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Carbon Capture and Storage in the Global Energy Perspectives

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International Energy Agency
on secondment from Schlumberger

Society of Petroleum Engineers
Distinguished Lecturer Program
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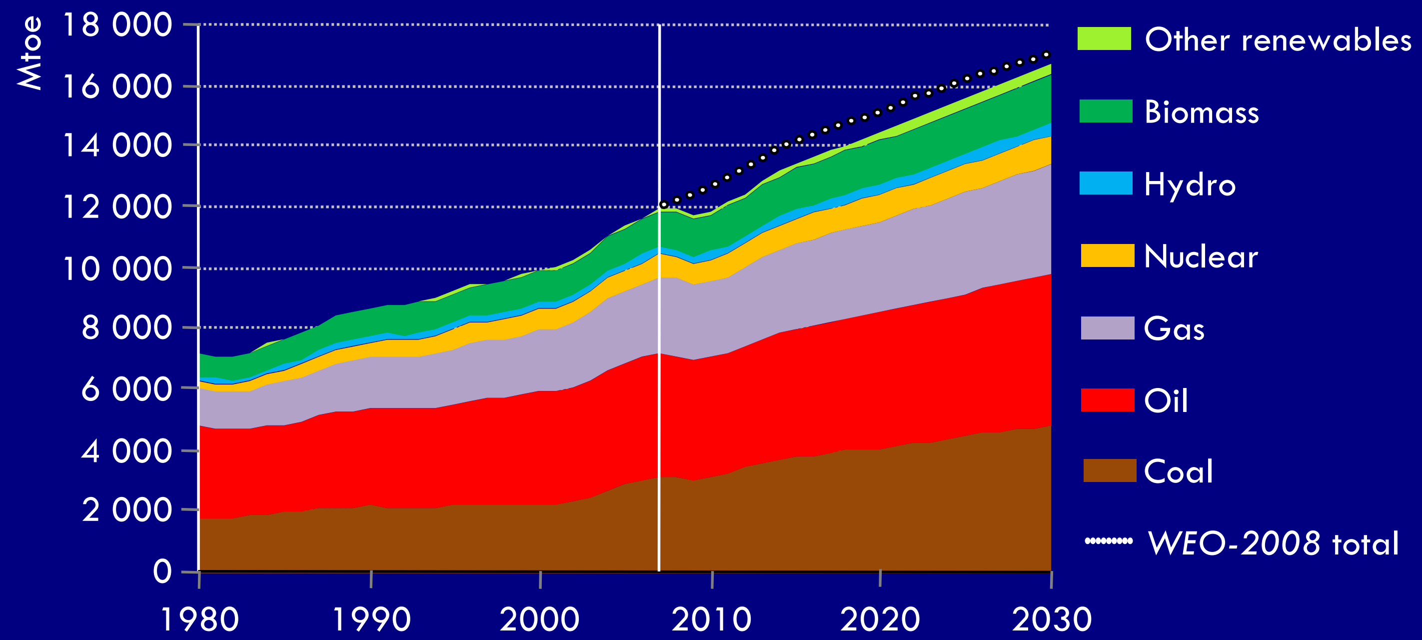
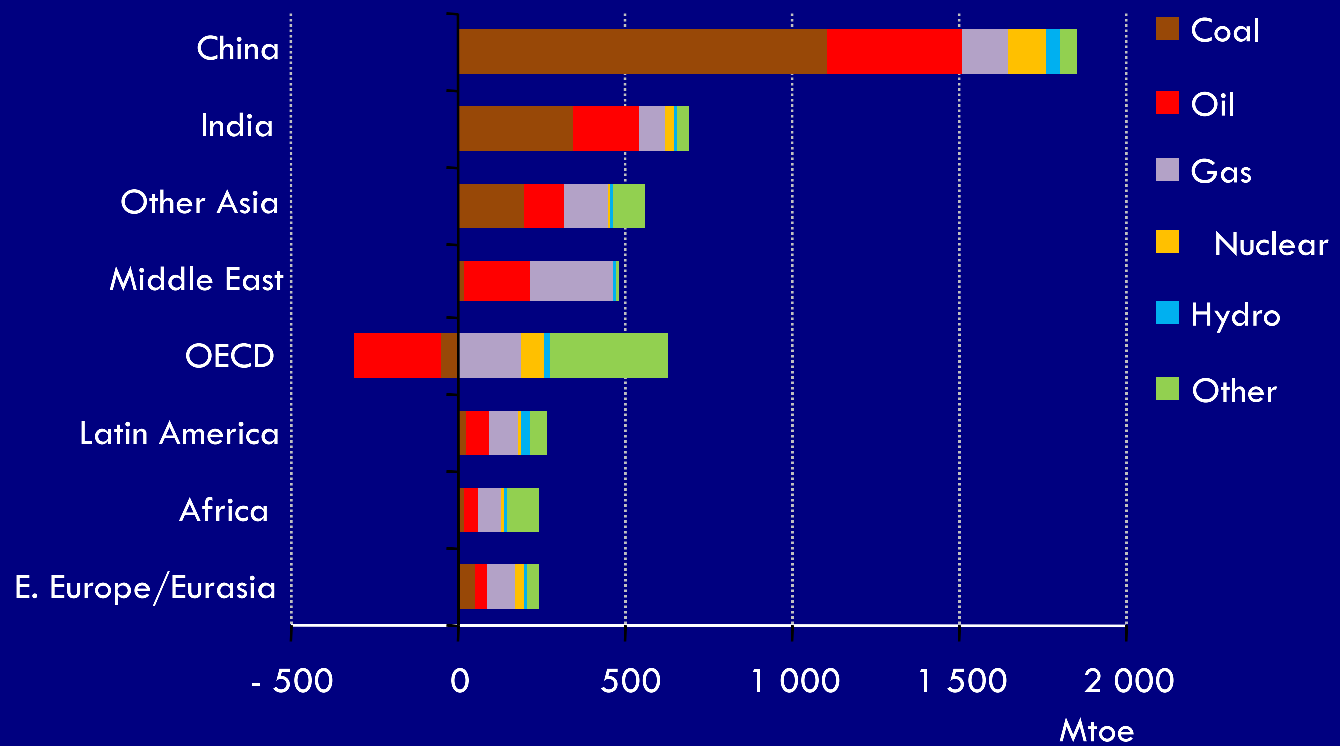
World primary energy demand by fuel in the Reference Scenario



Global demand grows by 40% between 2007 and 2030, with coal use rising most in absolute terms

