Energy trends and technologies in the coming decades

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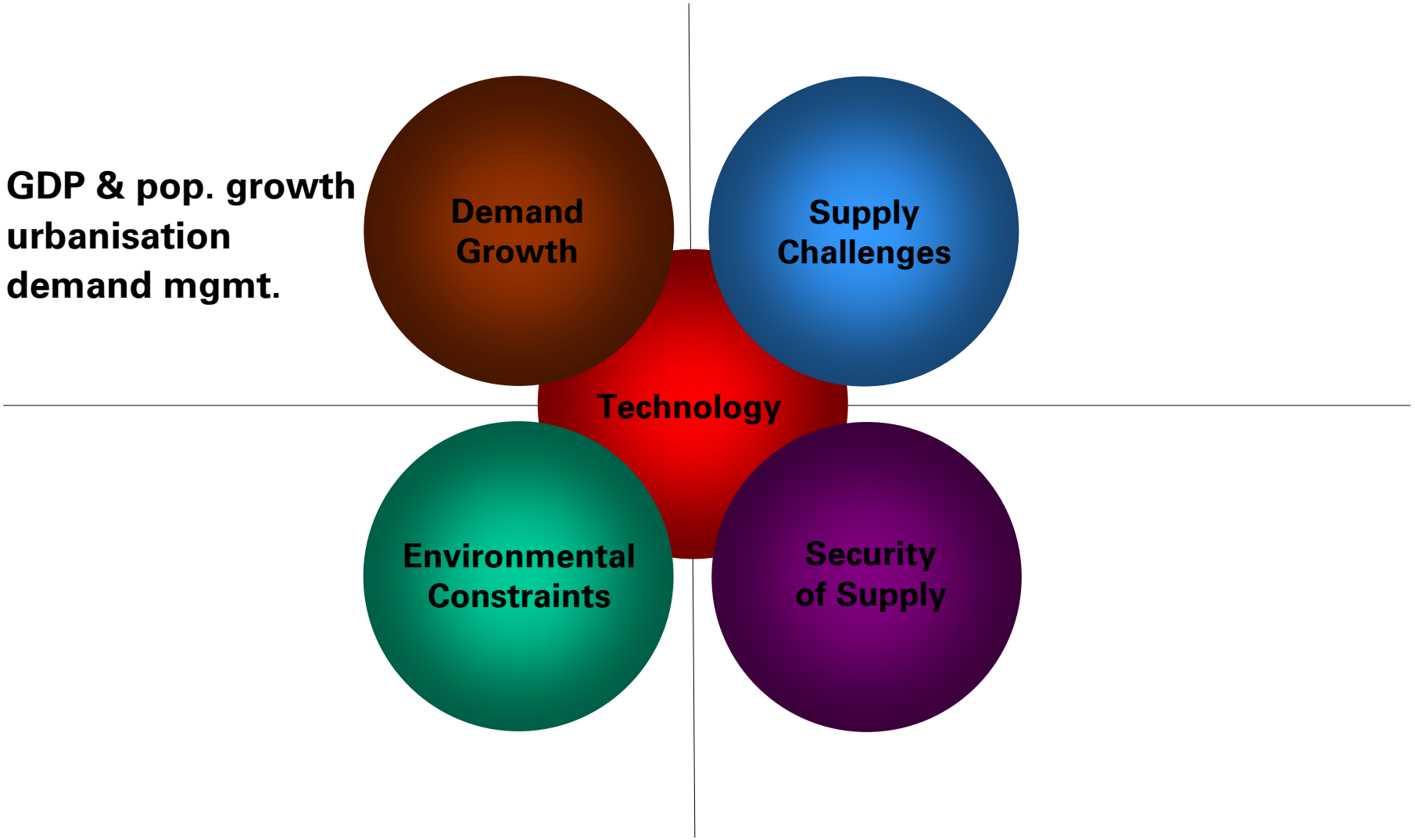
GUIRR

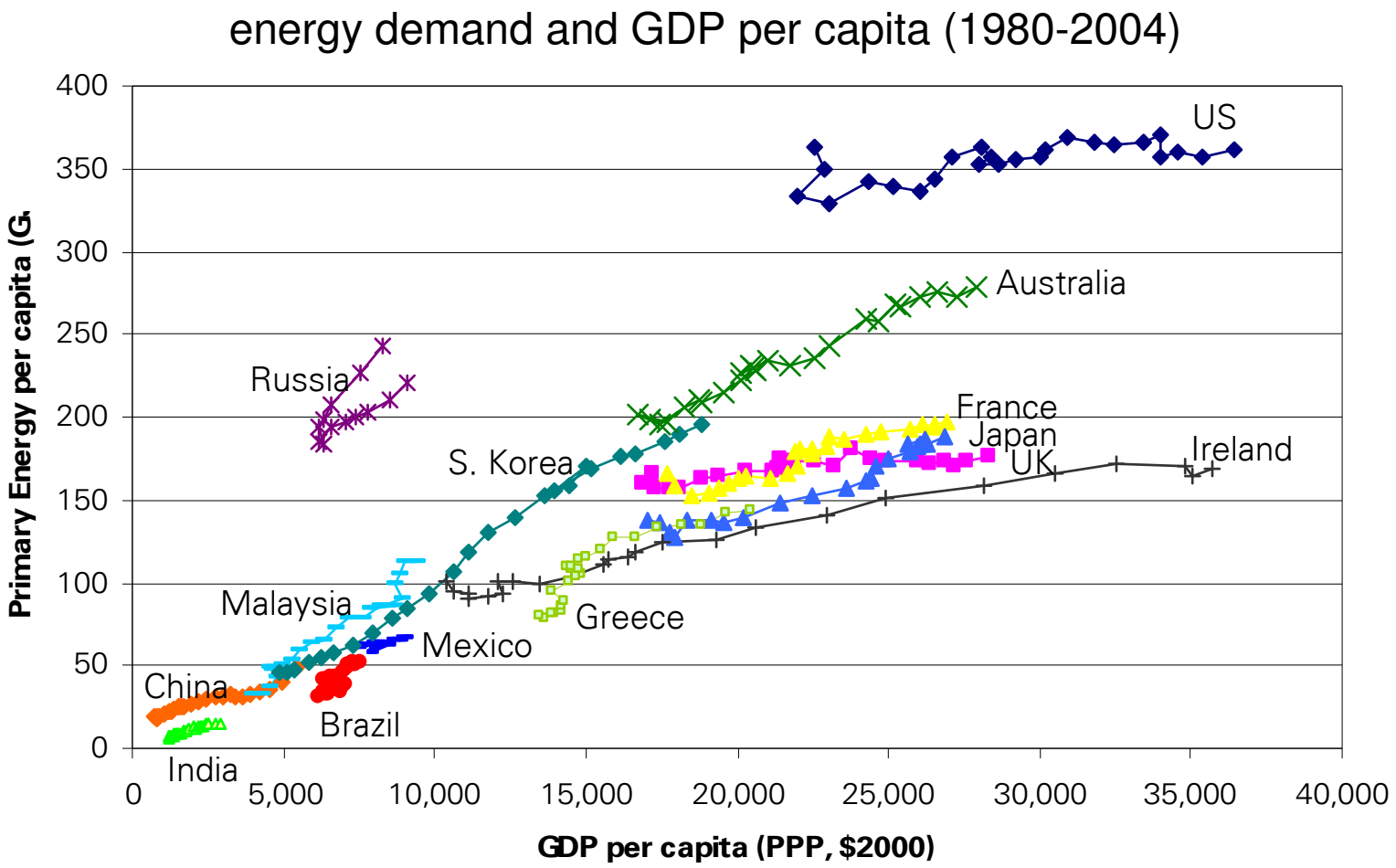
February 19, 2007

key drivers of the energy future

- GDP & pop. growth
- urbanisation
- demand mgmt.

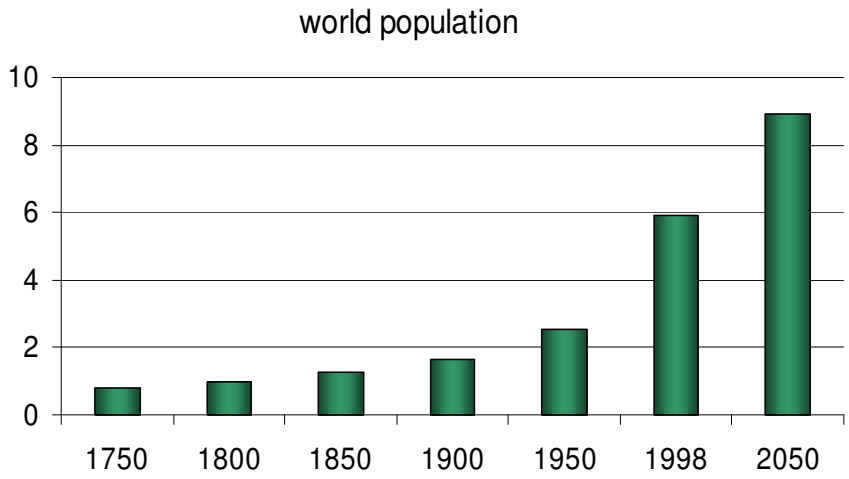


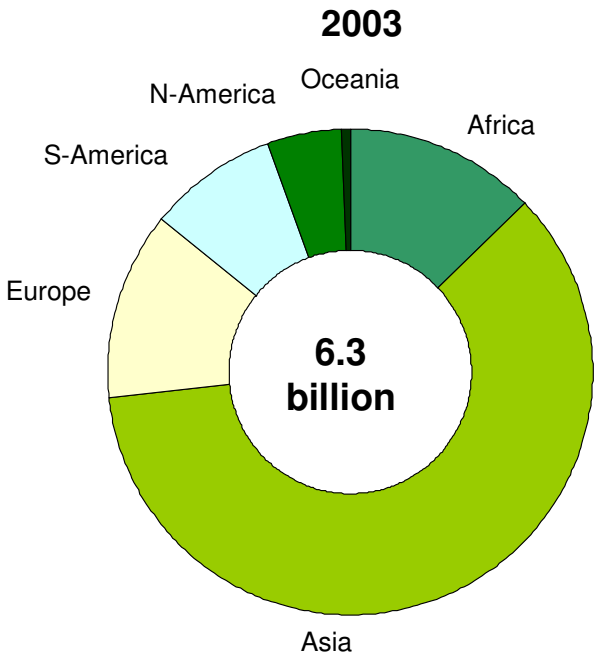
energy use grows with economic development

