Building Energy and Emission Scenarios

How can we do this?

Lars Strupeit

Malé Declaration: Emission inventory preparation / scenarios / atmospheric transport modelling and soil acidification workshop

UNEP RRCAP, Bangkok, Thailand. 28 January to 1 February 2008

the international institute for
industrial environmental economics
Lund University, Sweden
iiiee

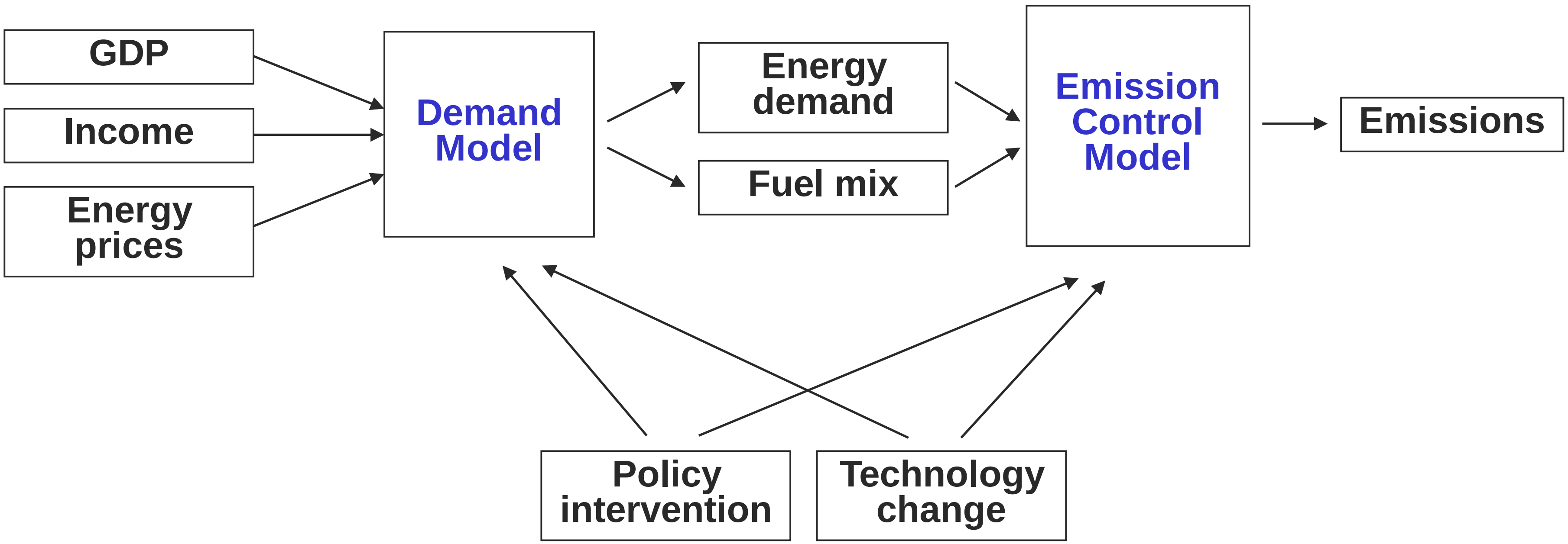
How can we foresee the future?

- We can learn from historical trends
- We can learn from other places
  - things happening in some parts of the world, may happen in other parts in a few years.
- Technology outlooks
- We have to make assumptions
  - especially with regard to the macro environment

Outline

- Economic development and energy demand
  - GDP and electricity demand
  - GDP and transport demand
- Energy prices, energy demand, and fuel mix
- Technology change
  - Example: transport sector
  - Example: power sector
- Policy intervention
- Models and tools

Building energy and emission scenarios

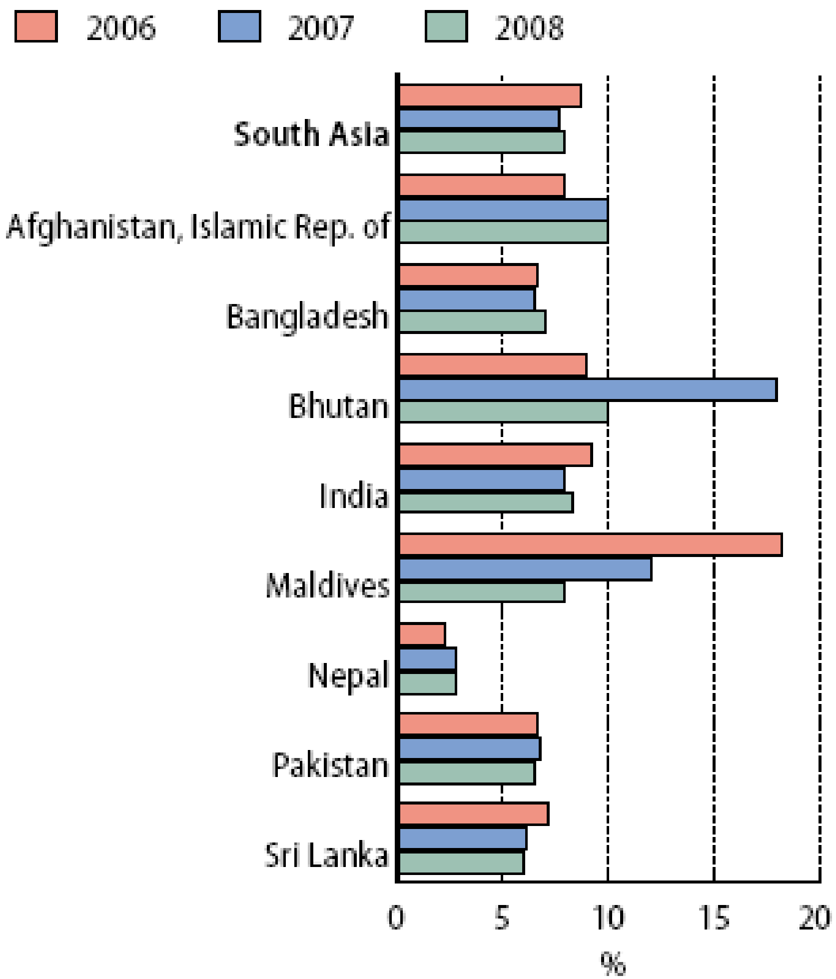


1 Economic development and energy demand

- Economic growth is by far the most important driver of energy demand
- Key factors determining economic development
  - Population development
  - Productivity
  - Innovation and technology change
  - Policies
  - Trade
  - and many more…