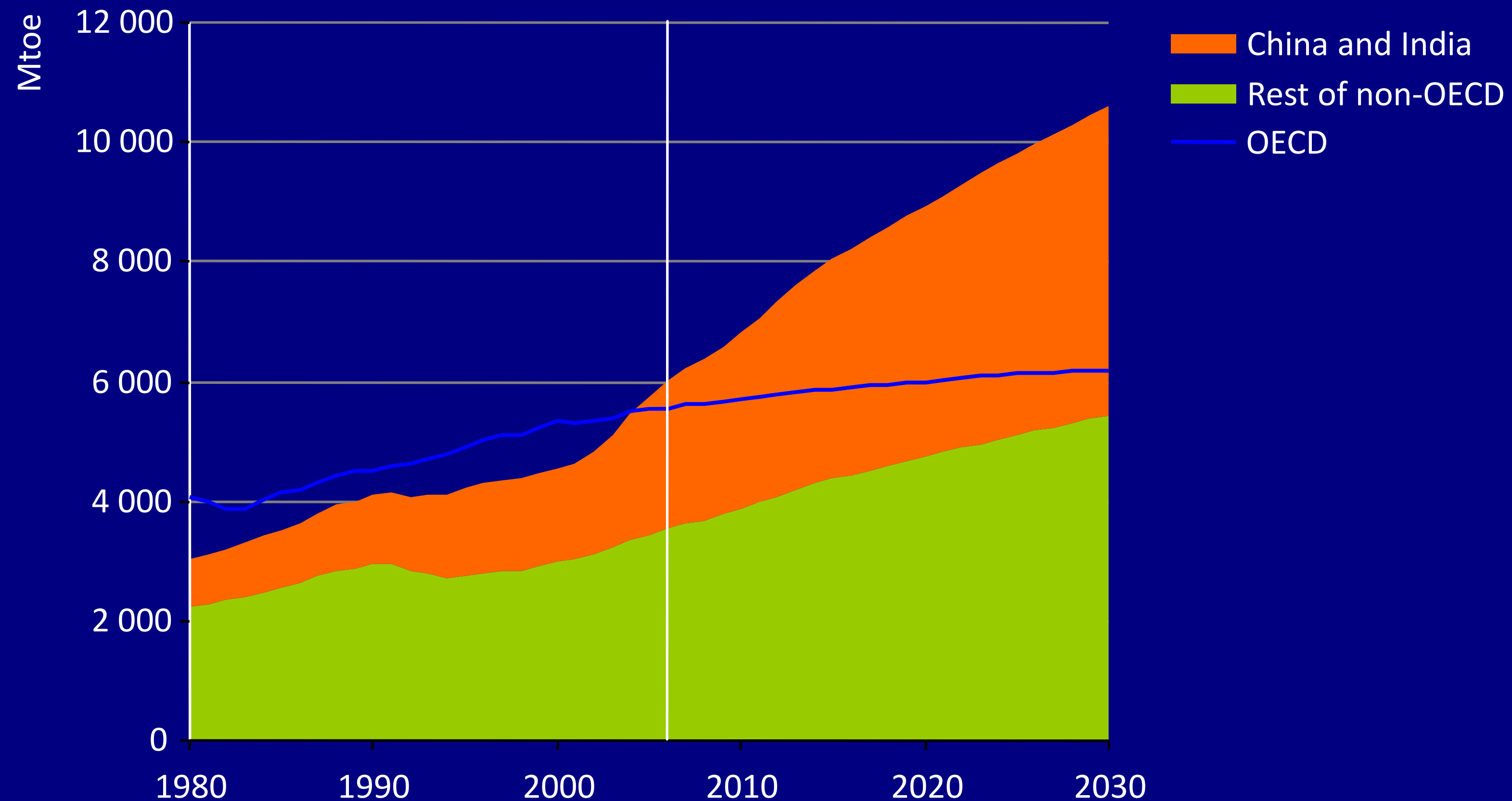
Source: IEA-WEO 2009

Change in primary energy demand by fuel in the Reference Scenario, 2007-2030



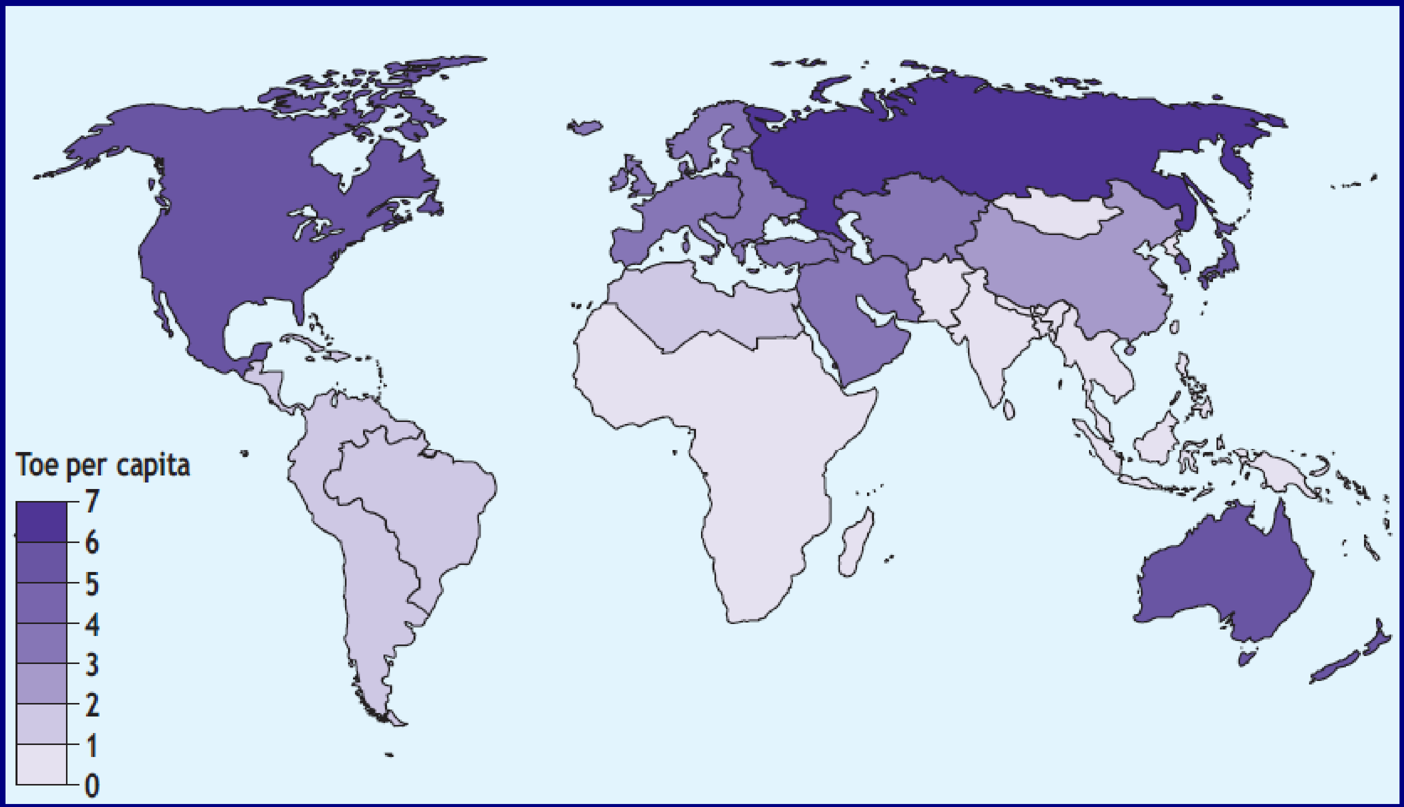
Source: WEO 2009

Increase in global demand by area



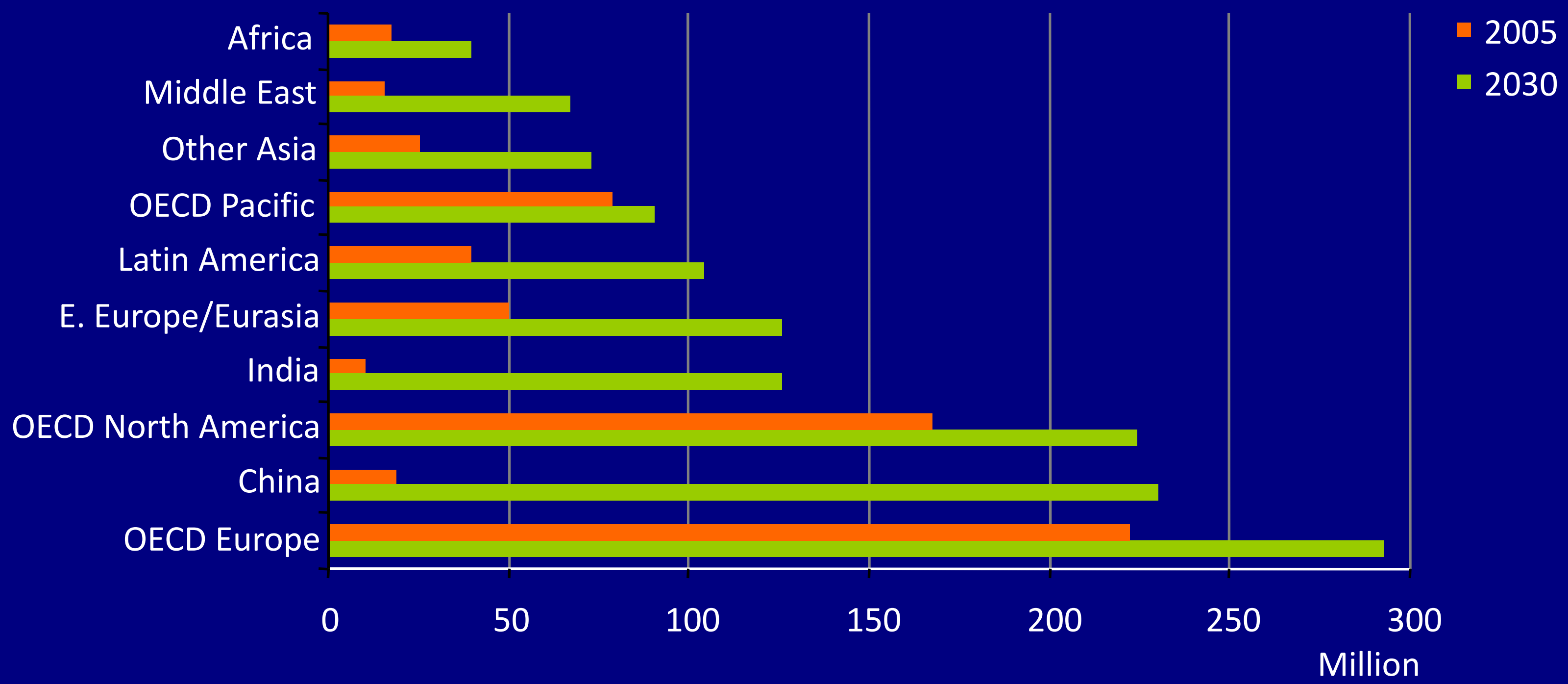
Non-OECD countries account for 87% of the increase in global demand between 2006 & 2030, driven largely by China & India

Per-capita primary energy demand in 2030



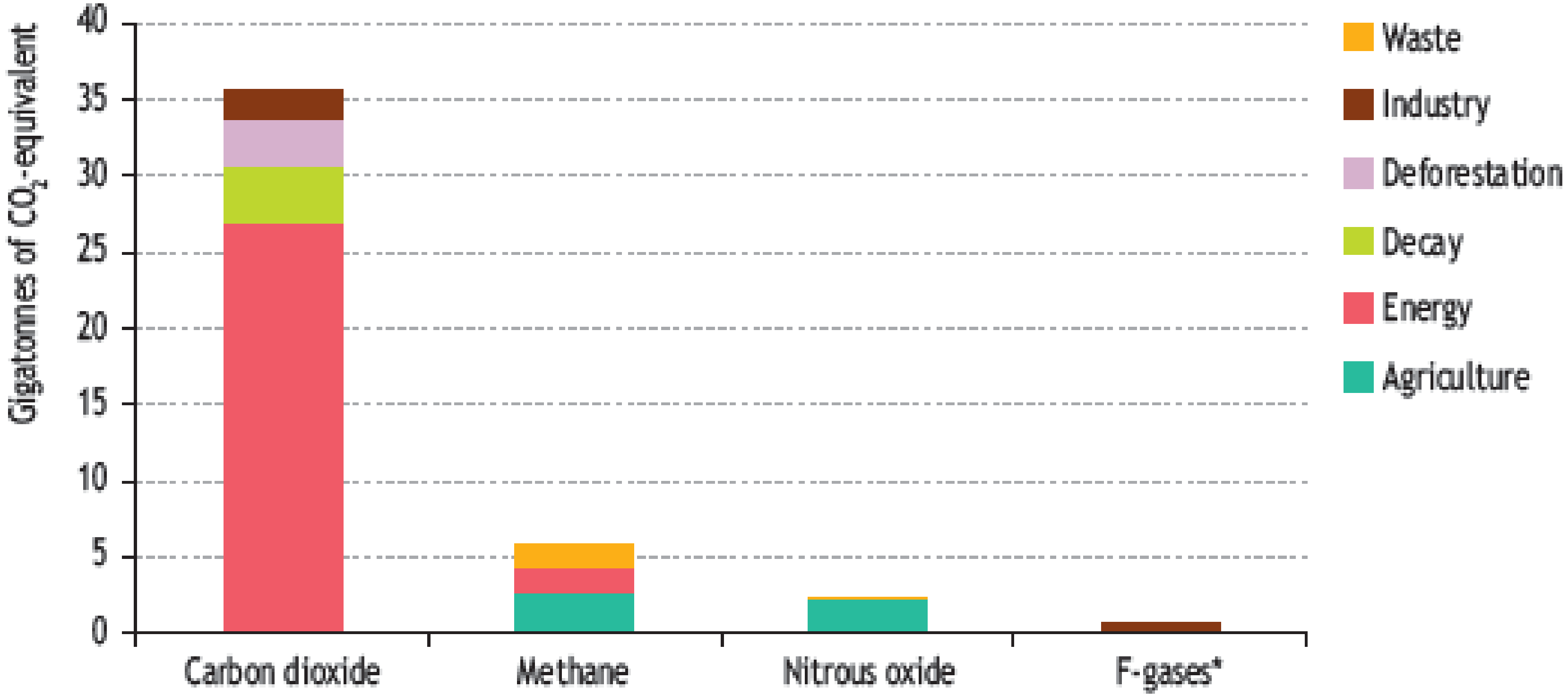
In 2030, disparities in per-capita energy consumption remain stark, ranging from 7 toe in Russia to 0.5 toe in sub-Saharan Africa

Light-duty vehicle fleet



The global light-duty vehicle stock rises from 650 million in 2005 to about 1.4 billion by 2030, with China accounting for almost one-third of the increase

World's anthropogenic greenhouse-gas emissions by source (2005)