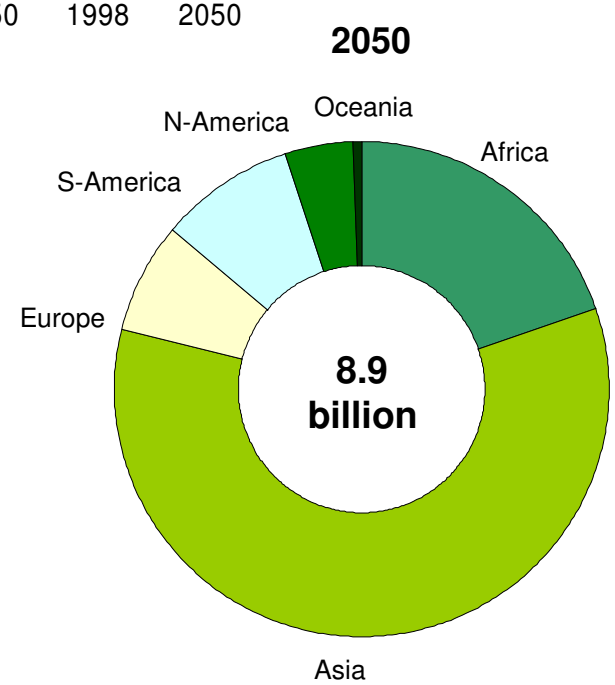


Source: UN and DOE EIA
Russia data 1992-2004 only

Demographic Transformations



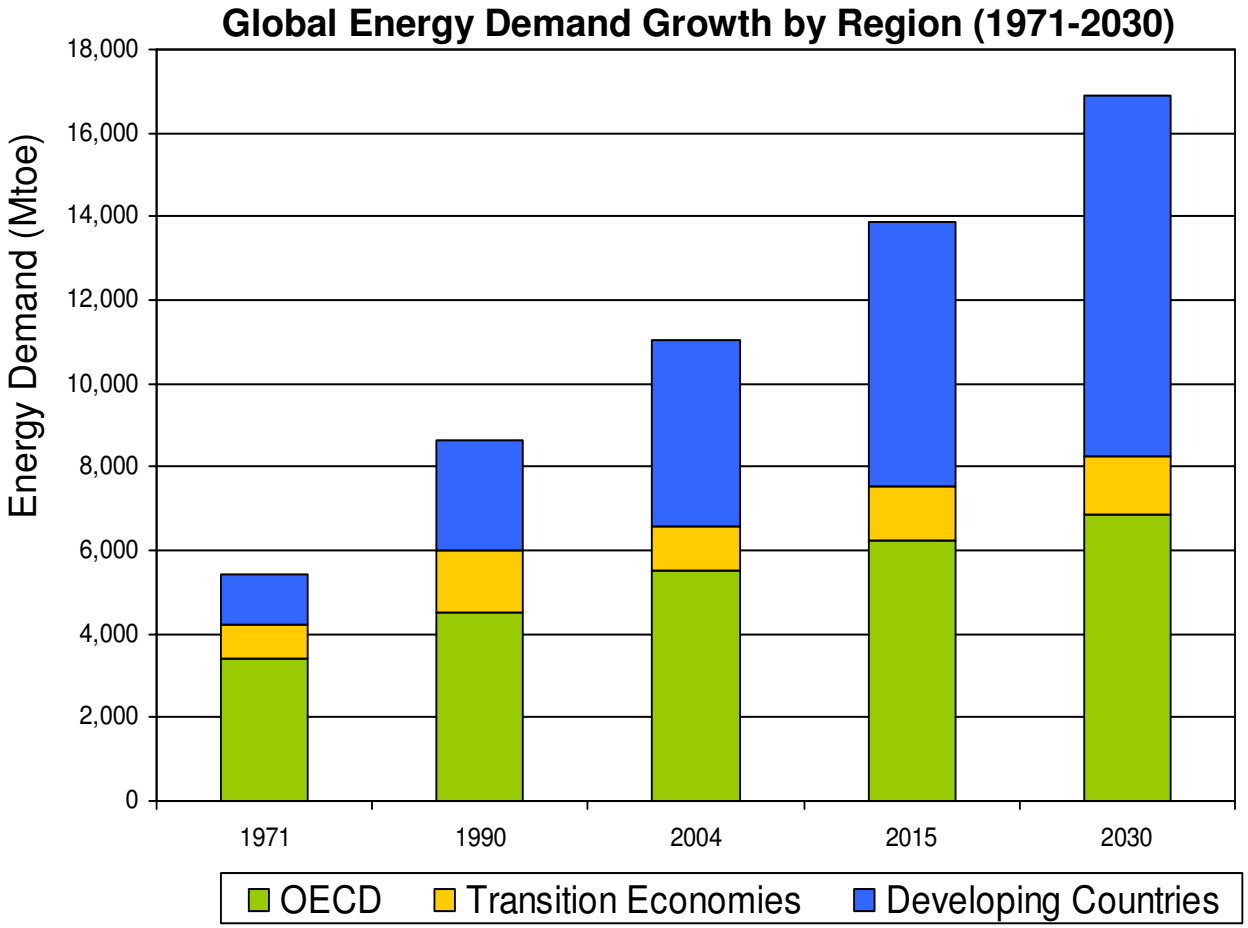




source: United Nations

energy demand – growth projections

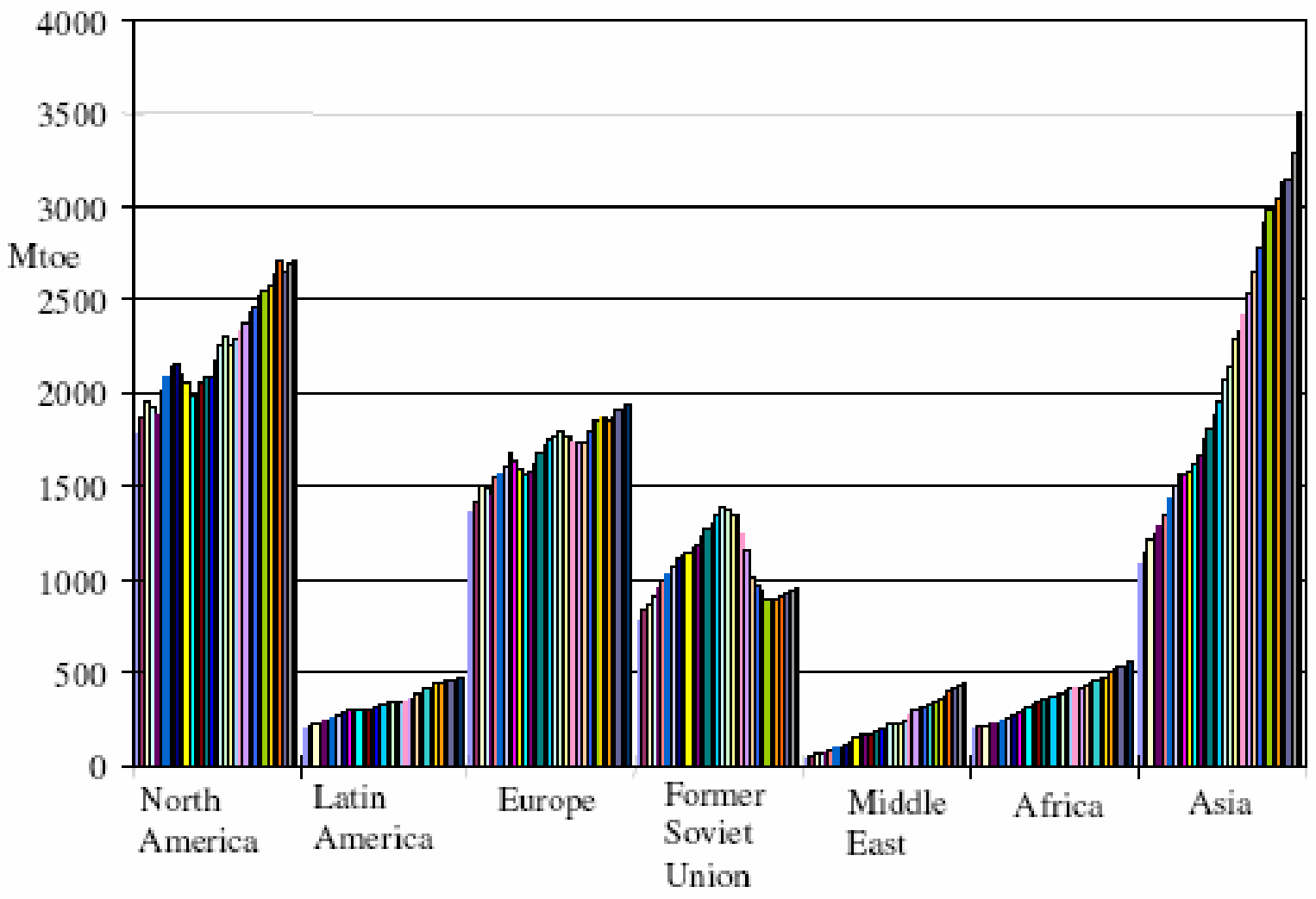
Global energy demand is projected to increase by just over one-half between now and 2030 – an average annual rate of 1.6%. Over 70% of this increased demand comes from developing countries



Notes: 1. OECD refers to North America, W. Europe, Japan, Korea, Australia and NZ
2. Transition Economies refers to FSU and Eastern European nations
3. Developing Countries is all other nations including China, India etc.

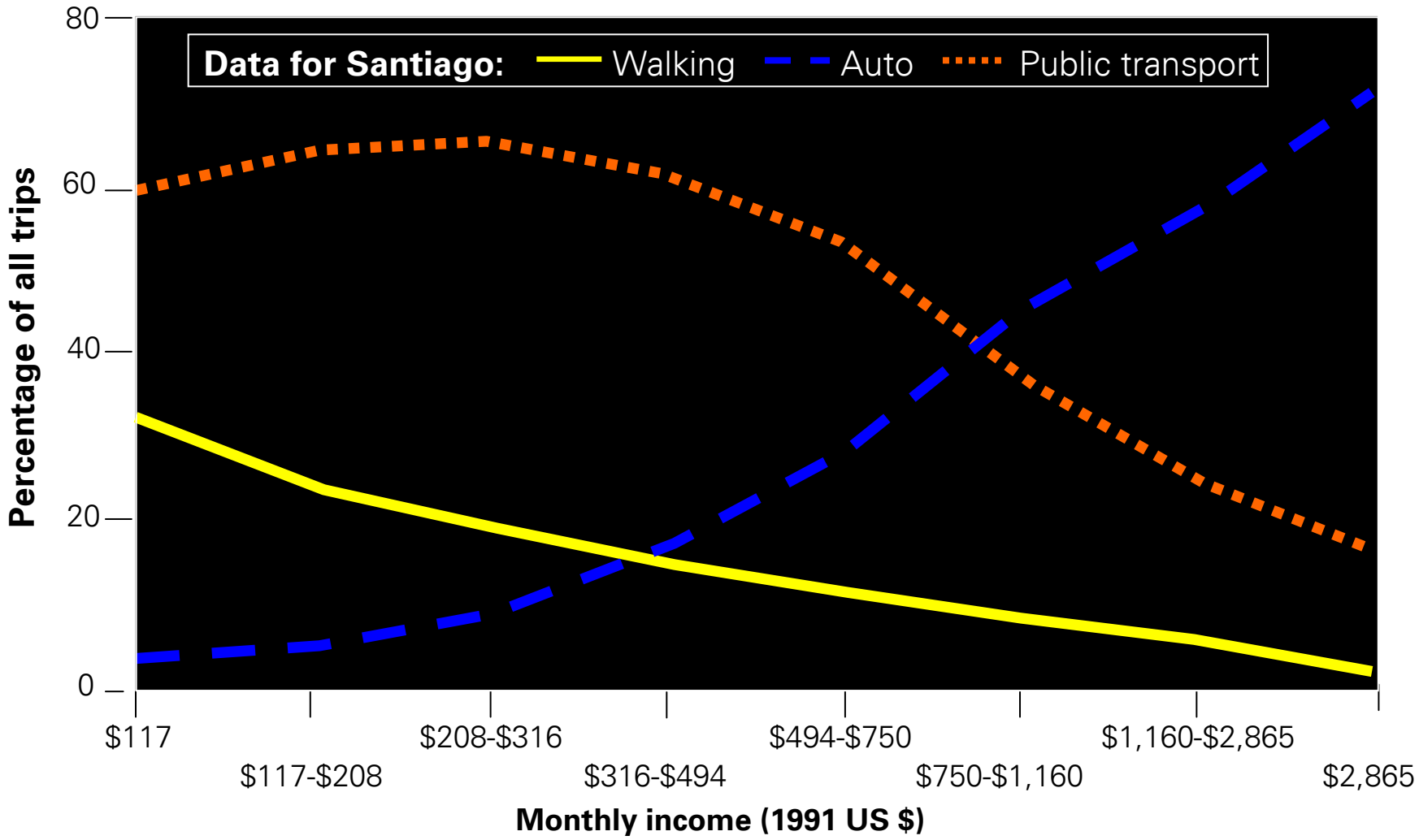
Source: IEA World Energy Outlook 2006

Annual primary energy demand 1971-2003



Source IEA, 2004 (Exclude biomass)

The Income Dependency of Mobility

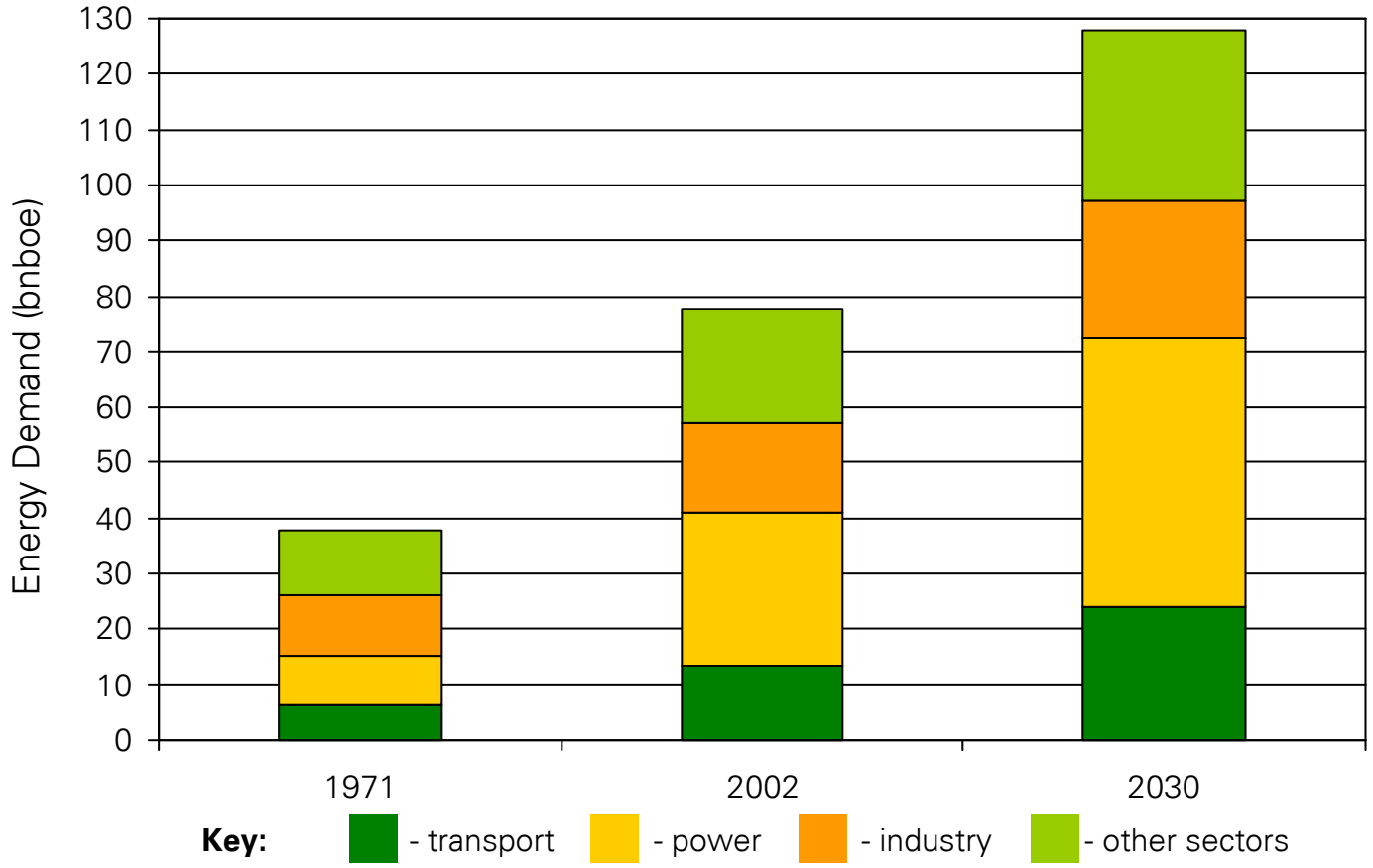


Note: Santiago does not add to 100%; not all modal shares included

Source: Arve Thorvik, WBCSD, Sustainable Mobility

growing energy demand is projected

Global Energy Demand Growth by Sector (1971-2030)



Notes: 1. Power includes heat generated at power plants
2. Other sectors includes residential, agricultural and service

Source: IEA WEO 2004

A word about energy efficiency

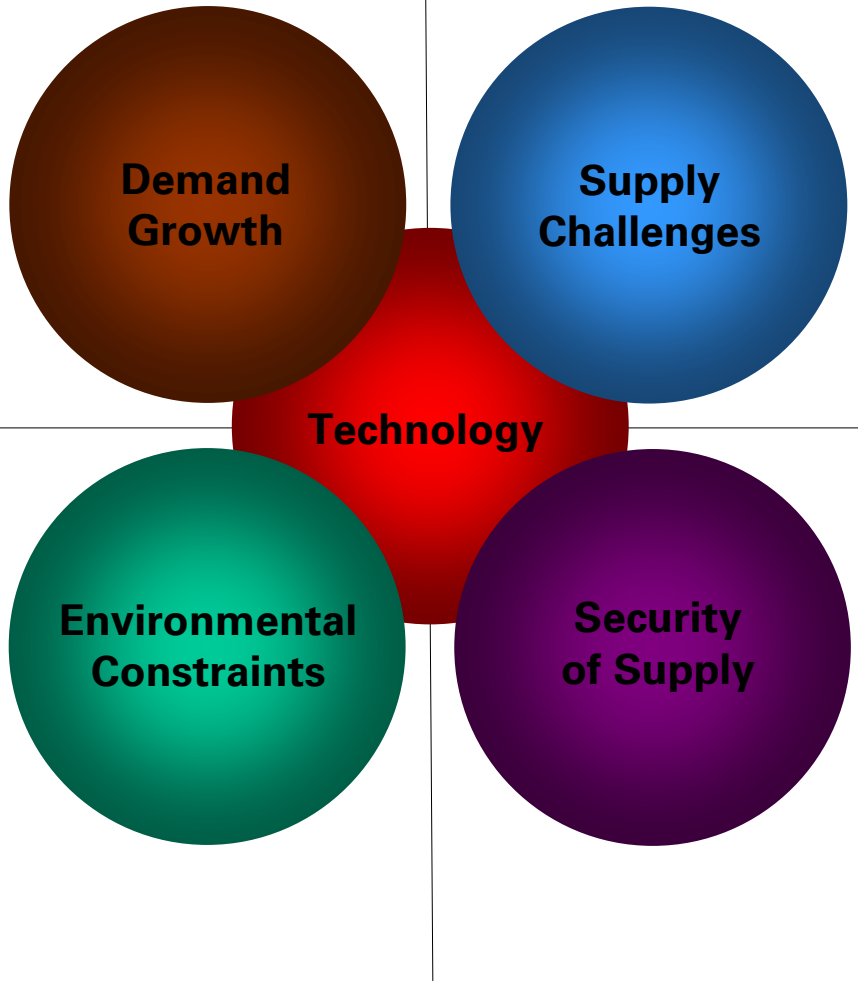
- Demand depends upon more than GDP
  - Multiple factors - geography, climate, demographics, urban planning, economic mix, technology choices
  - For example, US per capita transport energy is > 3 times Japan
- Efficiency through technology is about paying today vs. tomorrow
  - Must be cost effective
  - May not reduce demand