Economic Growth in South Asia

1.3.3 GDP growth, South Asia

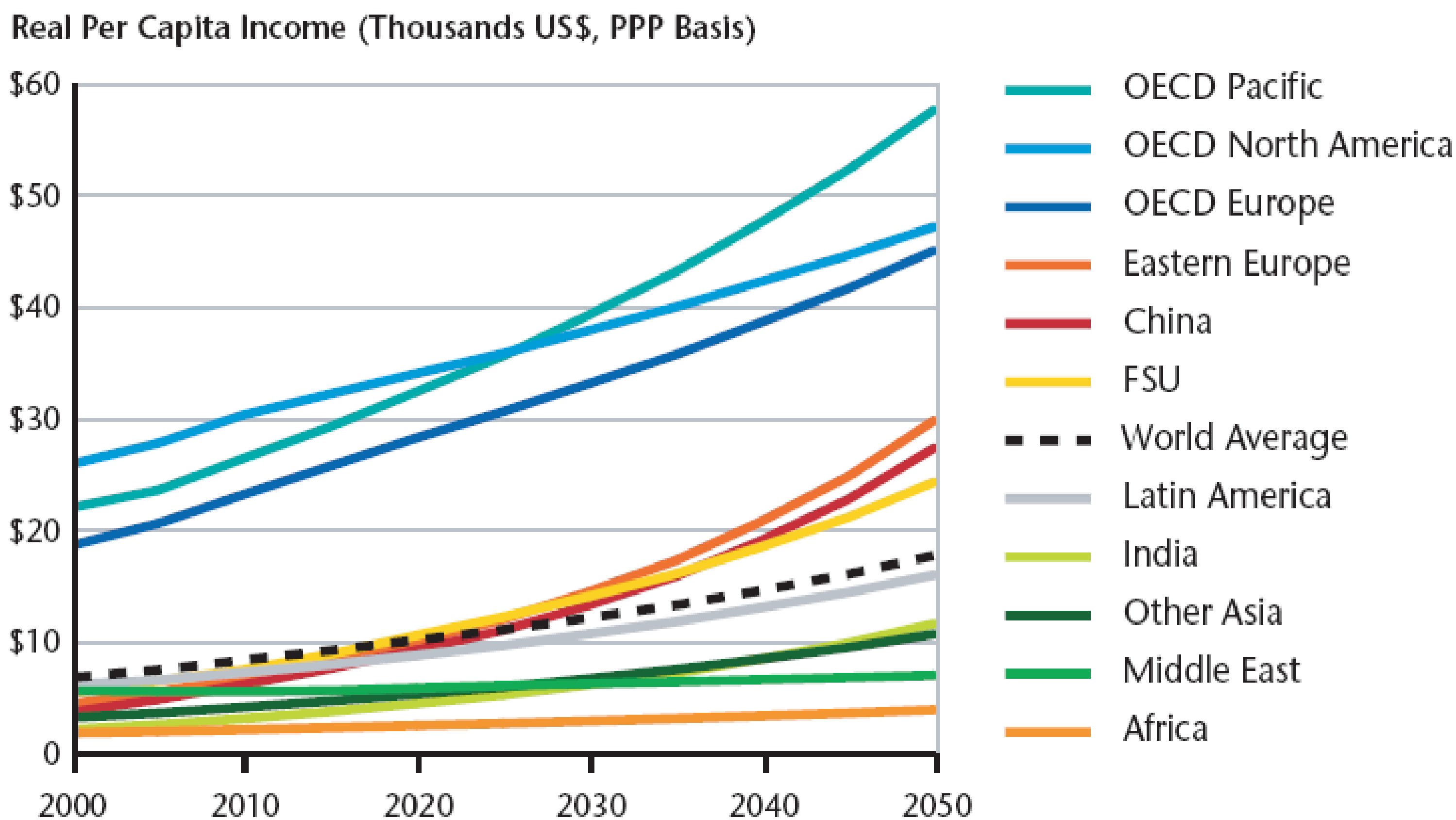


(ADB, 2007)

Sources: Asian Development Outlook database; staff estimates.

Economic Growth Scenarios

Figure 2.1 Real GDP per capita, purchasing power parity (PPP) basis



(WBCSD, 2004)

Source: Data for 2000, IEA: projections 2000-2030, **IEA 2002, p. 408**; projections for 2030-2050, SMP extrapolation of IEA projections.

Trends in global energy intensity

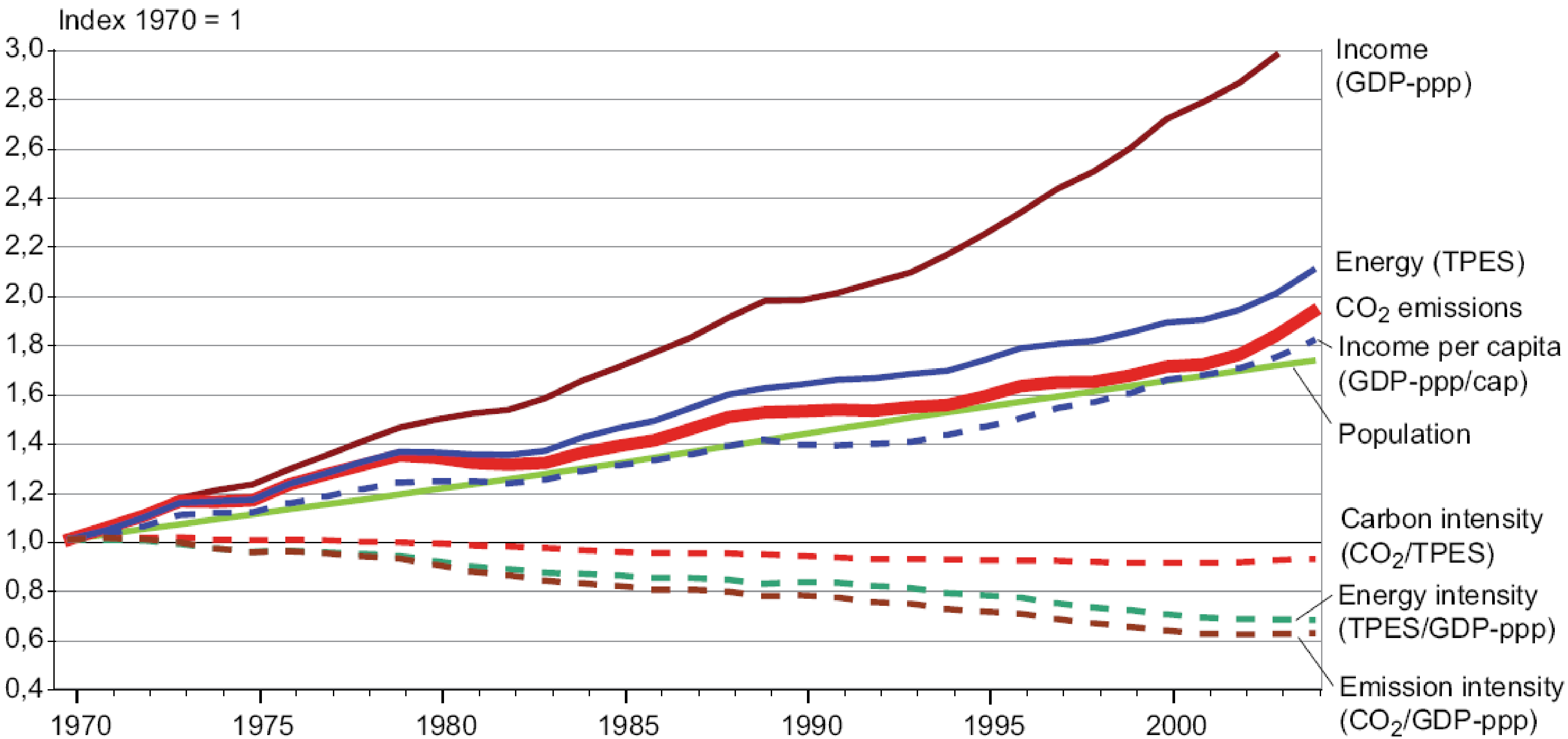


Figure 1.5: *Intensities of energy use and CO_2 emissions, 1970–2004.*

Data Source: IEA data

(IPCC, 2007)

