Energy trends and technologies in the coming decades

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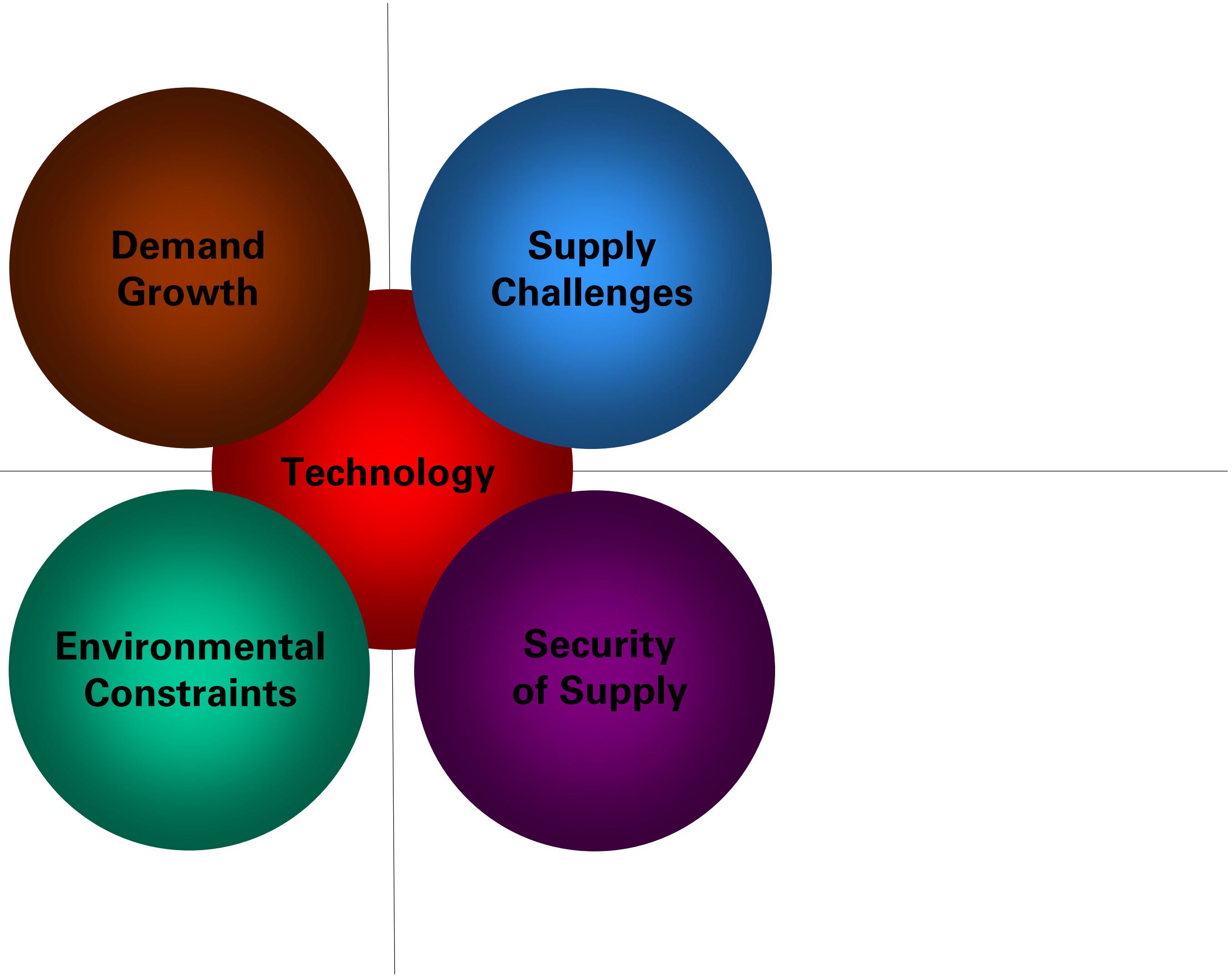
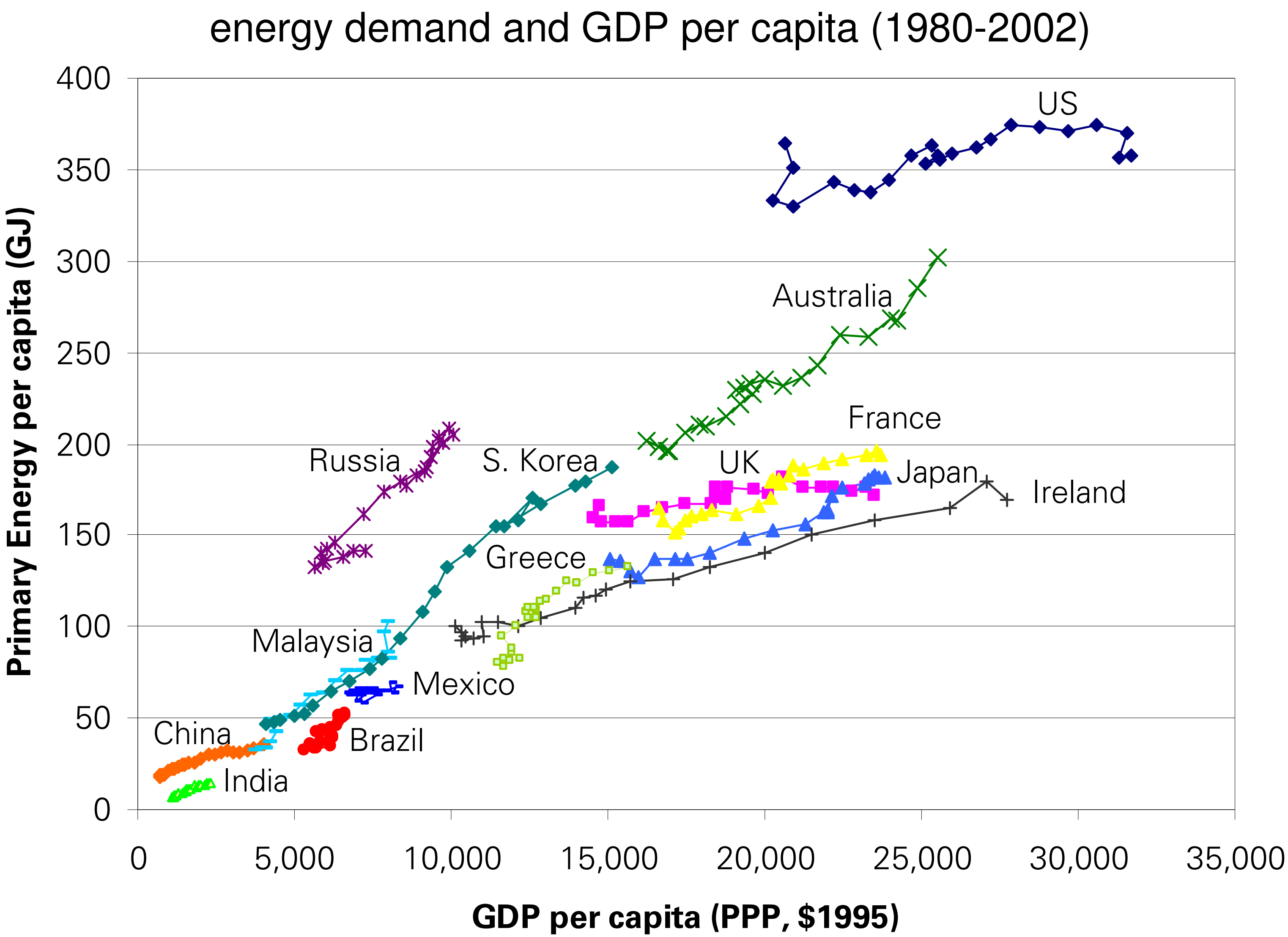
key drivers of the energy future

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



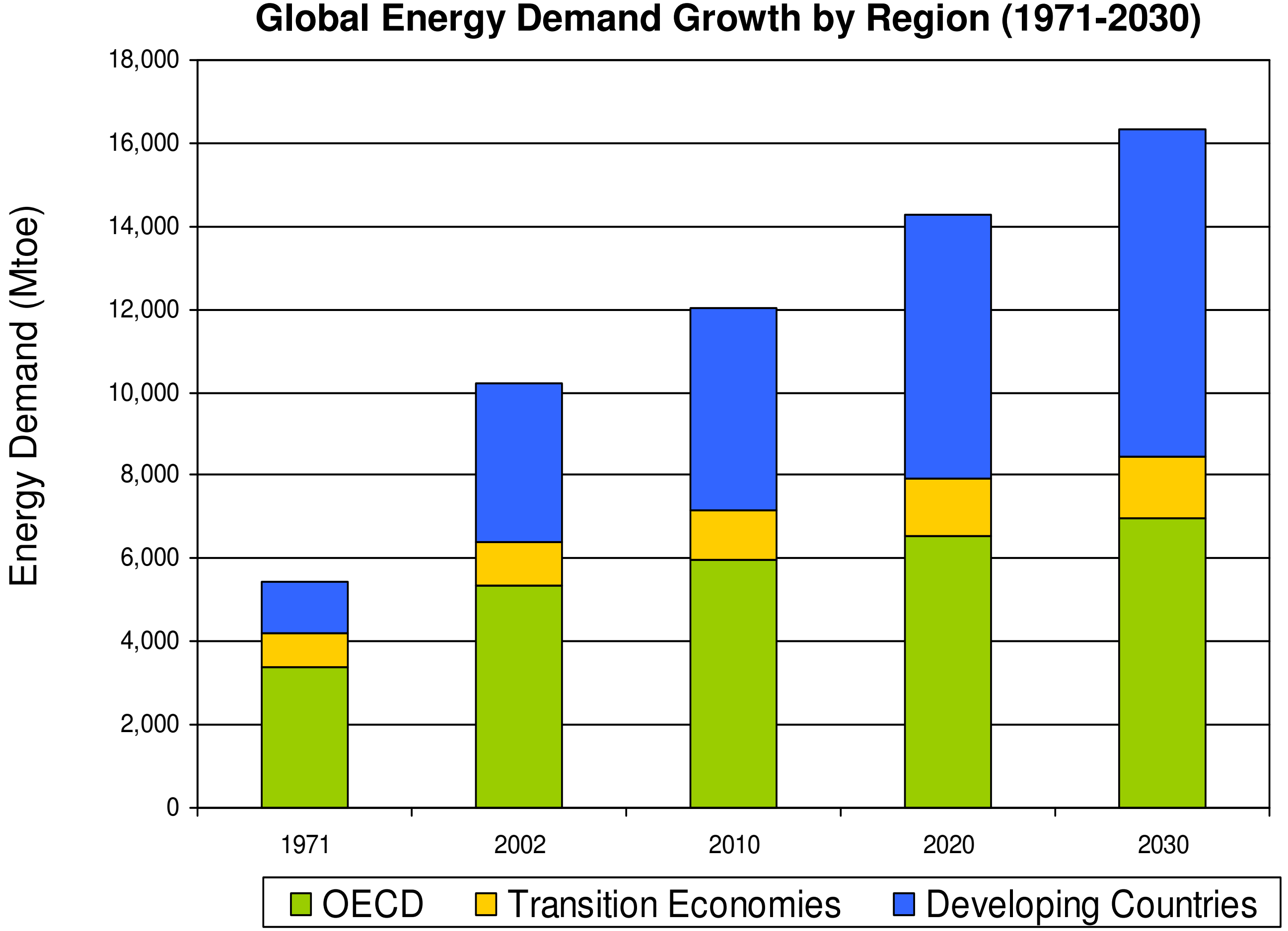
Energy use grows with economic development