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%**

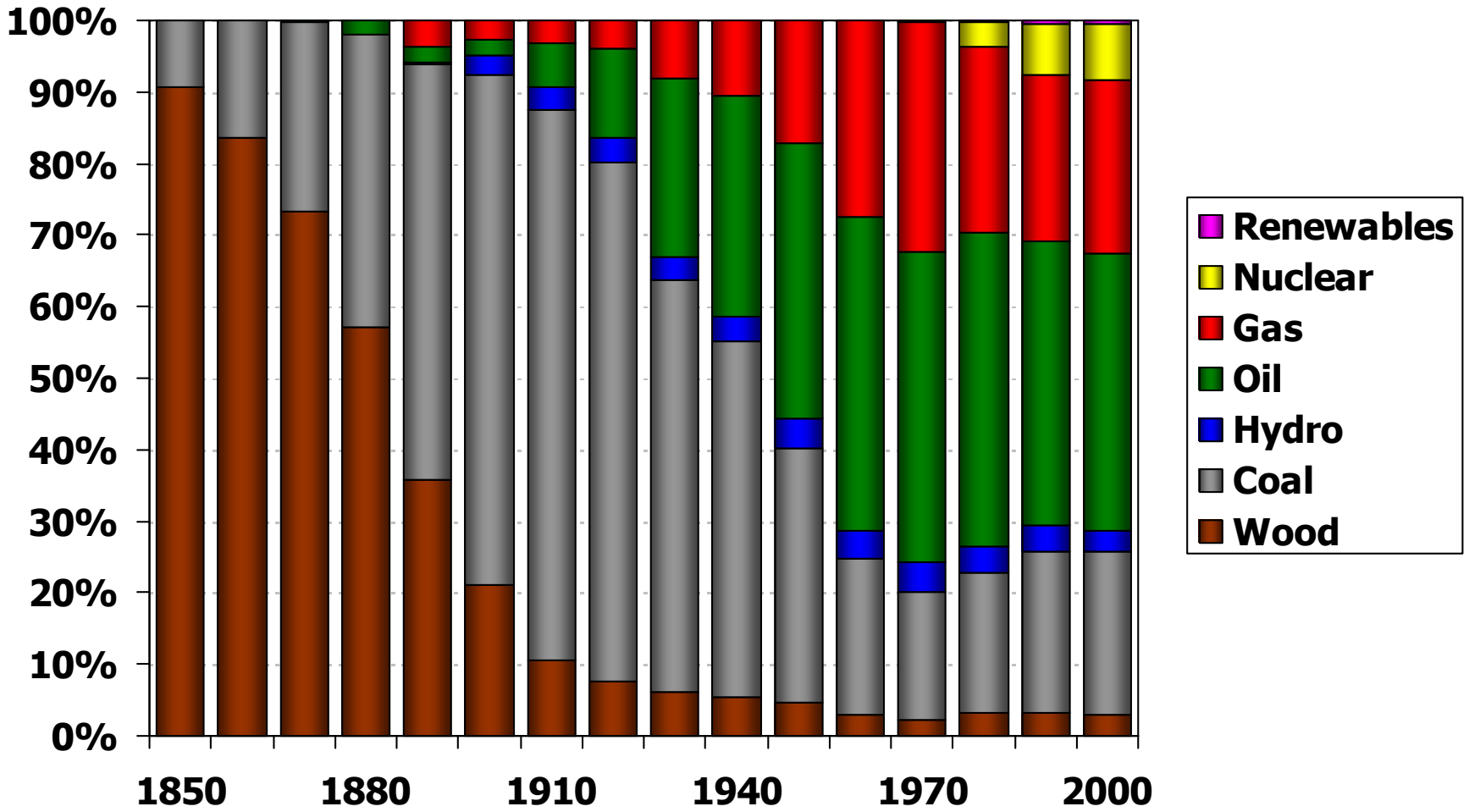
key drivers of the energy future

- GDP & pop. growth
- urbanisation
- demand mgmt.



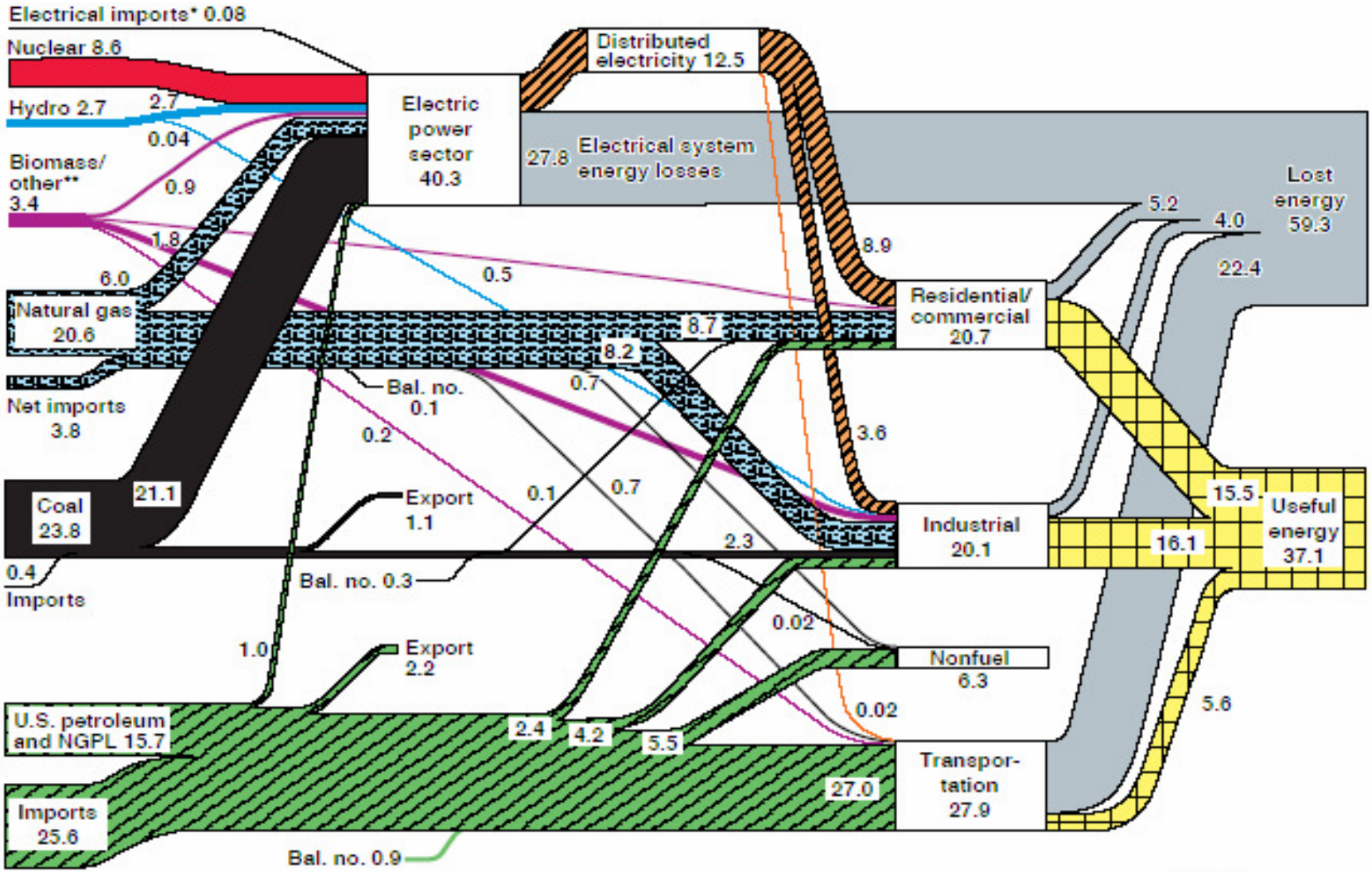
- **significant resources**
- **infrastructure**
- **non-conventionals**

US energy supply since 1850



Source: EIA

2002 US energy
(Net primary consumption = 103 Exajoules)

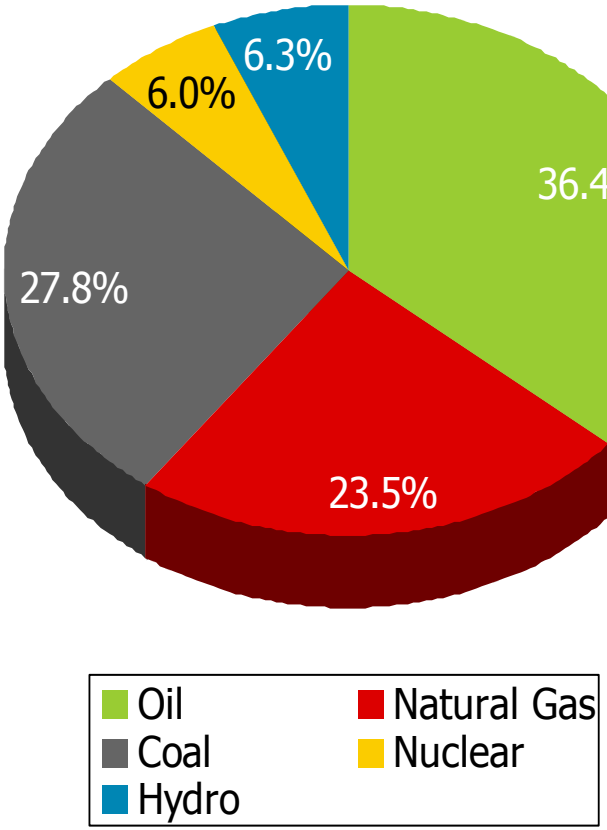


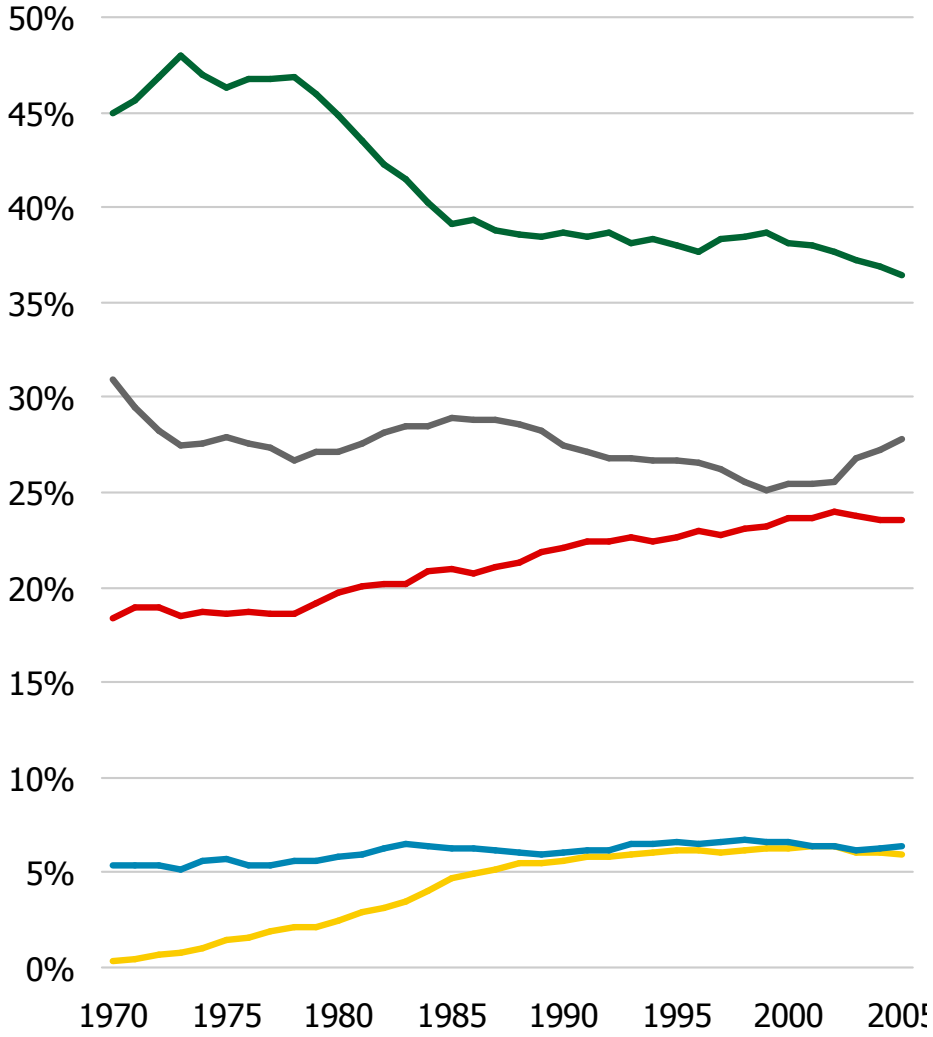
Source: Production and end-use data from Energy Information Administration, *Annual Energy Review 2002*.
*Net fossil-fuel electrical imports.
**Biomass/other includes wood, waste, alcohol, geothermal, solar, and wind.

June 2004
Lawrence Livermore National Laboratory
http://eed.llnl.gov/flow

current and historical global energy mix

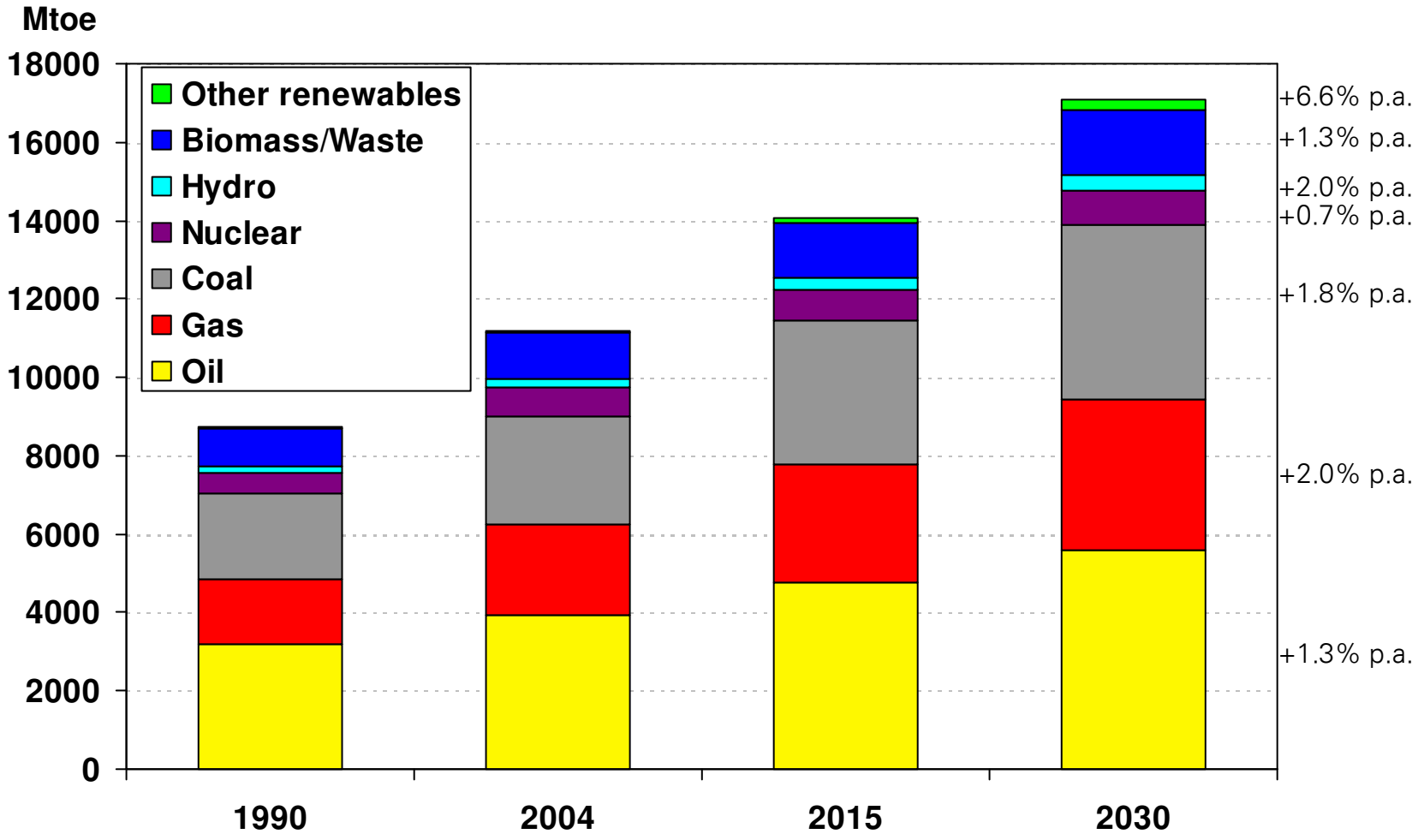
Current global energy supply is dominated by fossil fuels – oil has been the largest component of the energy mix for many decades; gas has grown strongly since the 1970's; coal has been growing in the last four years; hydro is constant and nuclear has plateaued





