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Houston we have a problem… how to realize a sustainable energy system?

Emerging Industrial Technology
Strategy Review Board (SRB) Meeting.
Taipei – Taiwan, November 19-22, 2007

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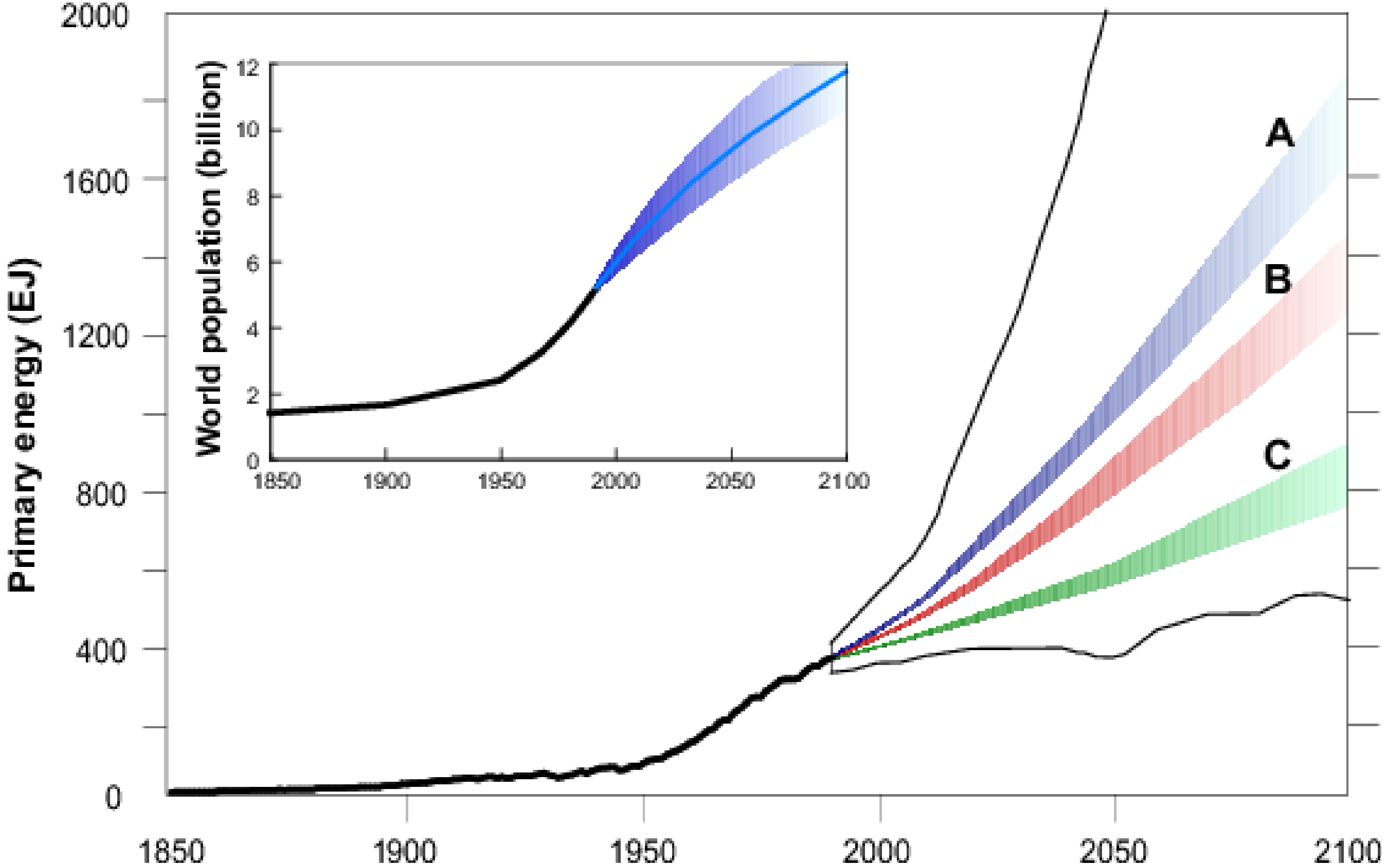
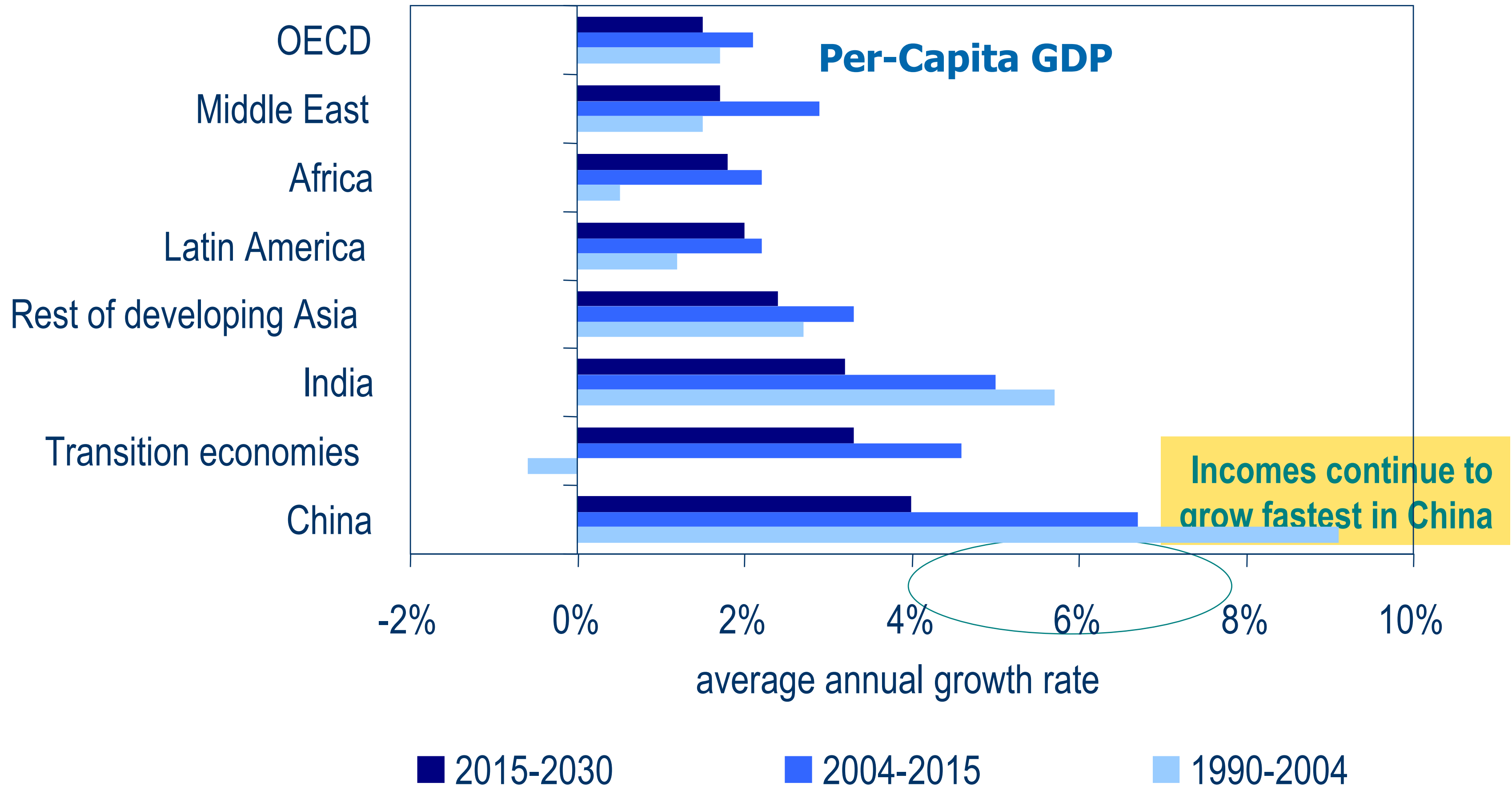
Sustainable Energy:

Energy that is produced and used in ways that simultaneously support human development over the long-term in ***all*** its social, economic, and environmental dimensions

Future Energy Use?



Economic development



Incomes in the OECD are still four times higher than in rest of the world in 2030

Per Capita Primary Energy Use, 2030

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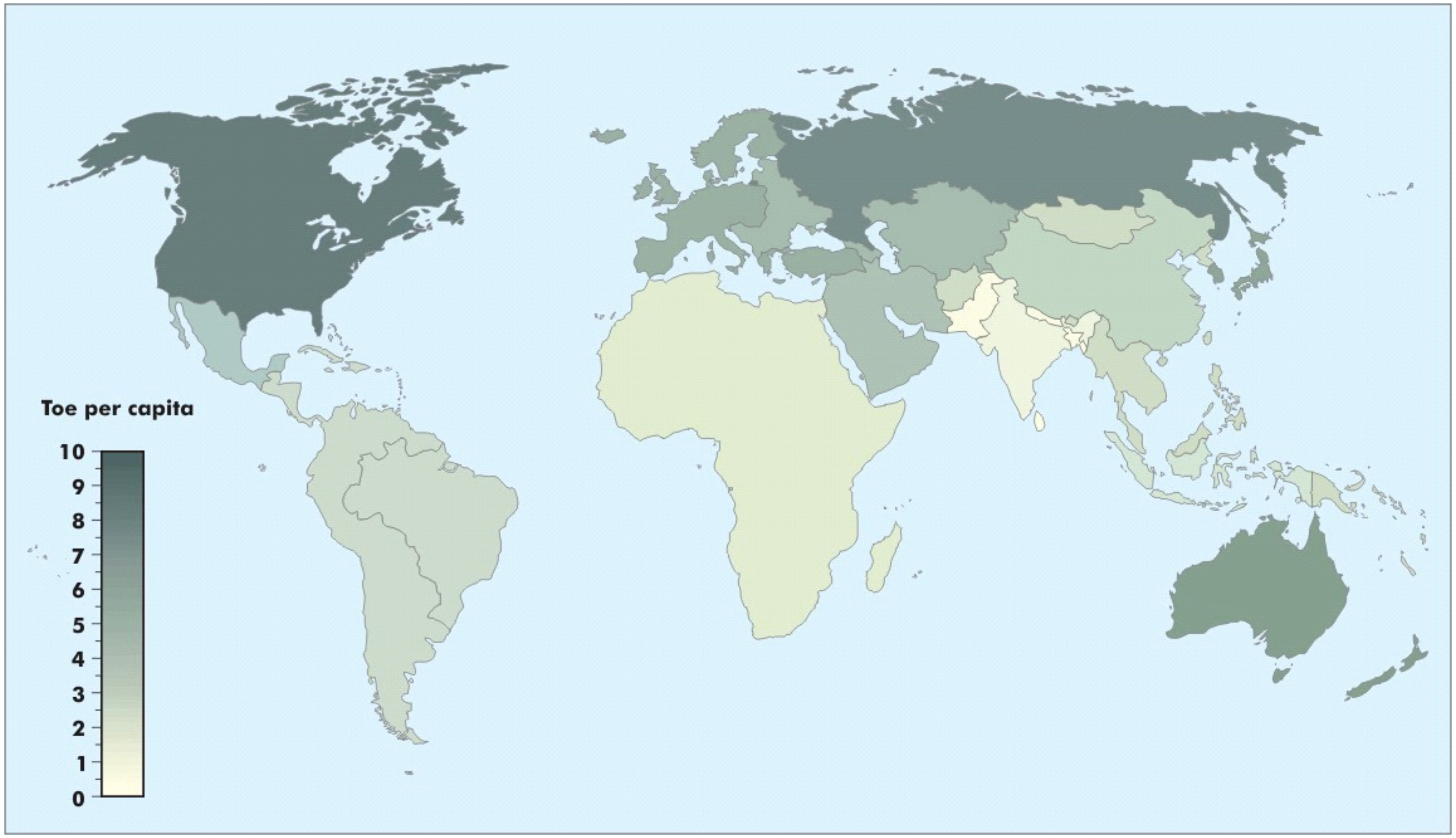