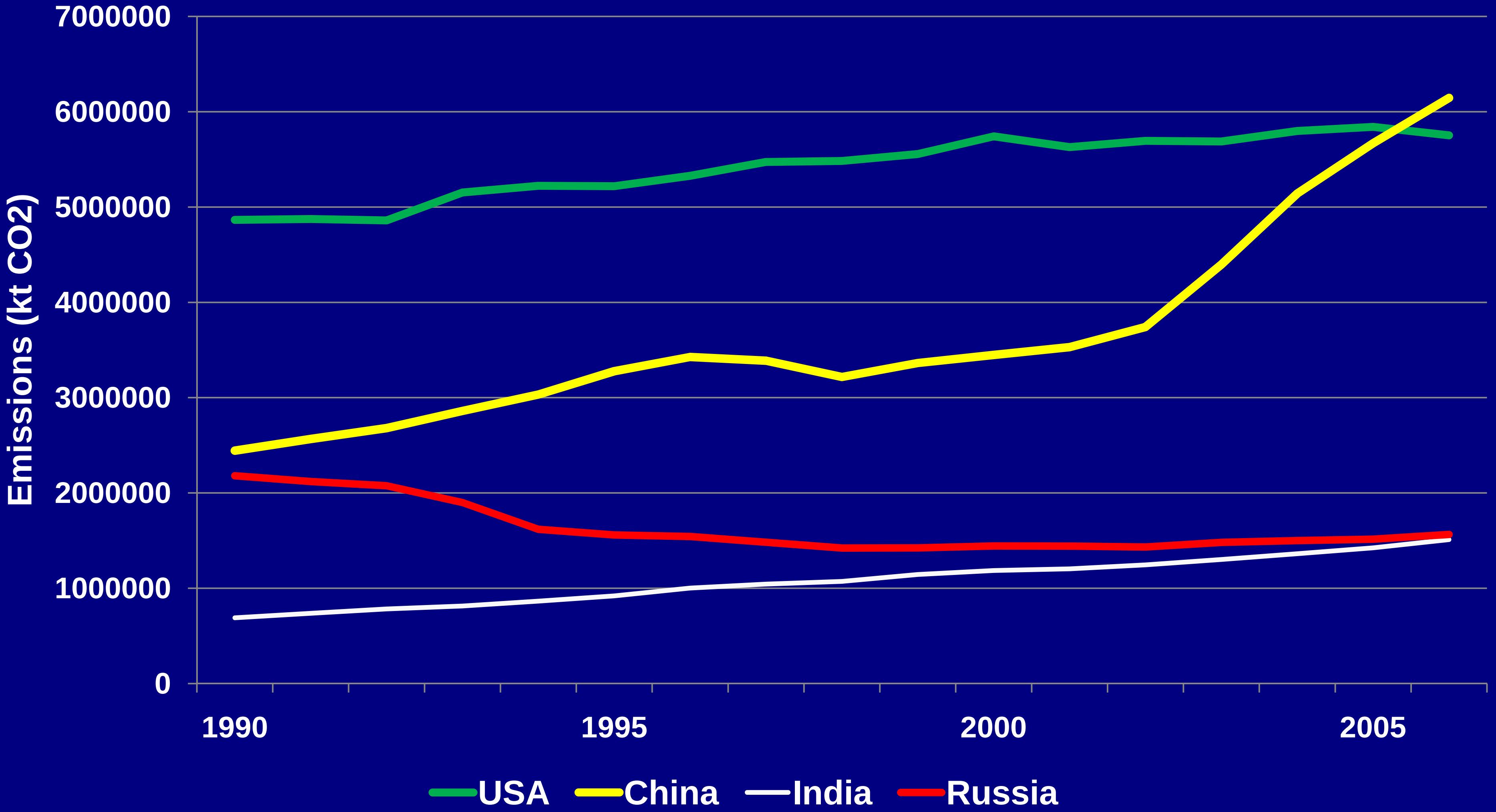


* F-gases include HFCs, PFCs and SF6 from several sectors, mainly industry.

Note: Industry CO_2 includes non-energy uses of fossil fuels, gas flaring, and process emissions. Energy methane includes coal mines, gas leakages, and fugitive emissions. Nitrous oxide from industry and waste amounts to 0.12 Gt CO_2-eq.

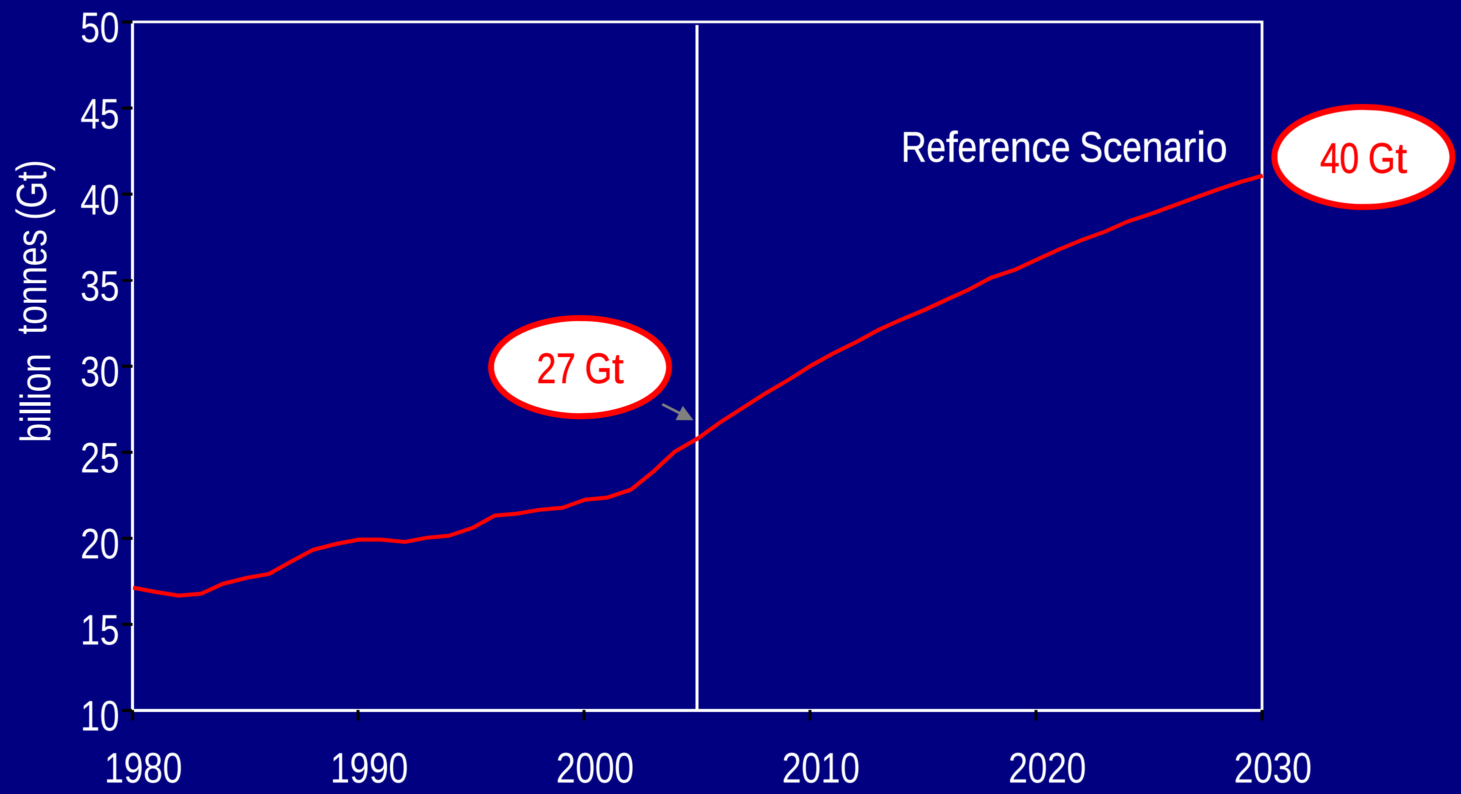
Sources: EPA data provided to the IEA; IEA databases; IPCC (2007); OECD (2008).

Historical Evolution of GHG Emissions



Source: BP (2009)

Global Energy-Related CO_2 Emissions

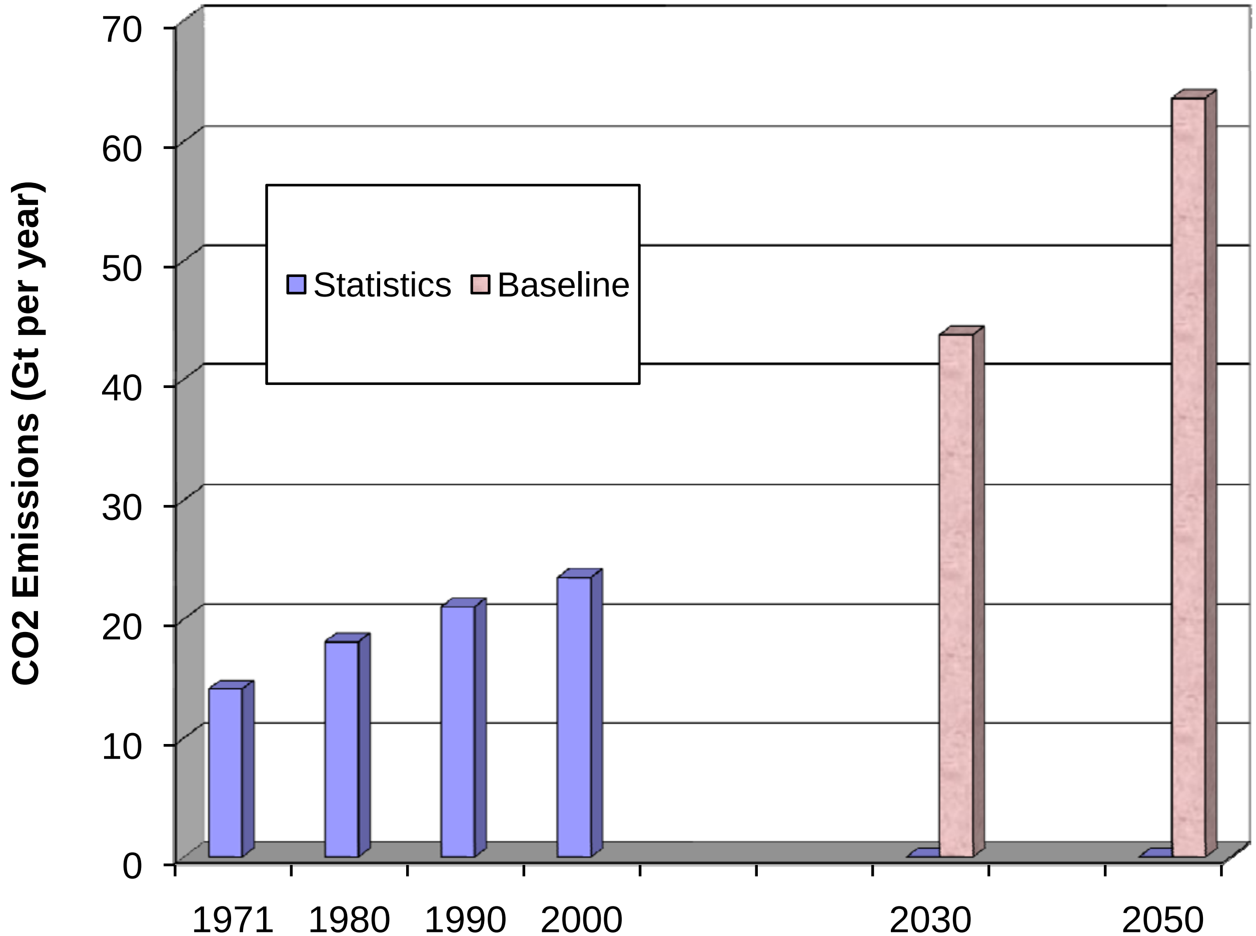


Global emissions grow by 48% from 27 Gt in 2005 to 40 Gt in 2030

IPCC 4th Assessment Report
Conclusions approved by all UNFCCC signatory countries

Temperature increase	All GHG	CO2	CO2 emissions 2050 (% of 2000 emissions)
(ºC)	(ppm CO2 eq.)	(ppm CO2)	(%)
2.0-2.4	445-490	350-400	-85 to -50
2.4-2.8	490-535	400-440	-60 to -30
2.8-3.2	535-590	440-485	-30 to +5
3.2-4.0	590-710	485-570	+10 to +60