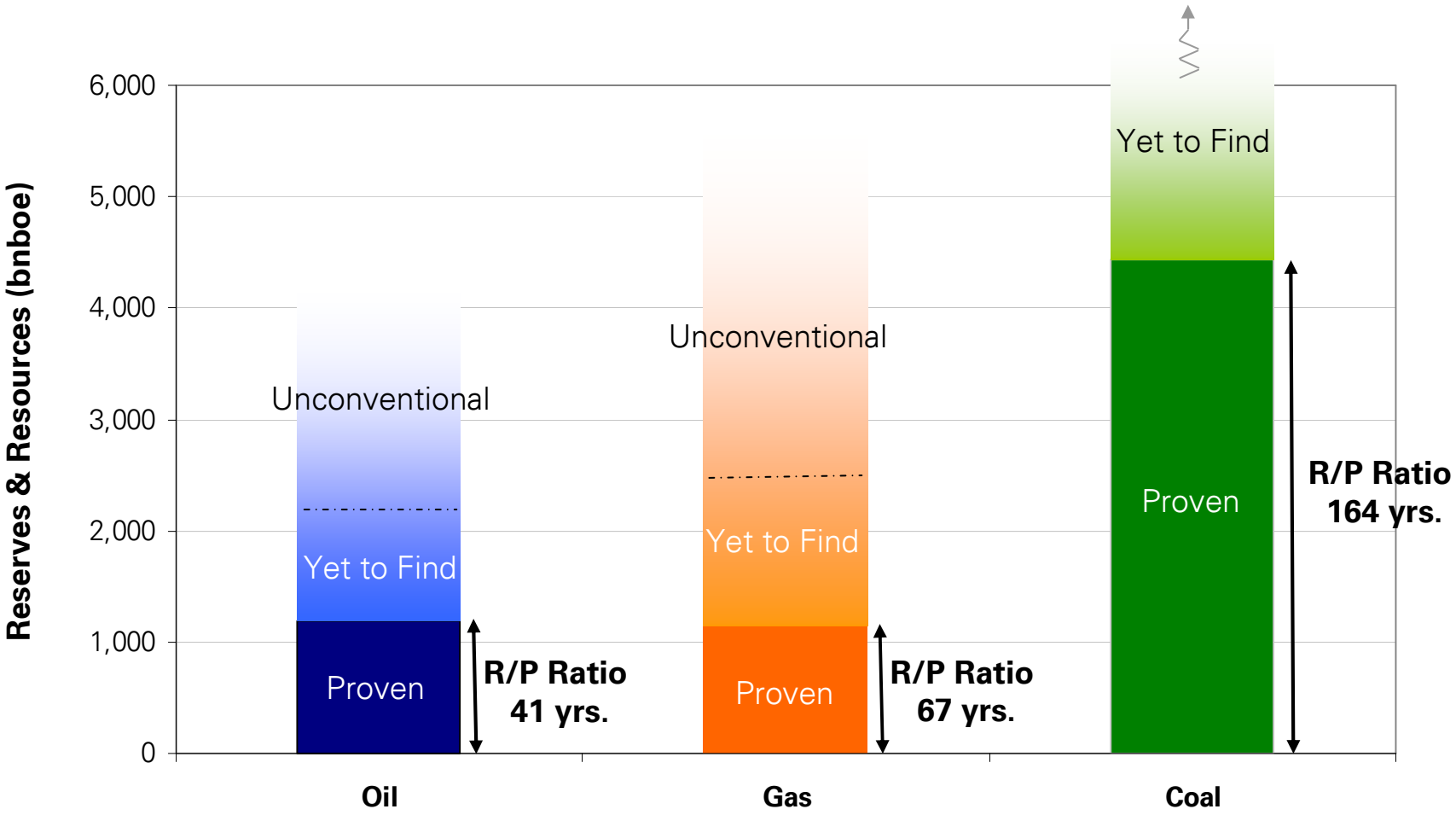
Source: BP Statistical Review

"Business as usual" energy supply forecast



Source: IEA WEO 2006

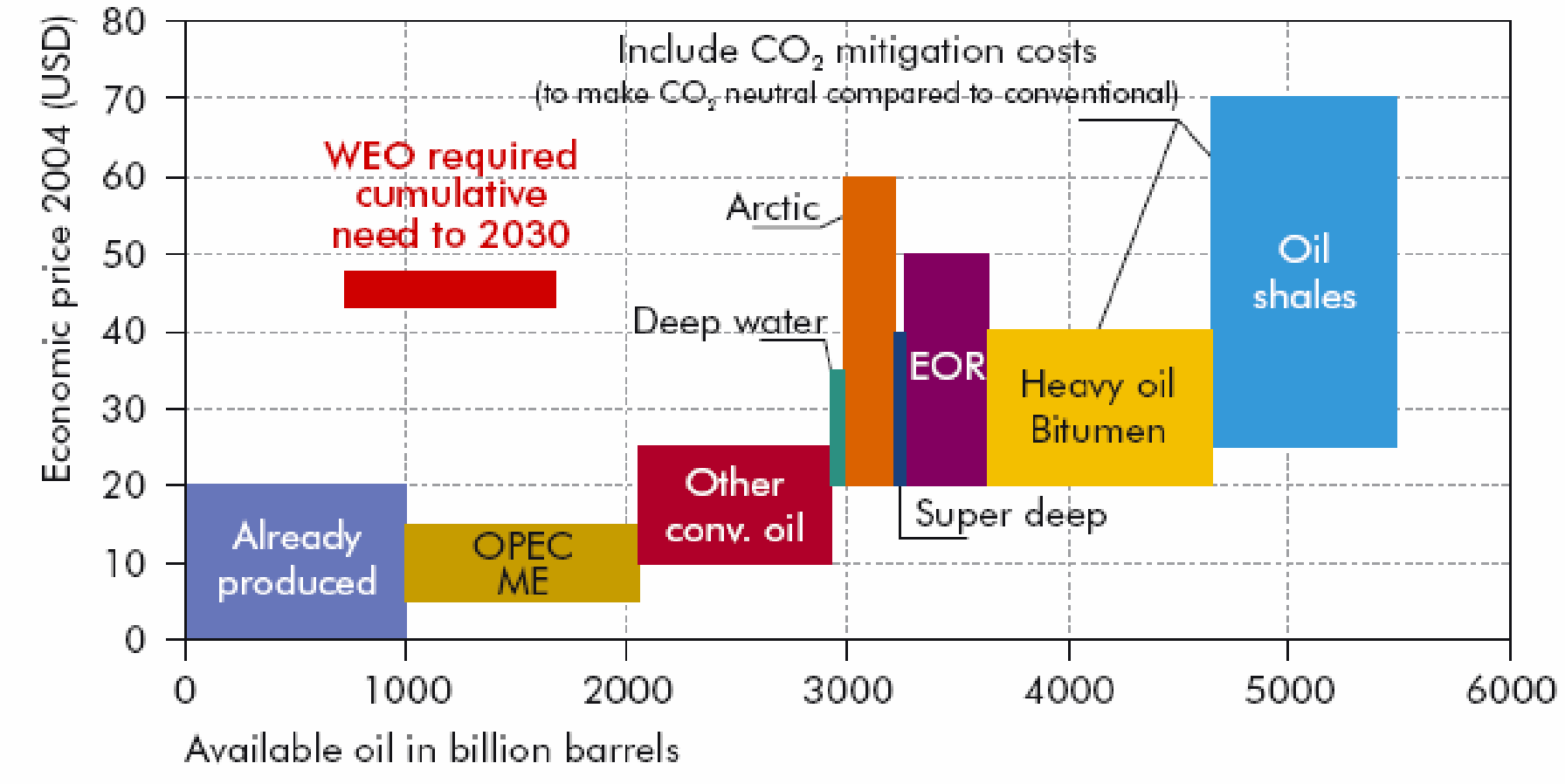
substantial global fossil resources



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

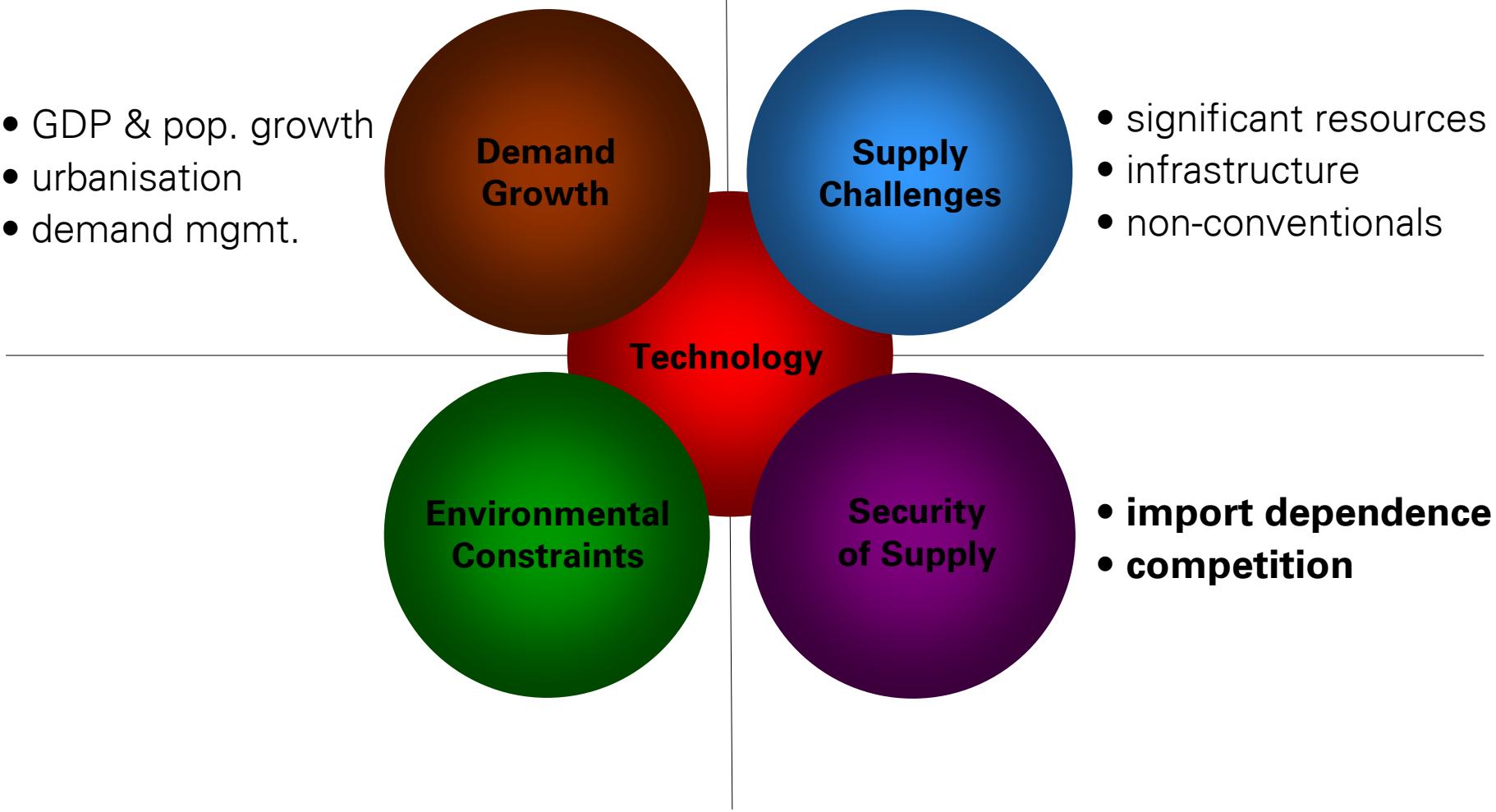
oil supply and cost curve

Availability of oil resources as a function of economic price



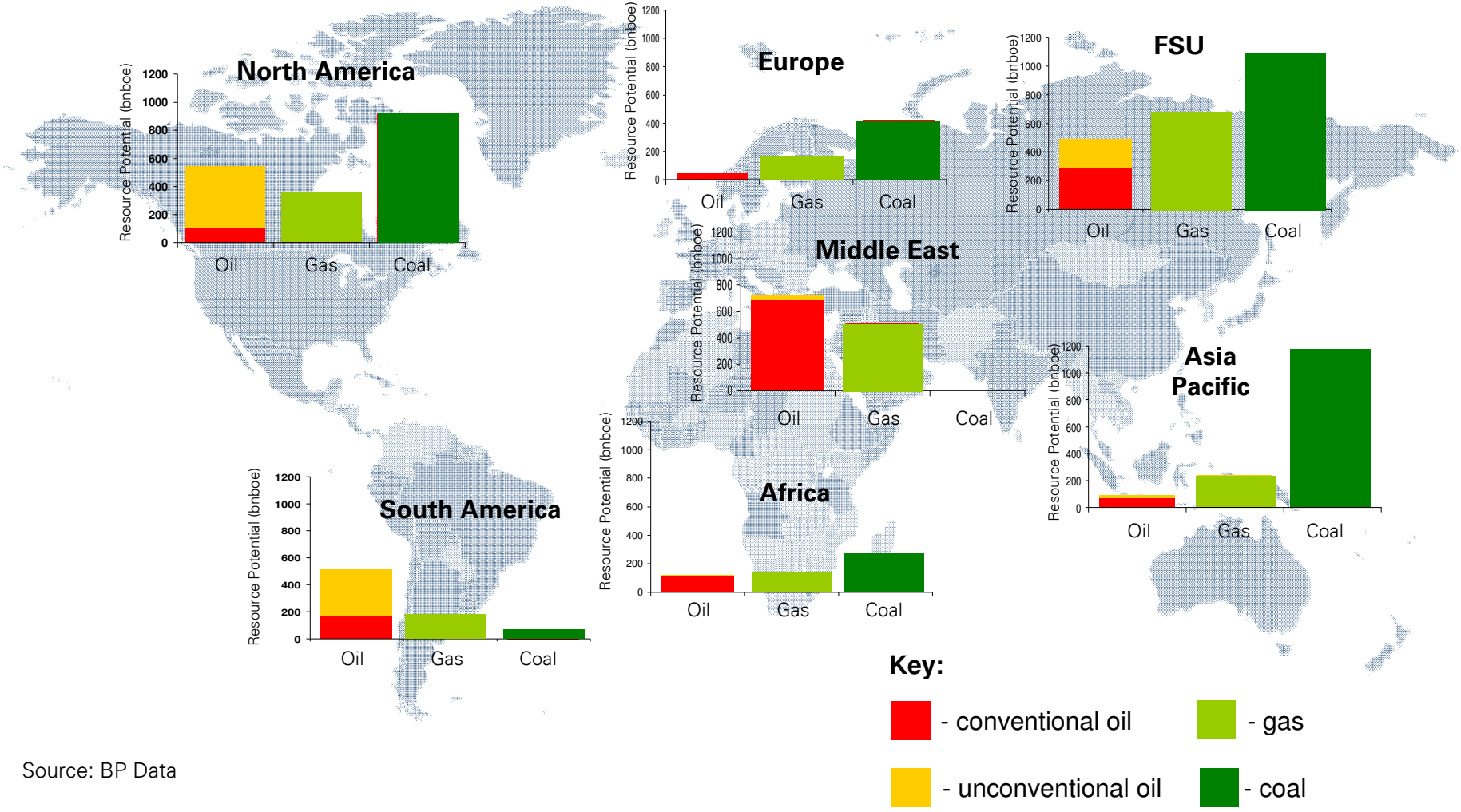
Source: IEA (2005)