Per capita energy use remains much lower in developing countries

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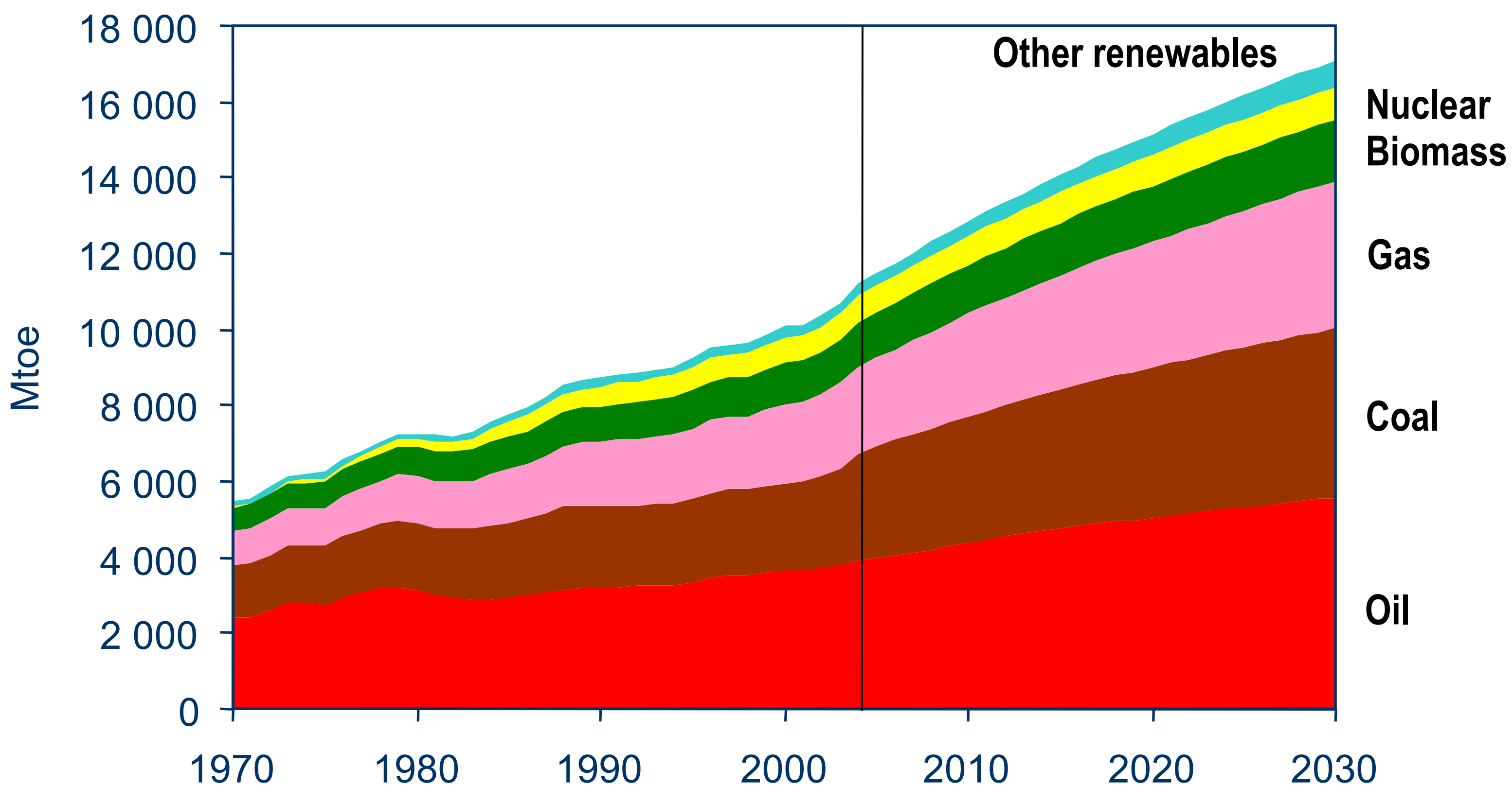
Energy problems

- Demand/consumption goes up
  - Climate !
  - Non GHG’s: acidification, urban air quality…
  - Exploitation, space, accidents…
- Stable and secure energy supply
- Costs
- Essential prerequisite for development

Nasa, 2003

Reference Scenario: World Primary Energy Demand



Global demand grows by more than half over the next quarter of a century, with coal use rising most in absolute terms

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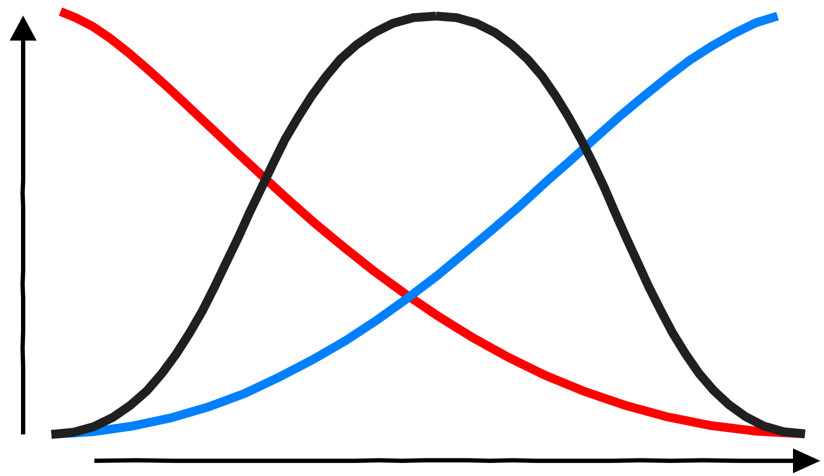
An Urban Environment Transition
From Sanitation to Sustainability



Shifting Environmental Burdens

Local → Global

Immediate → Delayed

Threaten Health → Threaten Life Support Systems

Reference Scenario: Energy-Related CO_2 emissions by Region

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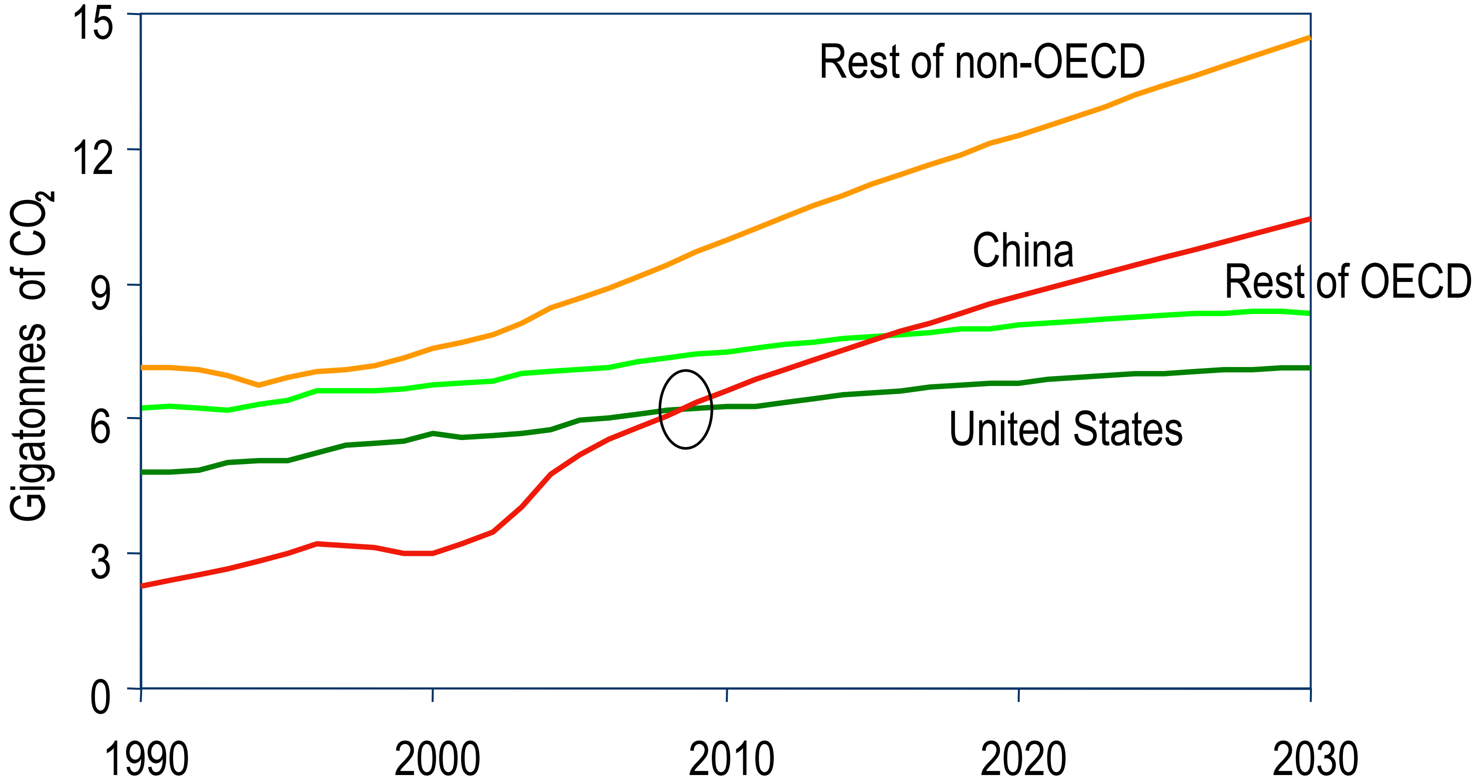

China overtakes the US as the world's biggest emitter before 2010, though its per capita emissions reach just 60% of those of the OECD in 2030