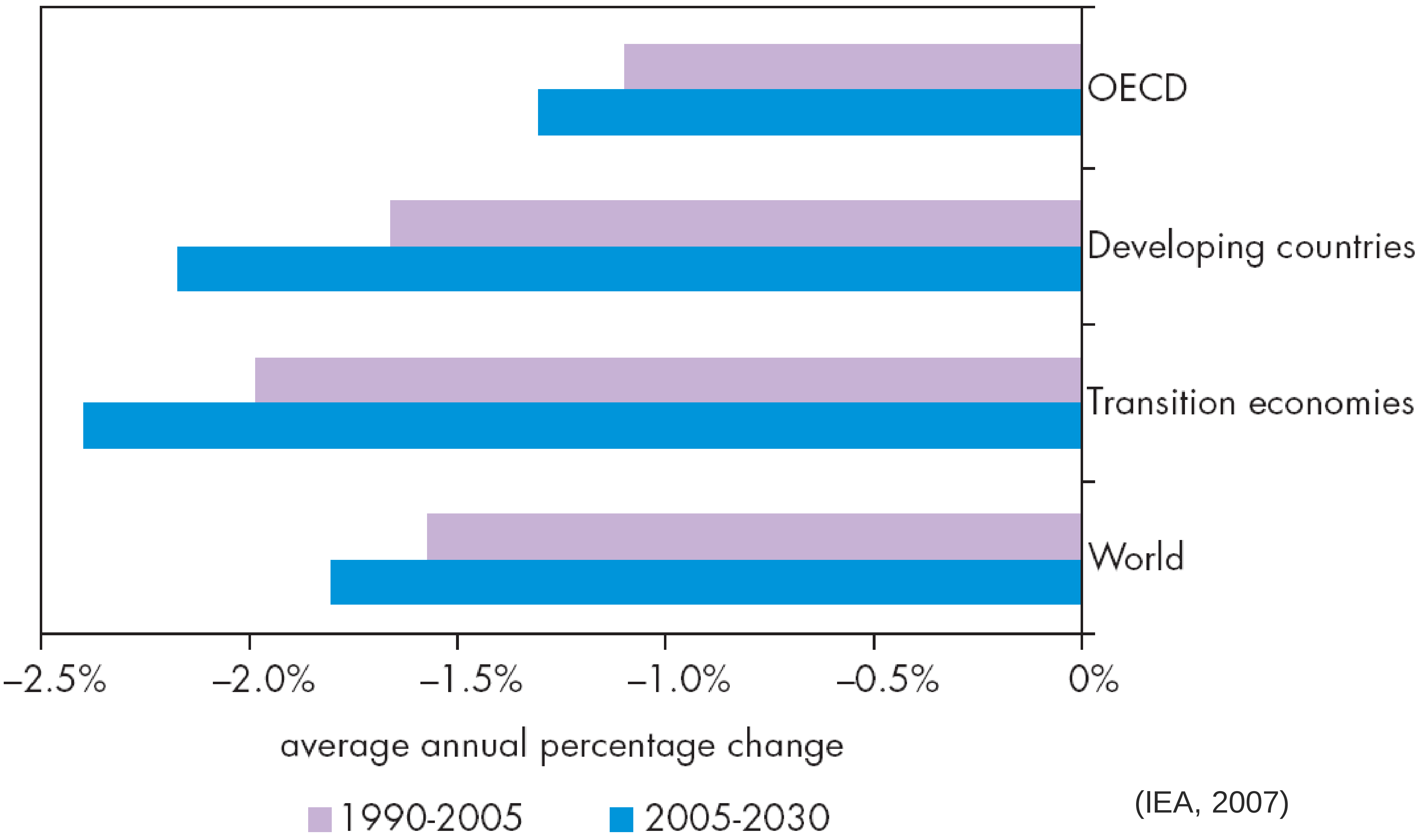
Key energy indicators for India

	1980	1990	2000	2005
Total primary energy demand (Mtoe)	209	320	459	537
Oil demand (mb/d)	0.7	1.2	2.3	2.6
Coal demand (Mtce)	75	152	235	297
Gas demand (bcm)	1.4	11.9	25.4	34.8
Biomass and waste (Mtoe)	116	133	149	158
Electricity output (TWh)	119	289	562	699
TPES/GDP (index, 2005=100)	163	142	120	100
Total primary energy demand per capita (toe)	0.30	0.38	0.45	0.49
CO_2 emissions per capita (tonne)	0.43	0.69	0.95	1.05
Oil imports (mb/d)	0.5	0.6	1.6	1.8
Electricity demand per capita (kWh)	174	341	553	639

(IEA, 2007)

Changes in energy intensity

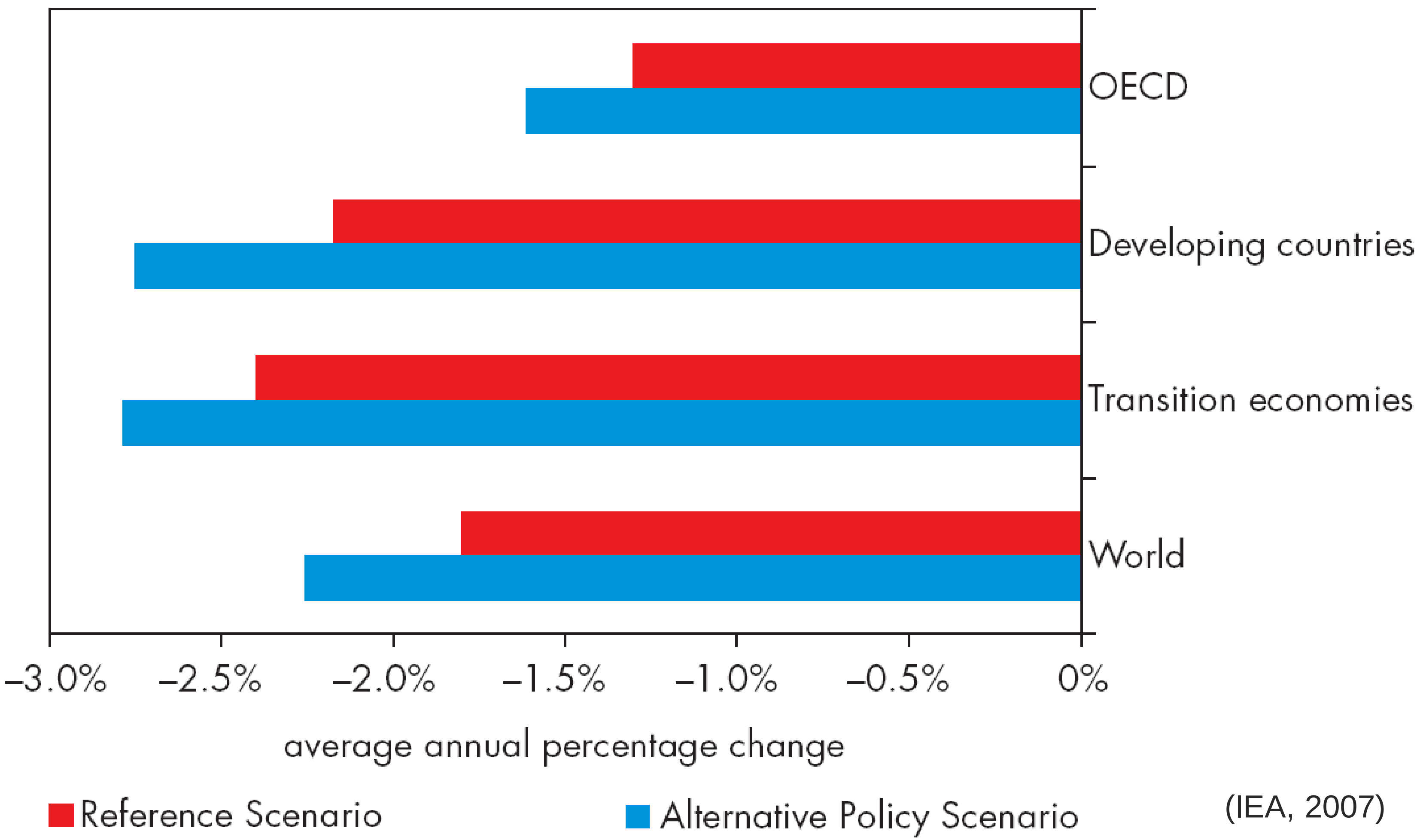
Figure 1.5: **Primary Energy Intensity in the Reference Scenario**



(IEA, 2007)

Changes in energy intensity

Figure 1.15: **Change in Primary Energy Intensity in the Reference and Alternative Policy Scenarios, 2005-2030**



(IEA, 2007)