Source: UN and DOE EIA

energy demand – growth projections

Global energy demand is set to grow by over 60% over the next 30 years – 74% of the growth is anticipated to be from non-OECD countries

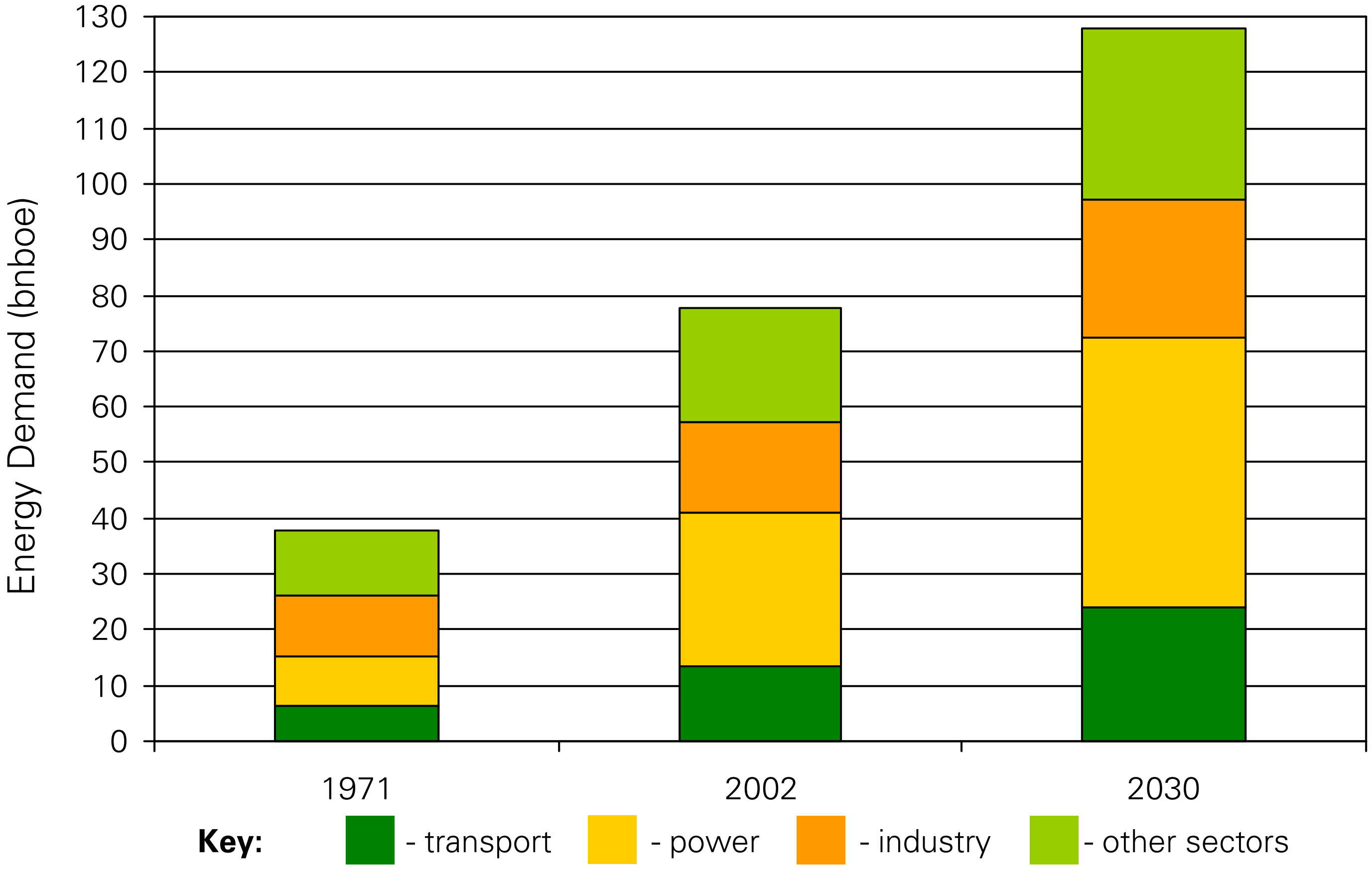


Notes: 1. OECD refers to North America, W. Europe, Japan, Korea, Australia and NZ
2. Transition Economies refers to FSU and Eastern European nations
3. Developing Countries is all other nations including China, India etc.

Source: IEA World Energy Outlook 2004

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%**

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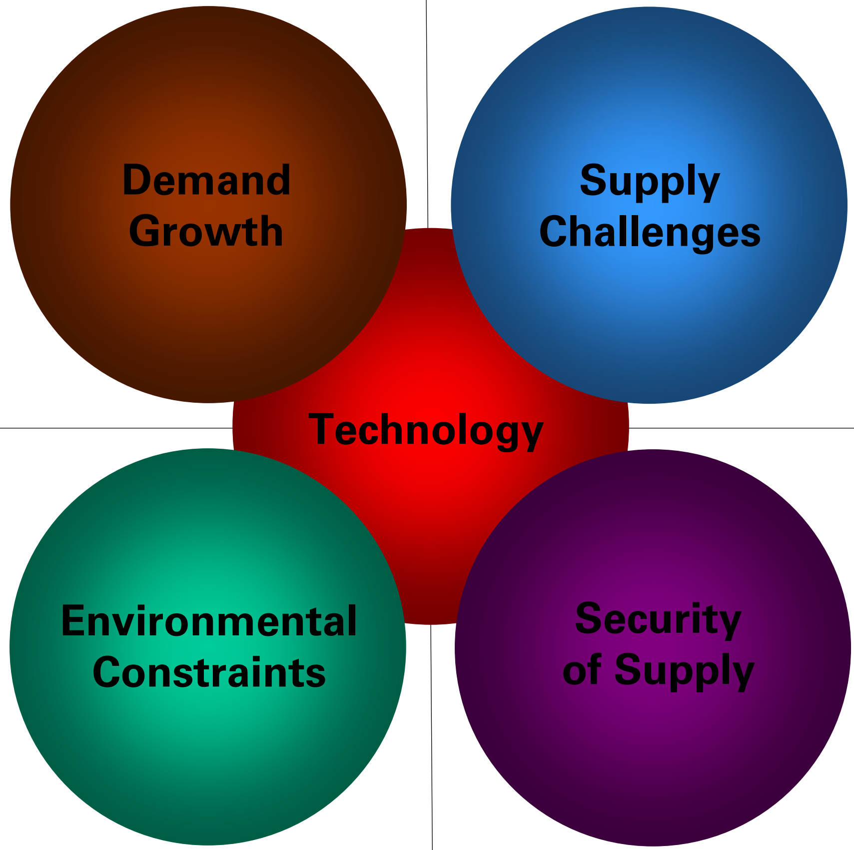
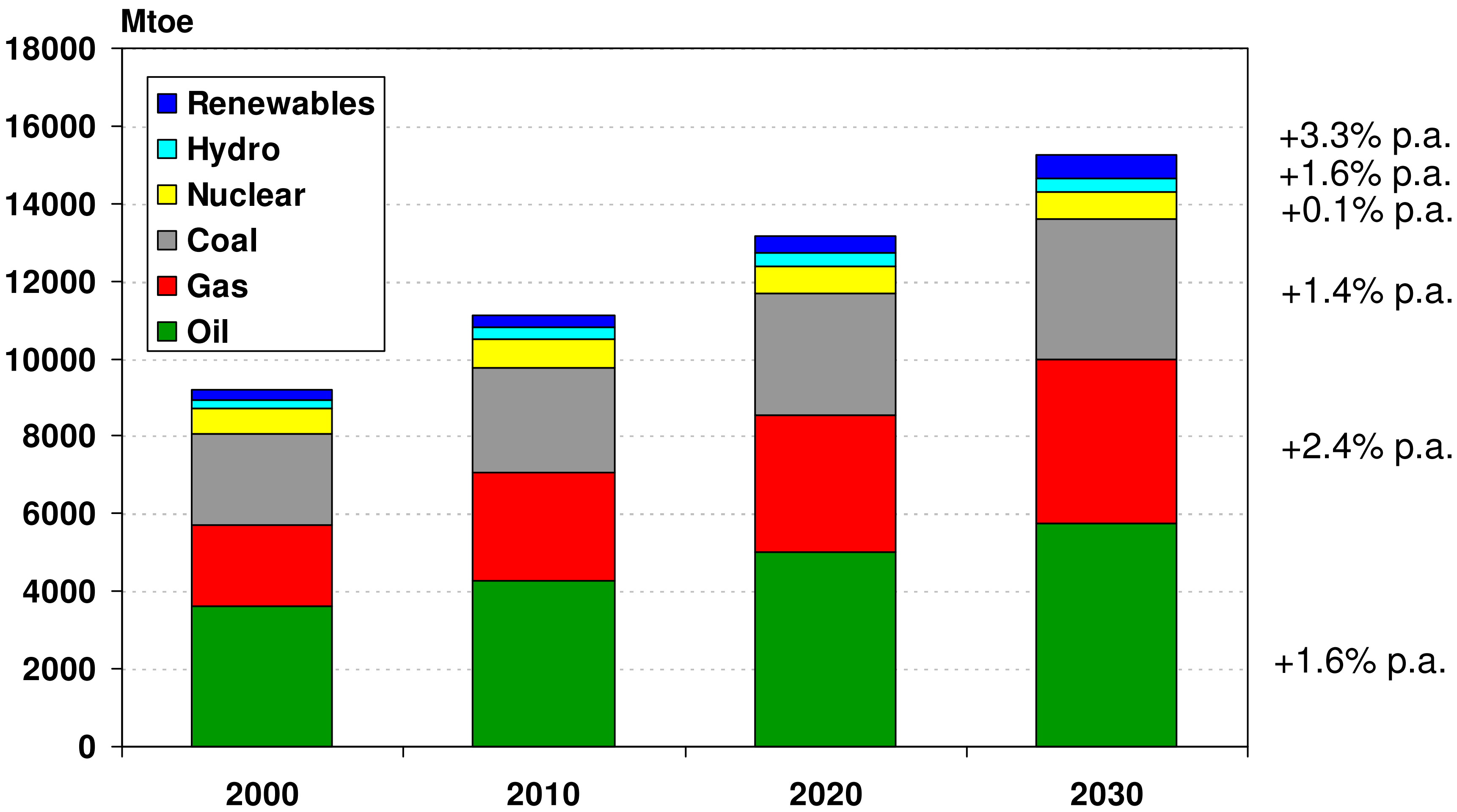