Reference Scenario: World Primary Energy Demand by Fuel

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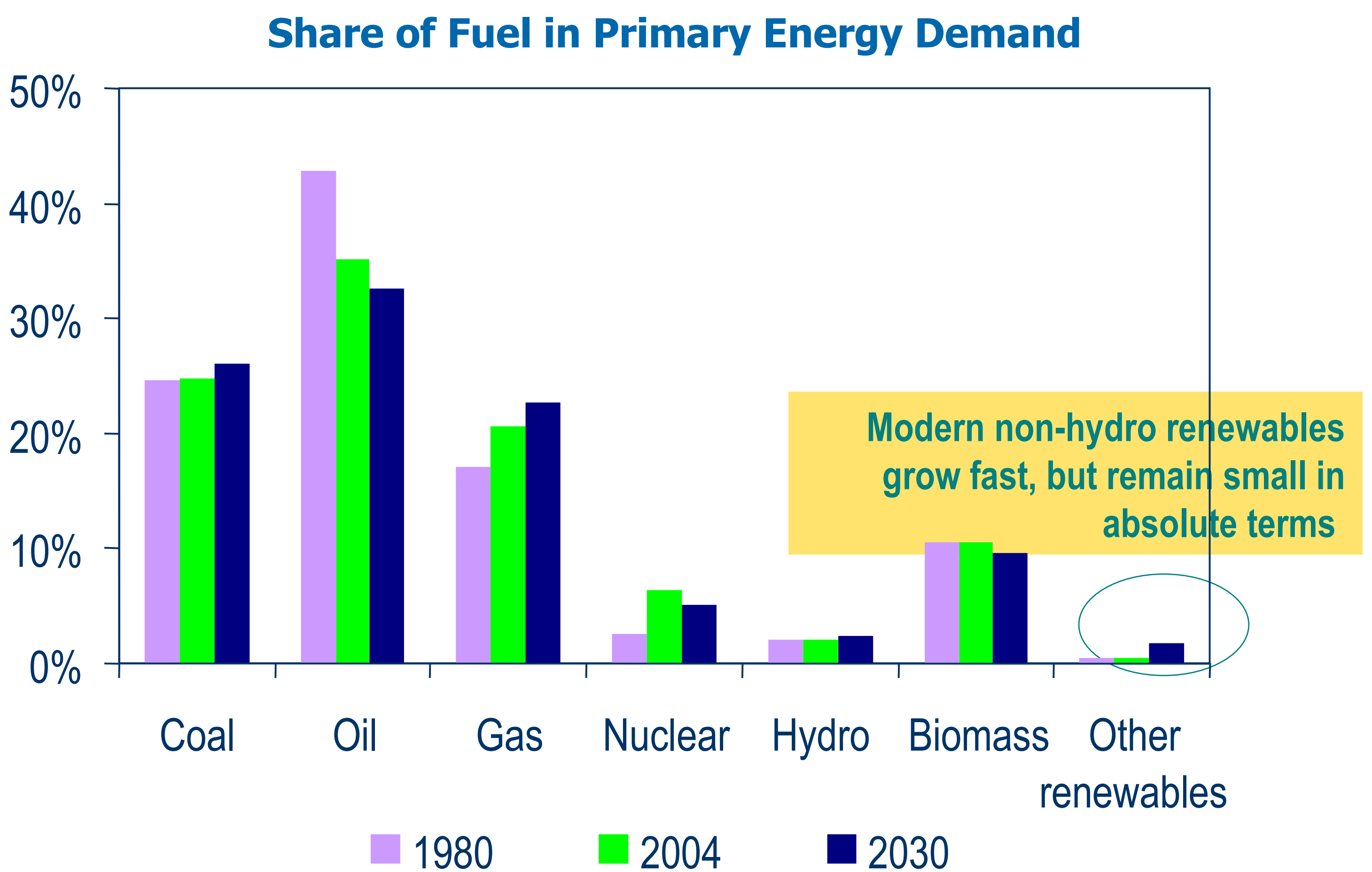
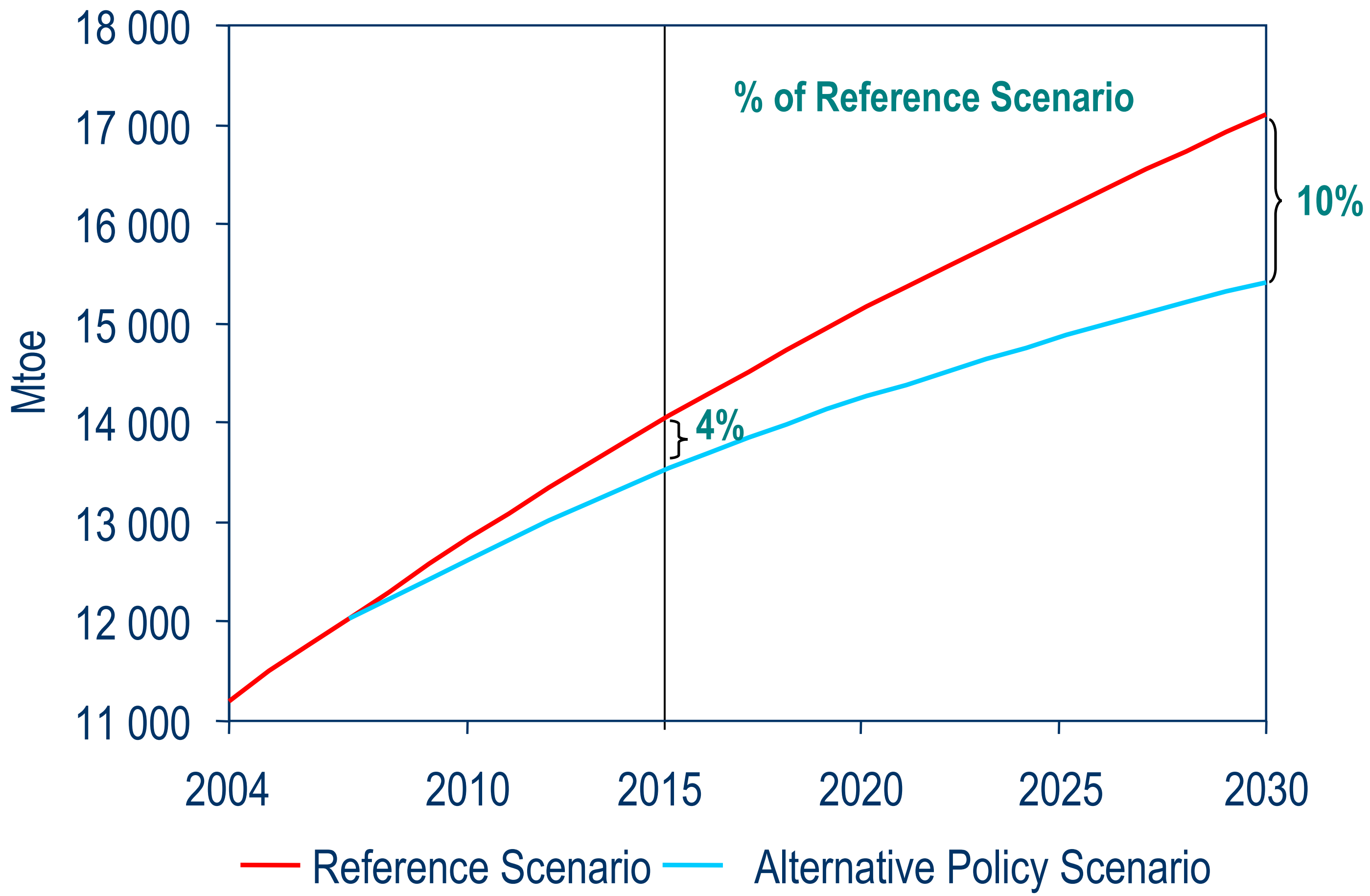


Oil remains the most important fuel, but its share in the global energy mix drops while those of gas, coal & modern renewables rise

Alternative Policy Scenario: World Primary Energy Demand



The impact of new policies – though far from negligible – is less marked in the period to 2015 because of the slow pace of capital stock turnover

Alternative Policy Scenario:

Global Savings in Energy-Related CO_2 Emissions

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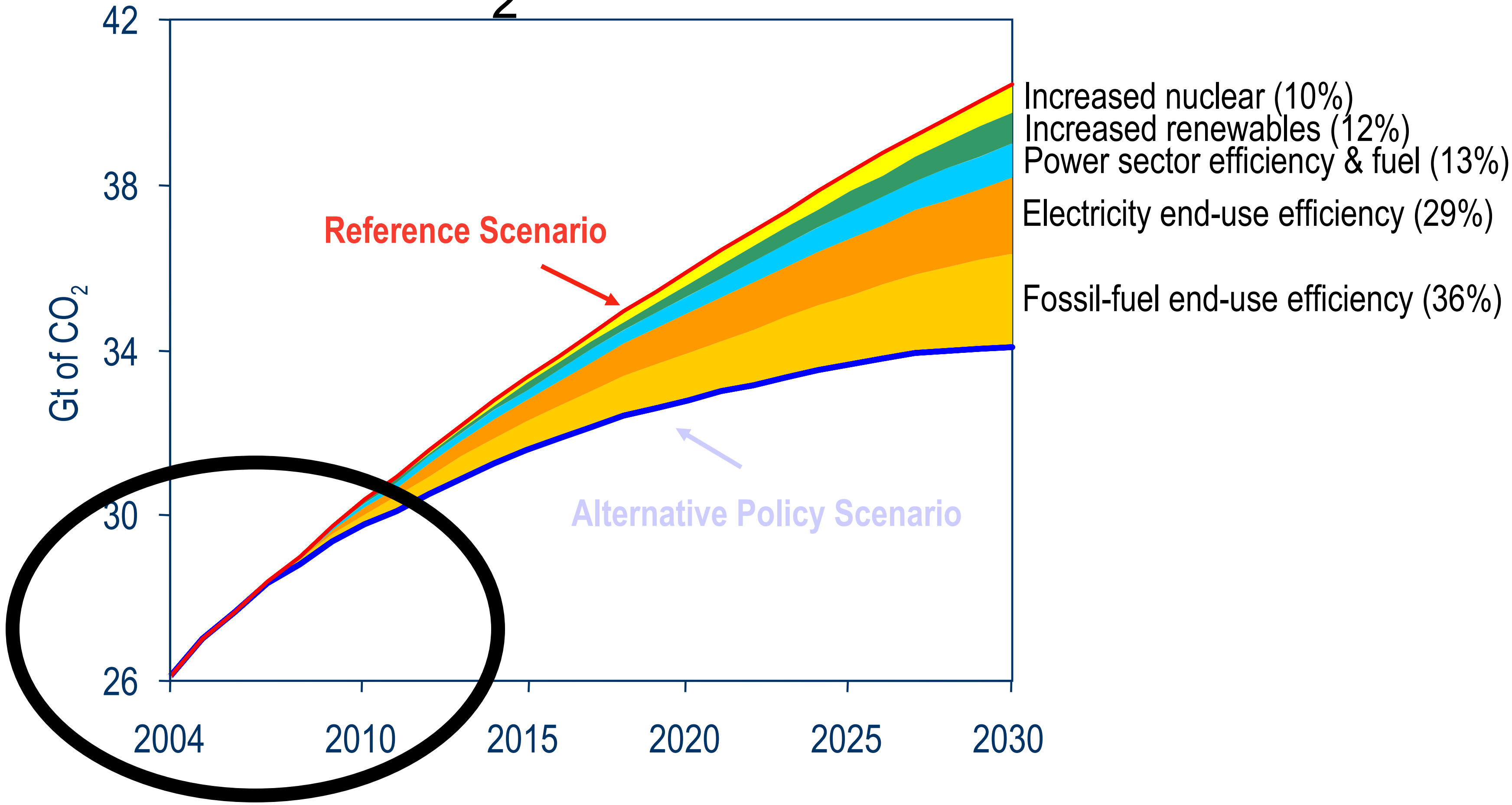