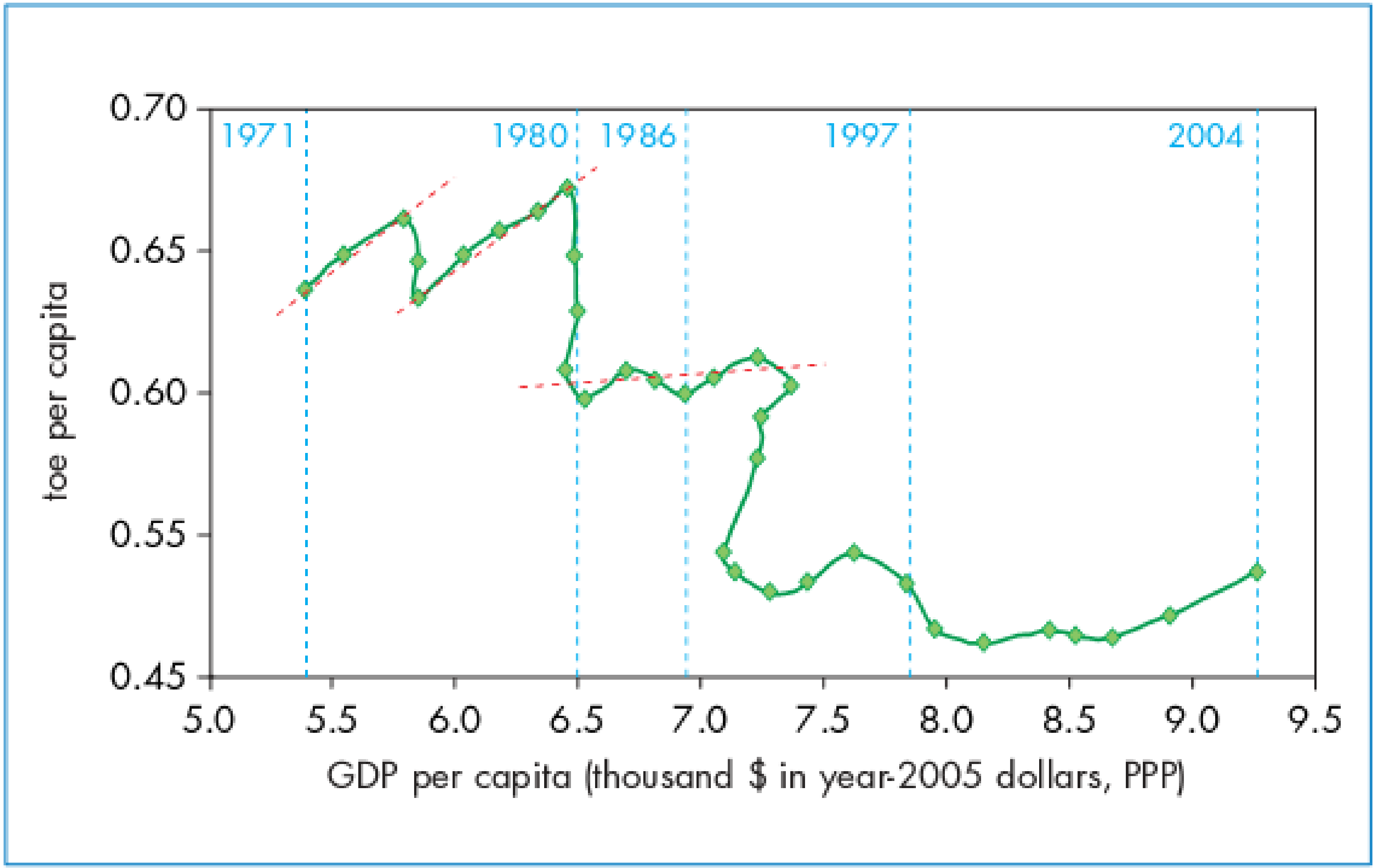
Economic development and energy demand

What does this mean? For example…

Average annual GDP growth rate	+ 6.0 %
Average annual change in energy intensity	- 2.5 %
Average annual change in energy demand	+ 3.5 %

Changes in energy intensity

Figure 11.15: **World Stationary Final Fossil Fuel Demand and Real GDP Per Capita**



Source: IEA analysis.

(IEA, 2006)

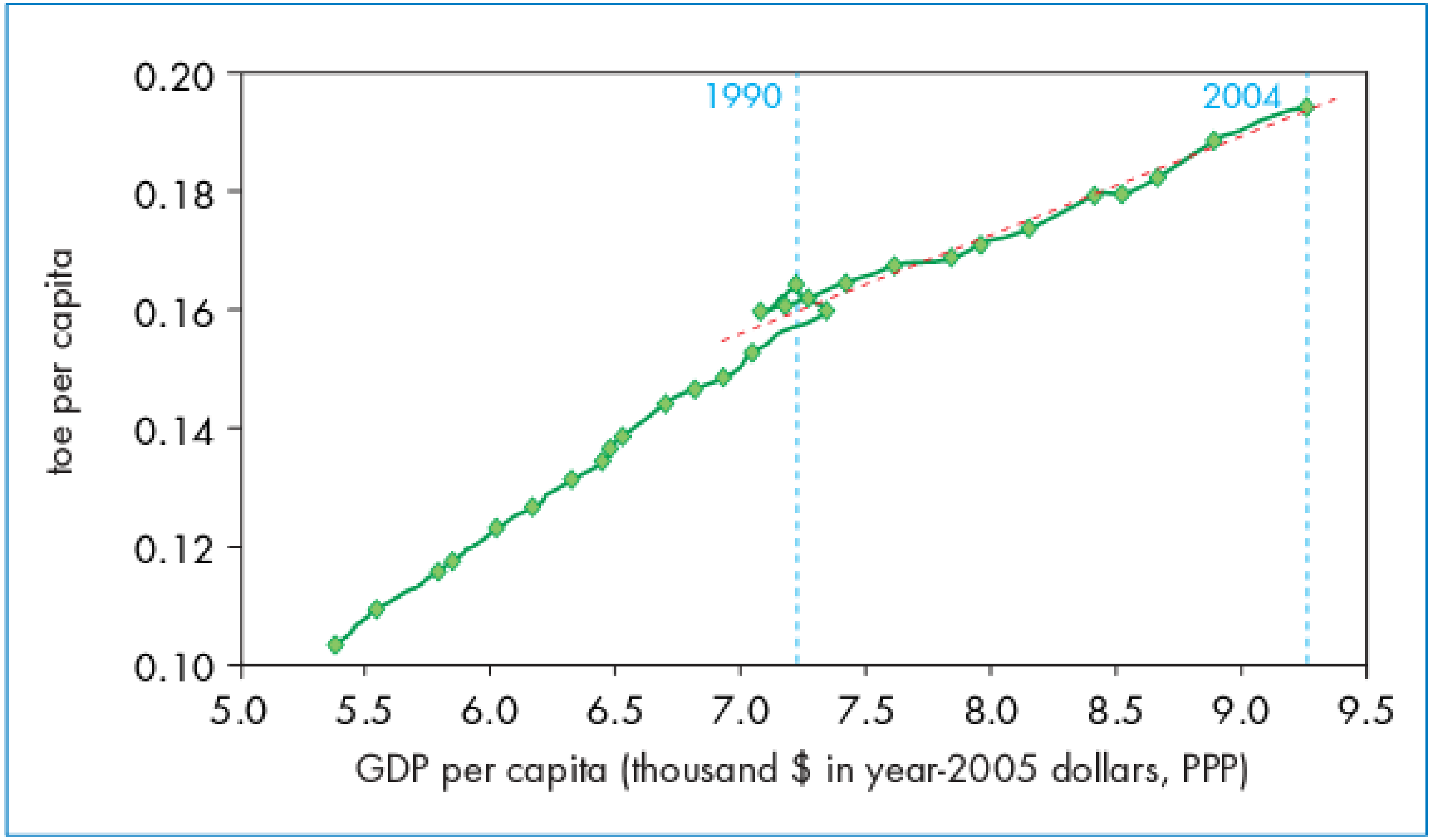
Economic development and energy demand

- In virtually all energy scenarios in the literature…
  - economic growth outpaces the increase in energy consumption, leading to substantial reductions in energy intensities and efficiencies

- Due to
  - structural changes towards less material-intensive, more knowledge-intensive products and services
  - technology developments
  - efforts into energy efficiency

GDP and electricity demand

Figure 11.16: **World Electricity Demand and Real GDP Per Capita**



Source: IEA analysis.

(IEA, 2006)