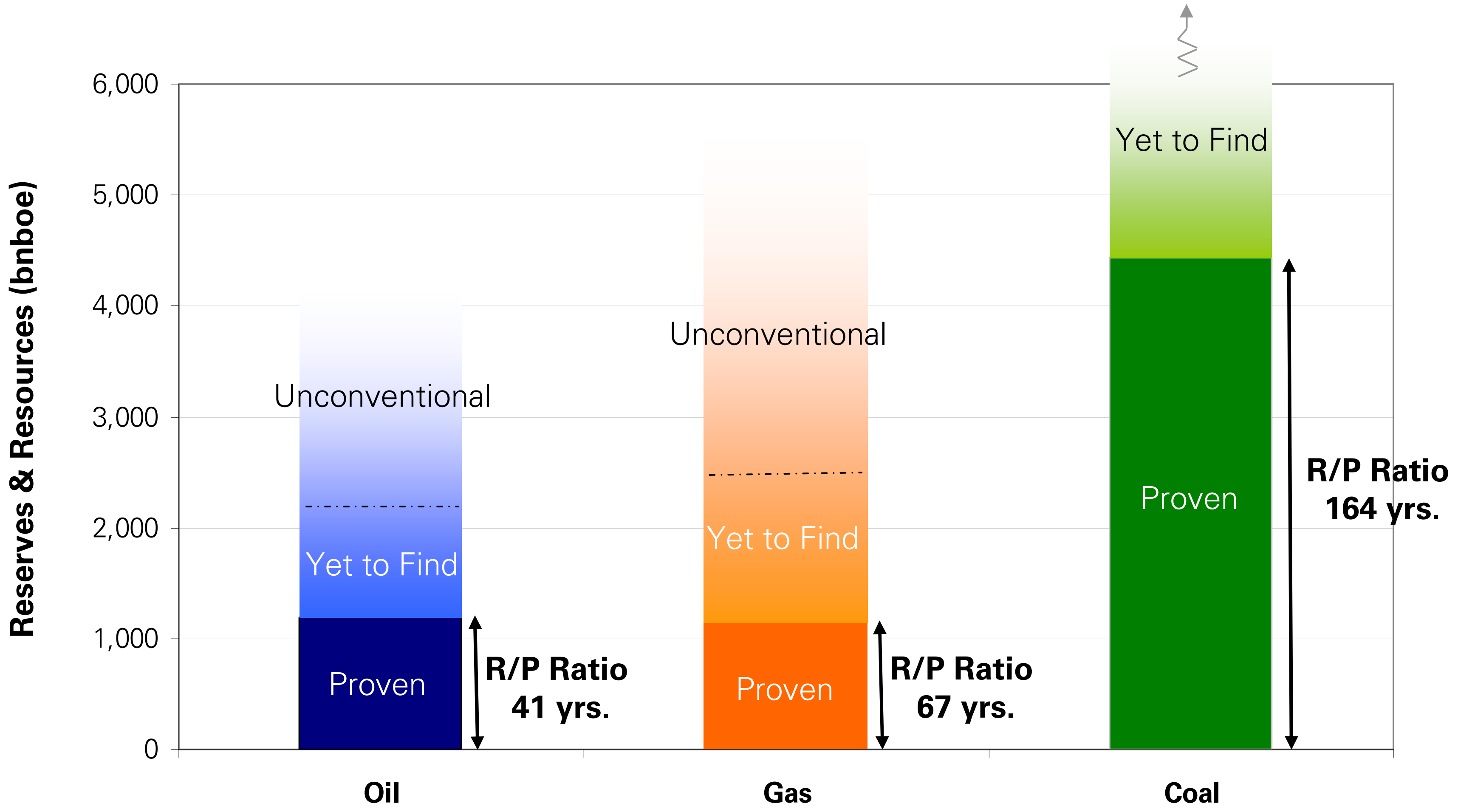
- **significant resources**
- **infrastructure**
- **non-conventionals**

"Business as usual" energy supply forecast



Source: IEA WEO 2002

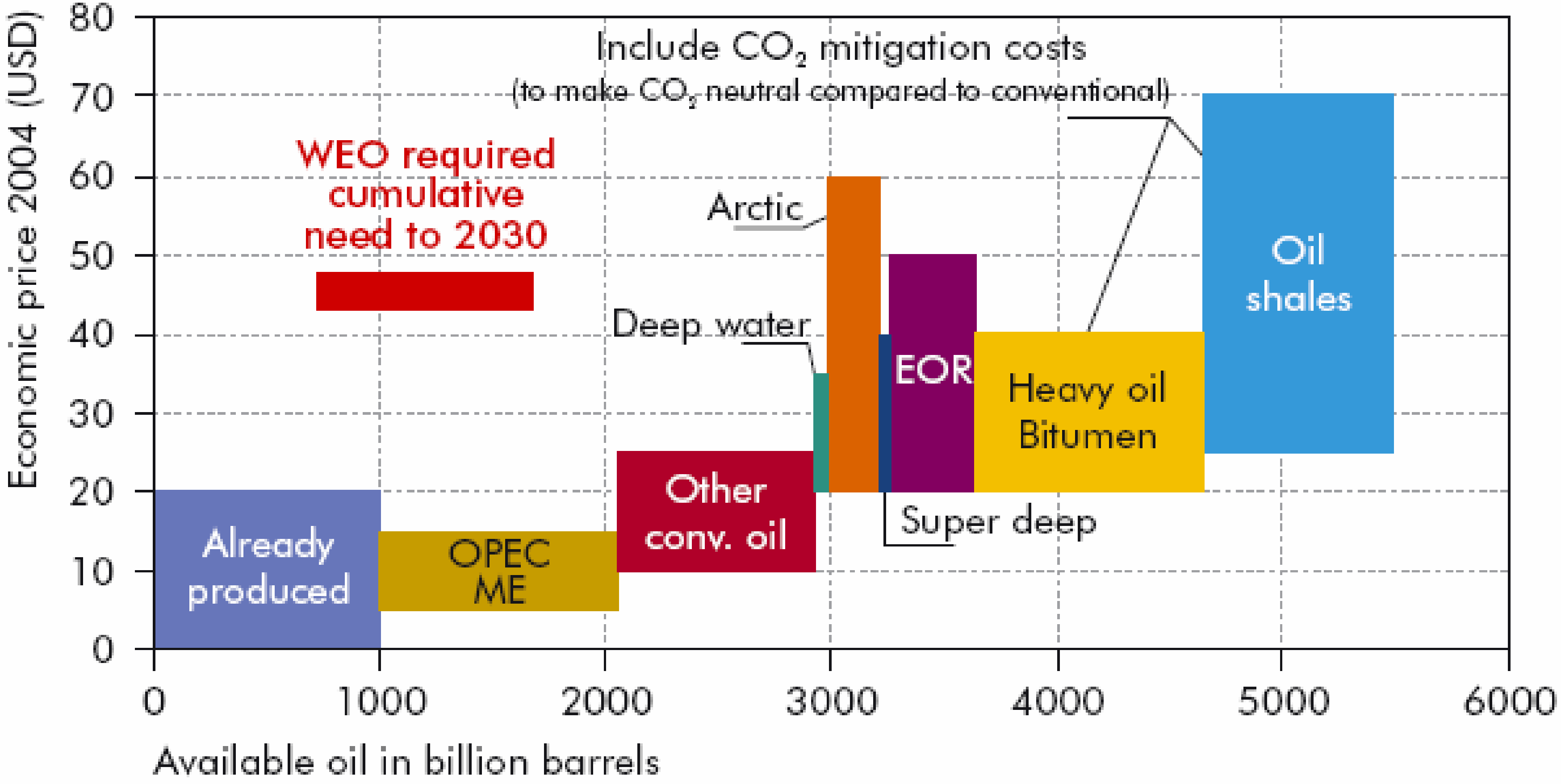
substantial global fossil resources



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

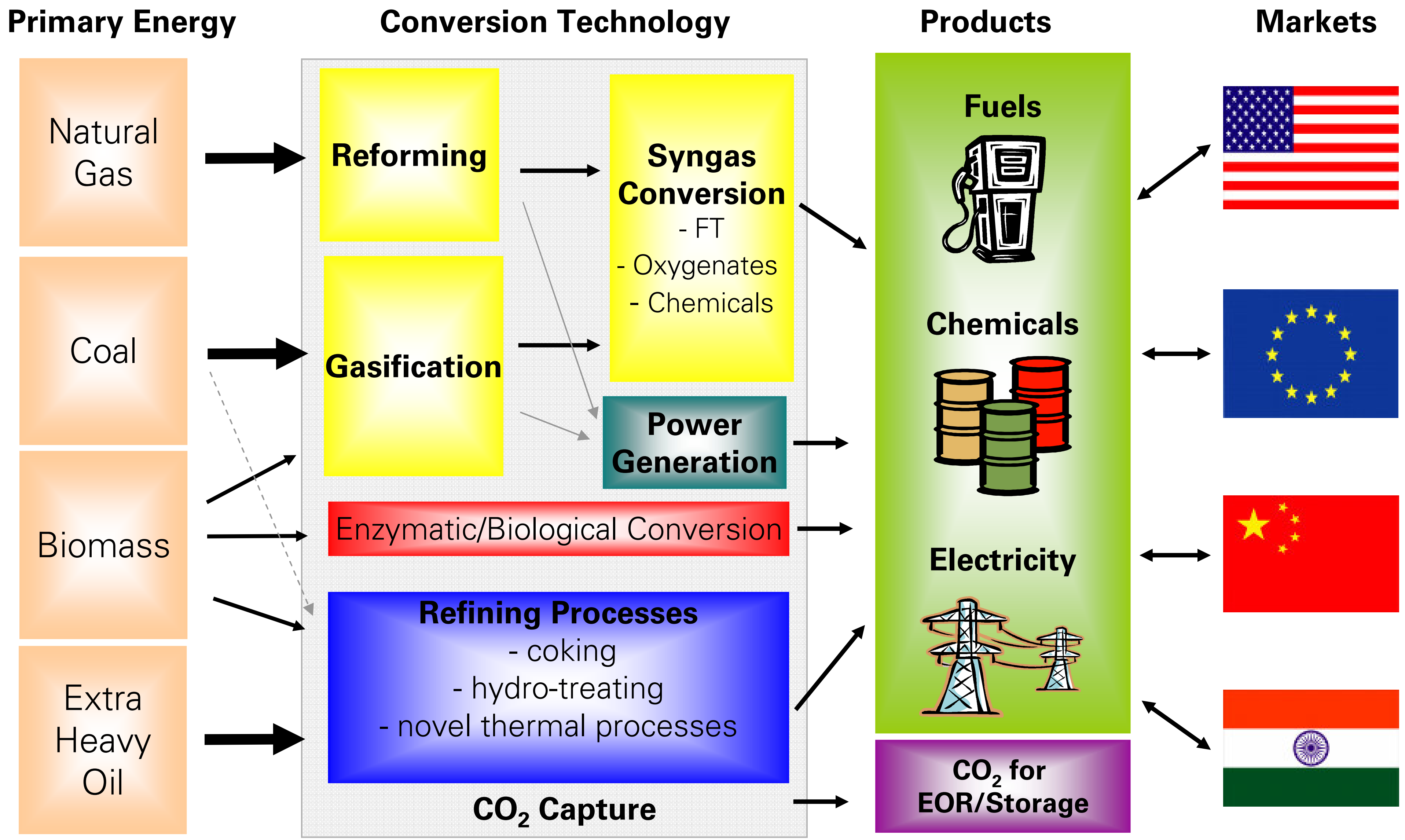
oil supply and cost curve

Availability of oil resources as a function of economic price



Source: IEA (2005)