Reference Scenario Projected to 2050



Energy Technology Perspectives 2008

IPCC 4th Assessment Report

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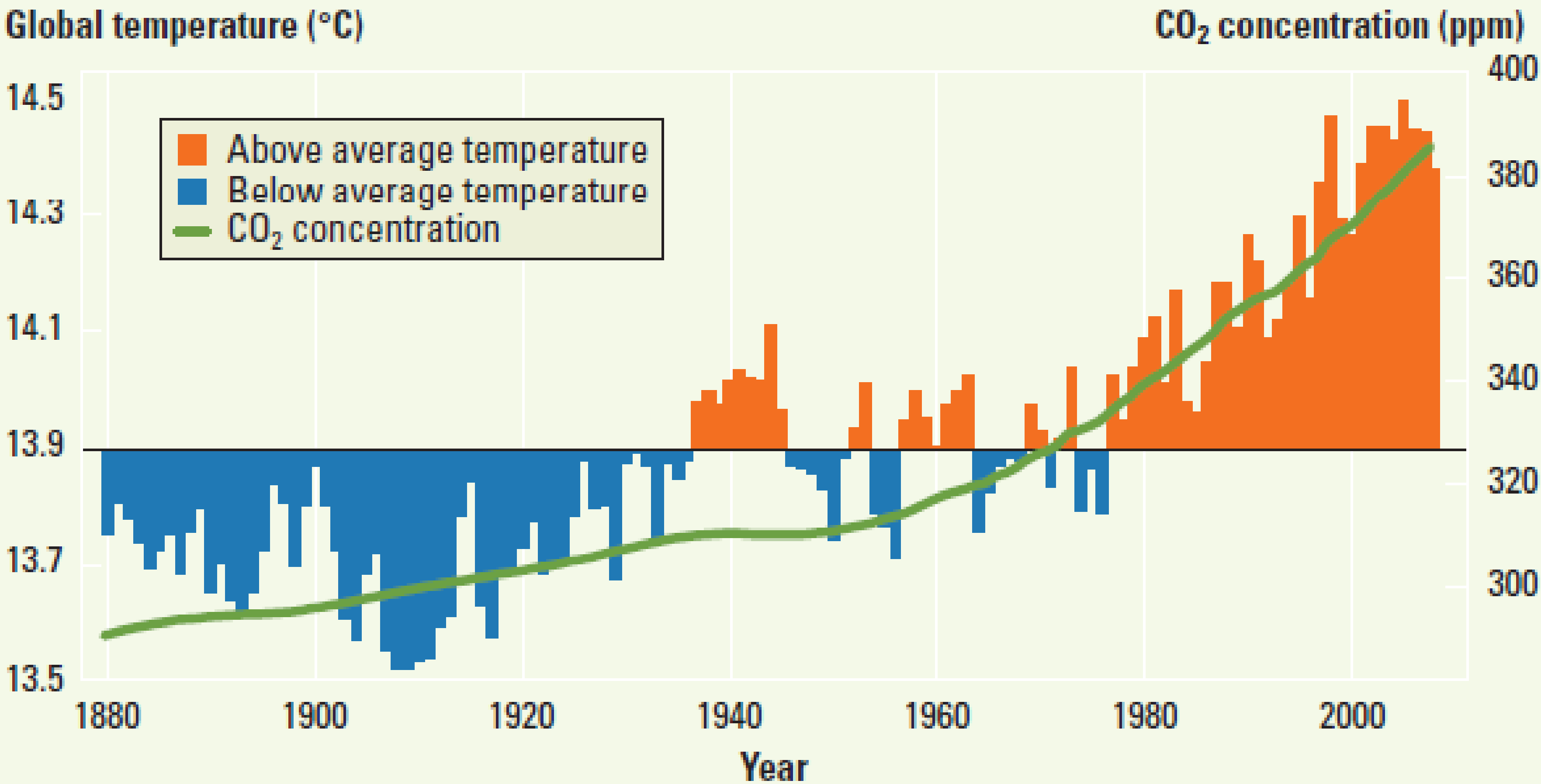
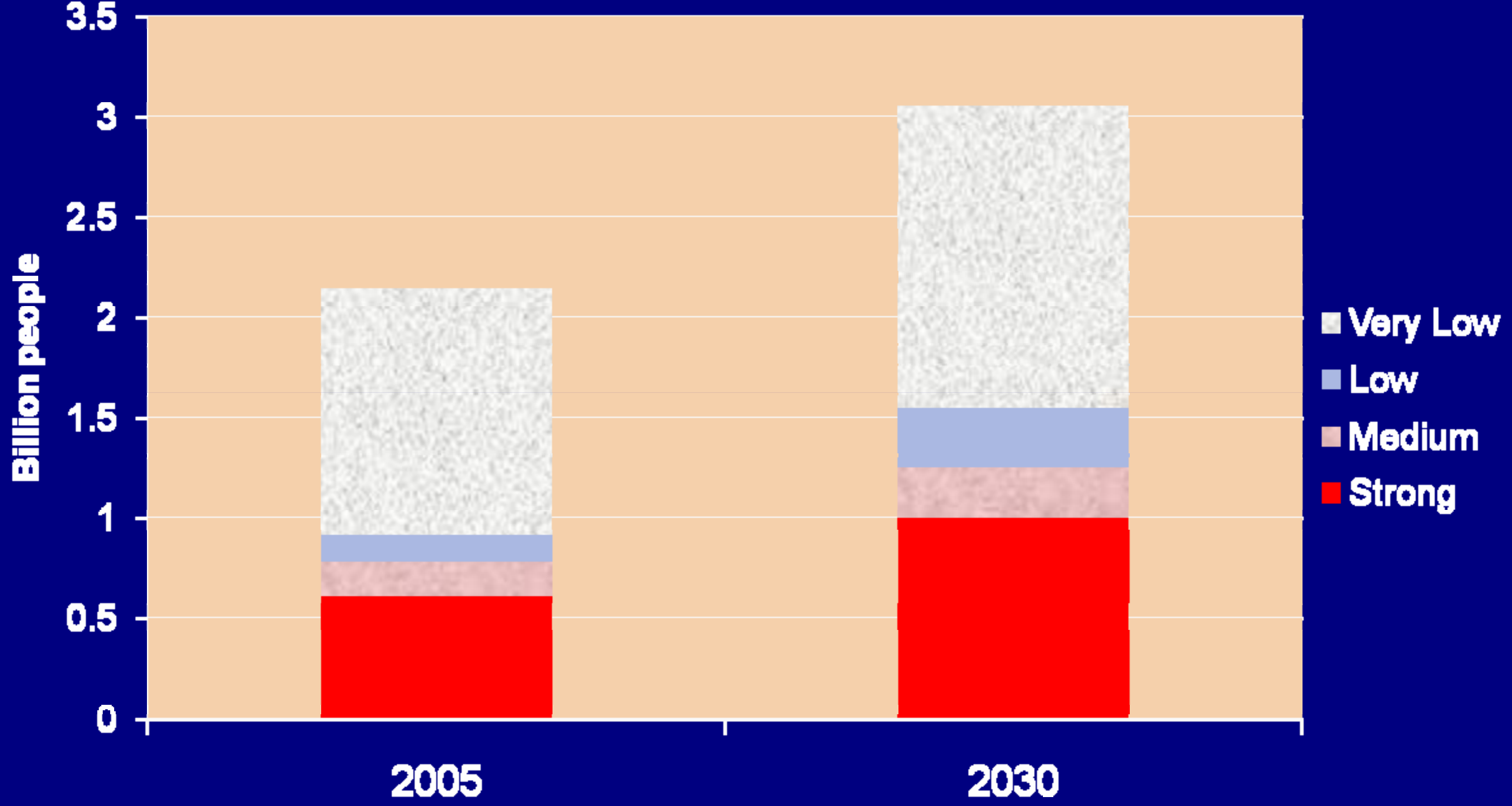
4.0-7.0			+135 (Reference)

Global temperatures



Source: Adapted from Karl, Melillo, and Peterson 2009.

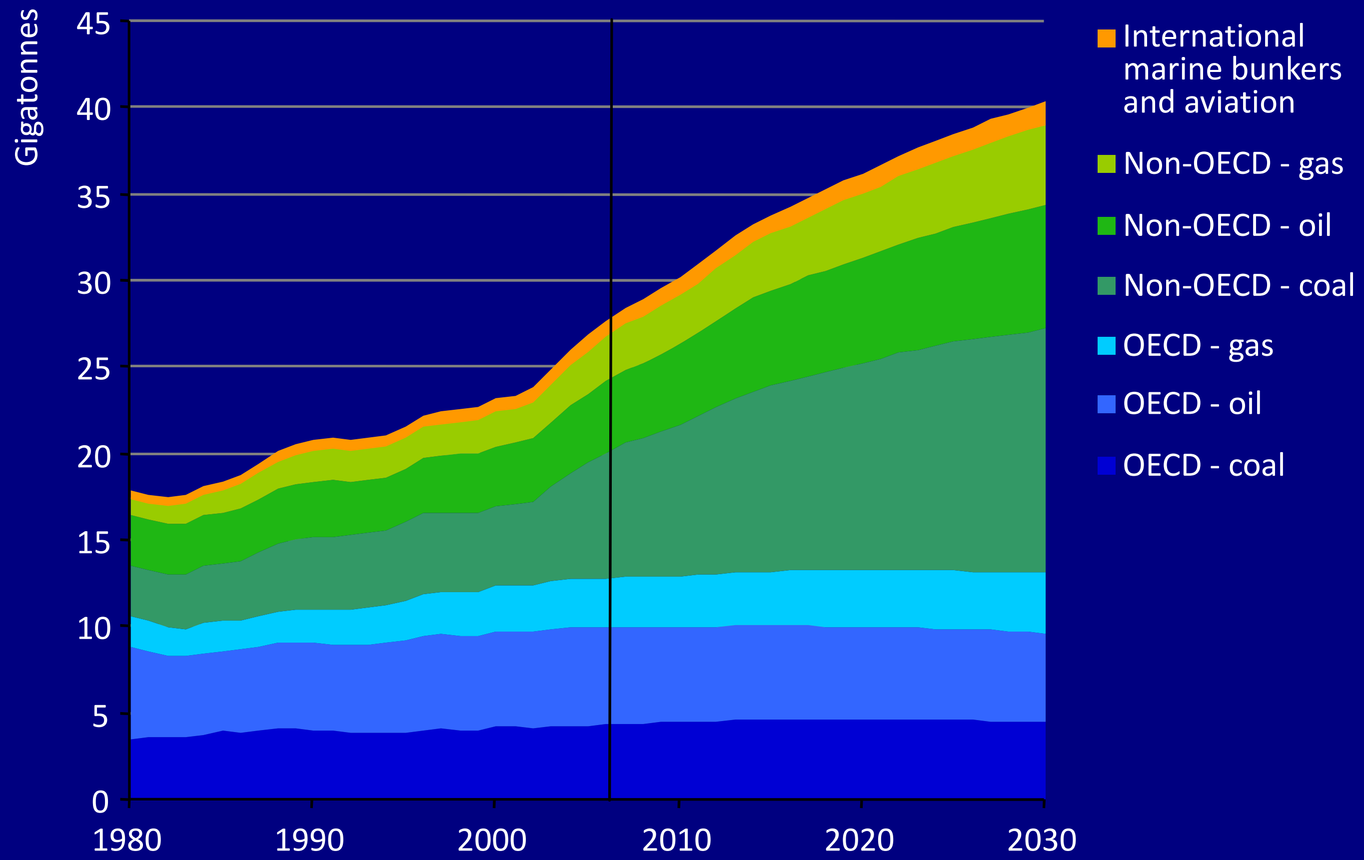
Implications on Water Availability



Number of people exposed to hydric stress in areas outside of OECD and BRIC countries