key drivers of the energy future



significant hydrocarbon resource potential

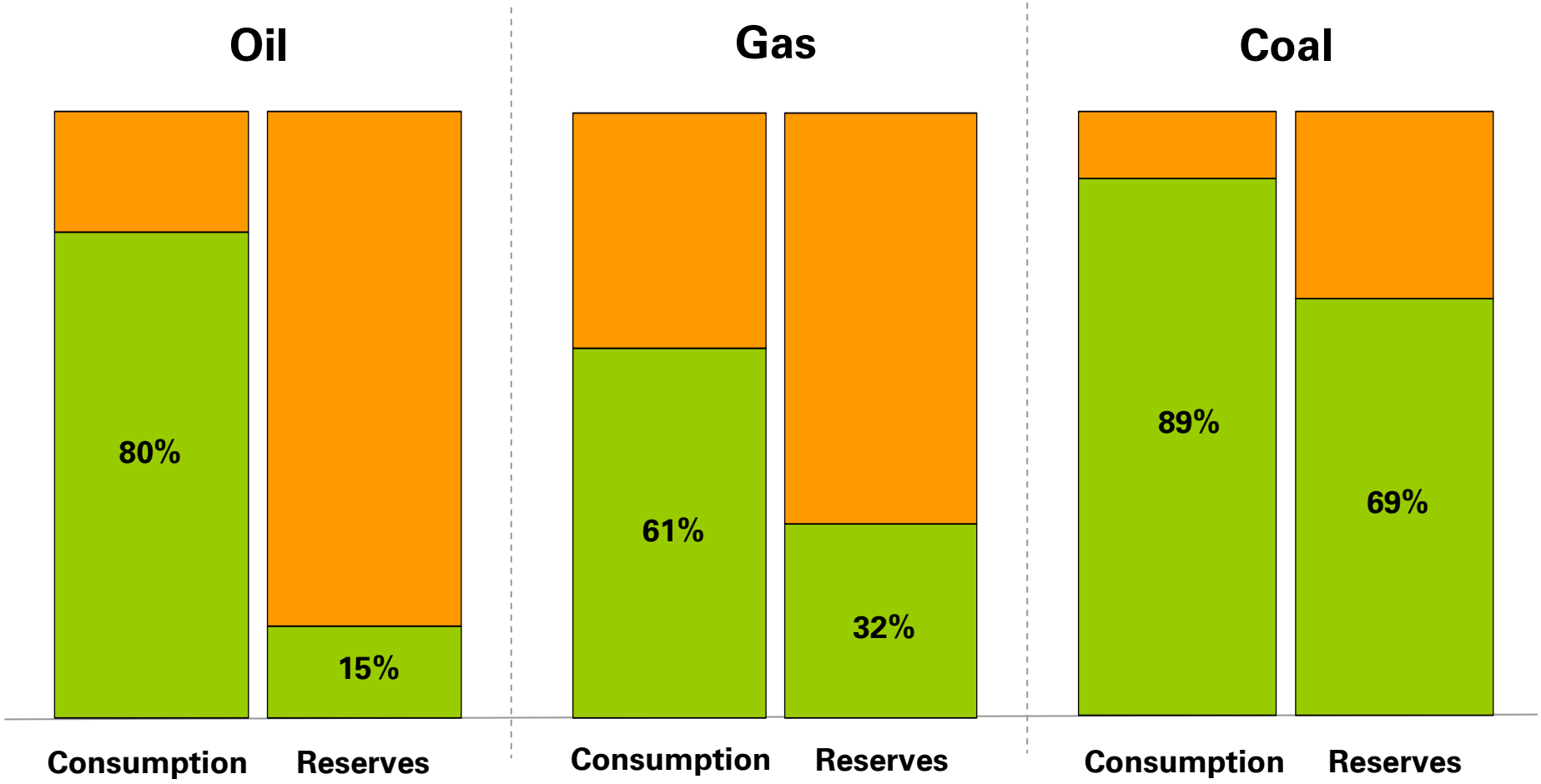
Oil, Gas and Coal Resources by Region (bnboe)



Source: BP Data

…and dislocation of supply & demand

Regional Share of 2002 Consumption v's Reserves for Oil, Gas & Coal



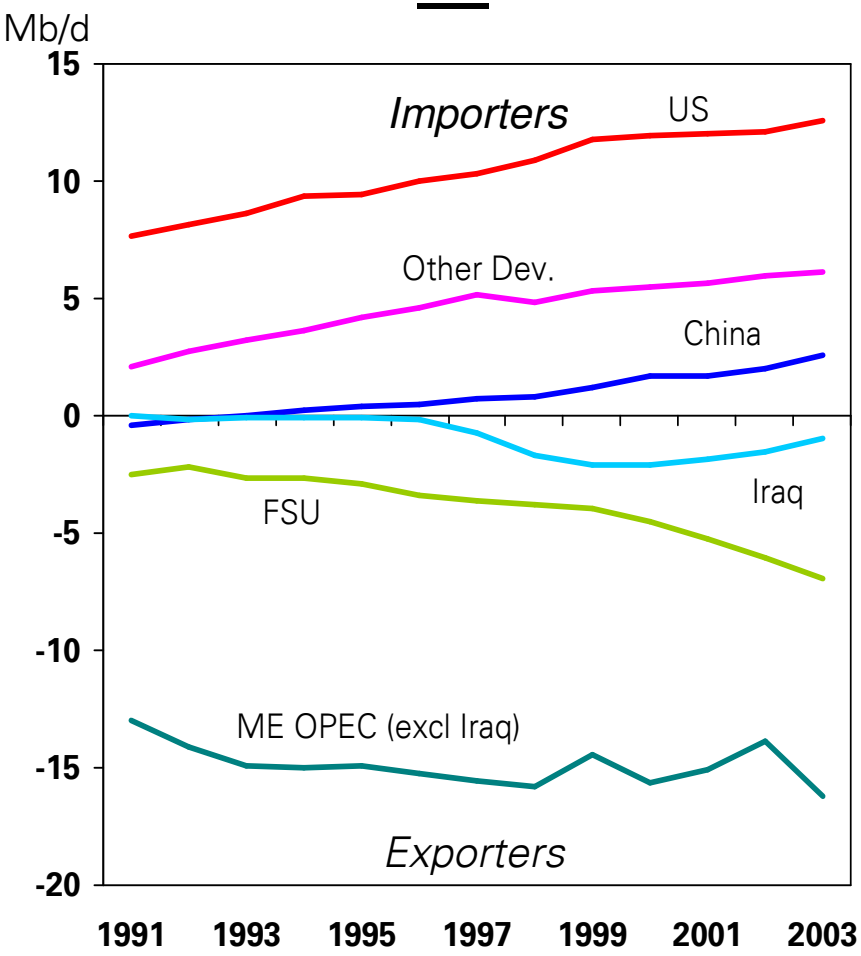
Note: oil reserve figures do not include unconventional reserves estimates

Source: BP Data, IEA WEO 2004

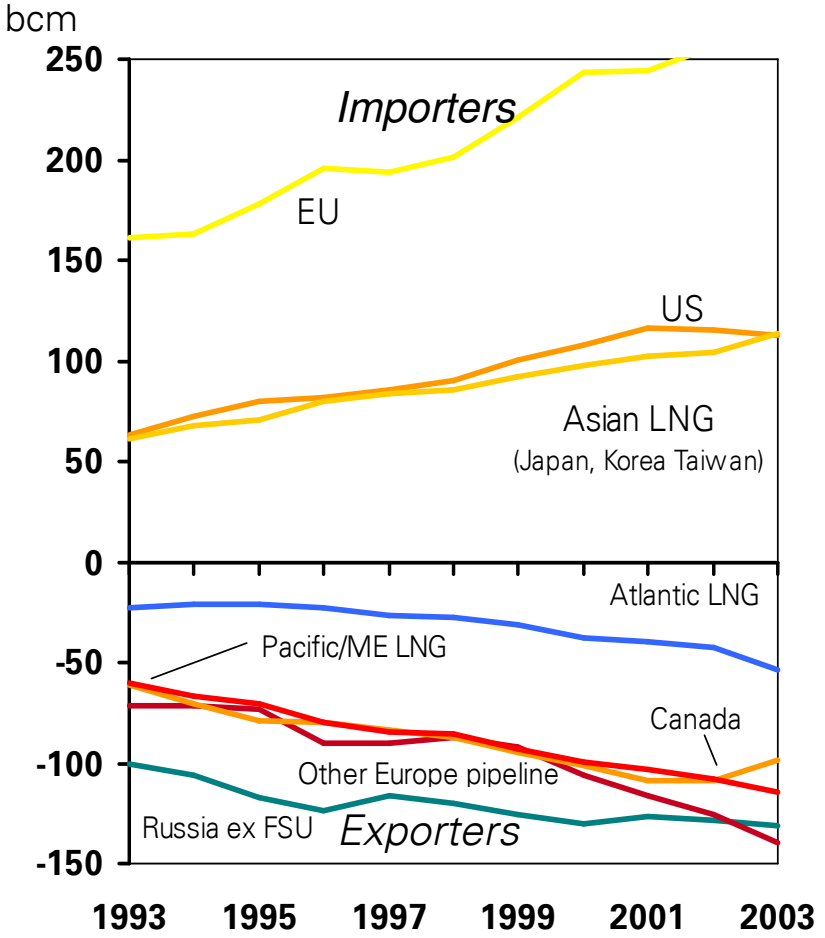
energy security - import dependence

Import dependence is rising in all the key markets; oil and gas production is also shifting increasingly away from OECD countries to non-OECD

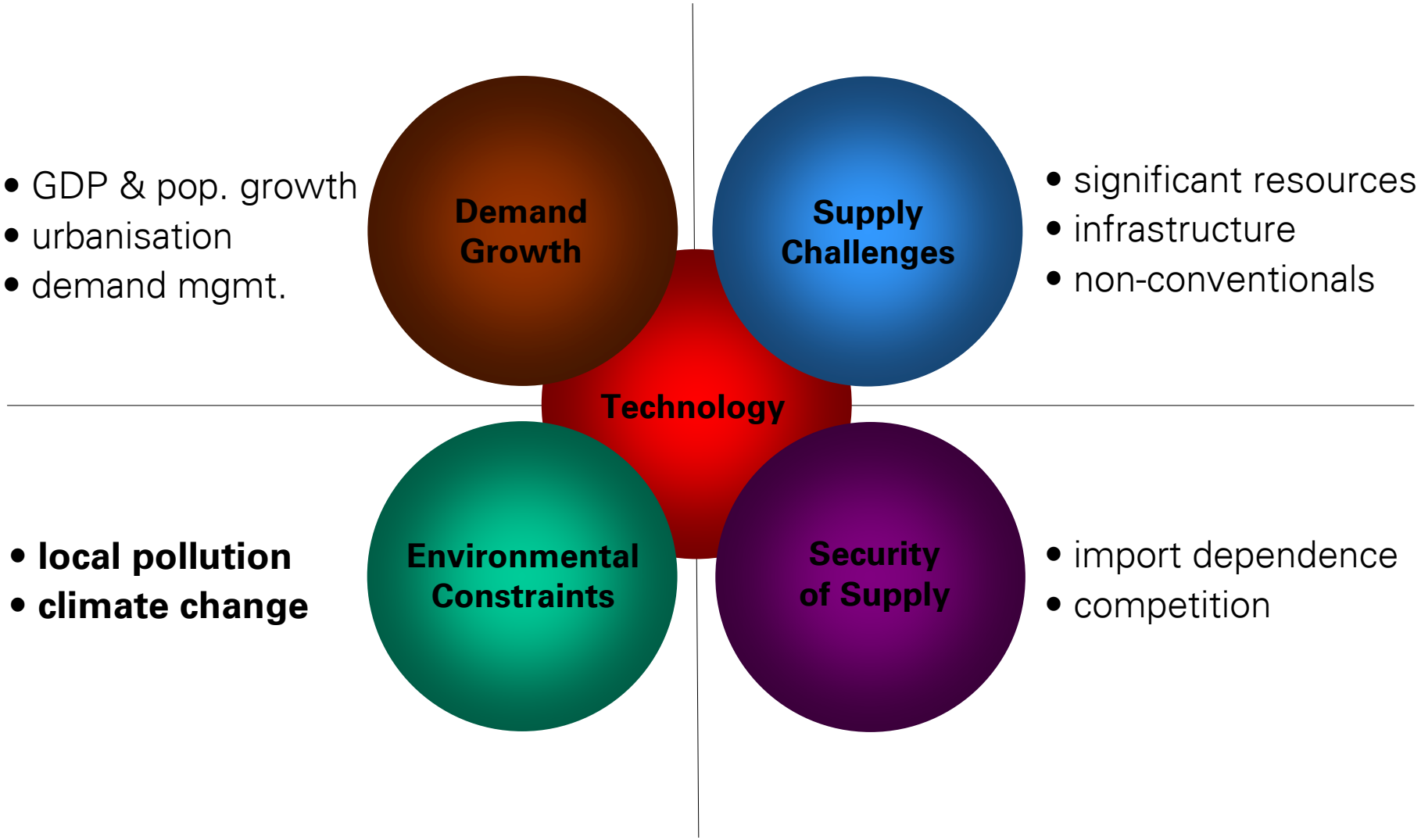
Oil



Natural gas

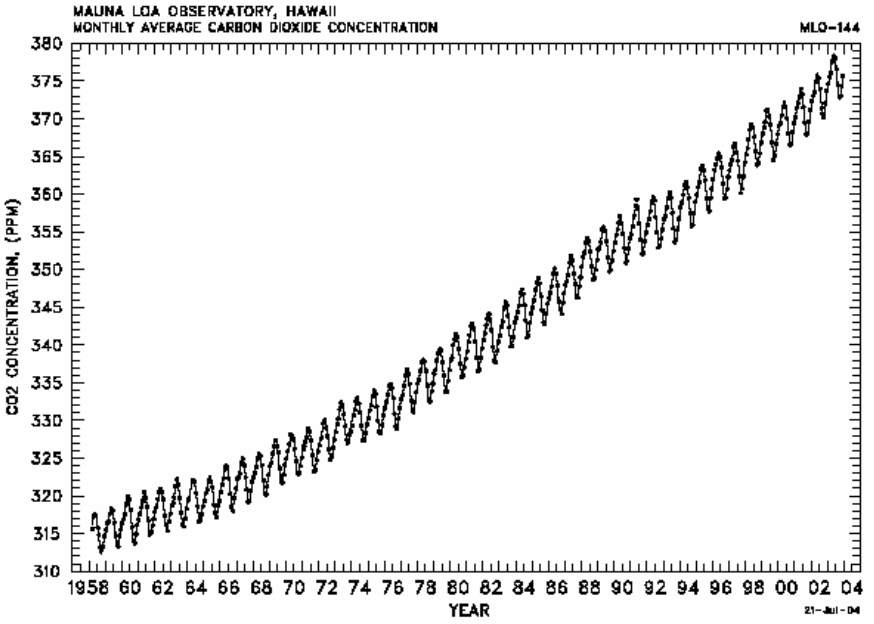


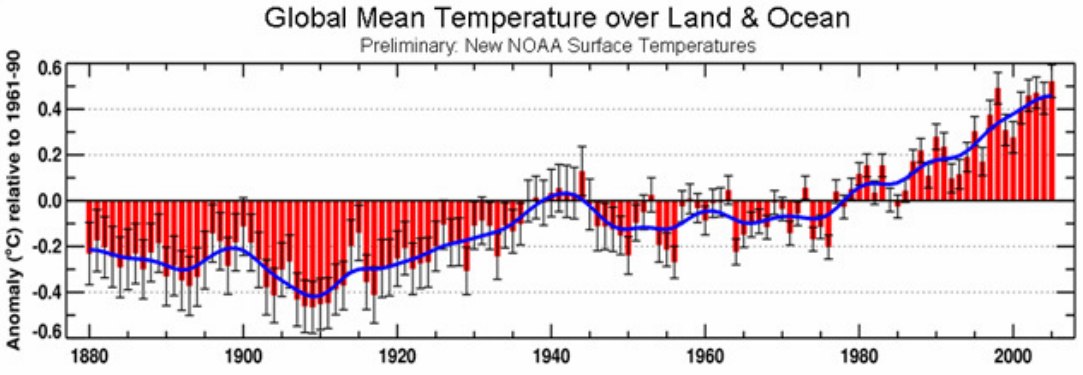
key drivers of the energy future



Climate change and CO_2 emissions

- **CO_2 concentration is rising due to fossil fuel use**
- **The global temperature is increasing**
  - **other indicators of climate change**
- **There is a plausible causal connection**
  - **but ~1% effect in a complex, noisy system**
  - **scientific case is complicated by natural variability, ill-understood forcings**
- **Impacts of higher CO_2 are uncertain**
  - **~ 2X pre-industrial is a widely discussed stabilization target (550 ppm)**
  - **Reached by 2050 under BAU**
- **Precautionary action is warranted**
  - **What could the world do?**
  - **Will we do it?**