increasing fungibility of fossil fuels



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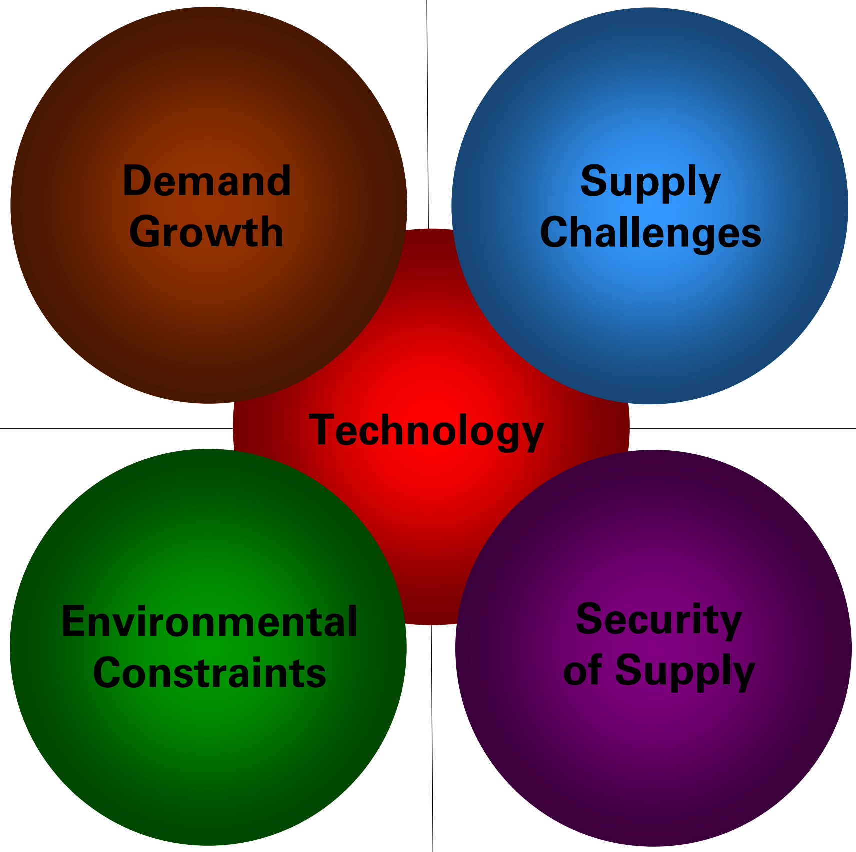
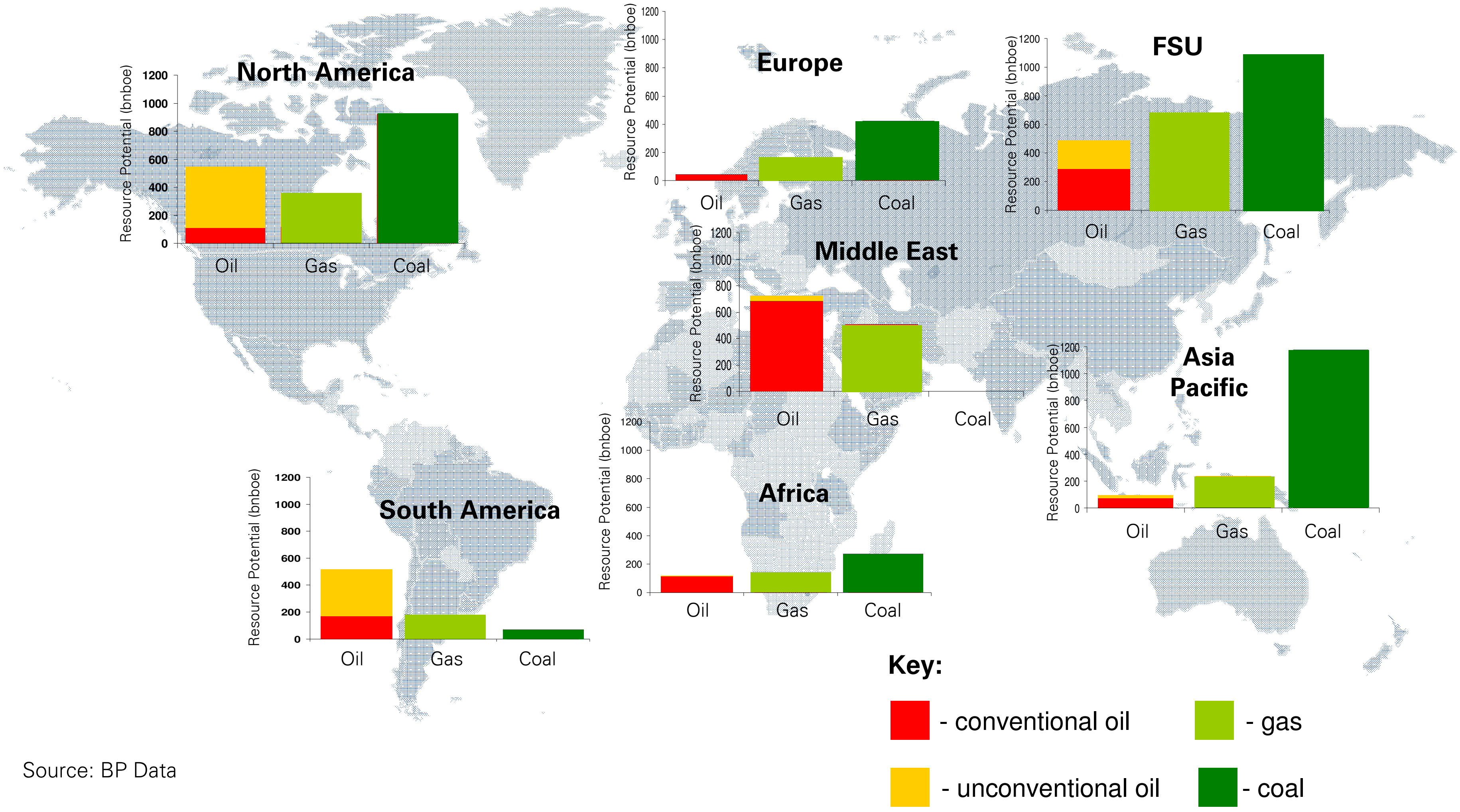


- significant resources
- infrastructure
- non-conventionals

- **import dependence**
- **competition**

significant hydrocarbon resource potential

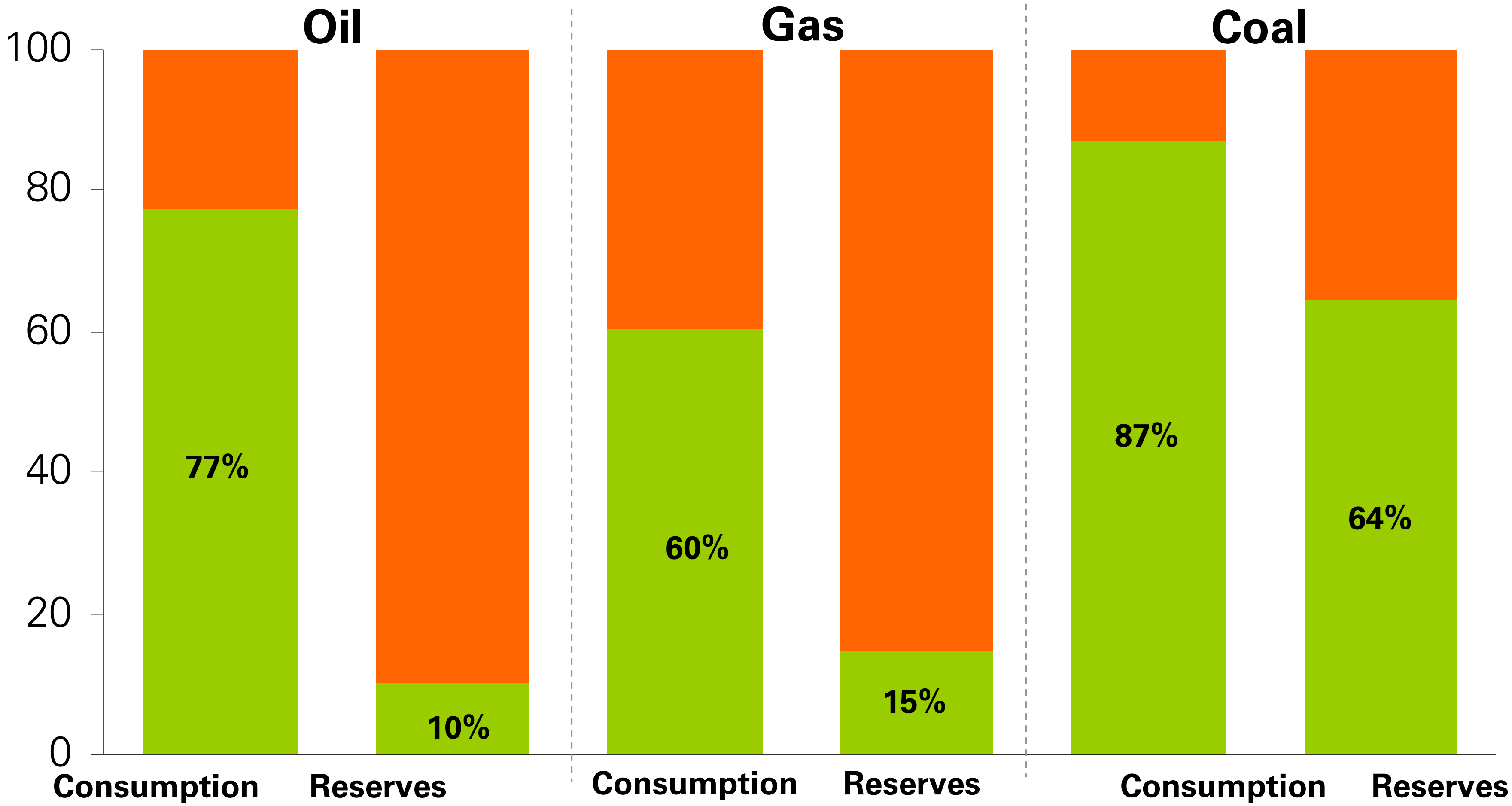
Oil, Gas and Coal Resources by Region (bnboe)



Source: BP Data

dislocation of supply & demand

Regional Share of 2004 Consumption vs Reserves



Key: - 3 largest energy markets (N. America, Europe and Asia Pacific) - Rest of World