Improved end-use efficiency of electricity & fossil fuels accounts for two-thirds of avoided emissions in 2030

Key policies that Make a Global Difference

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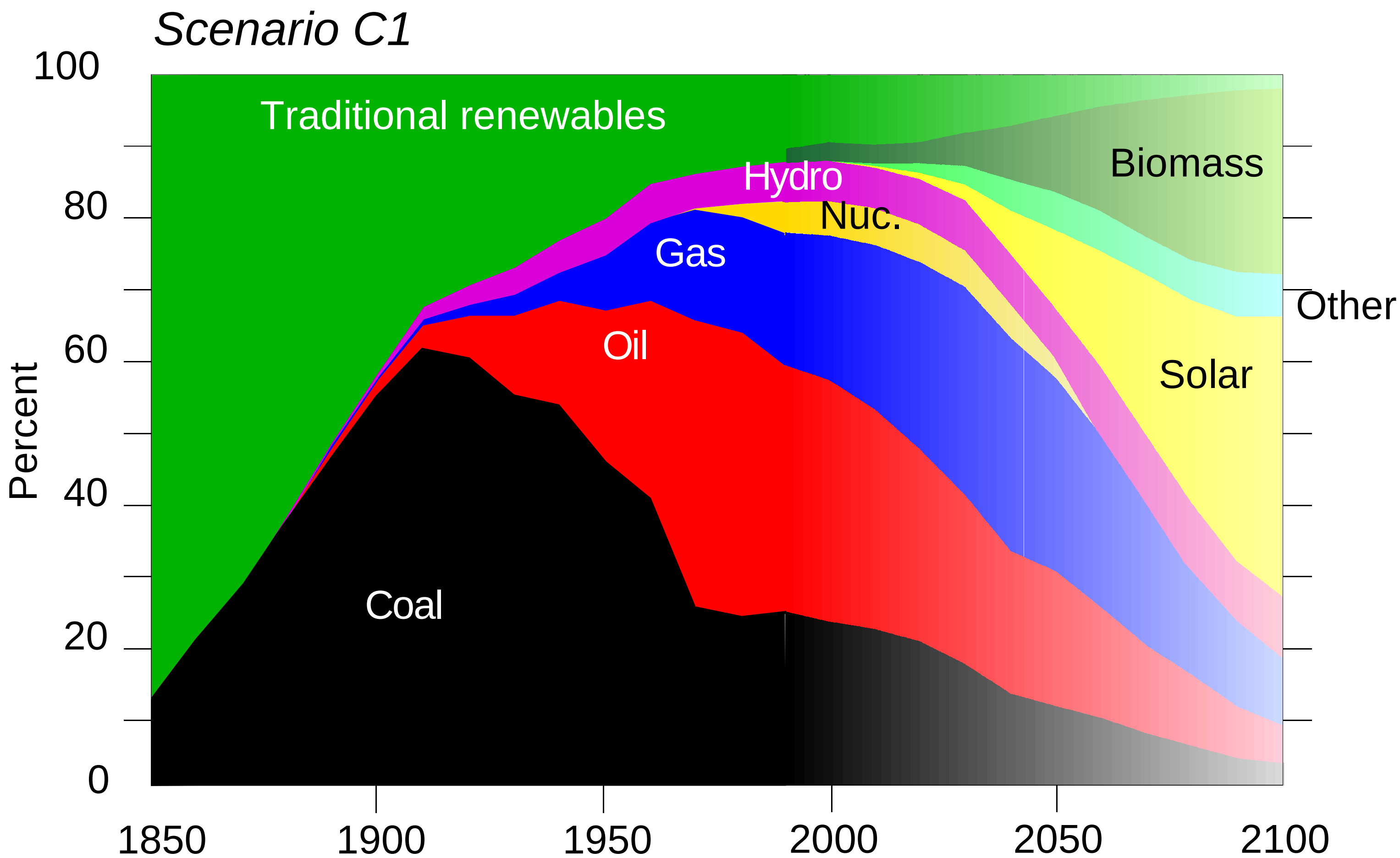
	Energy efficiency	*Power generation*
US	• Tighter CAFE standards • Improved efficiency in residential & commercial sectors	• Increased use of renewables
EU	• Increased vehicle fuel economy • Improved efficiency in electricity use in the commercial sector	• Increased use of renewables
China	• Improved efficiency in electricity use in industry • Improved efficiency in electricity use in the residential sector	• Increased efficiency of coal-fired plants • Increased use of renewables • Increased reliance on nuclear
India	•Minimum requirements for energy-efficient design of buildings •Improved efficiency in iron and steel sector	•Increased use of renewables •Reduced transmission and distribution losses

Just fifteen policies in the US, EU, China and India account for over 40% of the global emissions reduction in 2030 in the Alternative Policy Scenario

Full transition to a sustainable energy system?



Source: N. Nakićenović et.al., IIASA, 2000

Future worlds…

material/economic

A1

population: 2050: 8.7 billion
2100: 7.1 billion
GDP: 2050: 24.2 10^3 billion $\$_{95}$/y
2100: 86.2 10^3 billion $\$_{95}$/y
technological growth: high
trade: maximal

A2

population: 2050: 11.3 billion
2100: 15.1 billion
GDP: 2050: 8.6 10^3 billion $\$_{95}$/y
2100: 17.9 10^3 billion $\$_{95}$/y
technological growth: low
trade: minimal

globally oriented

regionally oriented

B1

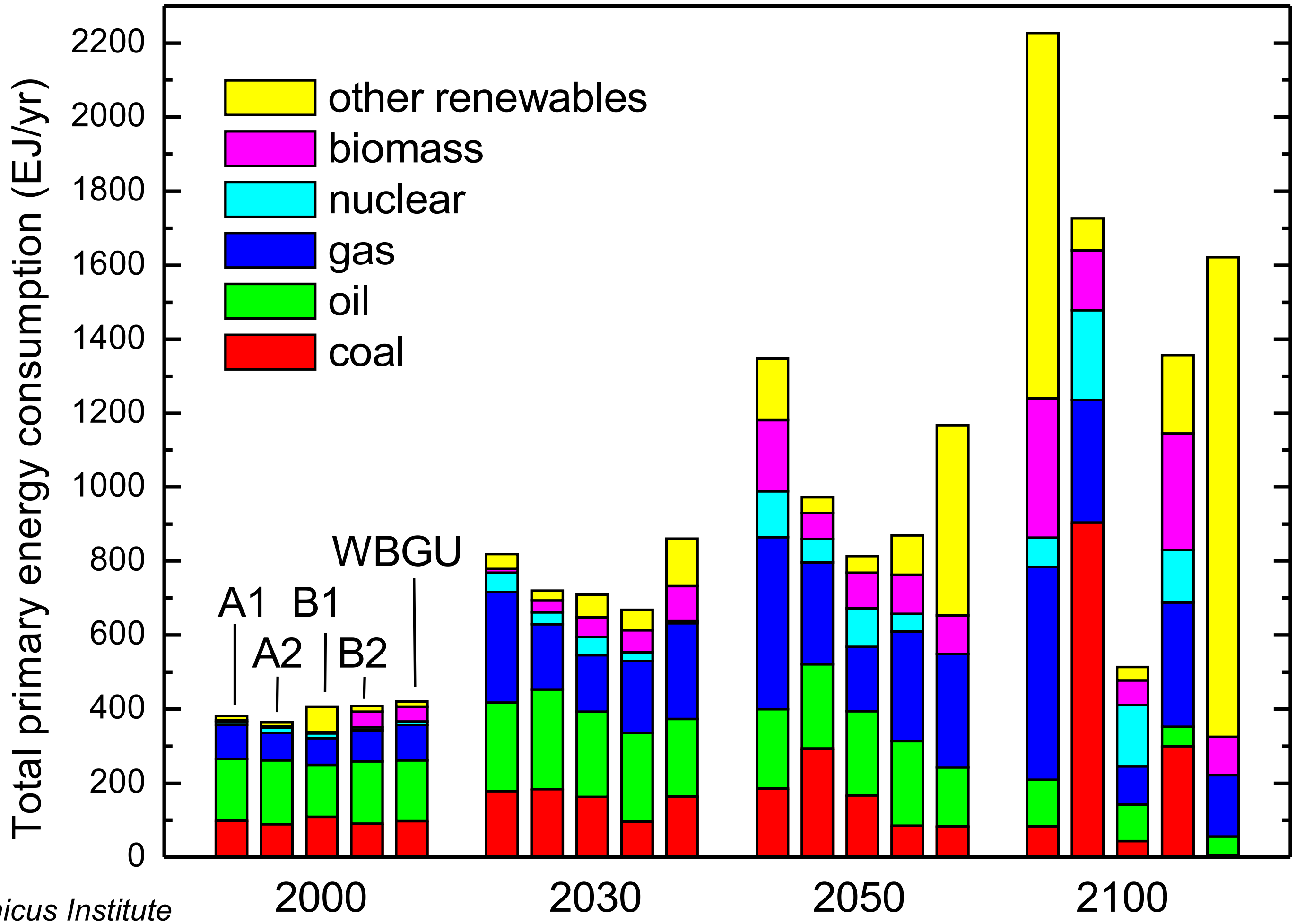
population: 2050: 8.7 billion
2100: 7.1 billion
GDP: 2050: 18.4 10^3 billion $\$_{95}$/y
2100: 53.9 10^3 billion $\$_{95}$/y
technological growth: high
trade: high

B2

population: 2050: 9.4 billion
2100: 10.4 billion
GDP: 2050: 13.6 10^3 billion $\$_{95}$/y
2100: 27.7$10^3$ billion $\$_{95}$/y
technological growth: low
trade: low