GDP and electricity demand

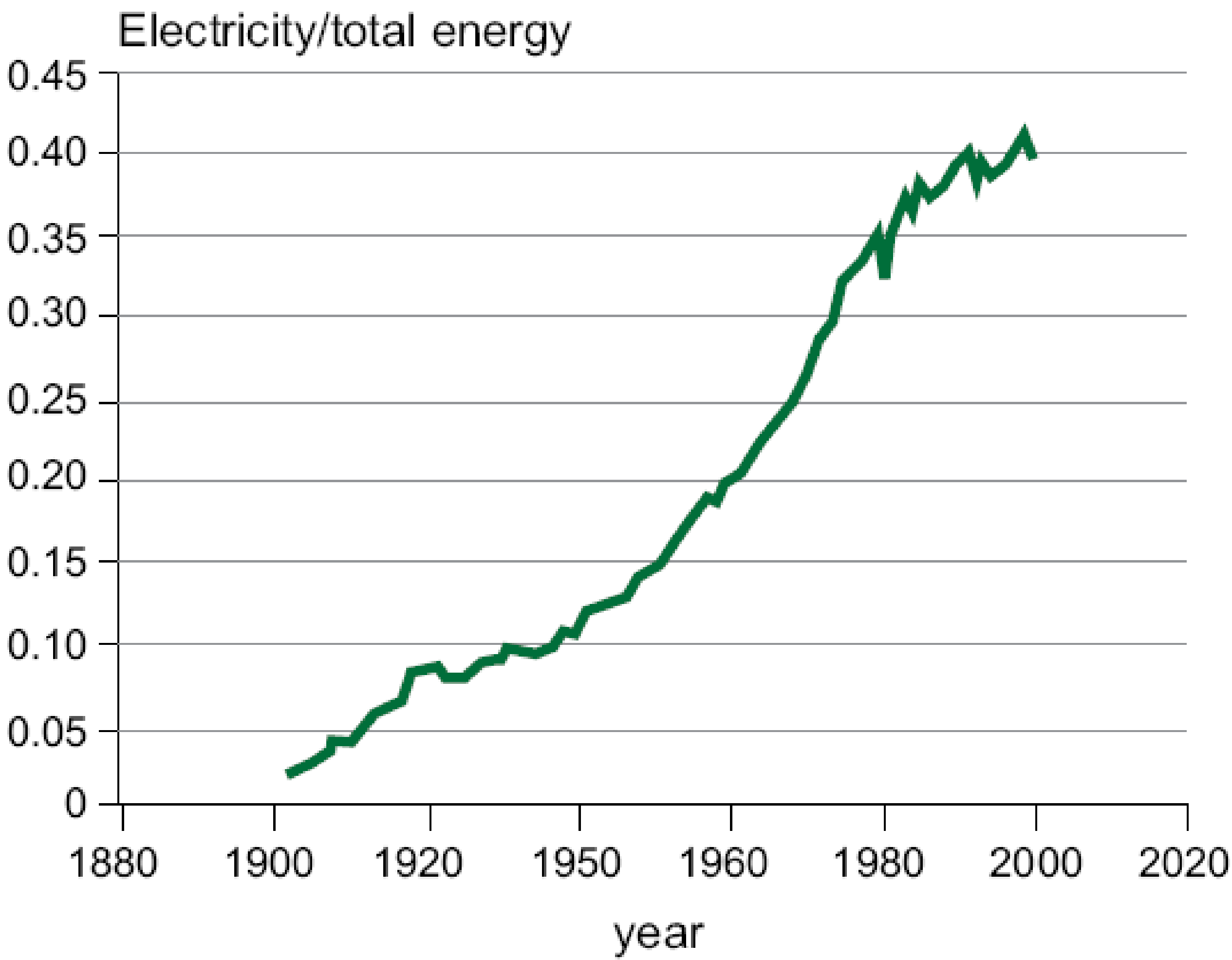
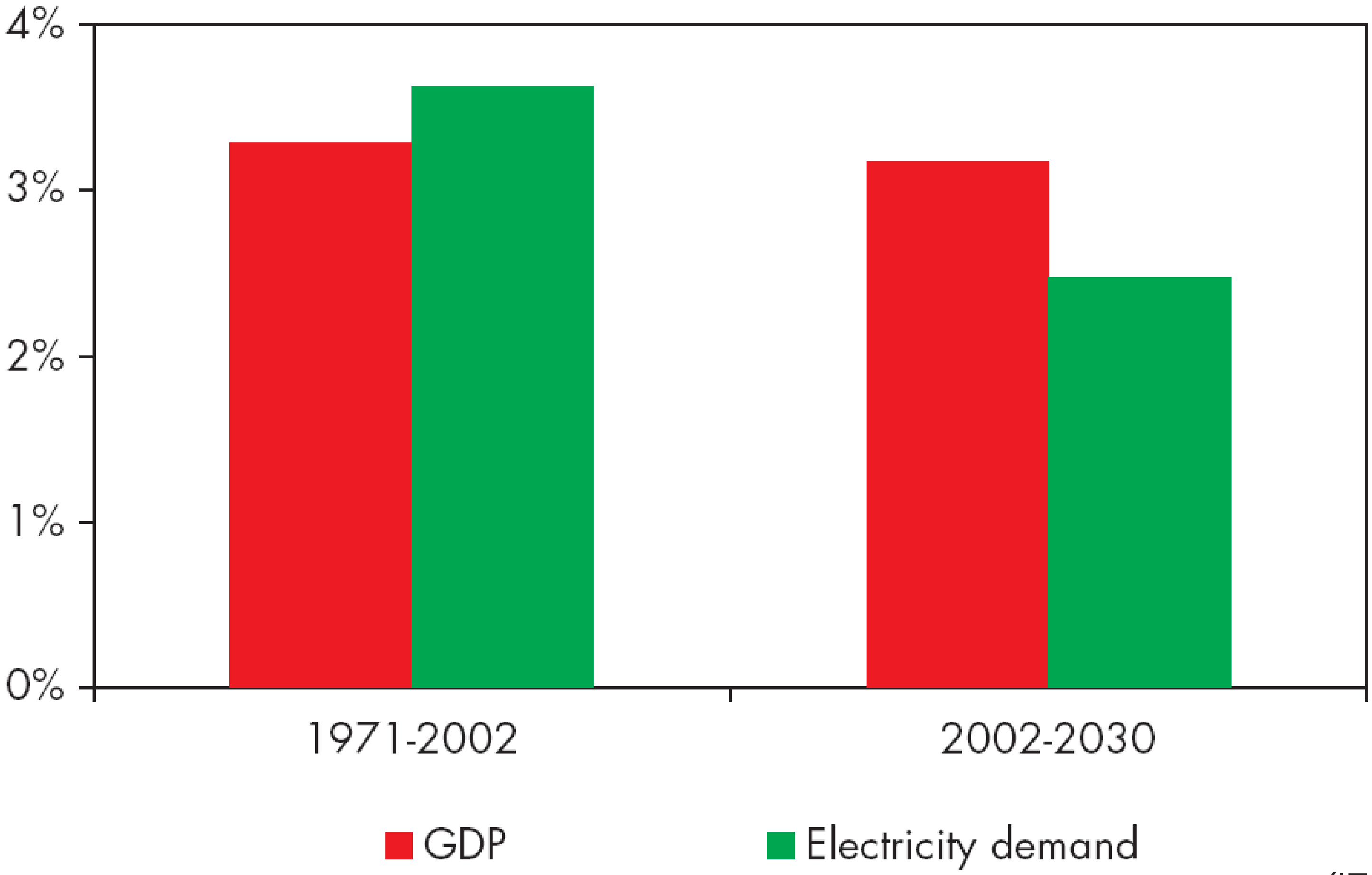


Figure 4.18: *Ratio of electricity to total primary energy in the US since 1900.*

Source: EPRI, 2003.

1.2 GDP and electricity demand growth



(IEA 2004)

1.2 Electricity and CO_2-emissions

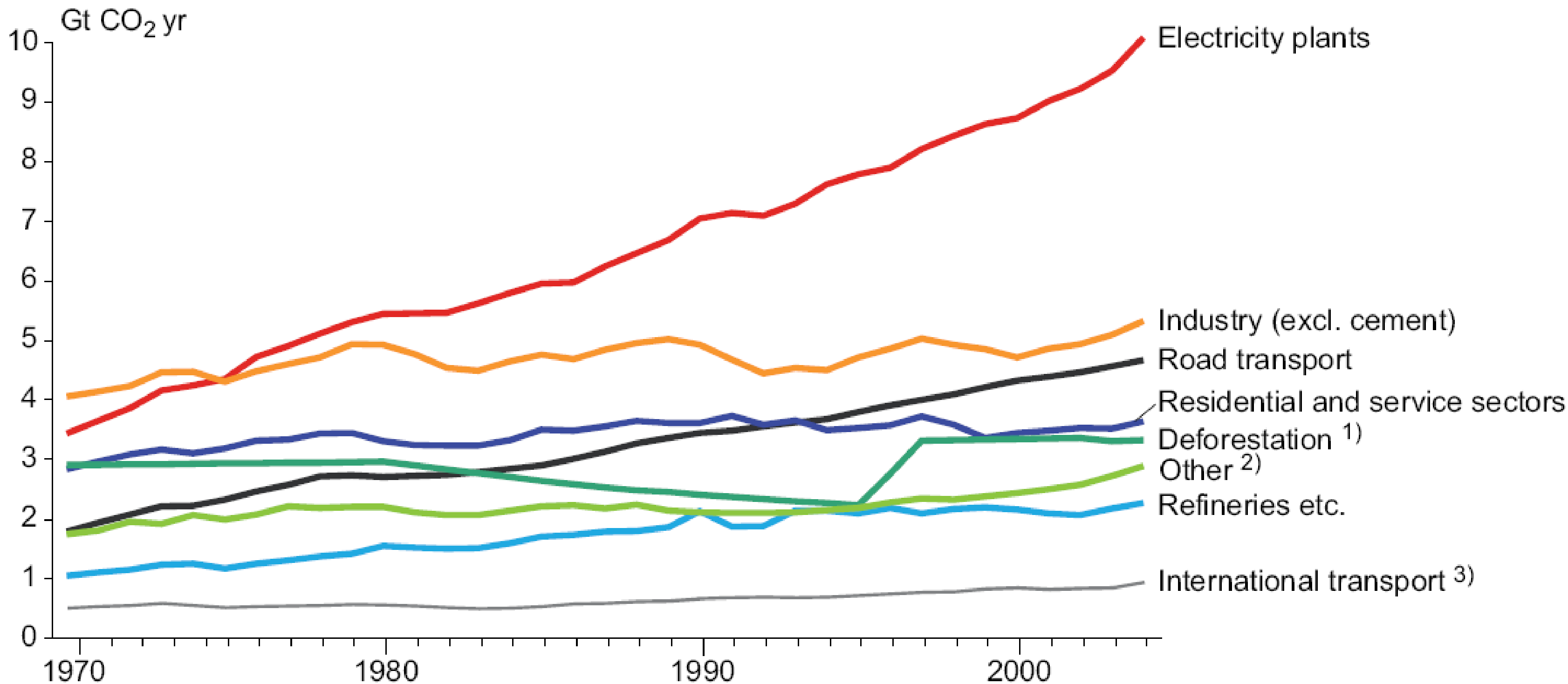


Figure 1.2: *Sources of global CO_2 emissions, 1970–2004 (only direct emissions by sector).*

[1] Including fuelwood at 10% net contribution. For large-scale biomass burning, averaged data for 1997–2002 are based on the Global Fire Emissions Database satellite data (van der Werf *et al*., 2003). Including decomposition and peat fires (Hooijer et al., 2006). Excluding fossil fuel fires.