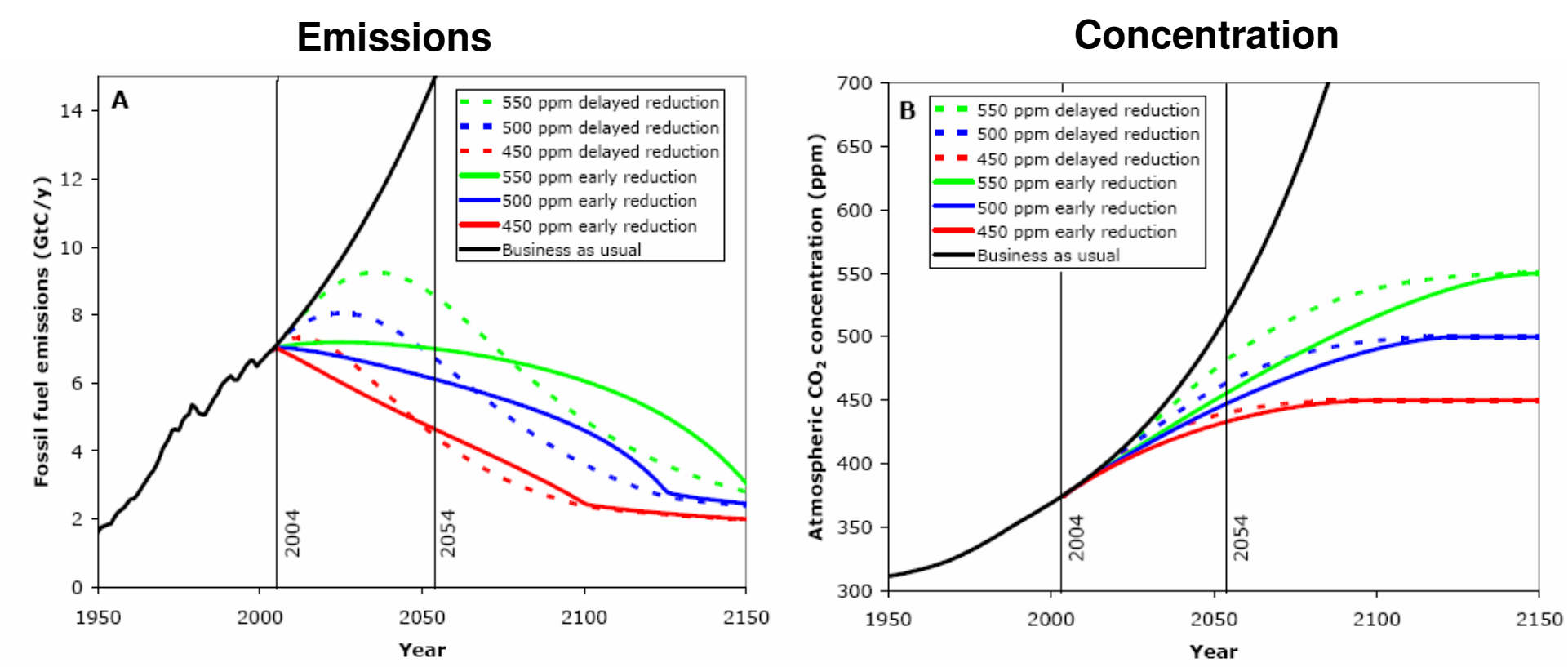




Salient facts about CO_2 science

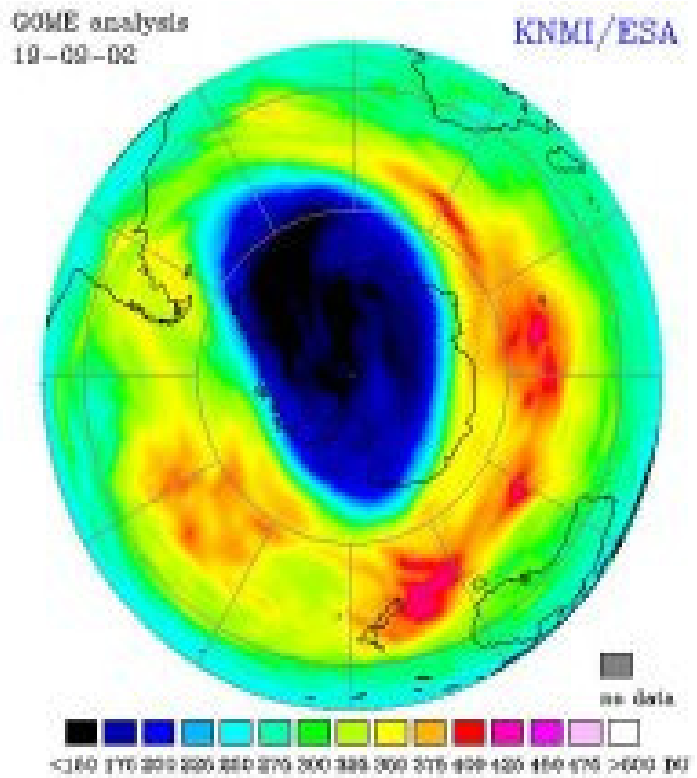
- **The earth absorbs anthropogenic CO_2 at a limited rate**
  - **Emissions would have to drop to about half of their current value by the end of this century to stabilize atmospheric concentration at 550 ppm**
  - **This in the face of a doubling of energy demand in the next 50 years (1.5% per year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

Some stabilization scenarios

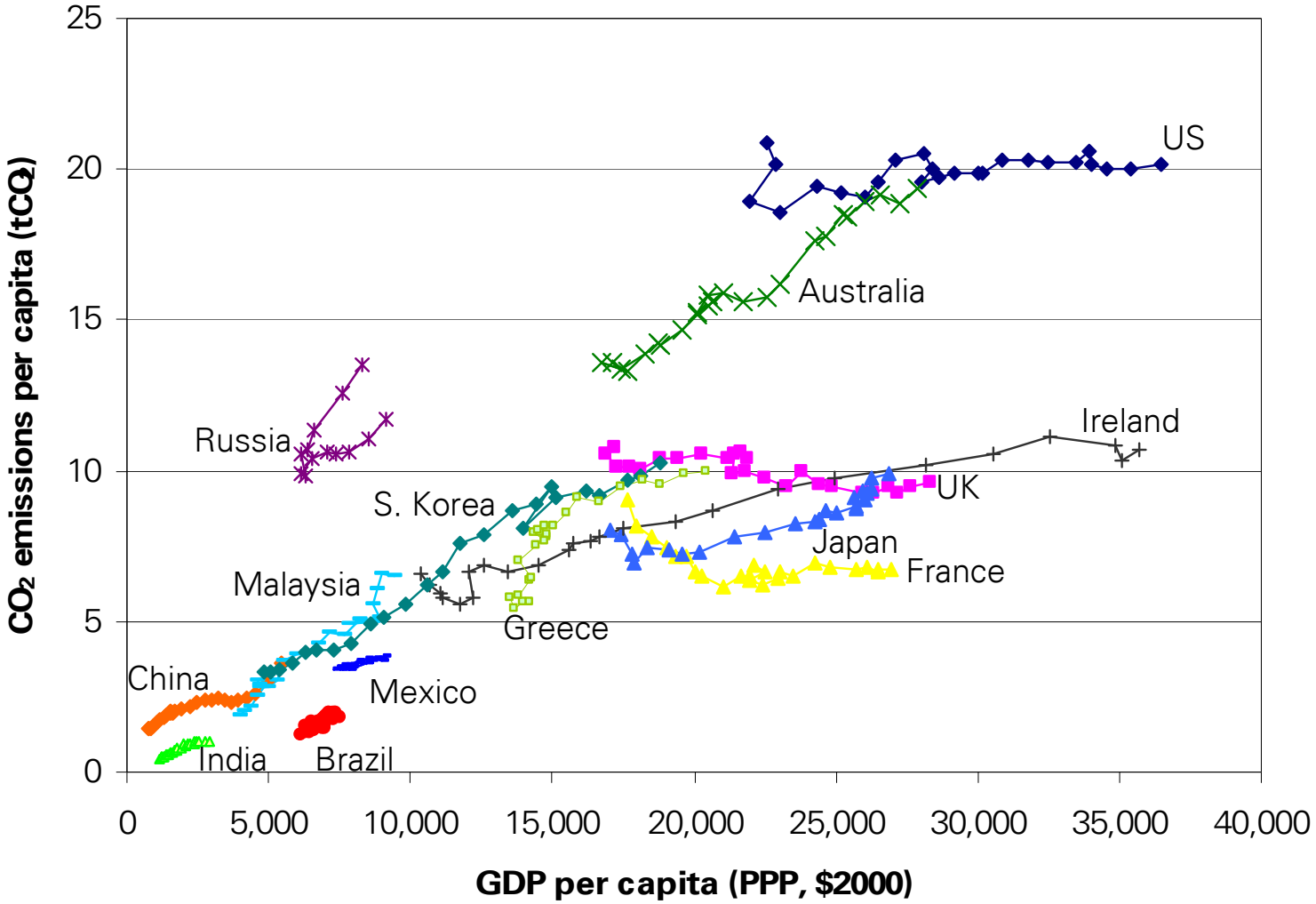


There are many social barriers to meaningful emissions reductions

- **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**



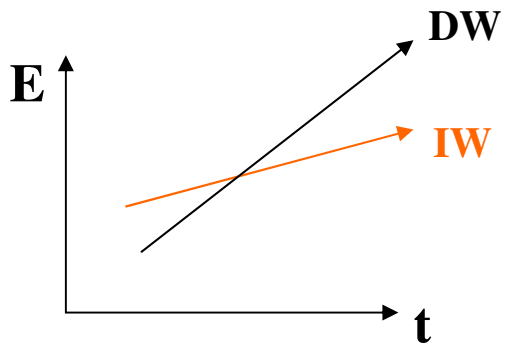
CO_2 emissions and GDP per capita (1980-2004)



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

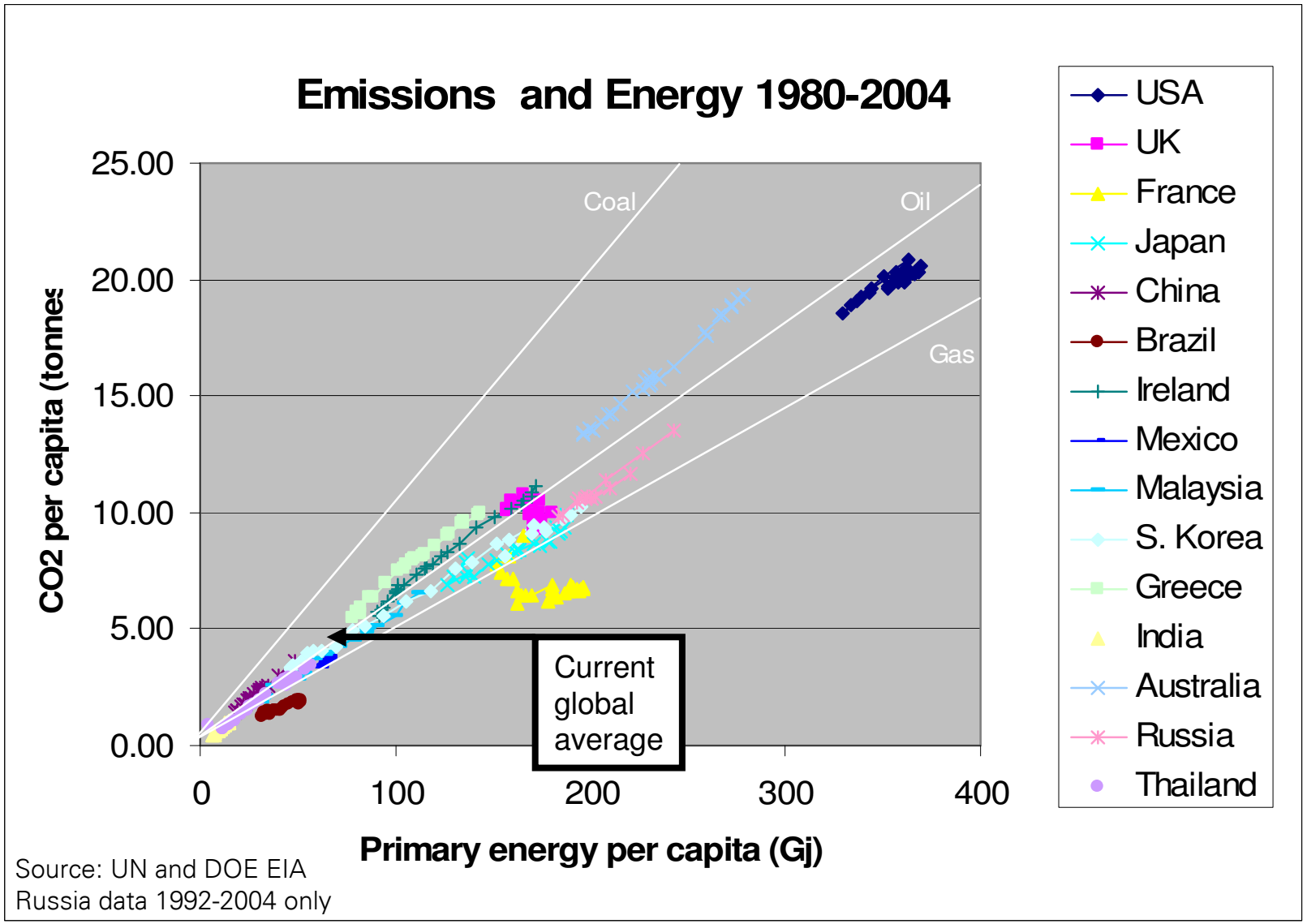
Implications of emissions heterogeneities

- **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**

CO_2 emissions and Energy per capita (1980-2004)



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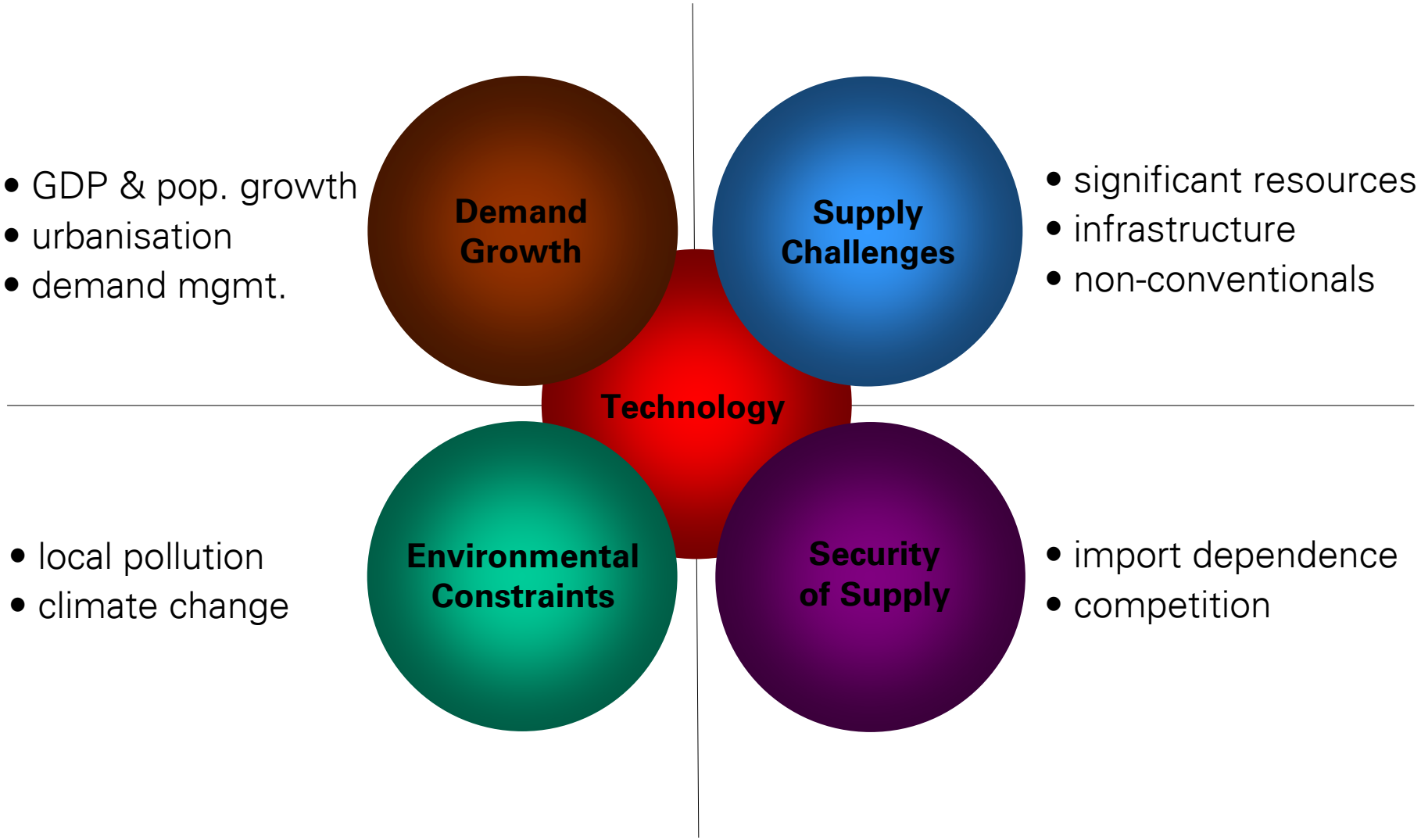
key drivers of the energy future