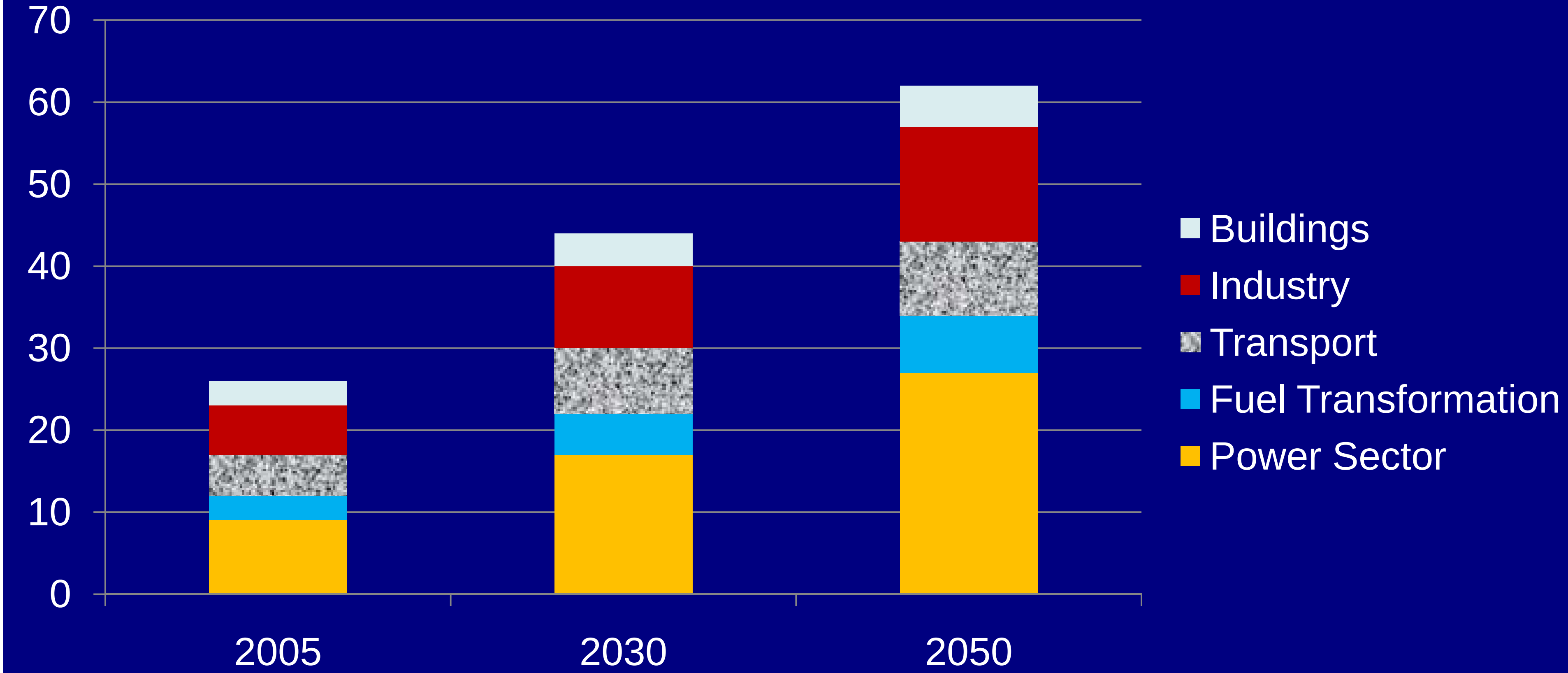
Source: OECD - 2008

Energy-related CO_2 emissions in the Reference Scenario

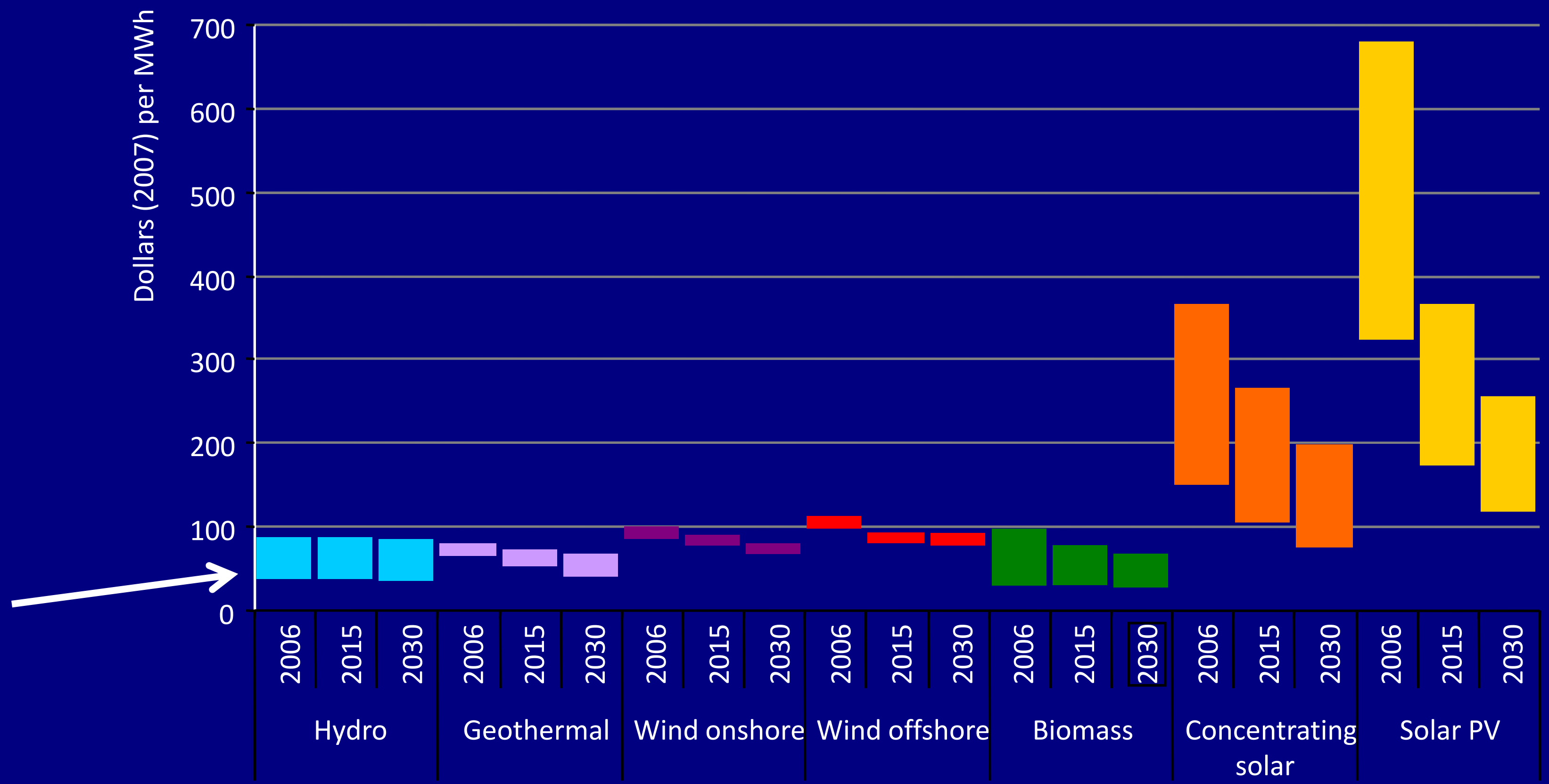


97% of the projected increase in emissions between now & 2030 comes from non-OECD countries – three-quarters from China, India & the Middle East alone

CO2 Emissions from the power sector are the largest



Reference Scenario: Generating costs of renewable energy technologies



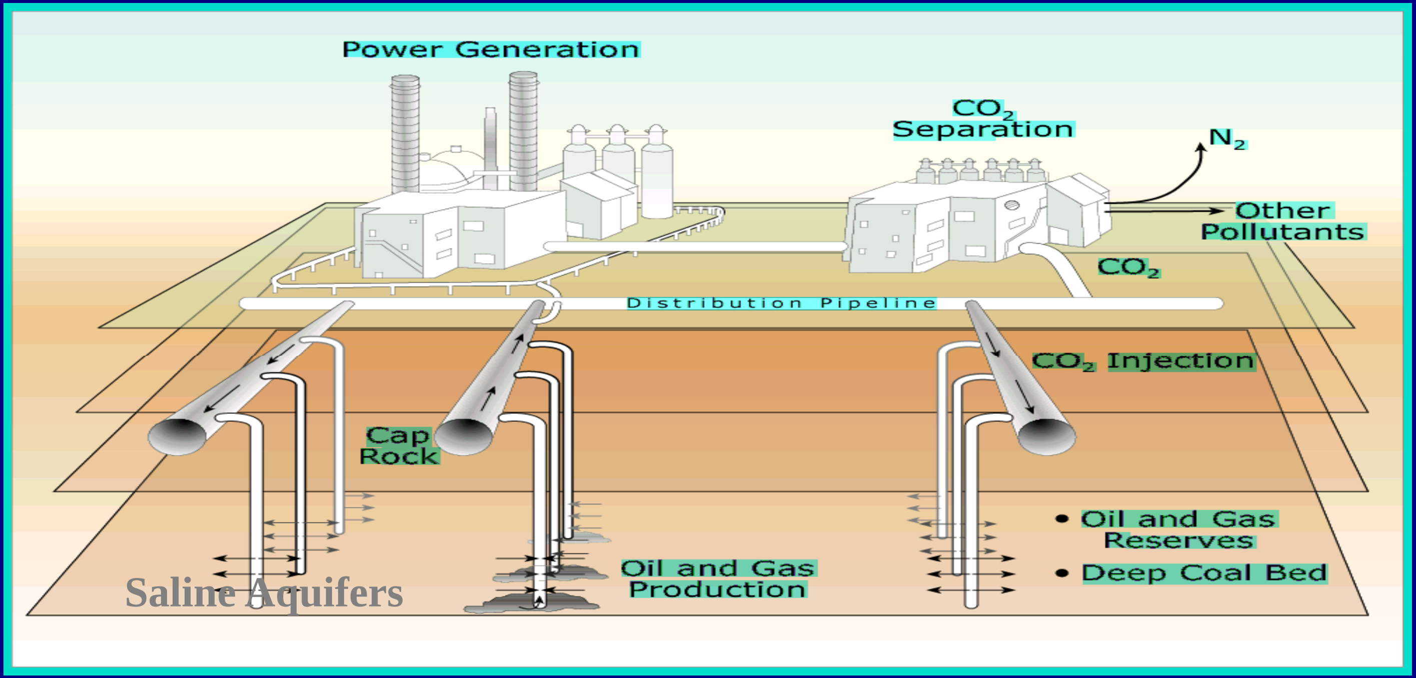
The costs of power generation from renewables are set to fall in response to increased deployment, which accelerates technological progress & increases economies of scale

Global Energy Technology Scenarios

- Scenarios analysed
  - Baseline Scenario
  - Accelerated Technology with CO_2 reduction incentives - ACT
  - A 50 % CO_2 reduction scenario – BLUE