Source: BP Statistical Review 2005

Note: oil reserve figures do not include unconventional reserves estimates

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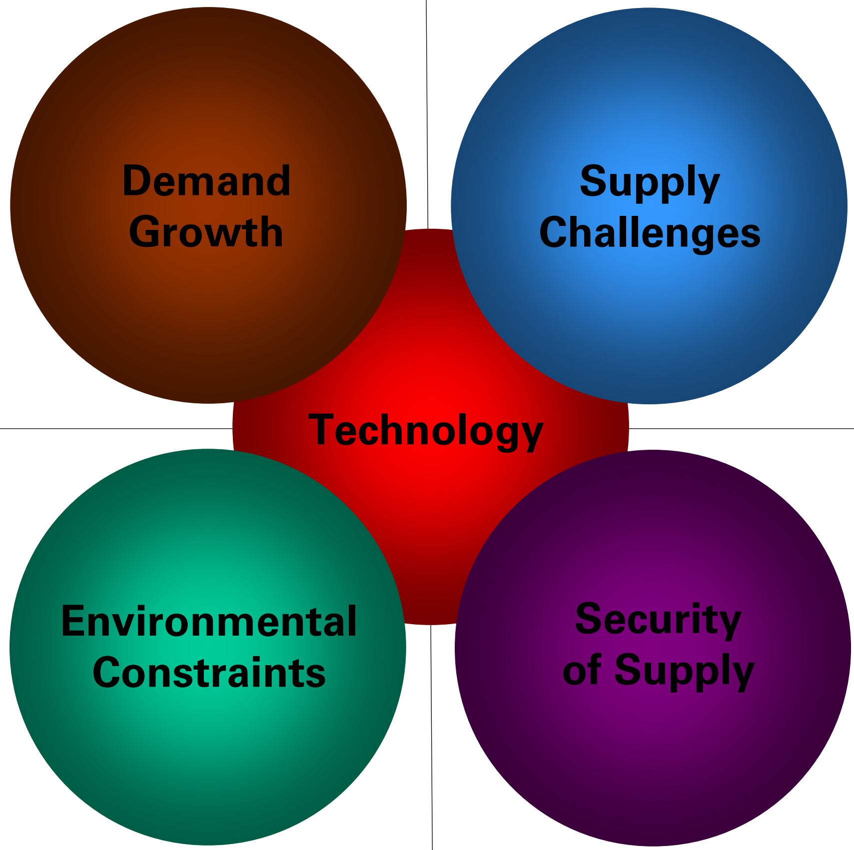
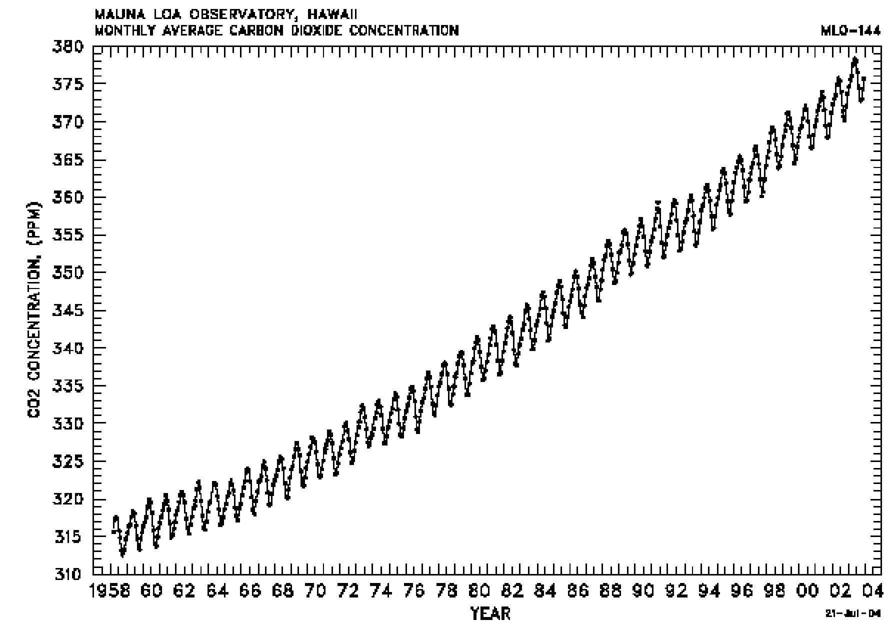


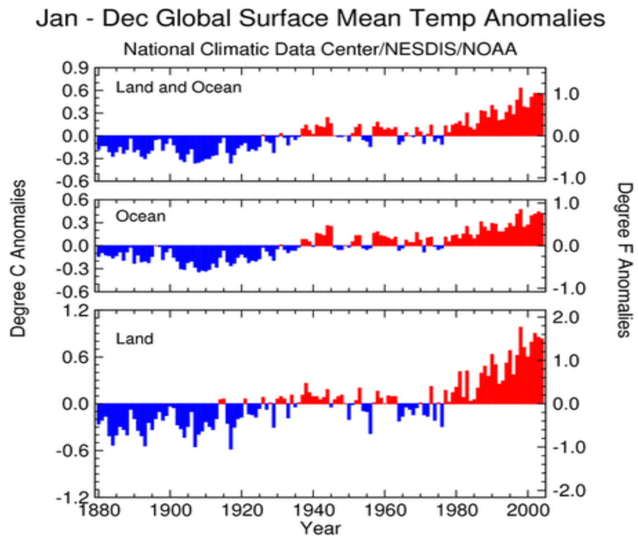
- **local pollution**
- **climate change**

- import dependence
- competition

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 the scientific case is not overwhelming (natural variability, forcings)**
- **Impacts of higher CO_2 quite 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?**



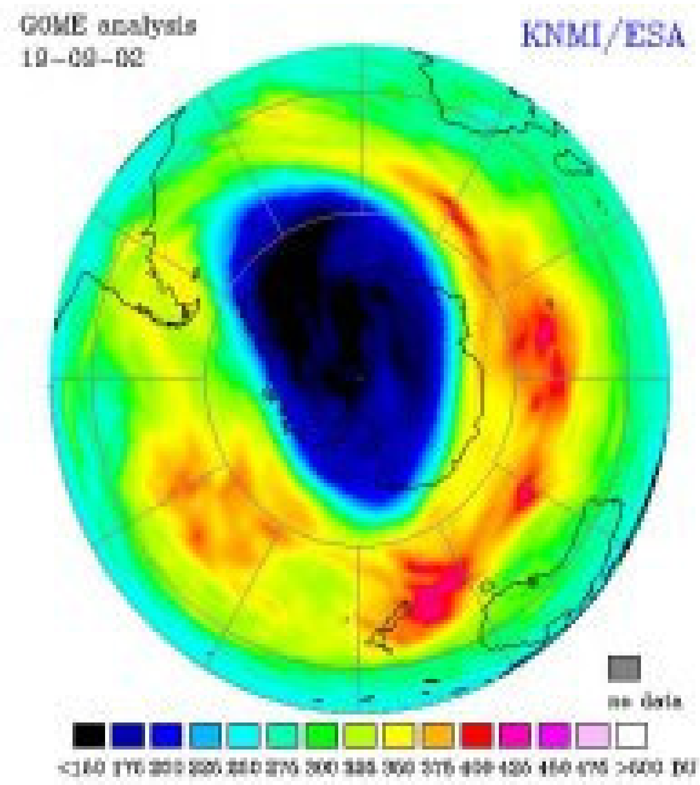


Salient facts about CO_2 science

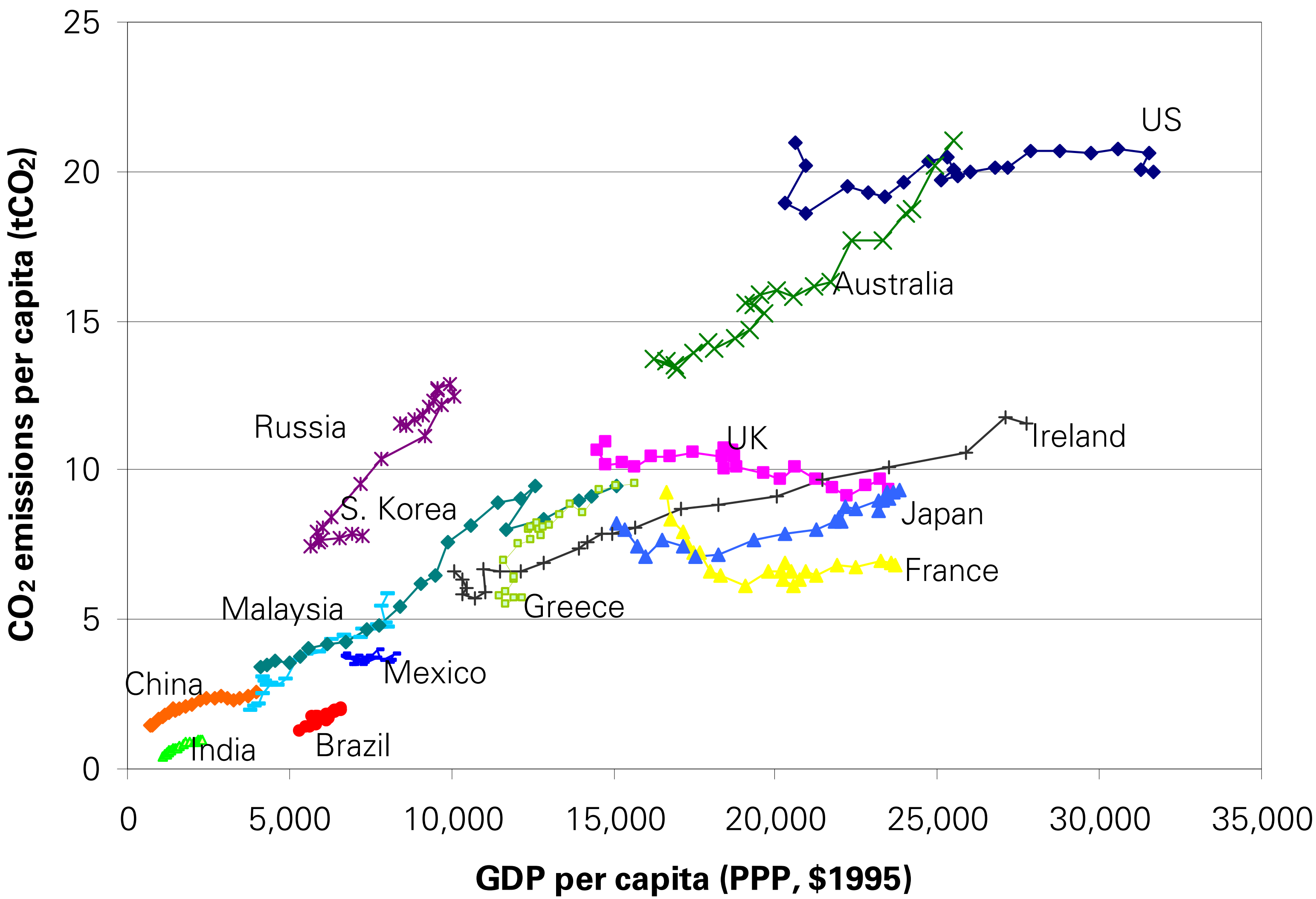
- **The earth absorbs anthropogenic CO_2 at a limited rate**
  - **Emissions must be no higher by 2050 and drop to about half of their current value by 2100 to stabilize at 550 ppm**
  - **This in the face of a doubling of energy demand in the next 50 years (1.5% per year emissions growth)**
- **The lifetime of CO_2 in the atmosphere is 200-300 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)**