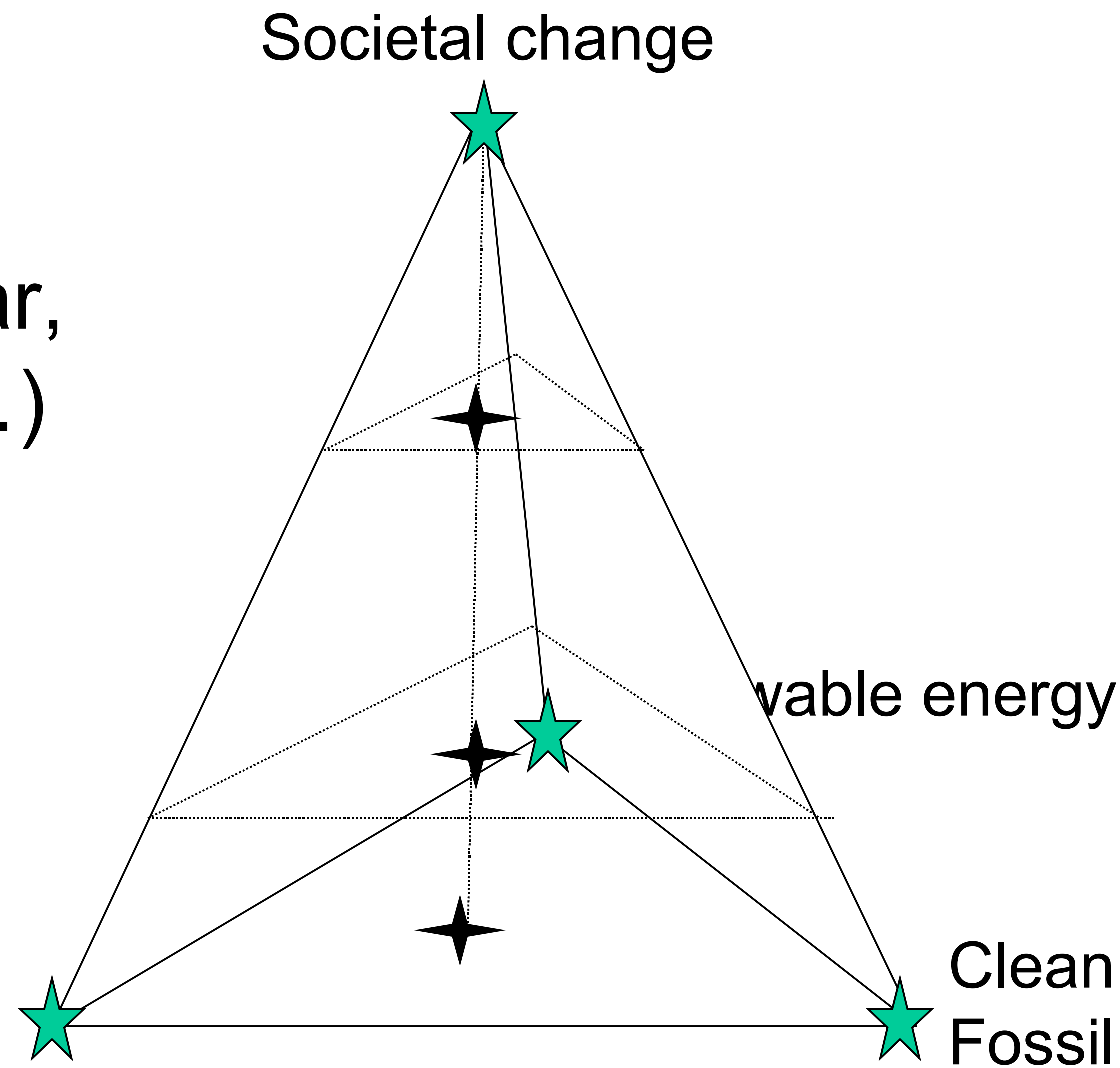
environmental/social

Total primary energy demand and energy mixture for the four SRES scenarios of the IPCC



The Options:

- Lifestyle
- Efficiency
- Renewables; solar, wind, biomass (…)
- Clean fossil fuels
- Nuclear



Energy Resources

Non-renewable resource base (thousands of Exajoules)

Resource	Consumed by end 1998	Consumed in 1998	Reserves	Resources	Resource base	Additonal occurences
Oil	5.14	0.14	11.11	21.31	32.42	45
- Conventional	4.85	0.13	6.00	6.07	12.08	
- Unconventional	0.29	0.01	5.11	15.24	20.35	45
Gas	2.38	0.08	14.88	34.93	49.81	930
- Conventional	2.35	0.08	5.45	11.11	16.57	
- Unconventional	0.03	0.00	9.42	23.81	33.24	930
Coal	5.99	0.09	20.67	179.00	199.67	
Fossil total	**13.51**	**0.32**	**46.66**	**235.24**	**281.89**	**975**
Uranium						
- Open Cycle	n.e.	0.04	1.89	3.00	4.88	7.1
- Closed Cycle	-	-	113	180	293	426
Non-renewable total	**n.e.**	**0.36**	**48**	**415**	**575**	**1,400**

Energy Resources

Renewable Resource Base (EJ/year)

Resource	Current Use	Technical Potential	Theoretical Potential
Hydropower	9	50	147
Biomass Energy	50	>276	2,900
Solar Energy	0.1	>1,575	3,900,000
Wind Energy	0.12	640	6,000
Geothermal Energy	0.6	5,000	140,000,000
Ocean Energy	n.e.	n.e.	7,400
Total	**56**	**>7,600**	**> 144,000,000**

Energy Resources

- Conventional oil and gas could last at least 50-100 years (but tightening fast…).
- Total fossil fuel resources will last at least several hundreds of years (especially coal)
- Renewable energy flows are some 1000 times current global energy use; bioenergy ad wind energy closest to the market with large possibilities.

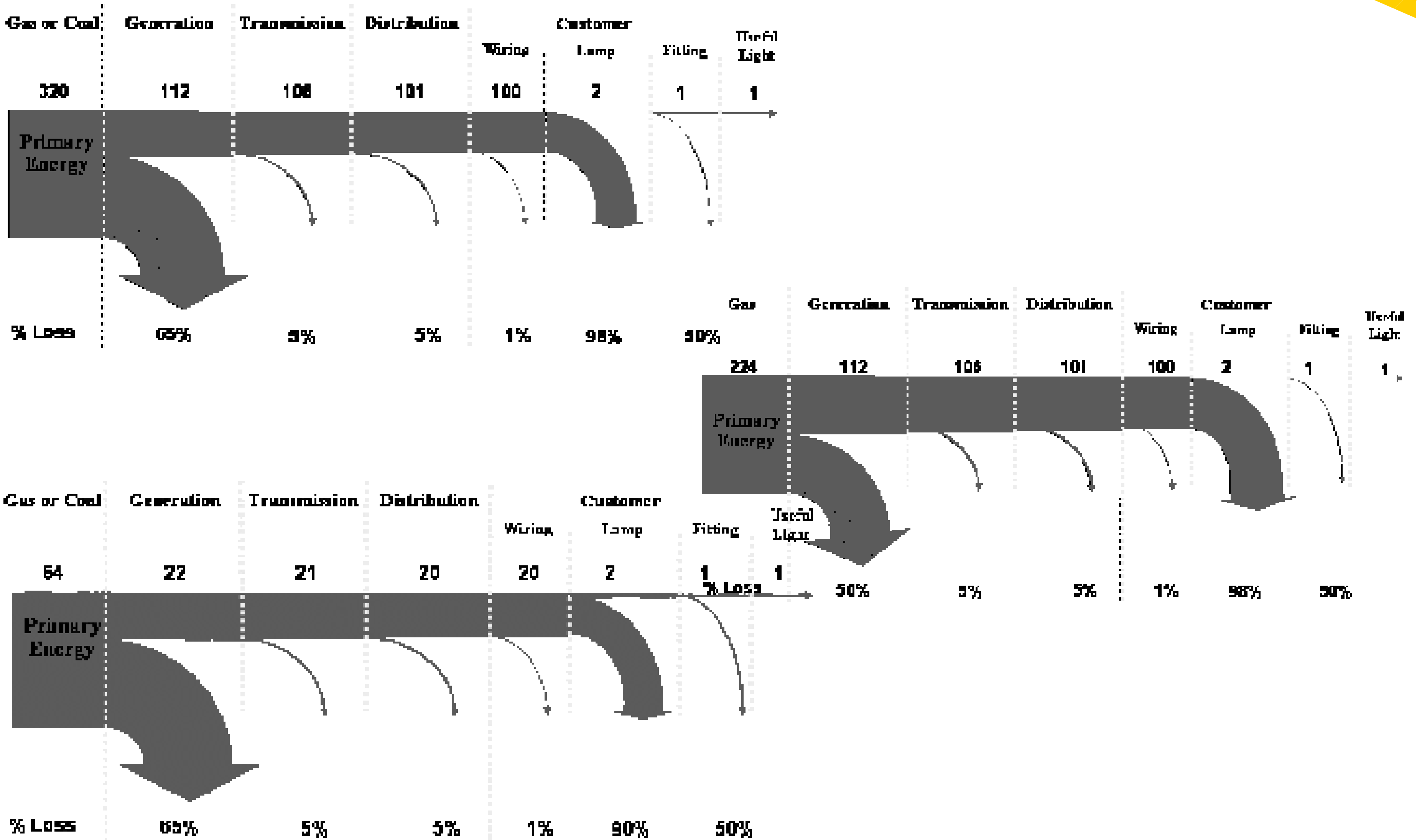
Options to enhance energy supply security

- Avoid over-dependence on imports by encouraging greater reliance on local resources
- Increase end-use efficiency,which can also reduce dependence on imported energy resources
- Diversity of supply
- Support international cooperation
- Encourage technology transfers
- Increase national and regional strategic reserves

Energy losses

	EJ	%
Primary energy	400	100
Final energy	300	75
Useful energy	150	37
Energy service	<60	<15

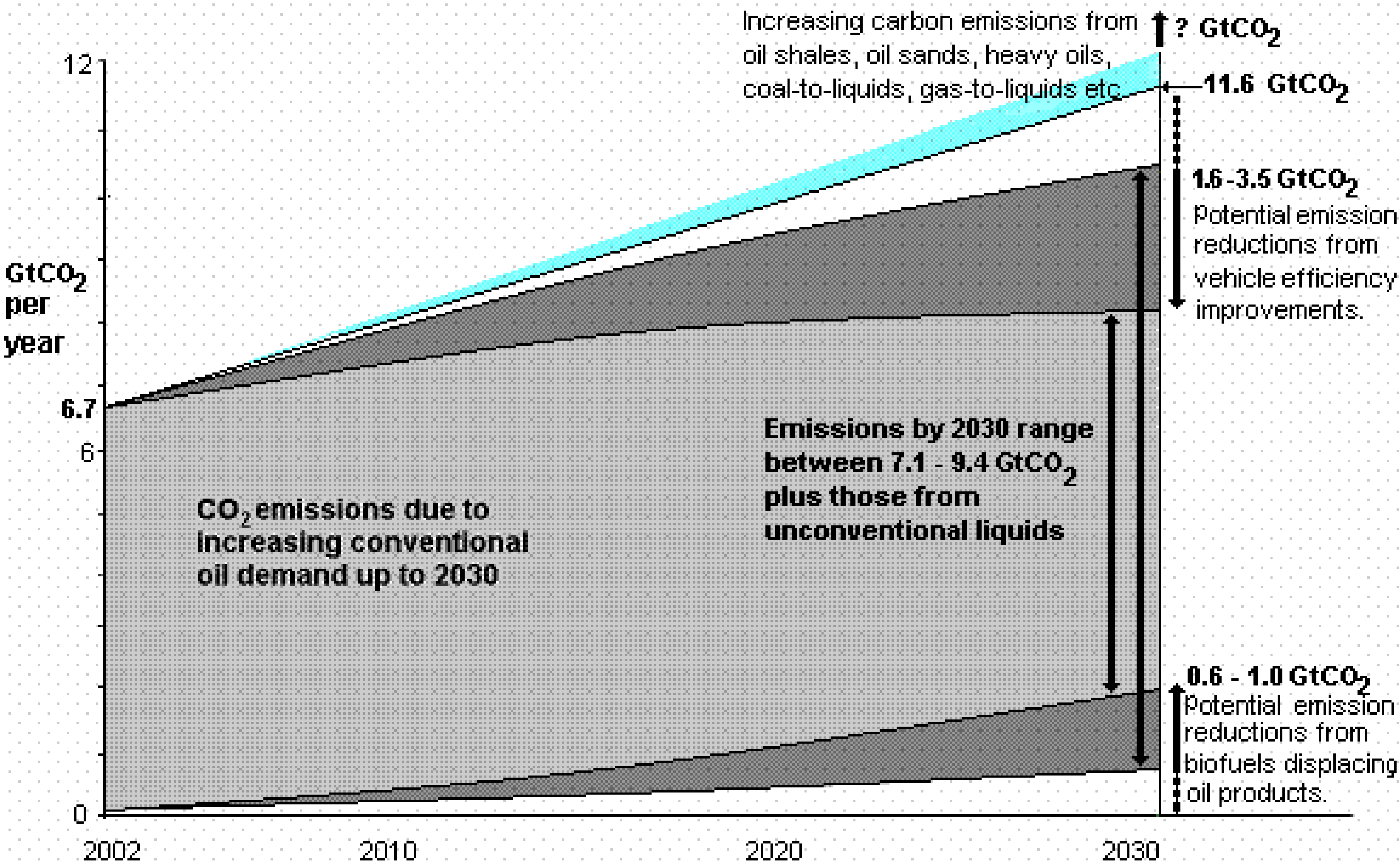
Lighting; an illustration:

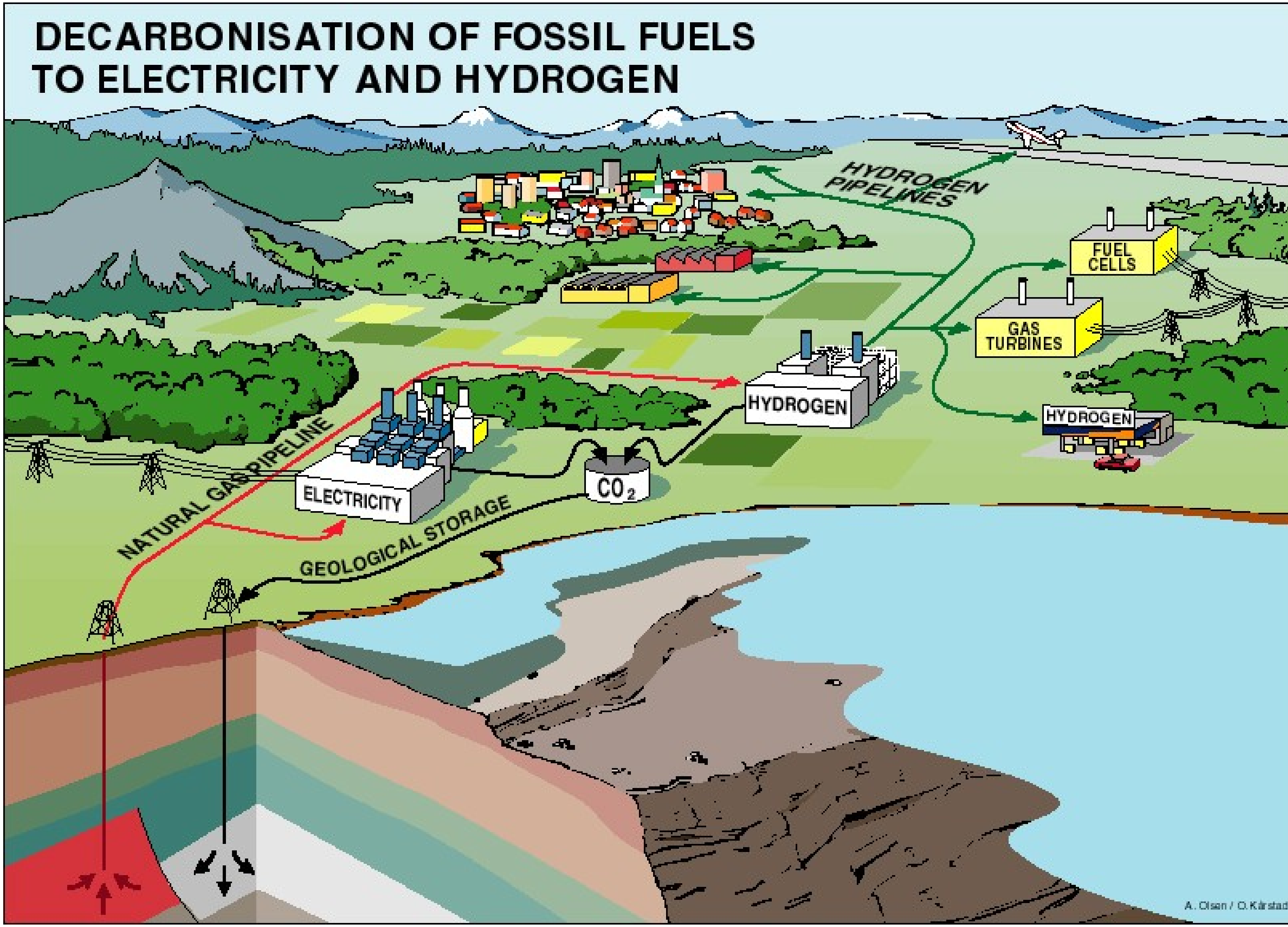


Outlook for More Efficient Use of Energy

- **Cost effective** over the next 20 years to reduce primary energy consumed per unit of energy services
  - OECD Countries 25-35%
  - Developing Countries 30- >45%
  - Economies in transition >40%
- **Greater gains** in efficiency feasible with advanced energy technologies that offer multiple benefits

Indicative mitigation potentials due to biofuels and vehicle efficiency improvements (based on IEA 2006b).





Source: Statoil

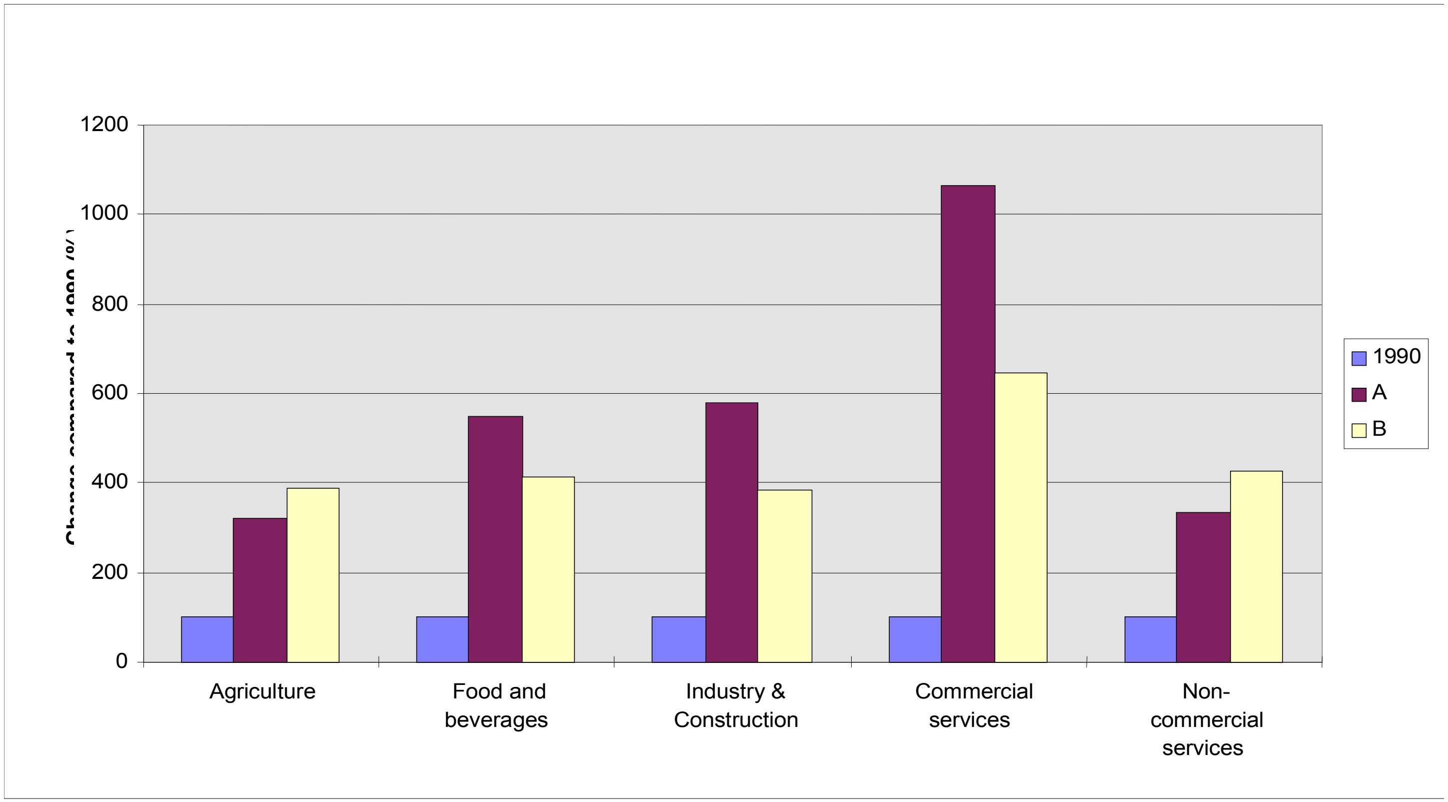
Sustainable energy systems on the long term; two visions on the Dutch energy system.

Exercise done for the national climate dialogue (‘COOL’), aimed to involve all key statkeholders in defining a national strategy for far reaching GHG emissions and changing the energy system.

Different worlds in 2050

	Vision A - Free Market	Vision B - Awareness
World	International orientation ‘Global Vilage’	Regional orientation, world trade unions
	Worldwide convergence	Wealth contrasts, cultural differences
Society	Individual	Social, Familial
	Low esteem natural environment	Environmentalism
	No leveling of income, inequity	Leveling of income, equity
	Self interest prevails	Care for fellow man

Value Added


1200
1000
800
600
400
200
0
Agriculture
Food and beverages
Industry & Construction
Commercial services
Non-commercial services
1990
A
B

COOL
Climate OptiOns for the Long term

Different worlds in 2050

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	Vision A - Free Market	Vision B - Awareness
Economy & consumption	Dynamic; high economical growth rates	Stability; more moderate economic growth
	Part of world economy	Part of EU
	Market-based solutions	Regulation.
	Intensive international travel.	Recreation and holidays in the region
	Quantity prevails over sustainability	Sustainable goods and quality
Land-use	Suburbanisation and high demand for mobility.	Spatial planning, intensive use of public transport
	Agri-business, factory	Ecological agriculture
	Park-like landscape	Large nature reserves and biomass production

The Energy Systems: 80% reduction of GHG emissions!