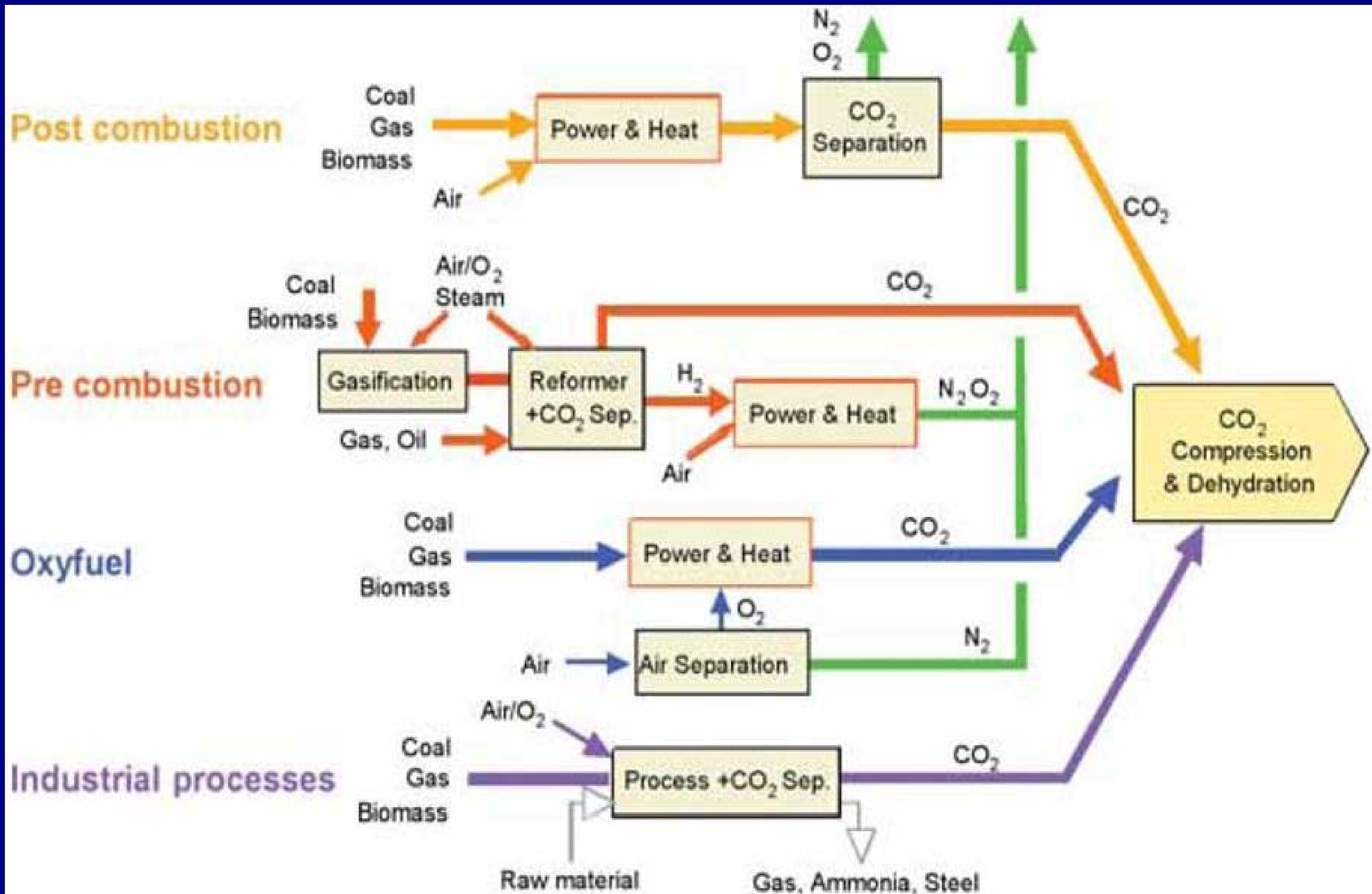
- ACT and BLUE scenarios
  - Analyse the impact from R,D&D measures
  - Incentives equivalent to 50 \$/tonne CO_2
  - Individual scenarios differ in terms of assumptions for key technology areas

CO_2 Capture and Storage

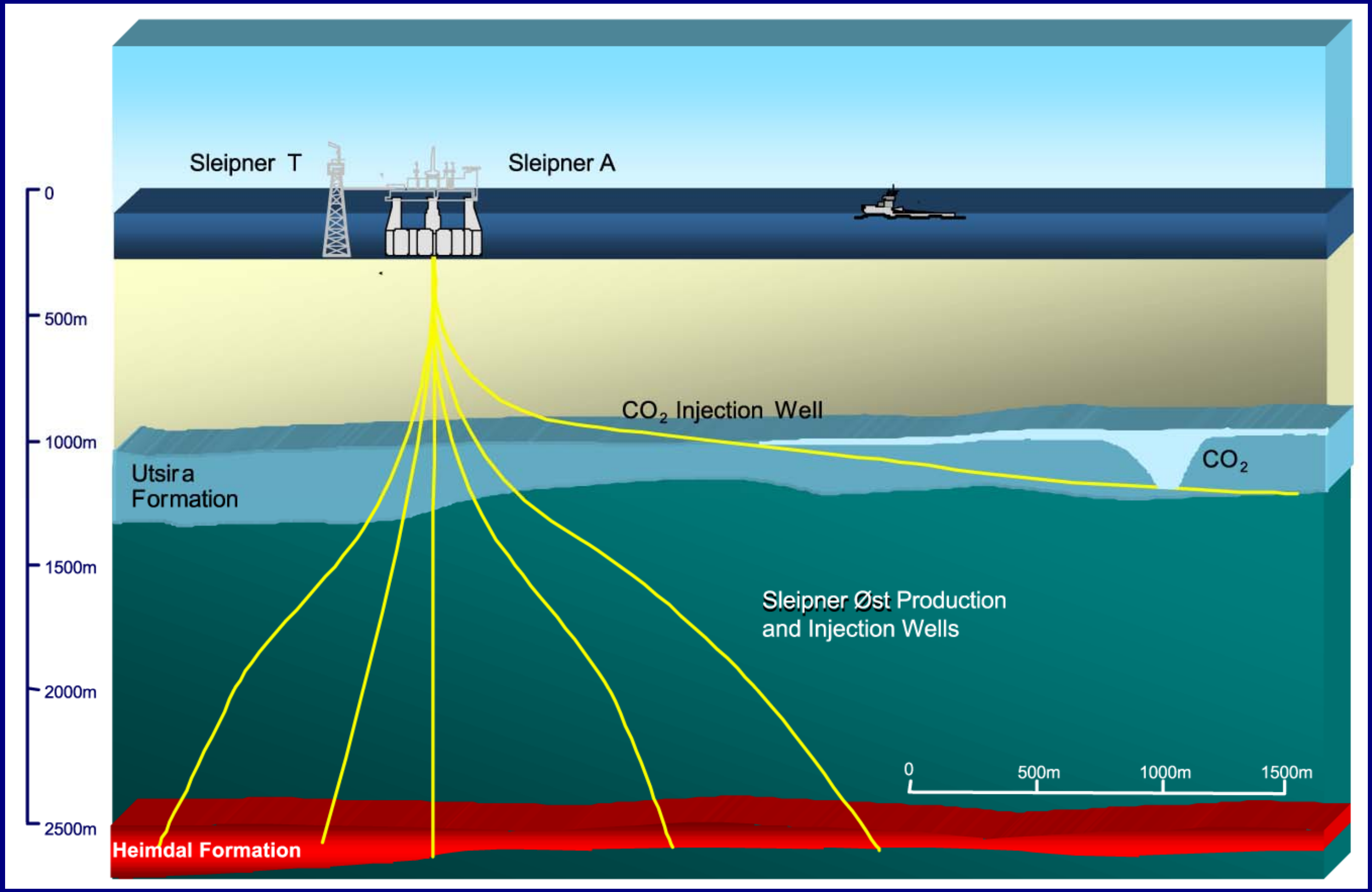


EOR: 2-3 bbl/t CO_2
EGR: 0.03-0.05 t methane/t CO_2
ECBM: 0.08-0.2 t methane/t CO_2

CO_2 Capture Processes



Sleipner CO_2 Injection



Courtesy: StatoilHydro

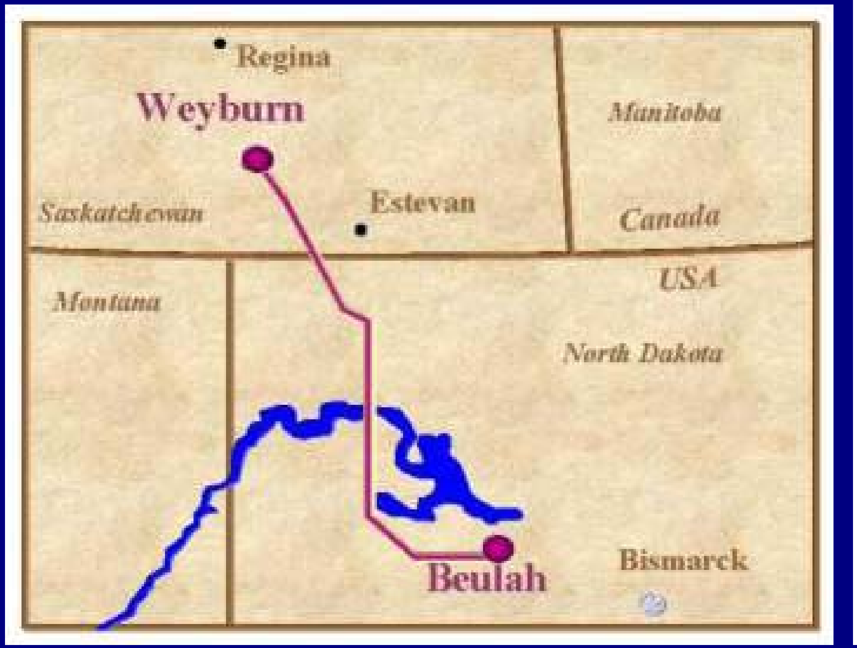
Sleipner

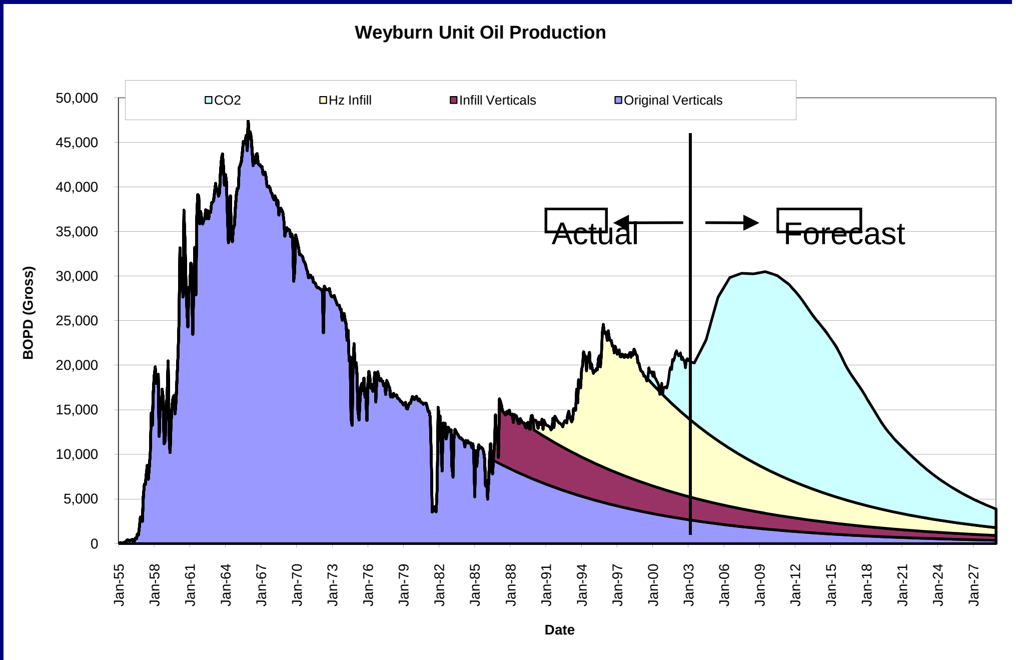
- Sleipner natural gas contains ~9% CO_2
  - Contract: 2.5% CO_2
  - CO_2 stored; about 1 Million tonnes annually
- CO_2 injected into thick Utsira sandstone layer
  - 800-1100 m depth below sea level
  - Porosity 35-40 %
  - Permeability 2-5 Darcy
  - Homogeneous sand + shale stringers
- CO_2 injection 1996-2020
- Time-lapse seismic: 1994, 1999, 2001, 2002 (and 2005)
- Time-lapse gravimetry: 2002 (and 2005)