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 perception of the threat vary greatly around the world**



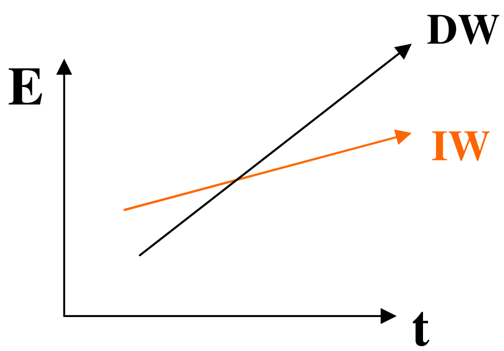
CO_2 emissions and GDP per capita (1980-2002)



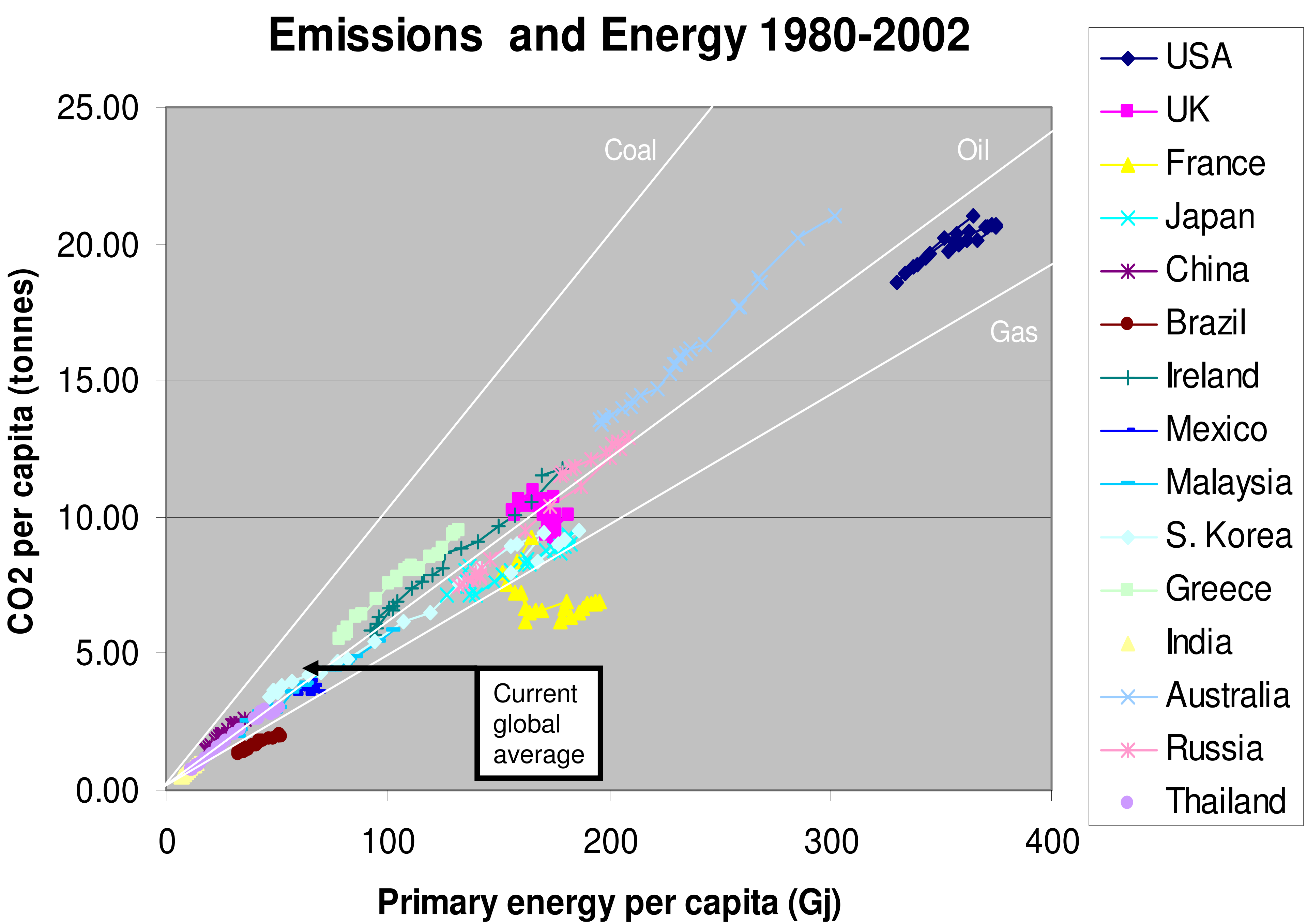
Source:

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**


Emissions and Energy 1980-2002
CO2 per capita (tonnes)
25.00
20.00
15.00
10.00
5.00
0.00
0
100
200
300
400
Primary energy per capita (Gj)
Coal
Oil
Gas
Current global average
USA
UK
France
Japan
China
Brazil
Ireland
Mexico
Malaysia
S. Korea
Greece
India
Australia
Russia
Thailand

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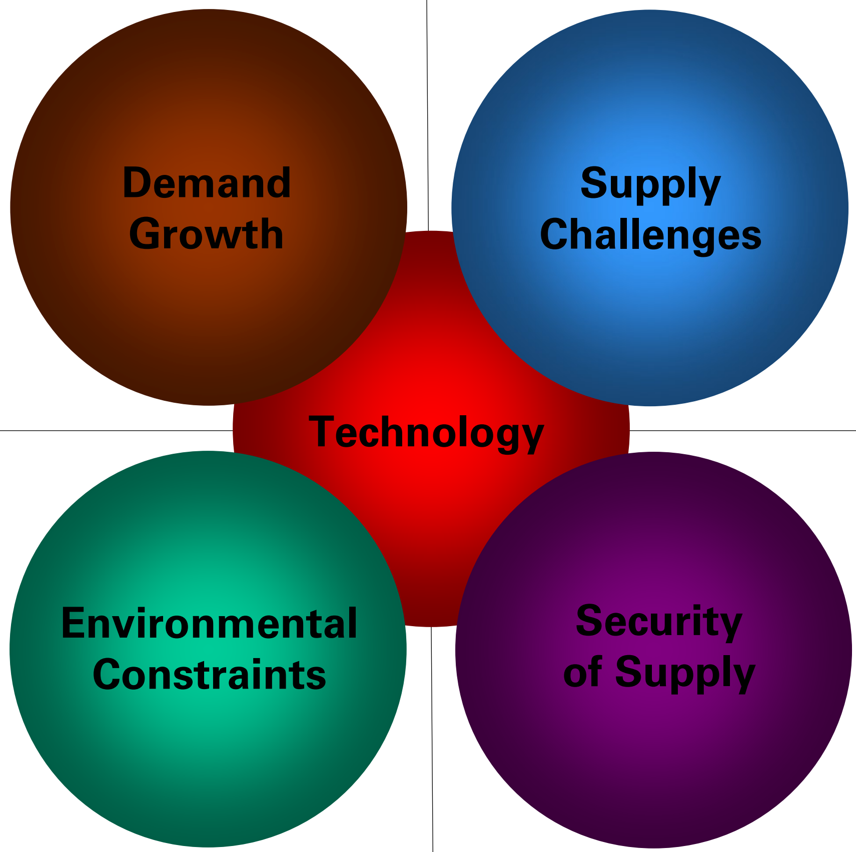