[2] Other domestic surface transport, non-energetic use of fuels, cement production and venting/flaring of gas from oil production.

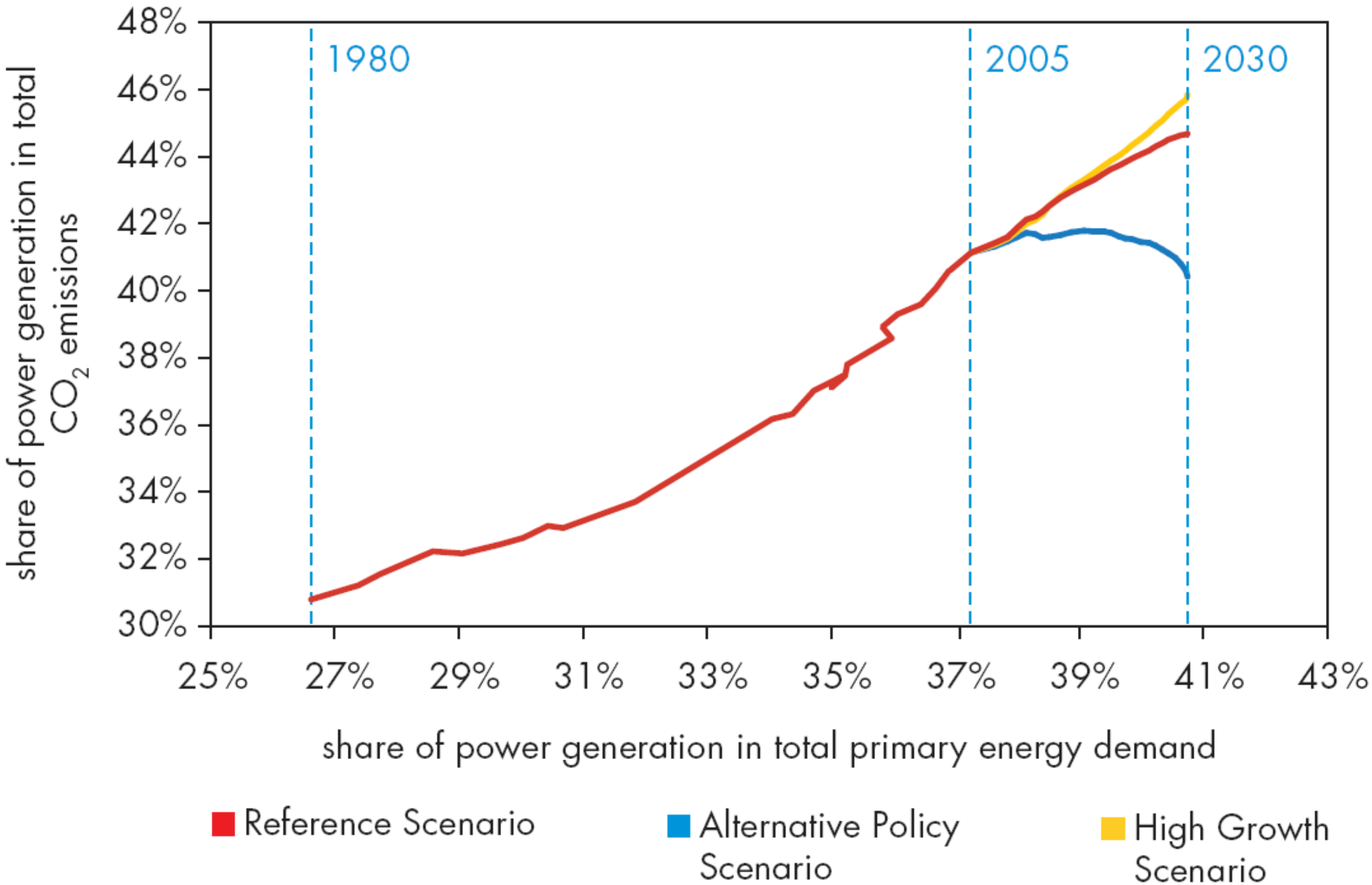
[3] Including aviation and marine transport.

Source: Adapted from Olivier et al., 2005; 2006).

(IPCC, 2007)

1.2 Electricity and CO_2-emissions

Figure 5.5: **Share of Power Generation in World Energy-Related CO_2 Emissions and in Primary Energy Demand, 1980-2030**



(IEA 2007)

Energy demand vs. electricity demand

	Total primary energy supply	Electricity production
	Average annual growth rate (1990-2002)	Average annual growth rate (1990-2002)
Bangladesh	4.4 %	7.5 %
Bhutan		
India	3.4 %	6.2 %
Iran	5.4 %	7.5 %
Maldives		
Nepal	3.4 %	7.3 %
Pakistan	3.6 %	6.0 %
Sri Lanka	3.7 %	6.7 %

(Worldbank, 2005)

GDP and transport demand

- The motorization of transport is expected to grow rapidly in the coming decades
- As incomes grow and the value of travelers´ time increases, travelers are expected to choose faster modes of transport
- Shifting from non-motorized to automotive, to air and high speed-rail
- the higher the speed, the higher the energy consumption