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:

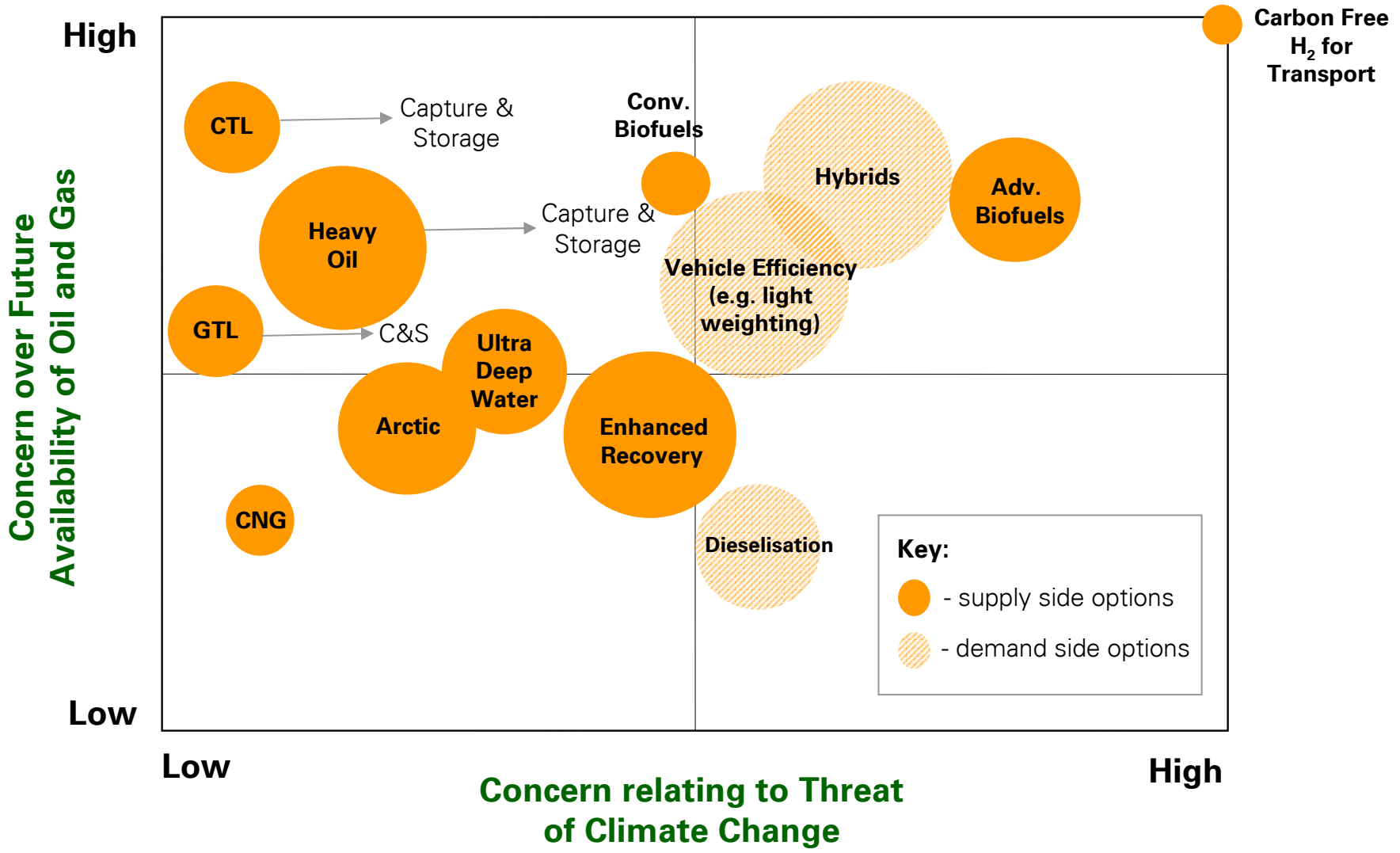
- ICEs
- Adv. Batteries
- Hybridisation
- Fuel cells
- Hydrogen storage
- Gas turbines
- Building efficiency
- Urban infrastructure
- Systems design
- Other efficiency technologies
- Appliances
- Retail technologies

evaluating energy technology options

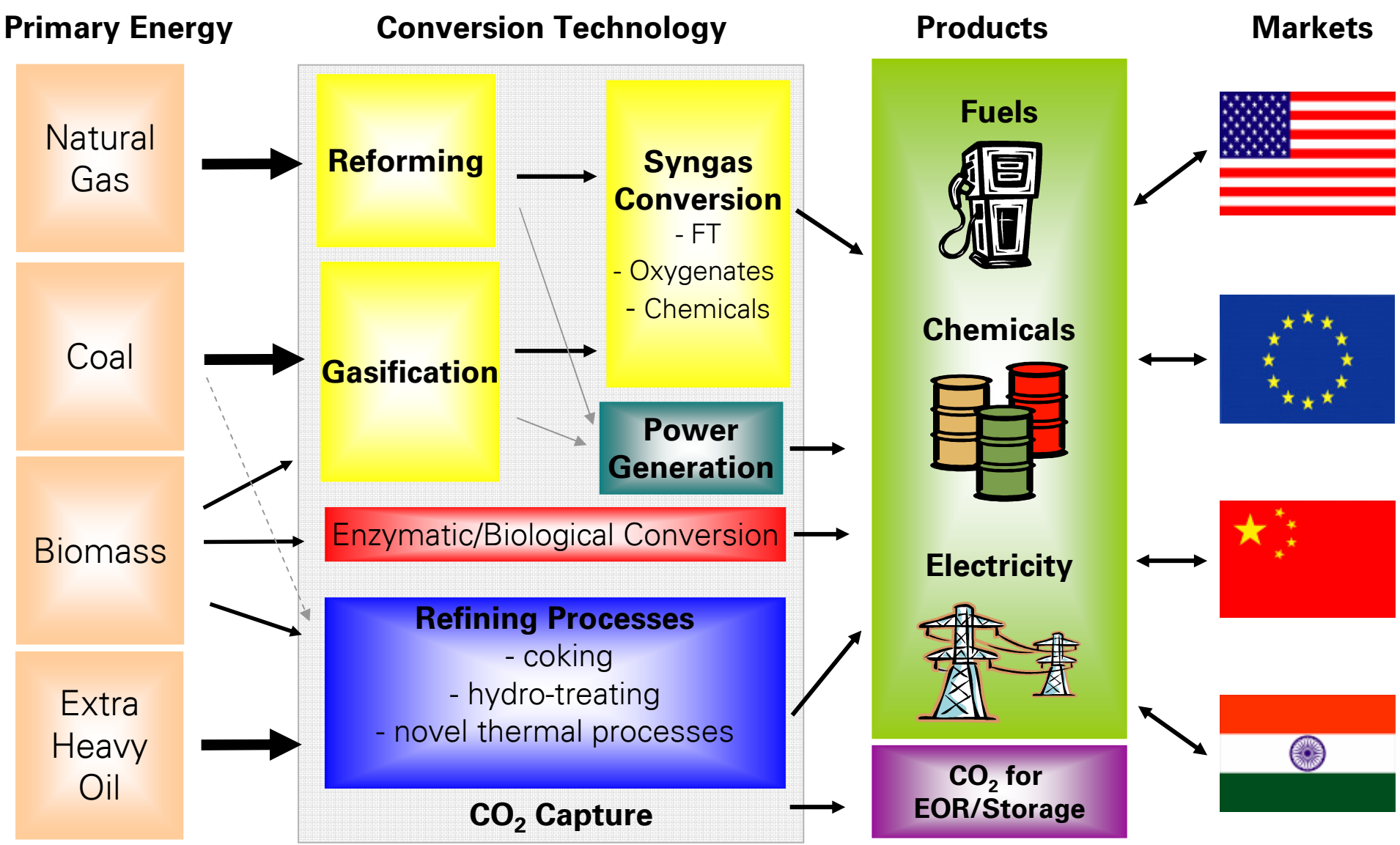
- Current **technology status** and plausible **technical headroom**
- **Budgets** for the three E's:
  - **Economic** (cost relative to other options)
  - **Energy** (output how many times greater than input)
  - **Emissions** (pollution and CO2; operations and capital)
- **Materiality** (at least 1TW = 5% of 2050 BAU energy demand)
- **Other costs** - reliability, intermittency etc.
- Social and political **acceptability**

But we also must know what problem we are trying to solve

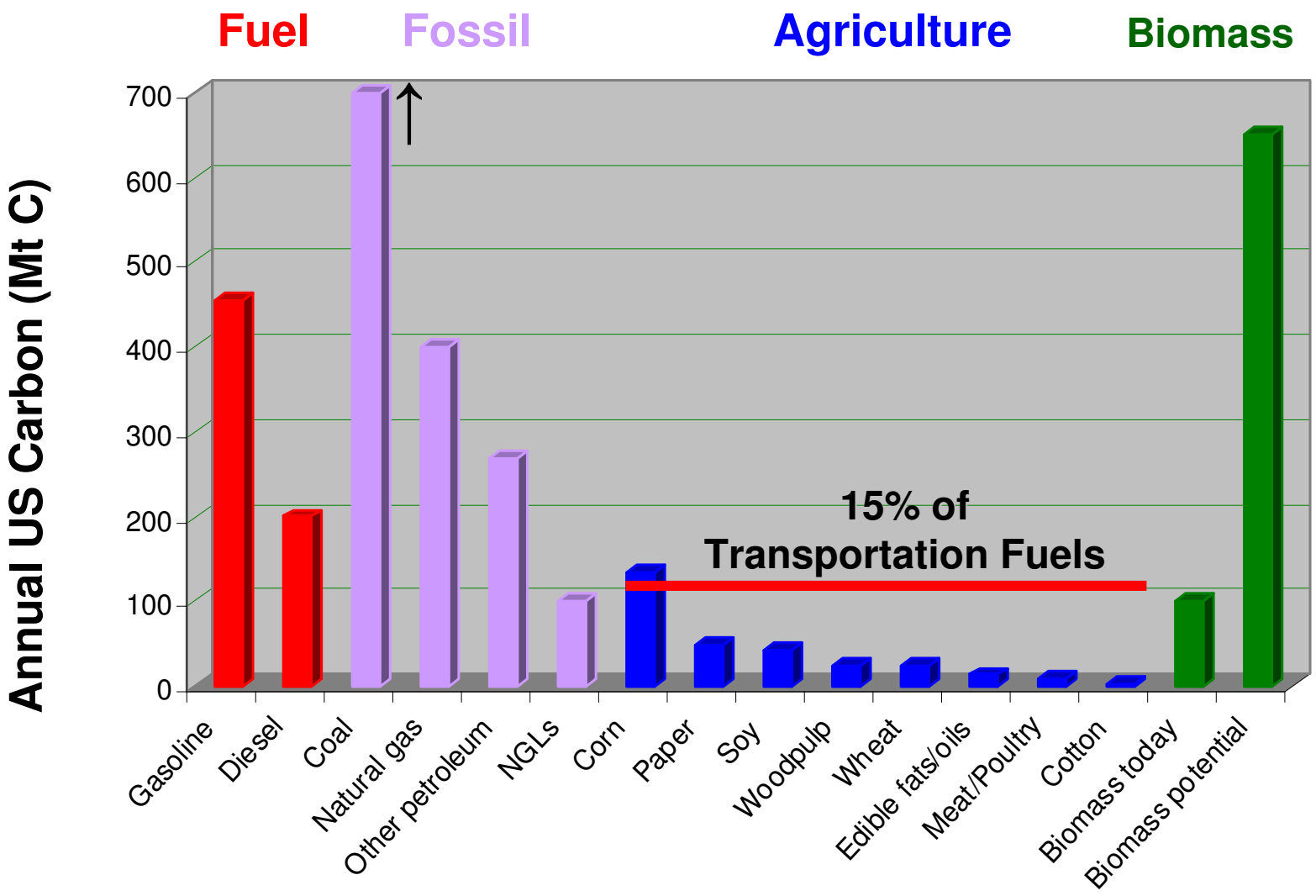
two key energy considerations – security & climate



The fungibility of carbon



what carbon "beyond petroleum"?