- local pollution
- climate change

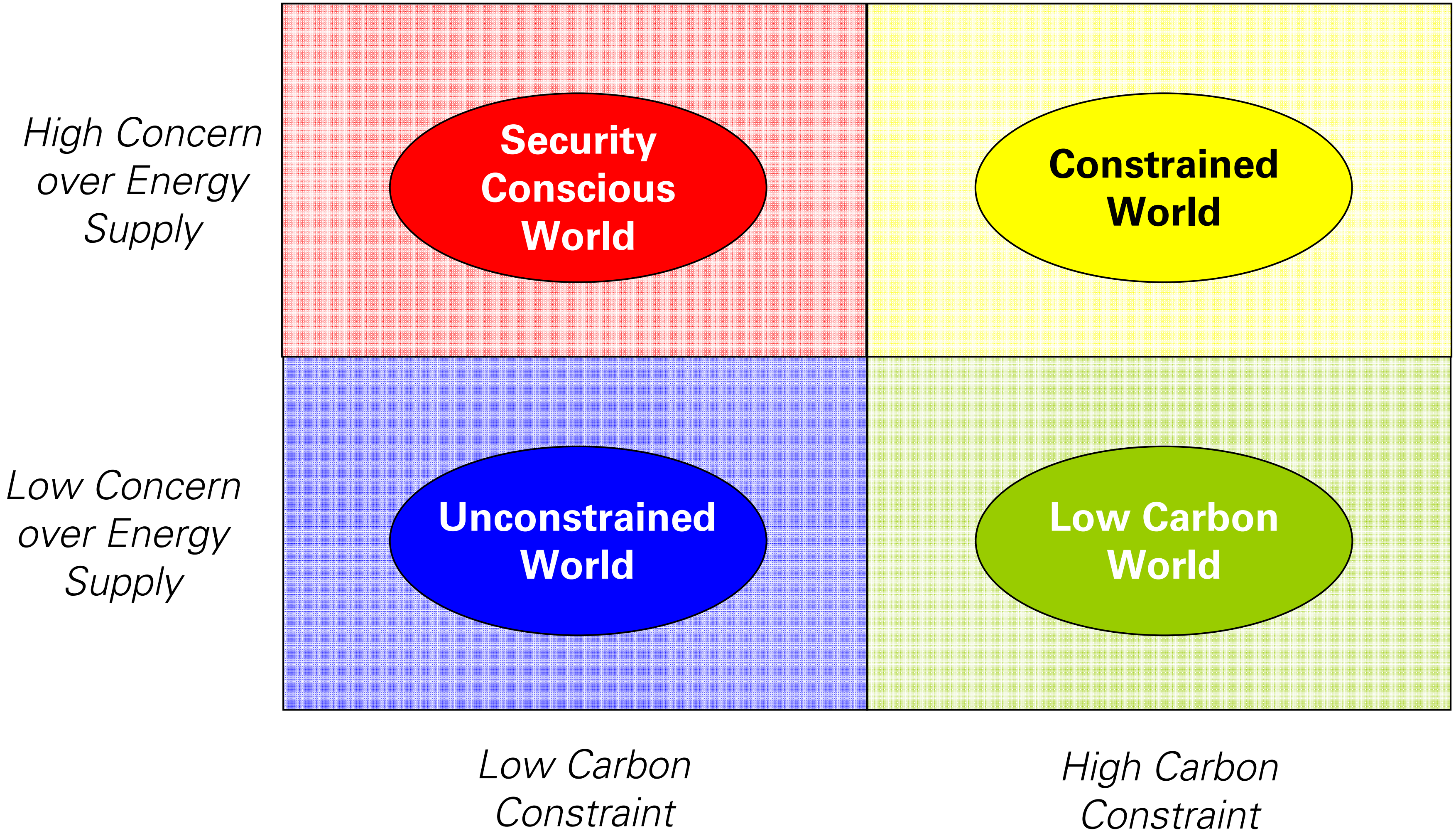
- import dependence
- competition

evaluating energy technology options

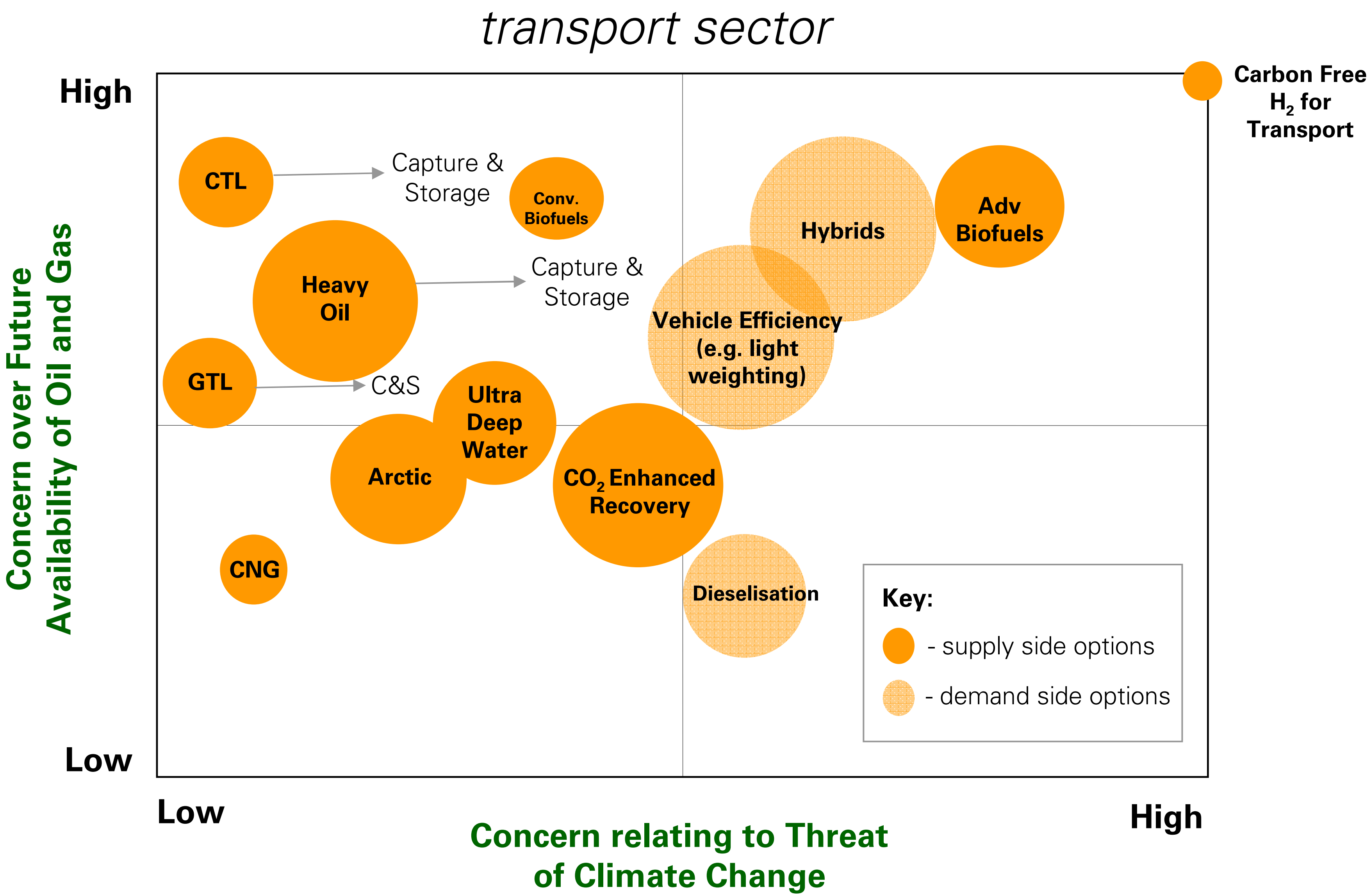
- Current **technology status** and plausible **technical headroom**
- **Budgets** for the three E's:
  - **Economic** (cost relative to other options)
  - **Energy** (output how many times greater than input)
  - **Emissions** (pollution and CO2; operations and capital)
- **Materiality** (at least 1TW = 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