GDP and vehicle ownership

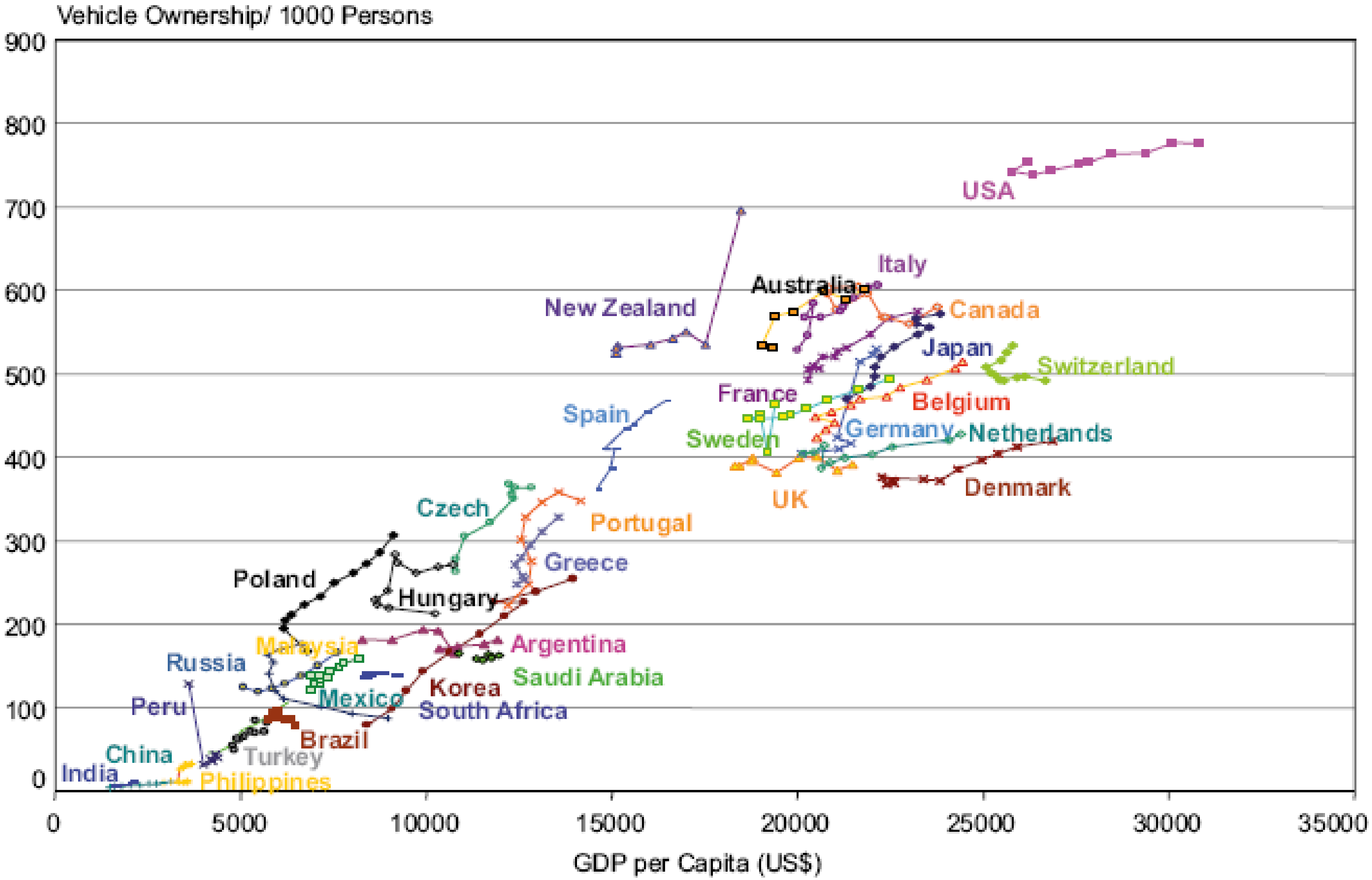


Figure TS.14: *Vehicle ownership and income per capita as a time line per country [Figure 5.2].*

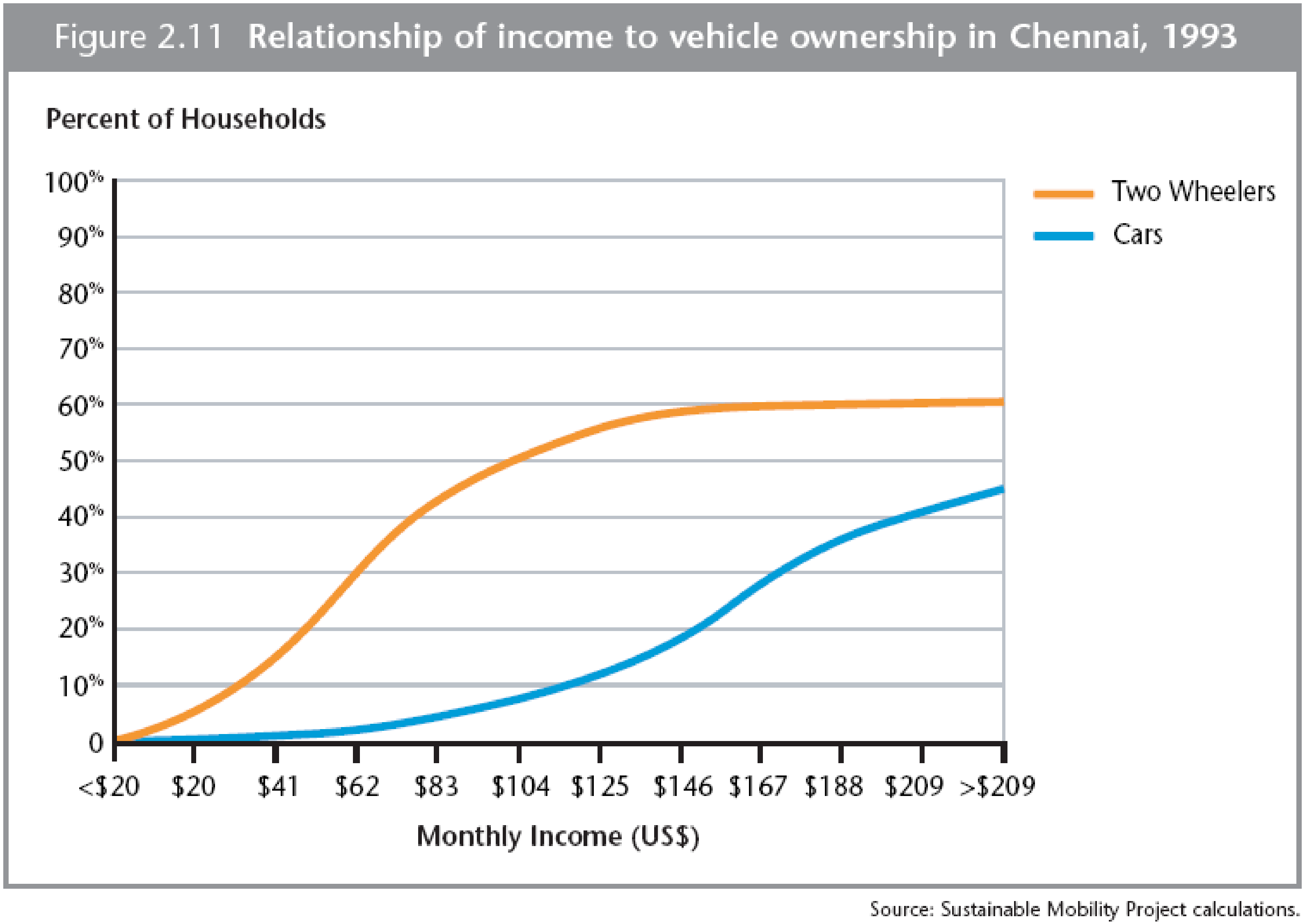
Income and vehicle ownership

- The relationship between vehicle ownership and per-capita income is highly non-linear. The income elasticity of vehicle ownership starts low but increases rapidly over the range of $3,000 to $10,000, when vehicle ownership increases twice as fast as per-capita income. Europe and Japan were at this stage in the 1960's.

- Many developing countries, especially in Asia, are currently experiencing similar developments and will continue to do so during the next two decades. When income levels increase to the range of $10,000 to $20,000, vehicle ownership increases only as fast as income.

- At very high levels of income, vehicle ownership growth decelerates and slowly approaches the saturation level. Most of the OECD countries are at this stage now.

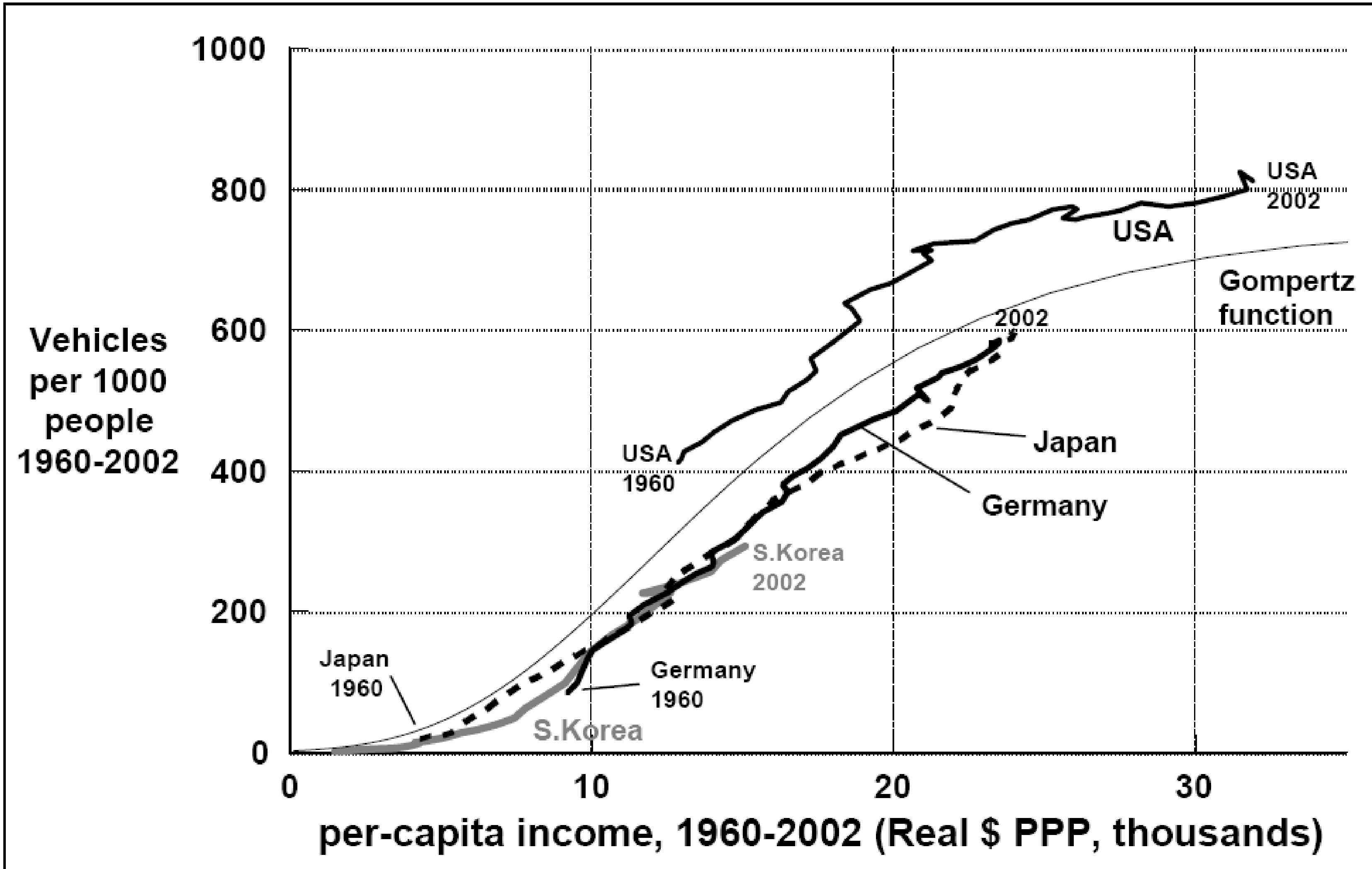
Income and vehicle ownership



(WBCSD, 2004)