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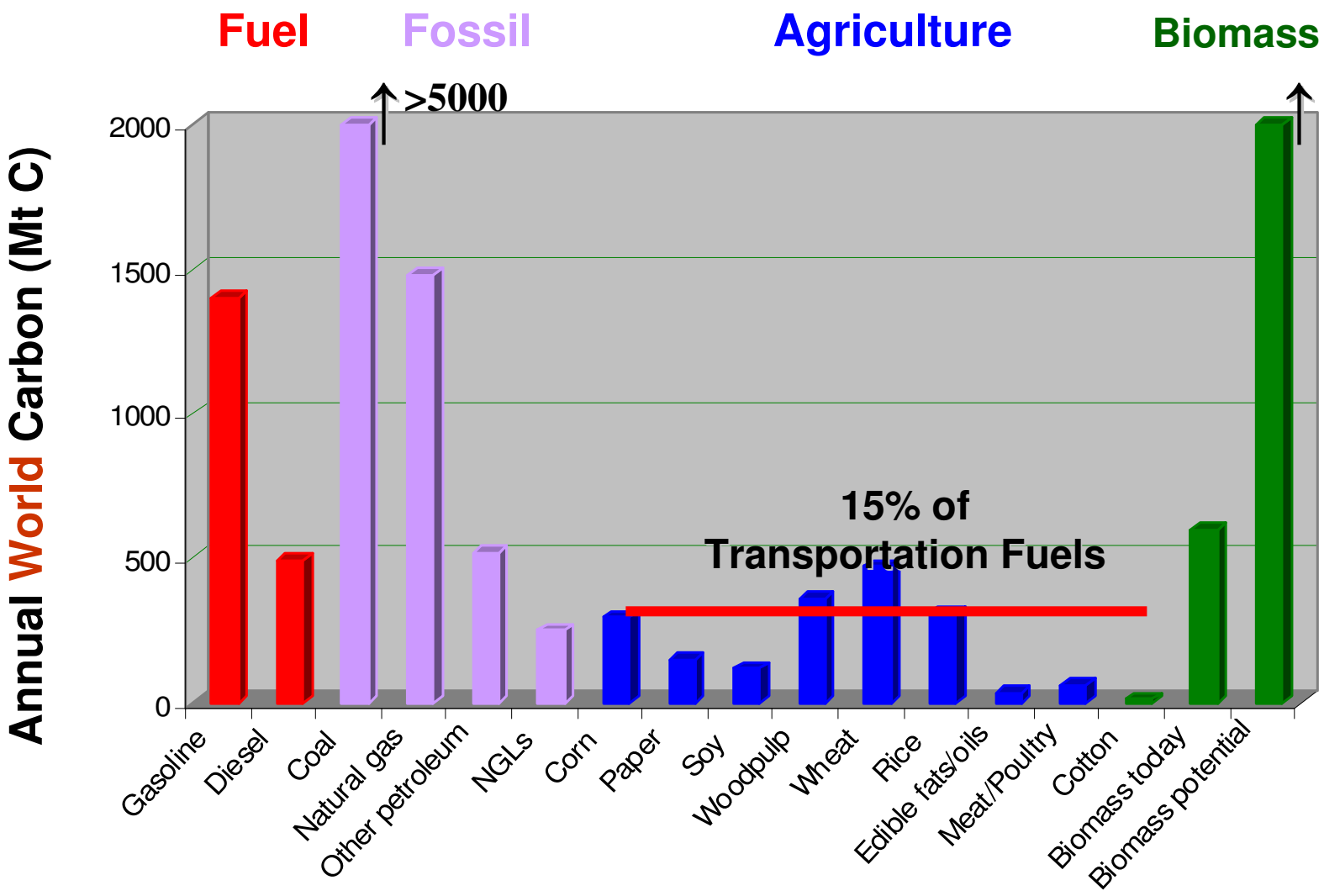
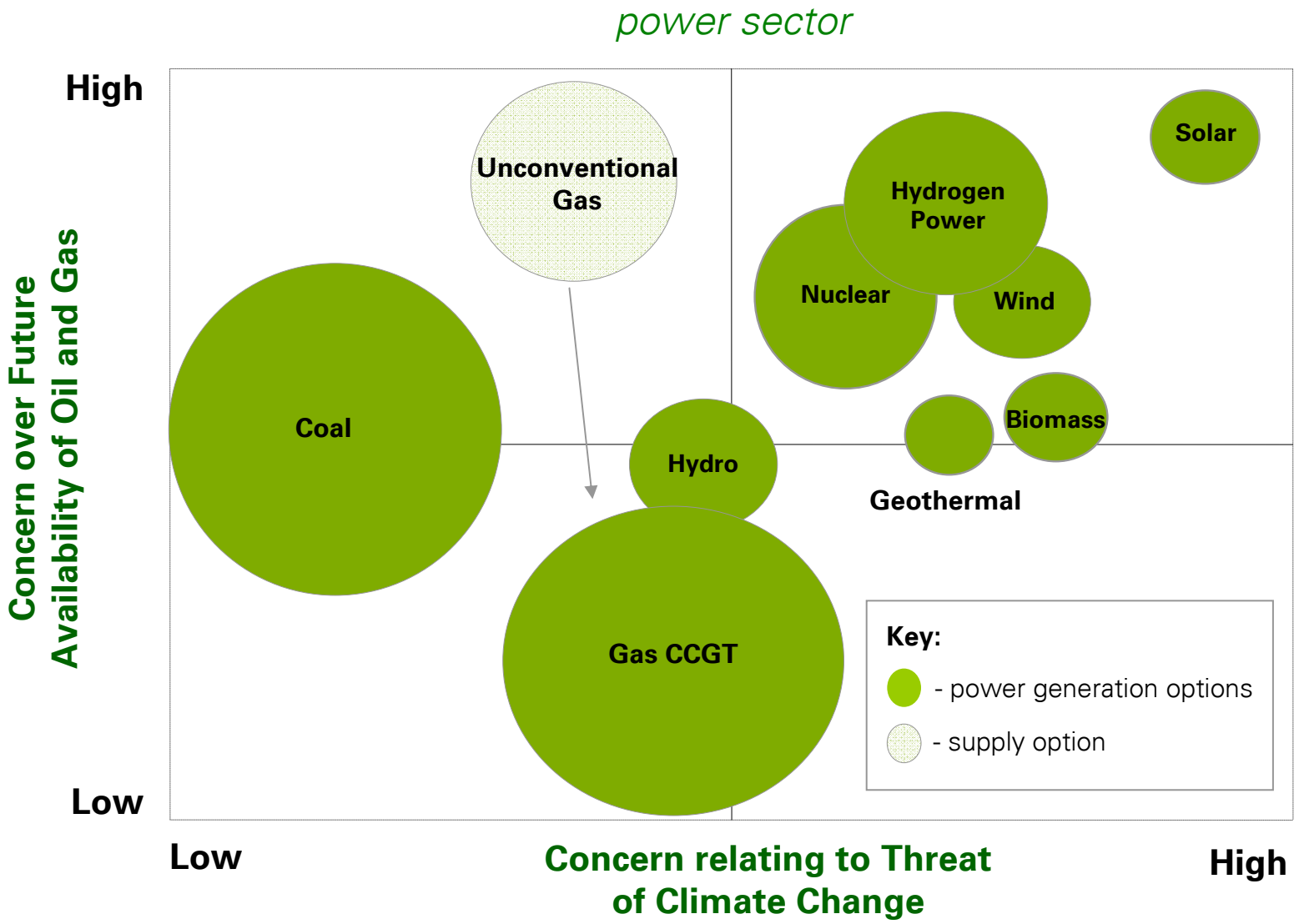
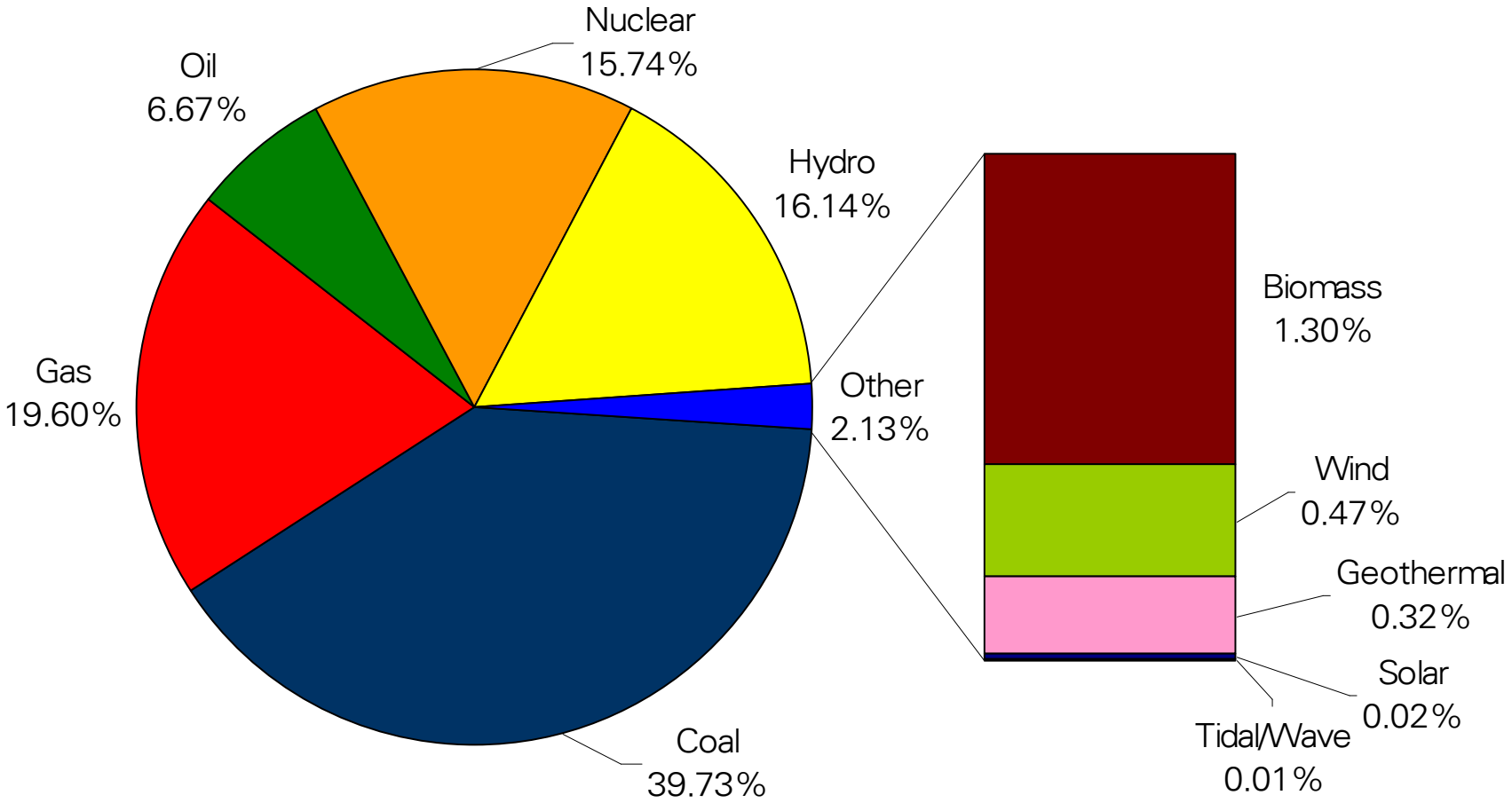


Evaluating power options

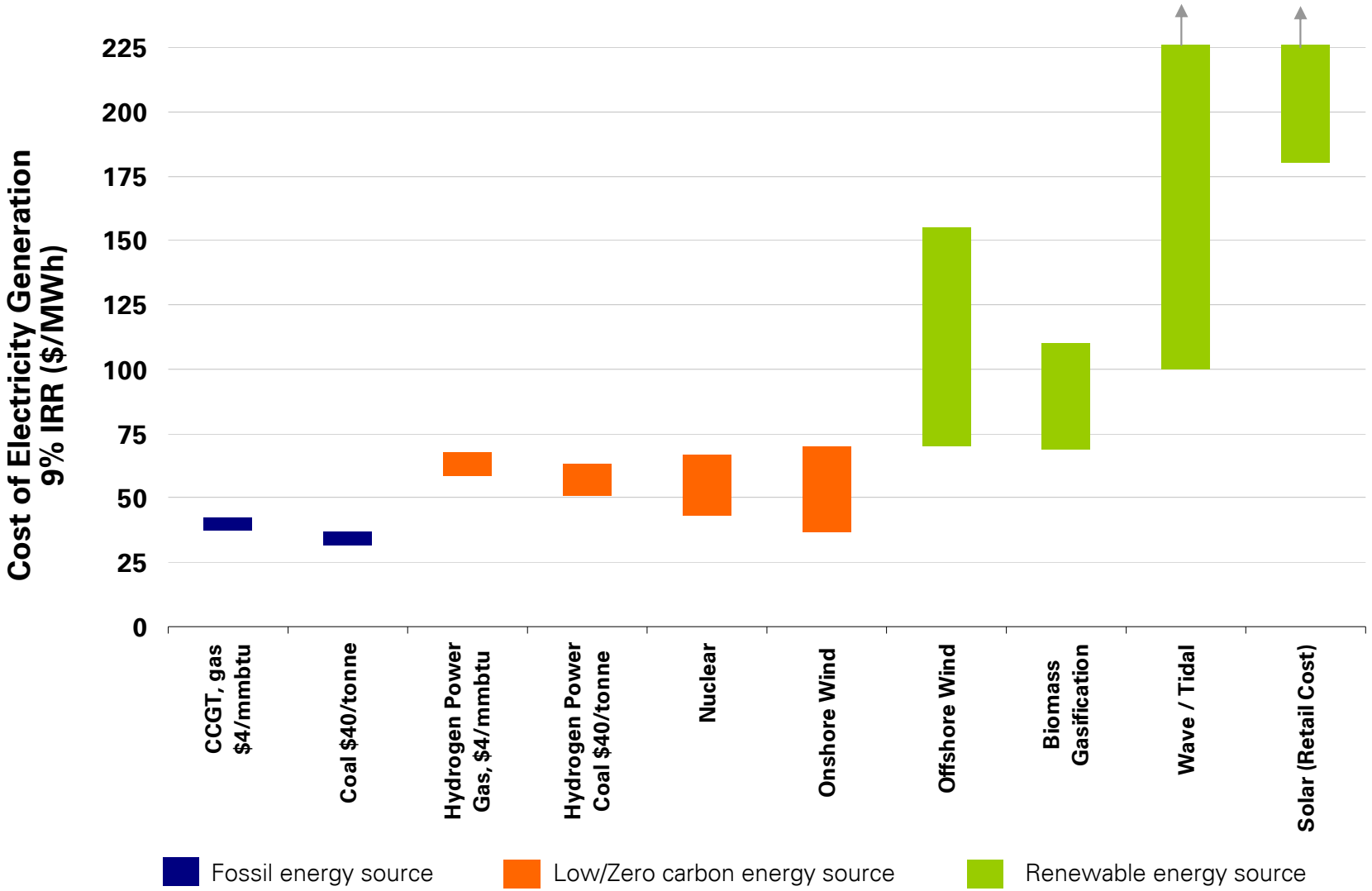


electricity generation shares by fuel - 2004



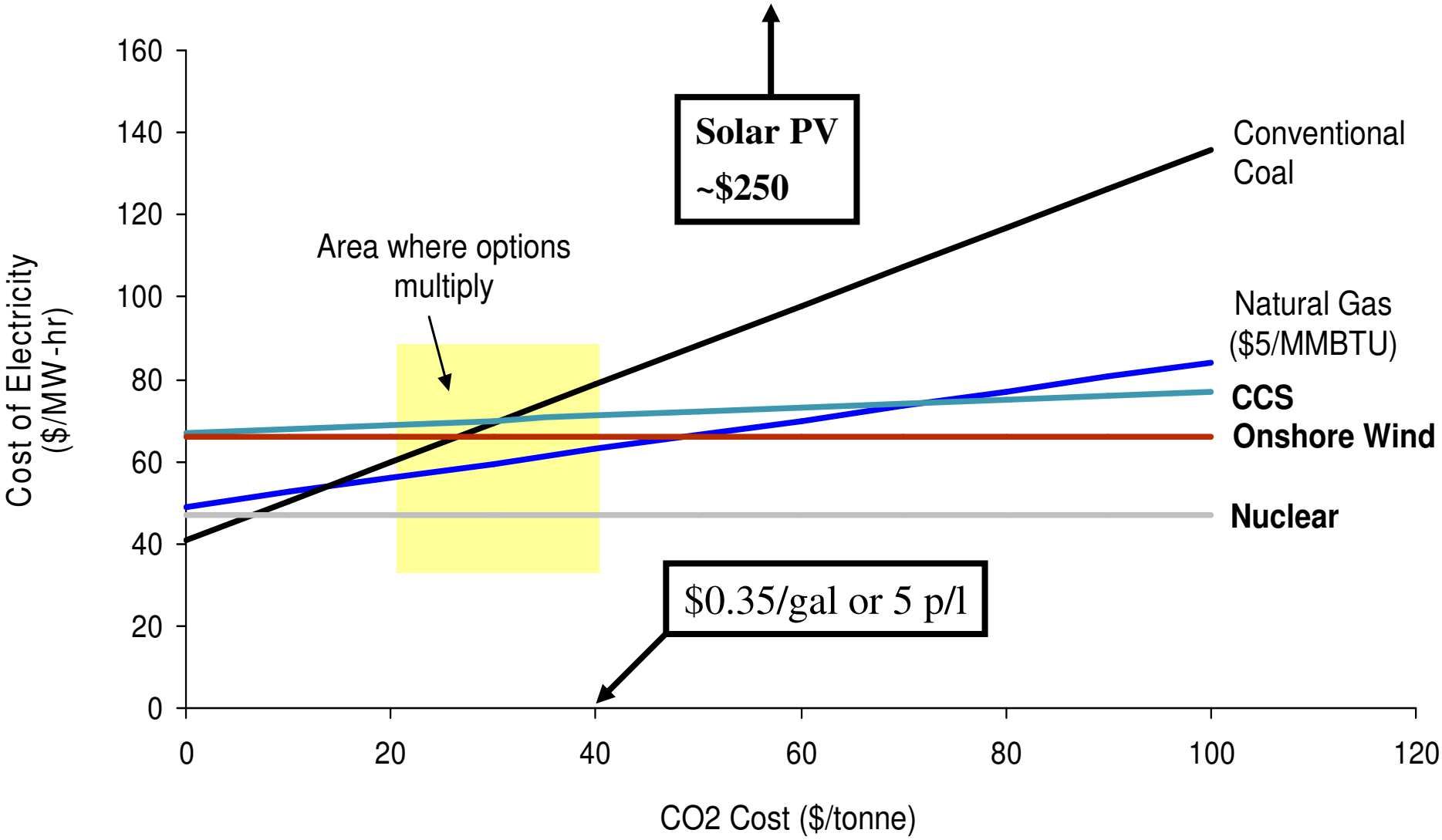
Source: IEA WEO 2006

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?

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
  - For short/mid-term technologies
    - Avoid picking winners/losers (emissions trading)
    - 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 and policy

Questions/Comments/Discussion


bp