	Vision A – Free Market	Vision B – Awareness
Context	- Cost minimization - Supply oriented. - Rapid diffusion of technology	- Principal choices; no nuclear, minimal fossil fuel use. - 'Environmentally driven'
Energy infrastructure	- Revised system; CO_2 storage and hydrogen economy. - Centralized – large scale.	- Optimization of current system; major role for renewables - Decentralized

Energy demand

	Vision A – Free Market	**Vision B – Awareness**
Built environment	Large dwellings; heat pumps and solar heating.	Compact cities; low energy dwellings, district & solar heating + PV.
Industry	State-of-the-art advanced technology and processes; Integrated complexes + CHP	Strong emphasis on energy and material efficiency Integrated complexes + CHP
Agriculture	Industrial, low emission systems.	Ecological agriculture
Transport	Very strong growth (road & air transport); FCV's fueled by hydrogen	Growth: Increased role for public transport (rail); FCV's fueled by bio-alcohols
Non –CO2	Far going reductions	Far going reductions

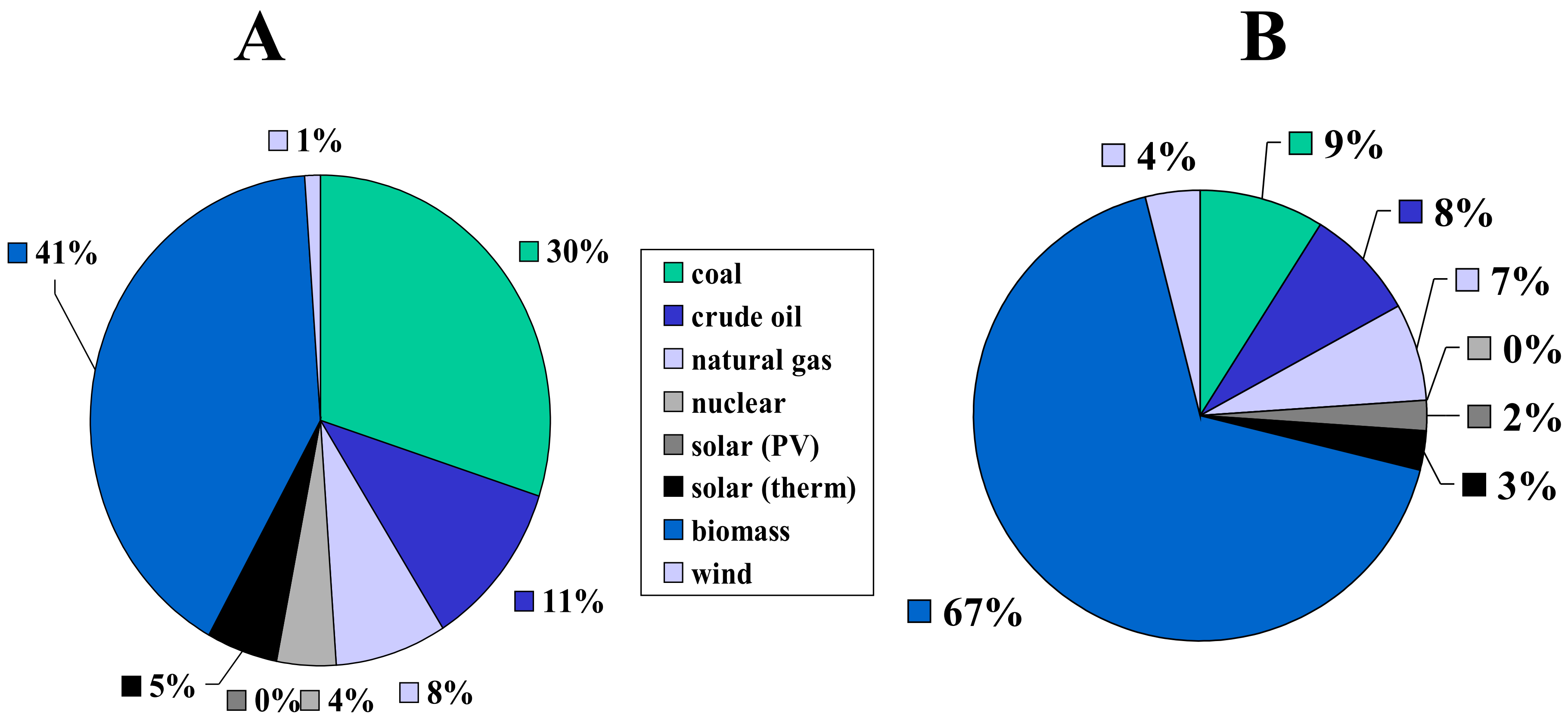
Energy supply

Vision A – Free Market	Vision B – Awareness
- Large scale application of imported coal with CO2 storage - Nuclear energy - Bio-energy (import) - Hydrogen for the transport sector - Heat pumps and solar energy in built environment	- Large scale application of solar energy (PV and passive) - Large scale wind energy production - Supportive role for natural gas and CBM. - Indigenous biomass - Large scale import of bio-energy (about 50% of energy mix)

Some key technologies

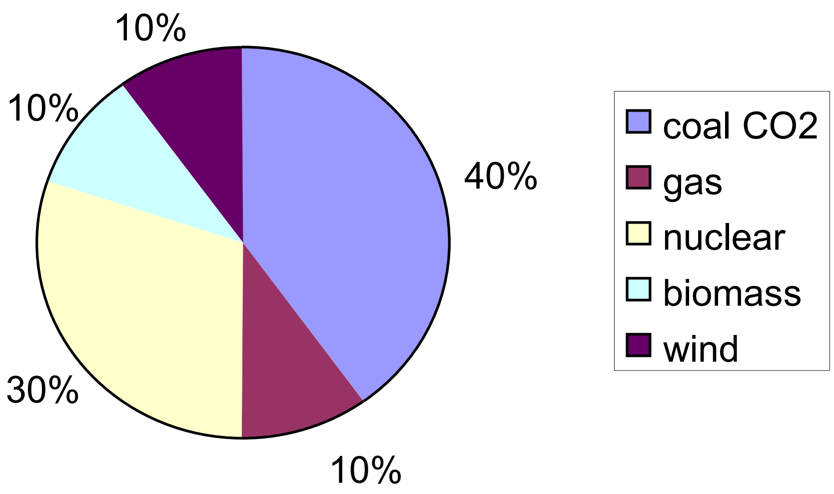
Vision A – Free Market	Vision B – Awareness
Fuel cell vehicles (H2)	Fuel cell vehicles (alcohols)
Large scale hydrogen and power production from coal (import!) and coal bed methane with CO2 removal and storage	Production of bio-alcohols, feedstocks and power from biomass (import!) in 'bio-refineries'.
Nuclear power (and heat) generation	Power generation with PV and large scale wind parks.
Energy efficient dwellings + heat pumps	Very energy efficient dwellings + solar heating

Primary energy carriers

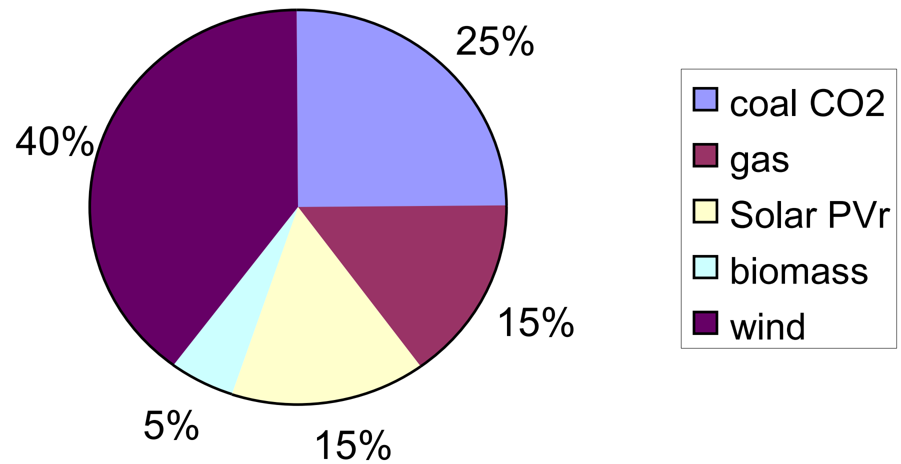


Electricity Production Mix

A



B



North Sea
Aquifers (
Gasfields

W
Aq
Ga

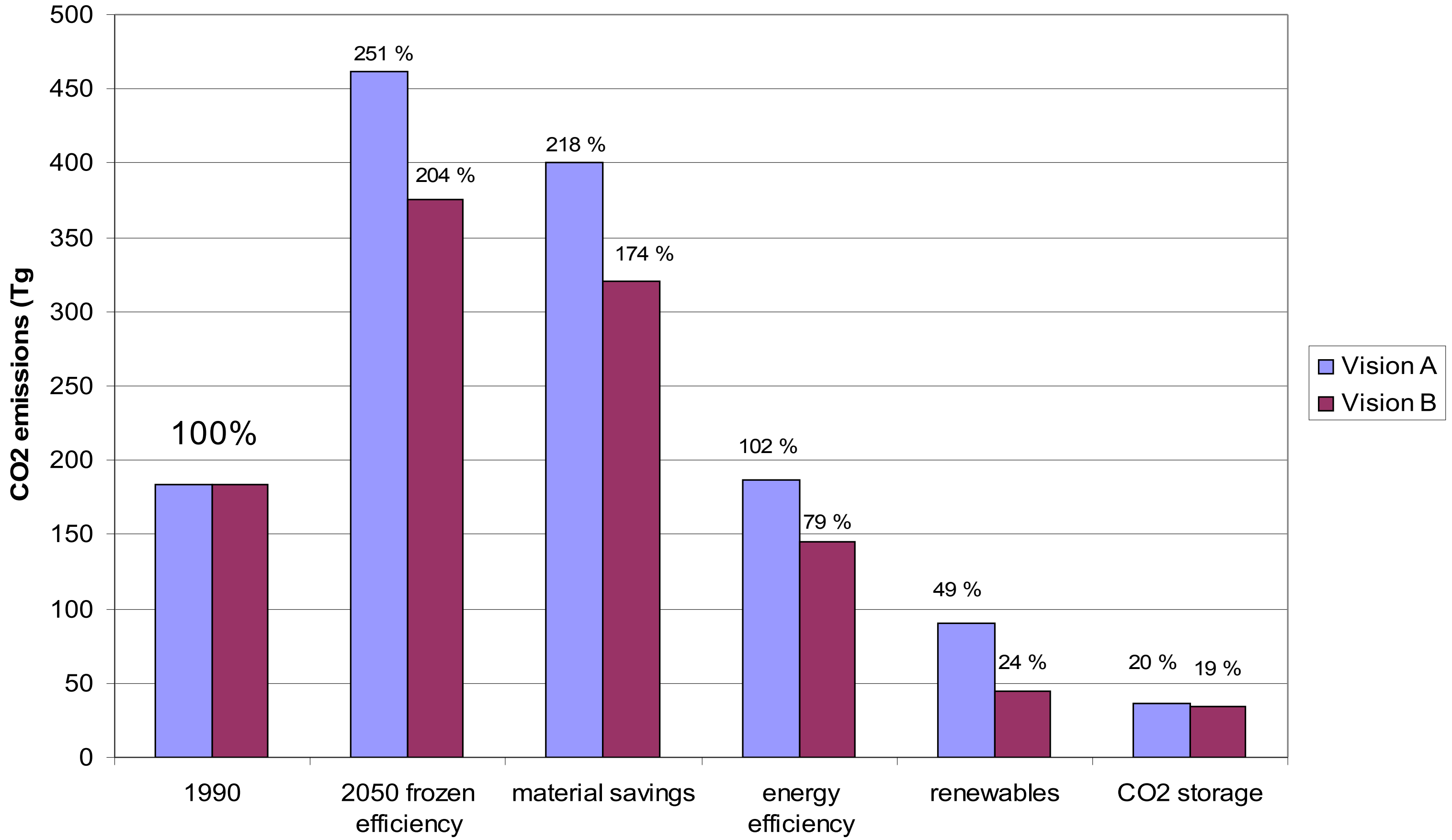
Southwest
Aquifers (200
Gasfields (50

Mt)

