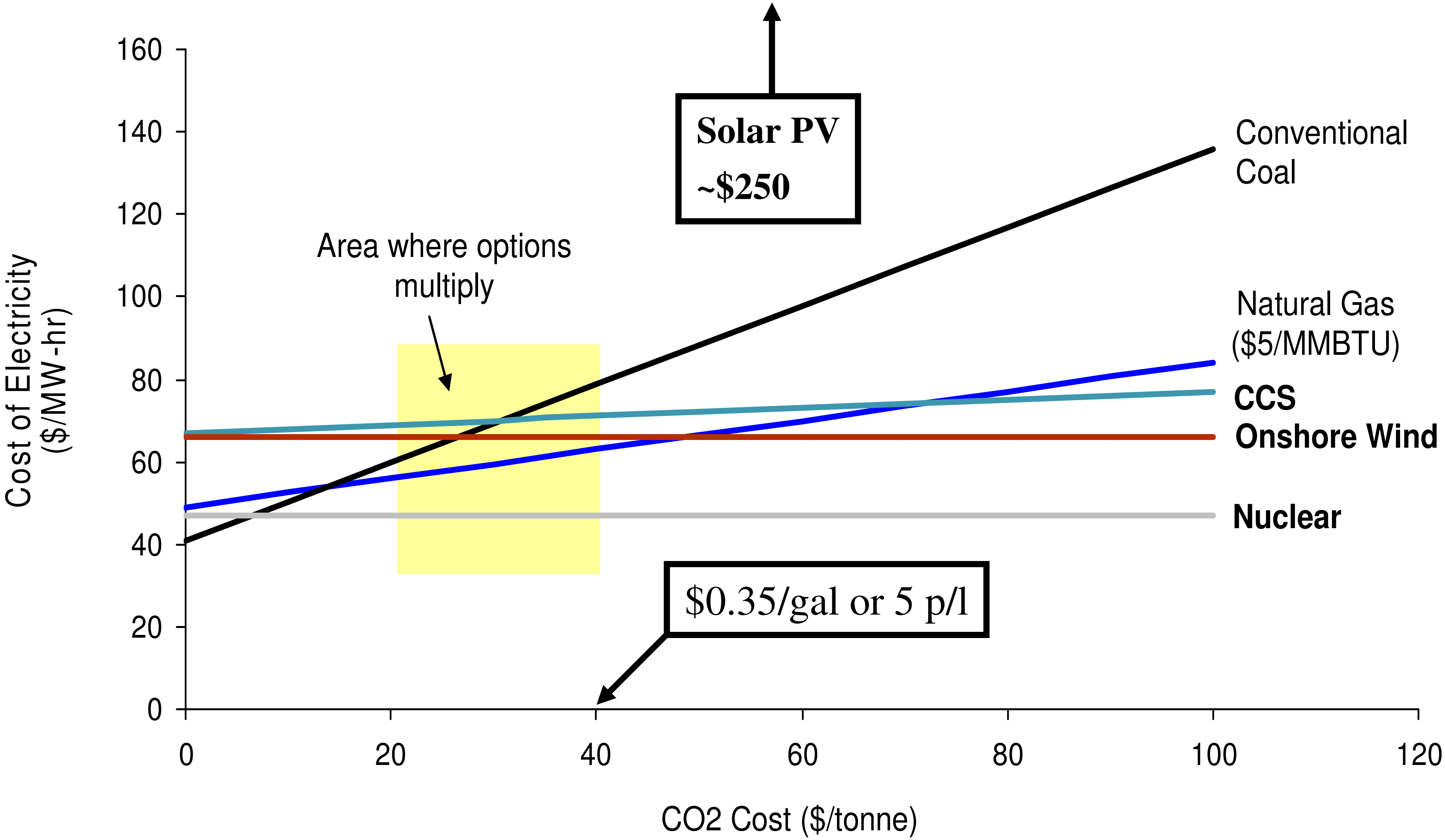
Source: IEA WEO 2006

levelised costs of electricity generation



Source: BP Estimates, Navigant Consulting

impact of CO_2 cost on levelised Cost of Electricity



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

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

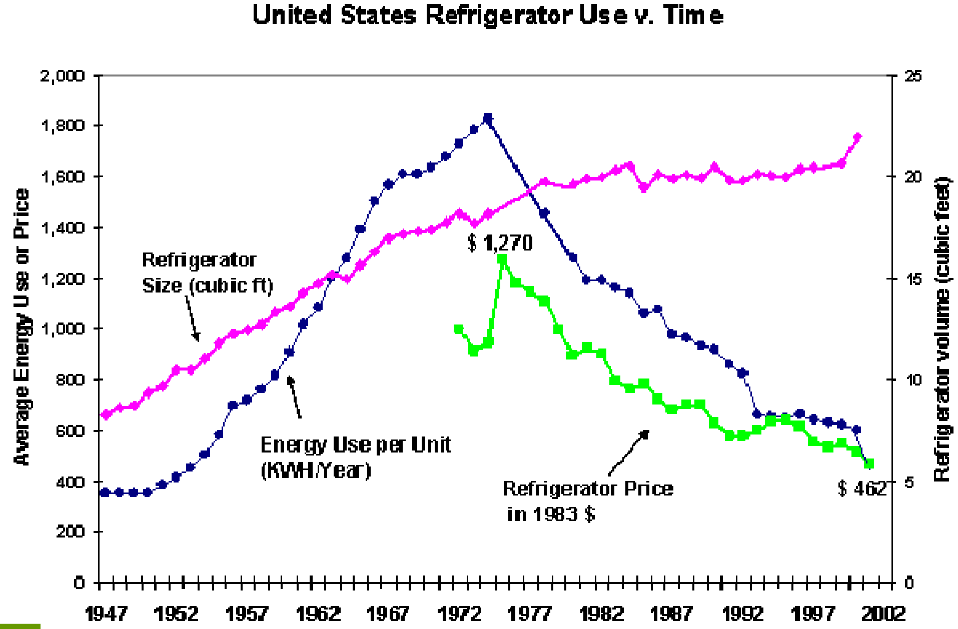
Urban Energy Systems

- 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?

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
- Either is politically difficult

likely 30-year energy future

- **Hydrocarbons will continue to dominate transportation (high energy density)**
  - Conventional crude / heavy oils / biofuels / CTL and GTL ensure continuity of supply at reasonable cost
  - Vehicle efficiency can be at least doubled (hybrids, plug-in hybrids, HCCI, diesel)
  - local pollution controllable at cost; CO_2 emissions now ~20% of the total
  - Hydrogen in vehicles is a long way off, if it's there at all
    - No production method simultaneously satisfies economy, security, emissions
    - Technical and economic barriers to distribution / on-board storage / fuel cells
    - Benefits are largely realizable by plausible evolution of existing technologies
- **Coal (security) and gas (cleanliness) will continue to dominate heat and power**
  - Capture and storage (H_2 power) practiced if CO_2 concern is to be addressed
  - Nuclear (energy security, CO_2) will be a fixed, if not growing, fraction of the mix
  - Renewables will find some application but will remain a small fraction of the total
    - Advanced solar a wildcard
- **Demand reduction will happen where economically effective or via policy**
- **CO_2 emissions (and concentrations) continue to rise absent dramatic global action**

necessary steps around the technology

- **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”**
- **Universities/labs must recognize and act on importance of energy research**
  - Technology <u>and</u> policy

Questions/Comments/Discussion