The two major axes of concern

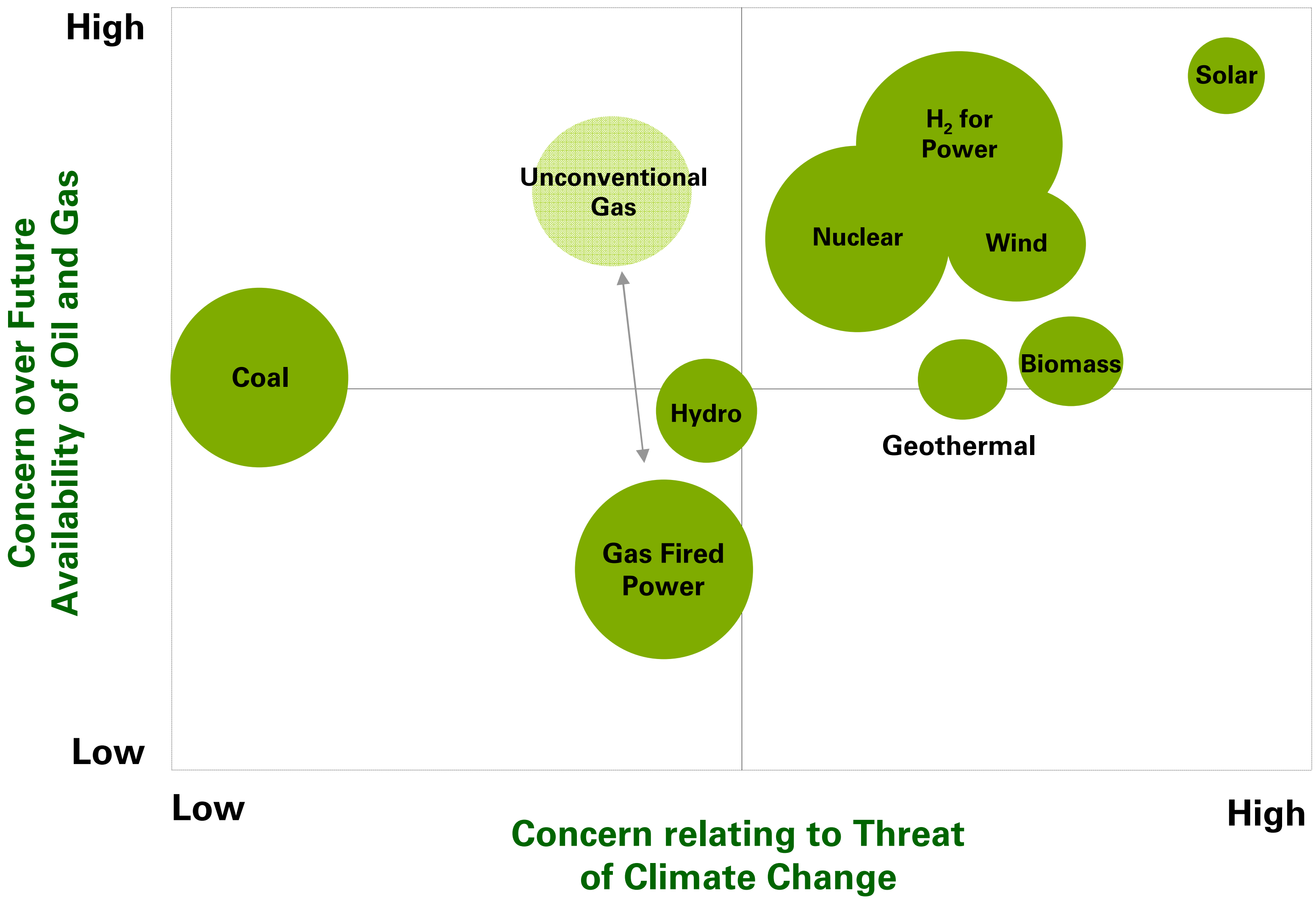


Evaluating mobility options



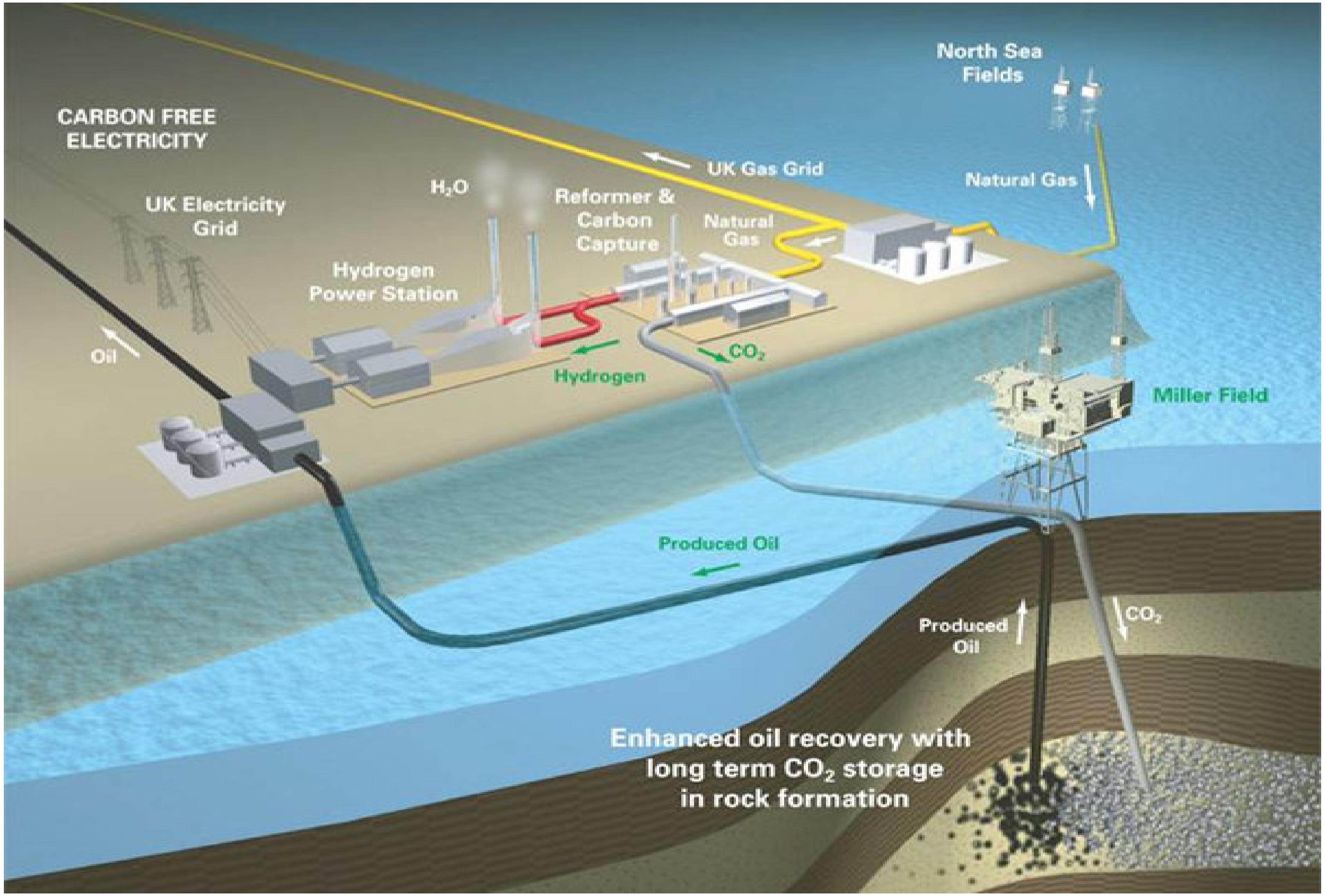
Evaluating power options

power sector

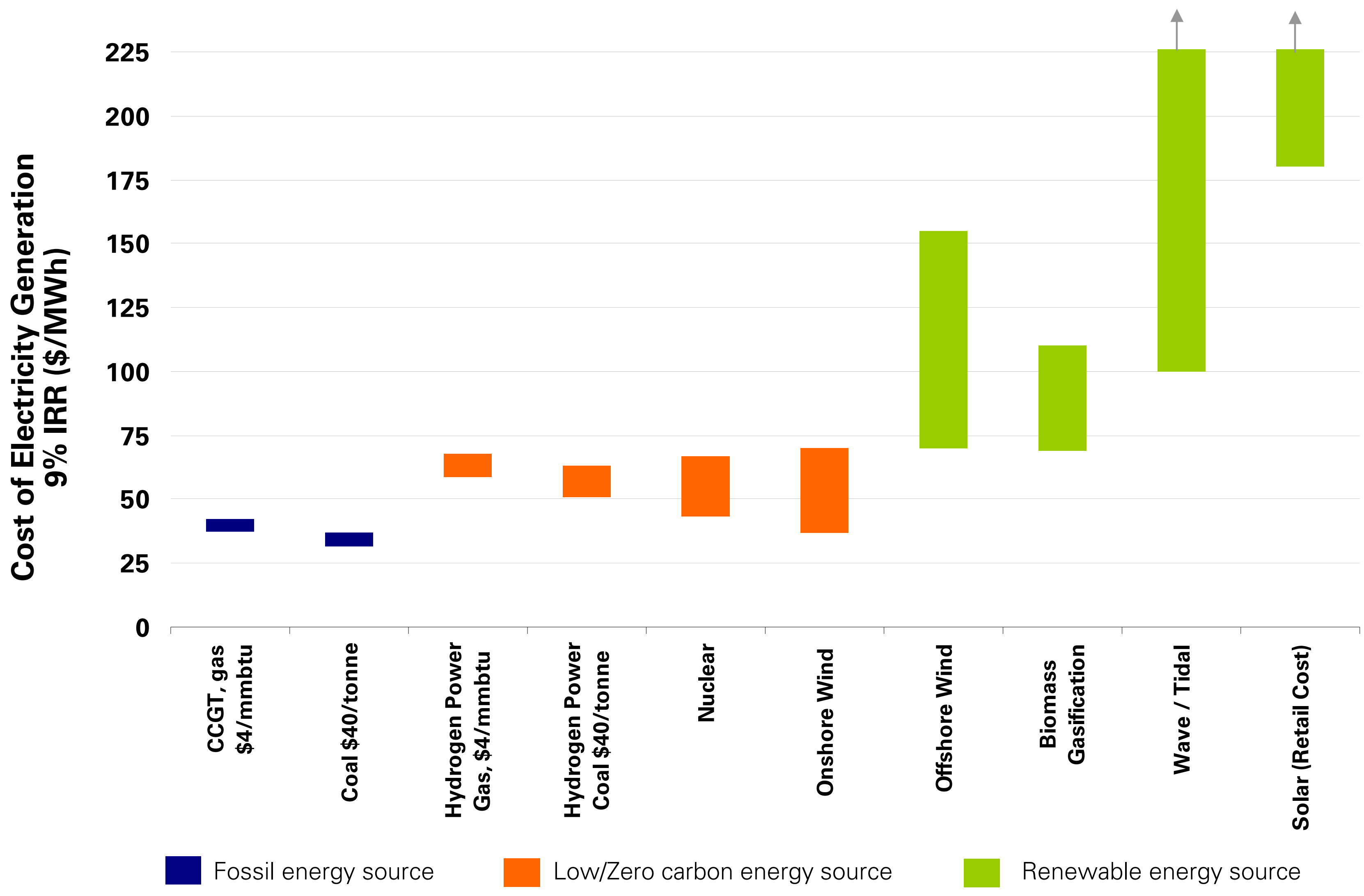


Hydrogen power - Peterhead and Miller

Schematic of BP Hydrogen for Power Project – DF1

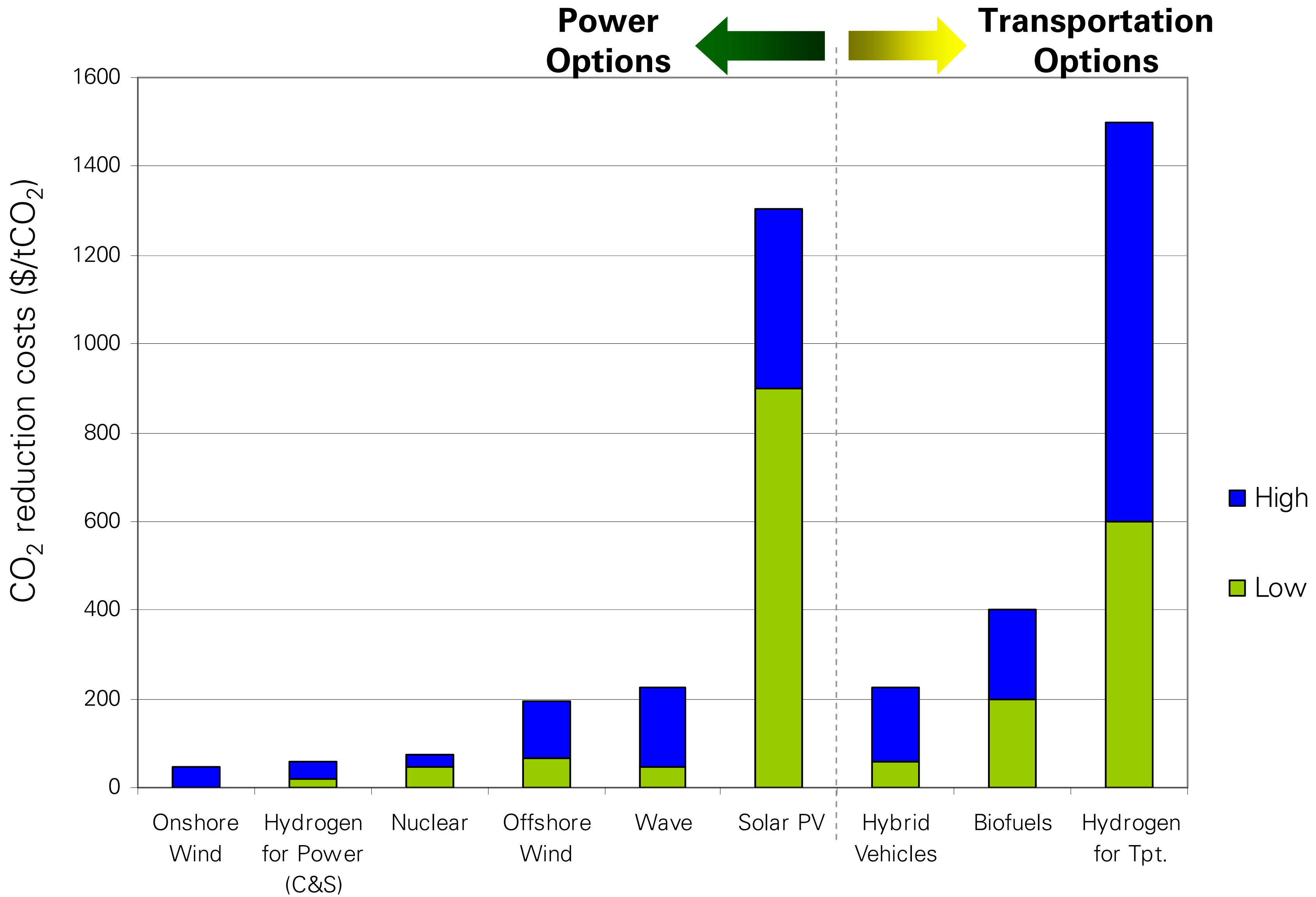


levelised costs of electricity generation



Source: BP Estimates, Navigant Consulting

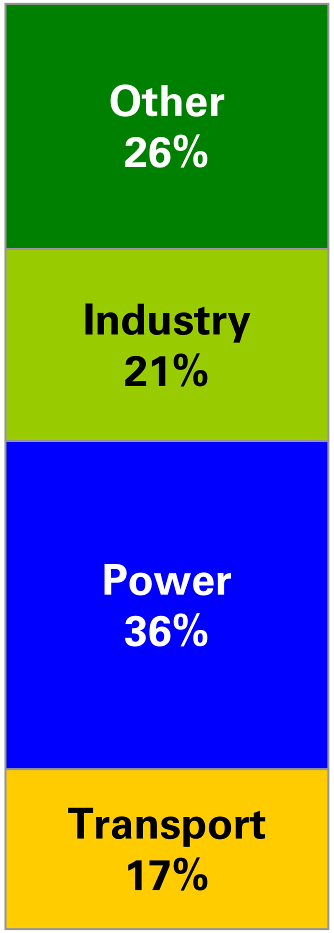
evaluating lower carbon technology options



Source: DTi (2003, Concawe, BP estimates

demand side options

Primary Energy Demand by Sector



Demand Side Technology Options

- Building efficiency
- Smart metering
- Smart appliances
- Solar PV

- Process intensification
- Process efficiency
- Substitution

- Power plant efficiency
- CHP
- Superconductivity
- Electricity storage
- High temp. fuels cells

- Engine technology
- Lightweighting
- Urban planning
- Congestion charging
- Hybrids
- Fuels
- Lubes

Note: Other includes residential, commercial, public service and agriculture

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 niche applications 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**

Questions/Comments/Discussion