North
Aquifers (130 Mt)
Groningen gasfield (7512 Mt)
Other gasfields (2000 Mt)

- H_2 Large scale hydrogen plant
- ~ Large scale power plant
- CO_2 pipeline
- Hydrogen pipeline
- Residential hydrogen market
- Industrial hydrogen market
- Automotive hydrogen market
- Storage reservoirs

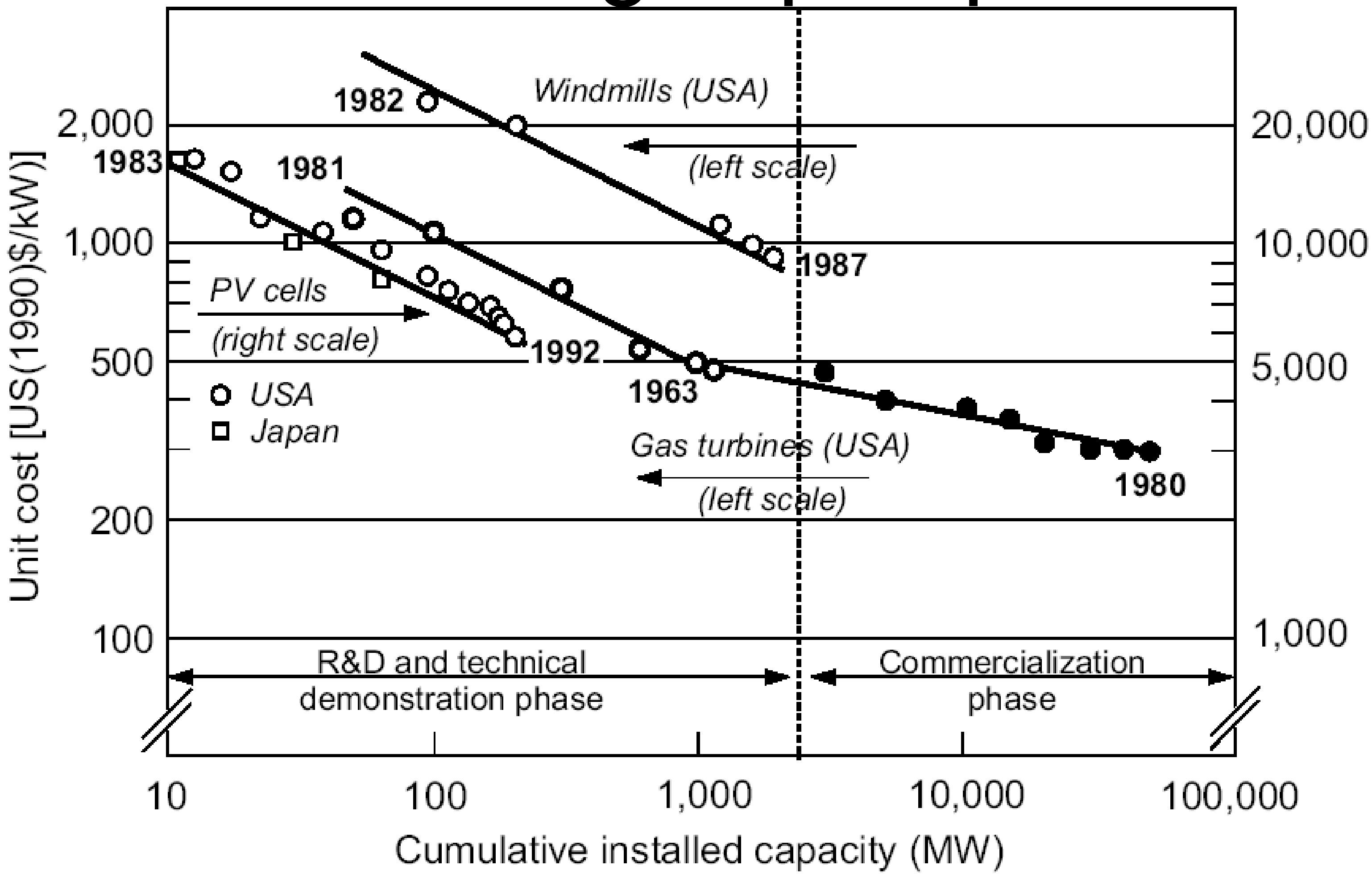
CO_2 emissions for the Netherlands: The visions compared



Findings...

- Two worlds, two systems, one, ‘feasible’, target.
- Strong economic growth can be combined with severe GHG emission reductions
- **Without** far going measures, strong economic growth can lead to very high GHG emission levels.
- Principal choices for the organization of the energy system in 2050 can be made: standards of living, consumption patterns, sustainable use of fossil fuels, nuclear energy, renewables, import, energy efficiency, material efficiency….
- Huge efforts required (R&D, revised infrastructure and processes…)
- No scenario’s, but starting points for the dialogue!

ESSENTIAL: Technological Learning in perspective



Source: N. Nakićenović et.al., IIASA, 1998

The Innovation Chain

- Research and Development
- Demonstration projects
- Early deployment (cost buy-down)
- Widespread dissemination

Reference Scenario: Will the Investment Come?

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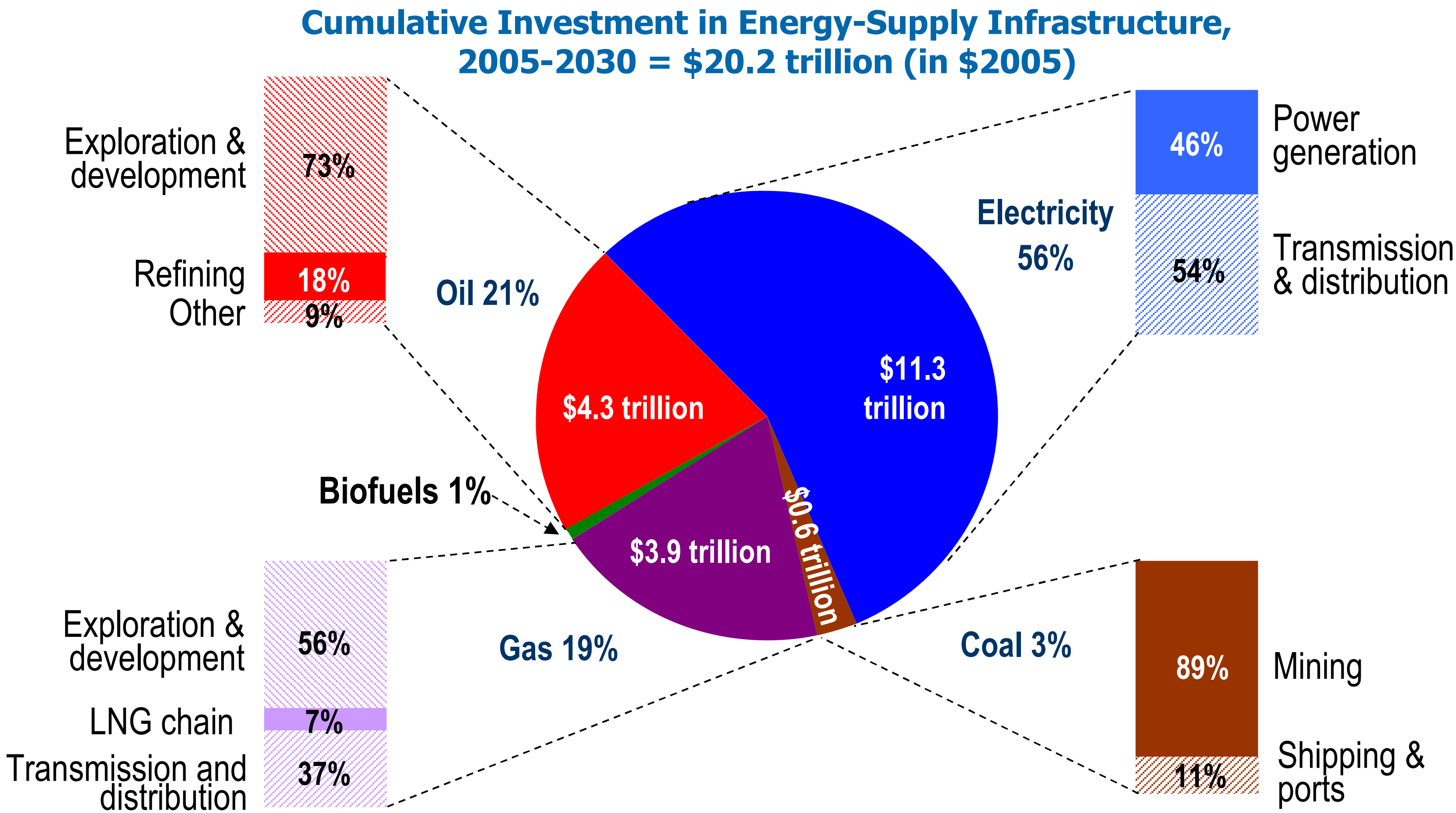

Just over half of all investment needs to 2030 are in developing countries, 18% in China alone

Energy R&D

Reported R&D budgets and GDP in IEA countries (billions U$-1998)

Year	Fossil	Nuclear (fission +fusion)	Energy conser-vation	Renew ables	Other	Billion U$	Percen-tage GDP	GDP (trillion 1998 U$)
1983	1.61	7.52	0.82	1.03	1.09	12.07	0.158	7.64
1990	1.74	5.02	0.54	0.58	1.21	9.90	0.056	16.23
1995	0.90	4.20	1.05	0.68	1.39	8.22	0.037	22.44
1997	0.69	3.87	0.94	0.59	1.43	7.52	0.034	21.99

The tragedy: increasing wealth and reduced expenditures on energy R&D, in particular for key alternatives!!!

Policies for Sustainable Energy

An energy future compatible with sustainable development will not happen by itself, thus policy change is required, including:

- Making markets work better, including mobilizing investments
- Focusing on the innovation chain
- Reforming the power sector
- Increasing capacity to support policy and institution building, and transfer of technology

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Making markets work better

- Setting the right framework conditions (including continued market reform and appropriate regulatory measures and policies) to encourage competitiveness in energy markets and protect public benefits
- Setting accurate price signals, including removal of subsidies to fossil fuel energy and some internalization of externalities (Subsidies of $100 - 200 billion/year to conventional energy.)
- Supporting technological leadership and capacity building in developing countries
- Encouraging greater international cooperation

Final remarks

- Technically, a sustainable energy system with a high level of economic development is possible around 2050…
- …provided all key options are pursued at high speed… (including saturation of demand and demographic development)…
- …and that requires fundamental changes in energy technology development, deployment and investment patterns.
- An international issue… (of course).