Illustrations courtesy of Statoil

Weyburn Field

- CO_2 from synfuels plant (N. Dakota /USA)
- Piped across border (2.7 Mm^3/day)
- CO_2 enhanced oil recovery / sequestration
- 344 MBbl –> 466 MBbl, enhanced oil recovery

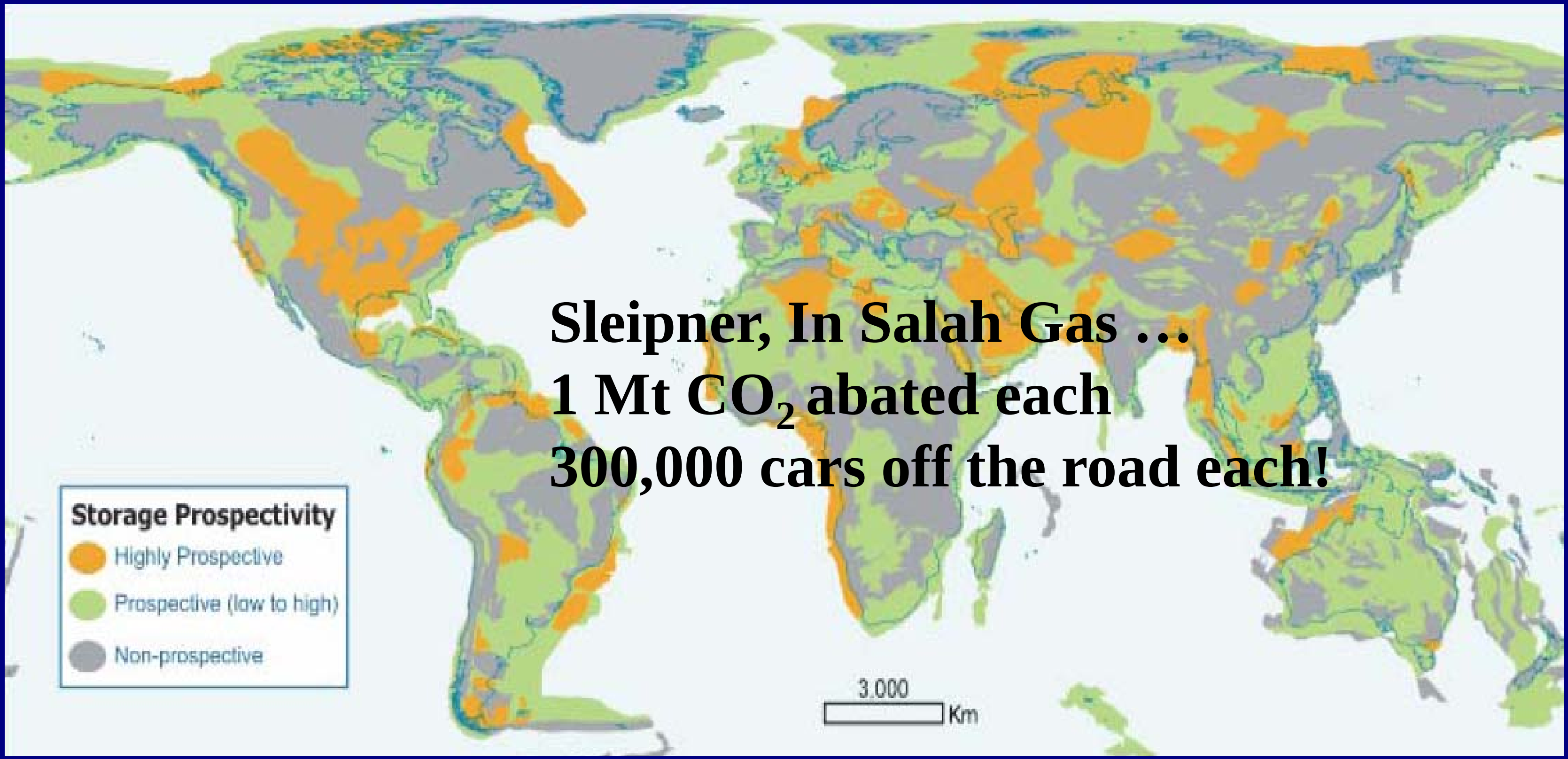




Key Energy Options

- Supply side
  - CCS power generation
  - Coal – increased efficiency
  - Nuclear III + IV
  - Solar – Photo-Voltaic
  - Solar – Concentrated
  - Wind
  - Geothermal
  - Biomass – Gasification & co-combustion
  - 2nd generation biofuels
  - Fuel switching
- Demand side
  - Energy efficiency in buildings
  - Energy efficient motor systems
  - Efficient internal combustion engines
  - Heat pumps
  - Plug-ins and electric vehicles
  - Fuel cell vehicles
  - Industrial CCS
  - Solar heating

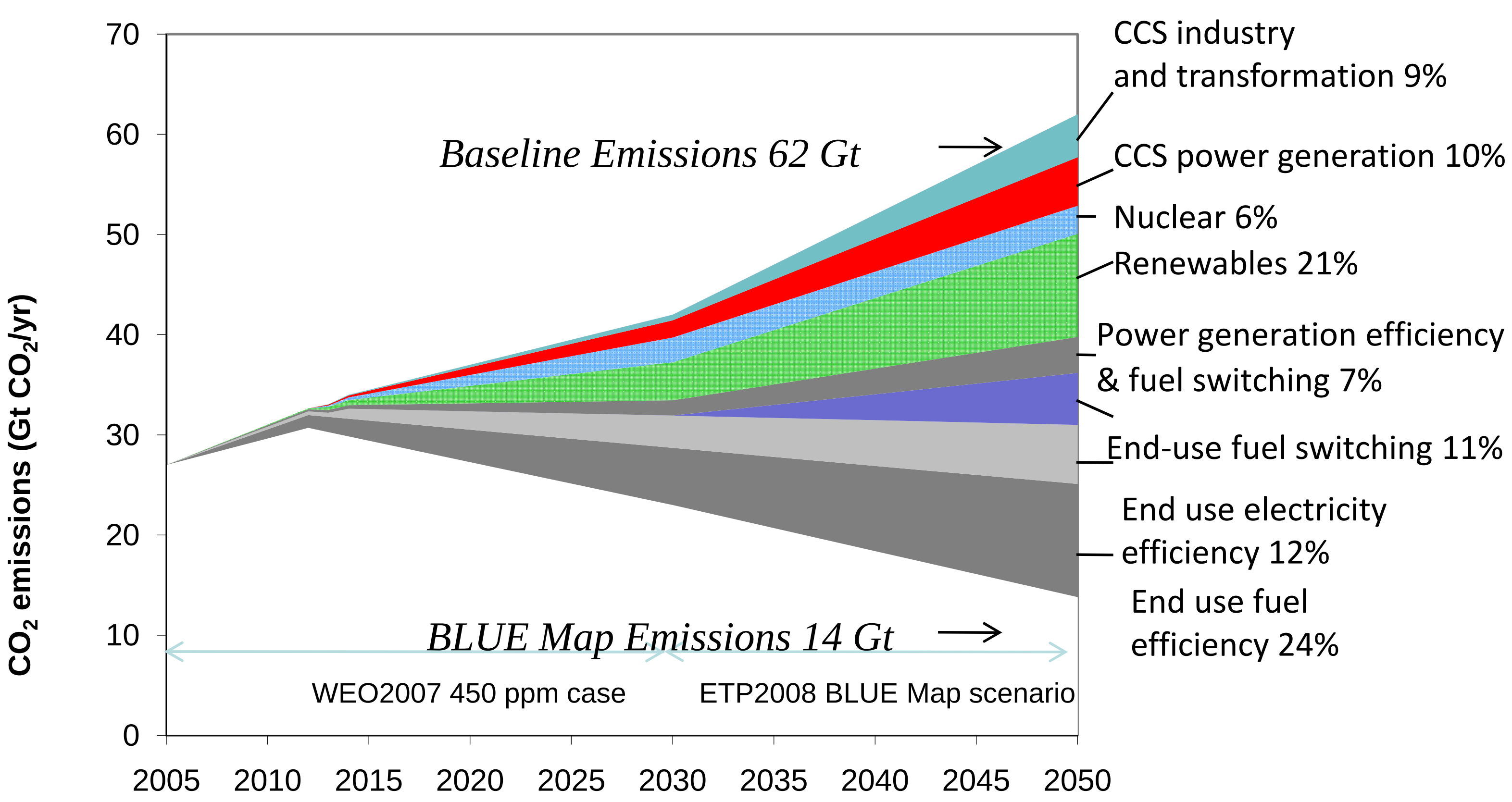
CO_2 Capture and Storage is a Major Carbon Abatement Option



Sleipner, In Salah Gas …
1 Mt CO_2 abated each
300,000 cars off the road each!

Courtesy: Bradshaw

CCS Contribution as a Carbon Abatement Technology Wedge



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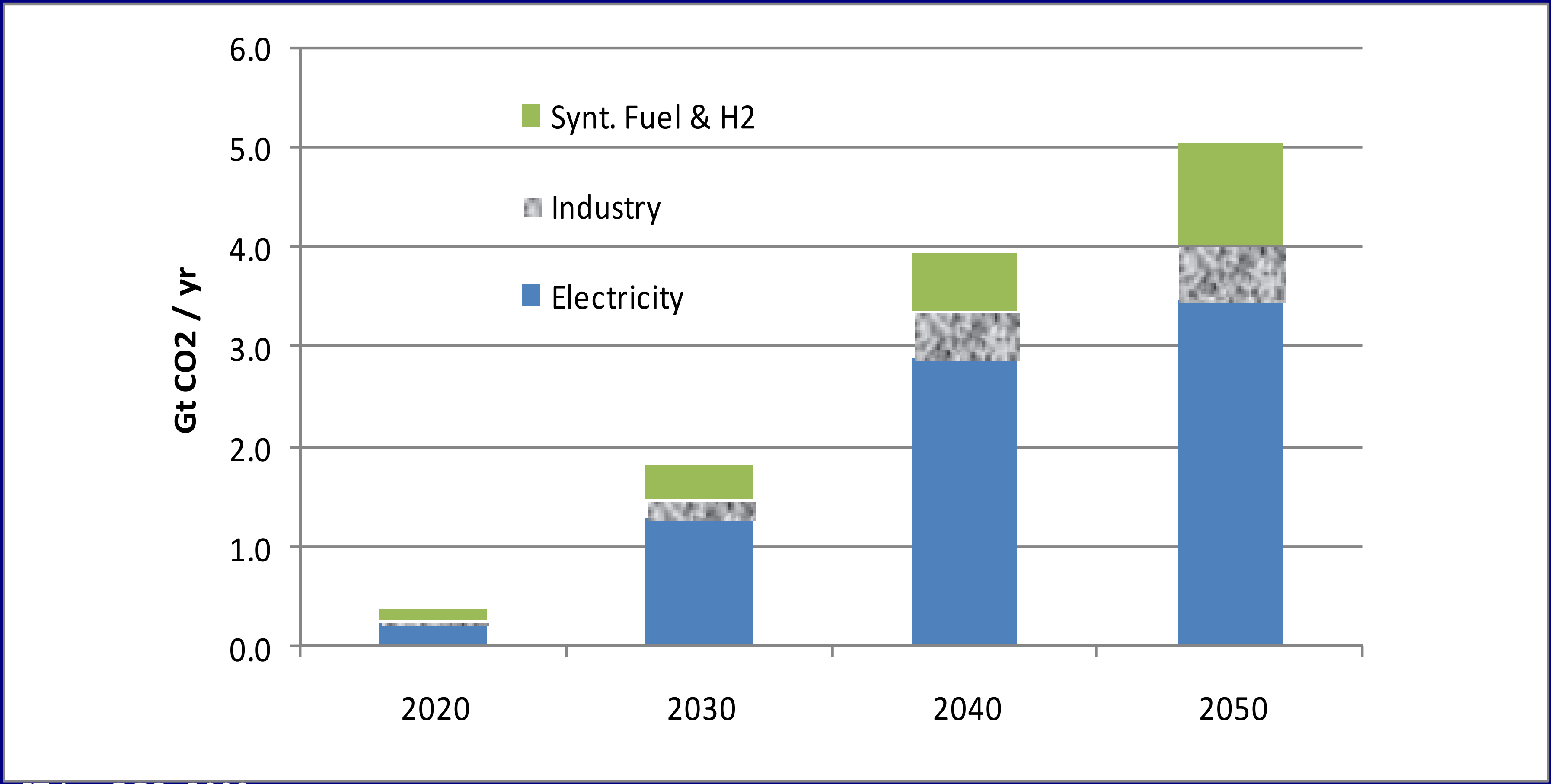
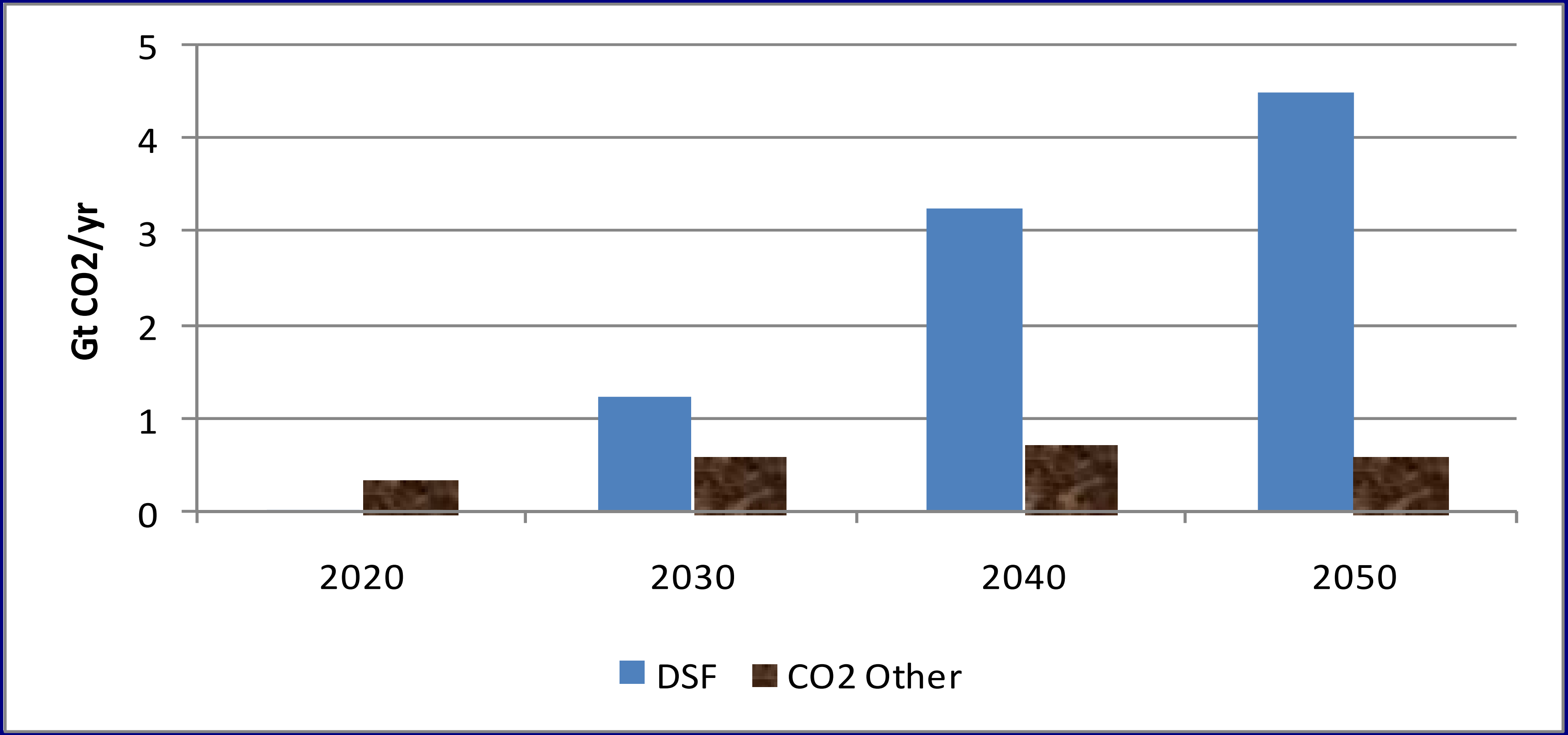
Projected CO_2 Capture in a 50 USD CO_2 Reduction Incentive Scenario



IEA – CCS -2008

Projected CO_2 Storage

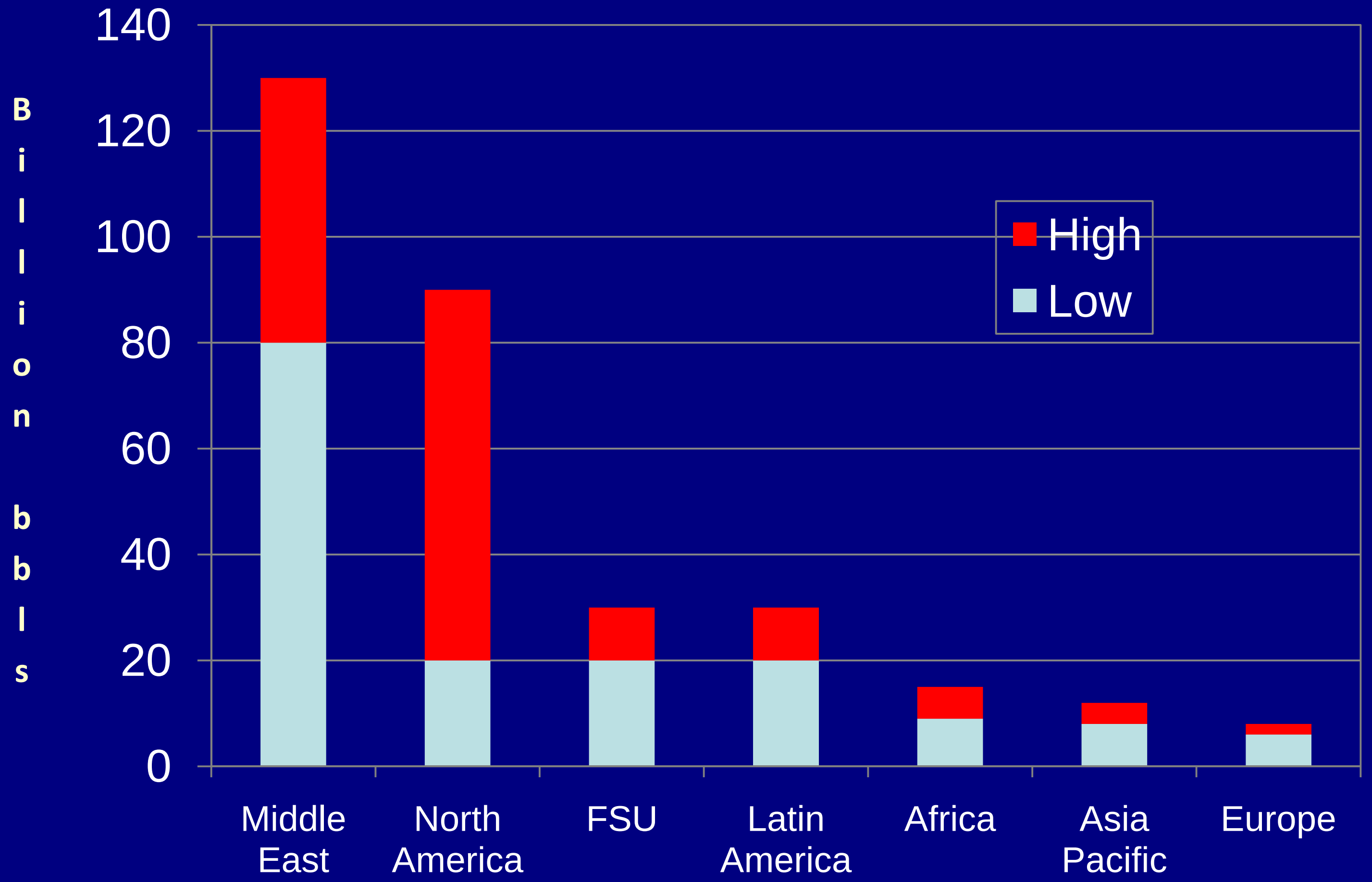


DSF = Deep Saline Formation

CO_2 Other+ EOR and Depleted Oil & Gas

IEA – CCS -2008

CO_2-EOR Potential



Sources: Petrotel, Shell, ARI

World Organizations and their role in CCS
The G8 – Gleaneagles (2005) & Aomori (2008)

- We face serious and linked challenges in tackling climate change, promoting clean energy and achieving sustainable development globally.
- We will work to accelerate the development and commercialization of Carbon Capture and Storage technology by:
  - …
  - working with industry and with national and international research programmes and partnerships to explore the potential of CCS technologies, including with developing countries.
- We strongly support the recommendation that 20 large-scale CCS demonstration projects need to be launched globally by 2010

Worldwide organizations and CCS

- The Carbon Sequestration Leadership Forum
- The International Energy Agency and the IEA Greenhouse Gas R&D Programme
- The UNFCCC and the IPCC
- Networks: CO2NET, Co2GeoNet, CCS Association …
- National and Regional CCS Organizations
- Professional Societies: SPE, SEG, AAPG, AIME, AiCHE, IEEE, ASCE …
- Non-Governmental Organizations

Summary of Key Findings

- Most energy still comes from fossil fuels in 2050
- CO_2 emissions can be returned towards today's level by 2050 with appropriate incentives
- Power generation can be substantially de-carbonised by 2050
- De-carbonising transport will take longer but must be achieved in the second half of the century

Main Implications

- An energy technology portfolio for carbon abatement will be needed
- Improving energy efficiency is top priority
- CCS is key for a sustainable energy future
- Other important technologies:
    - Renewables
    - Nuclear
    - Efficient use of natural gas
    - In time and with effort, hydrogen and fuel cells