Income and vehicle ownership

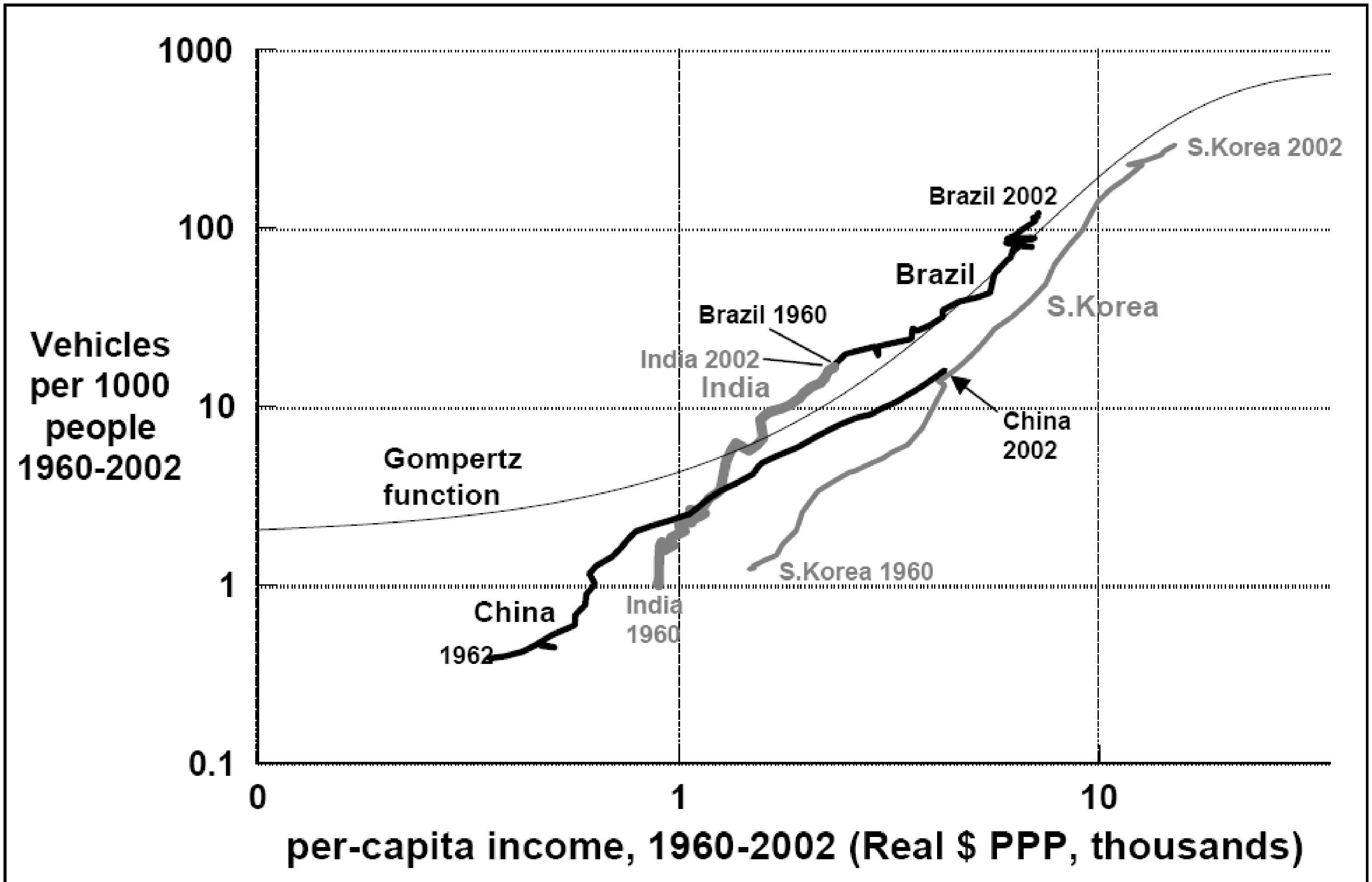
Figure 1. Vehicle Ownership and Per-Capita Income for USA, Germany, Japan, and South Korea, with an Illustrative Gompertz Function, 1960-2002



(Dargay, Gately, Sommer, 2006)

Income and vehicle ownership

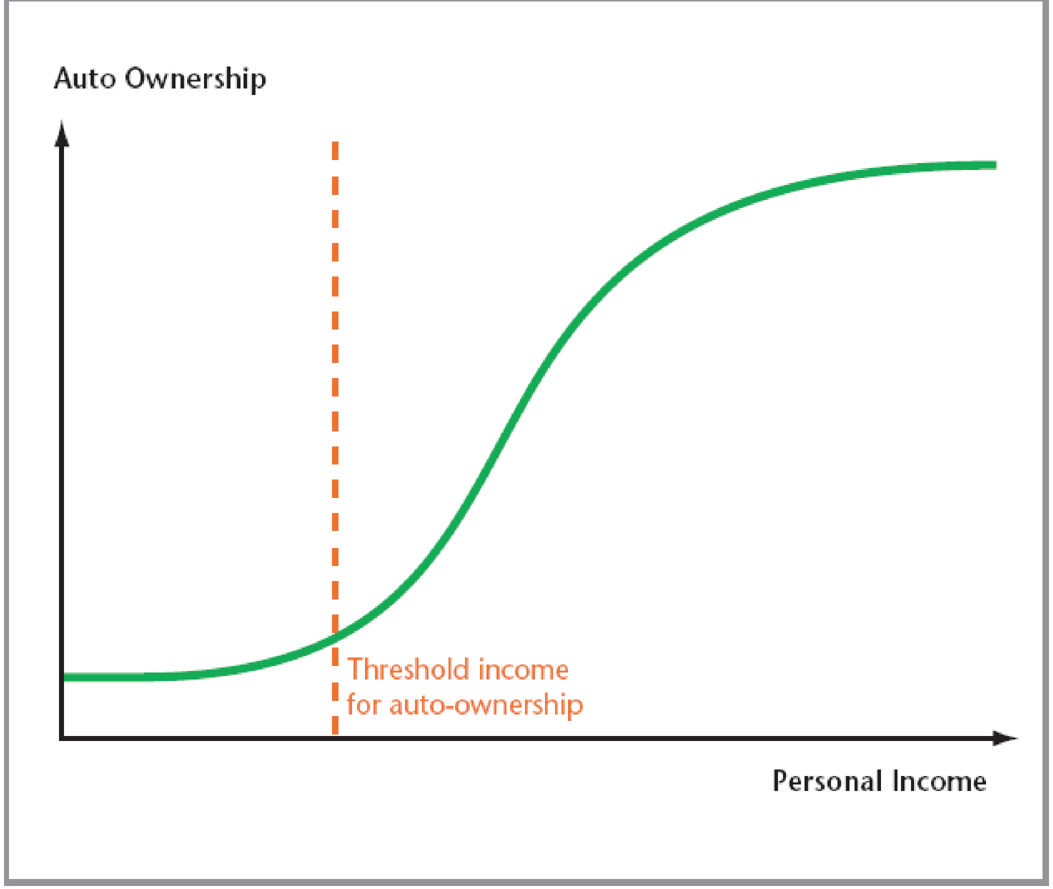
Figure 2. Vehicle Ownership and Per-capita Income for South Korea, Brazil, China, and India, with the Same Illustrative Gompertz Function, 1960-2002



(Dargay, Gately, Sommer, 2006)

Income and vehicle ownership

Figure A.1 Stylized Auto Ownership Curve



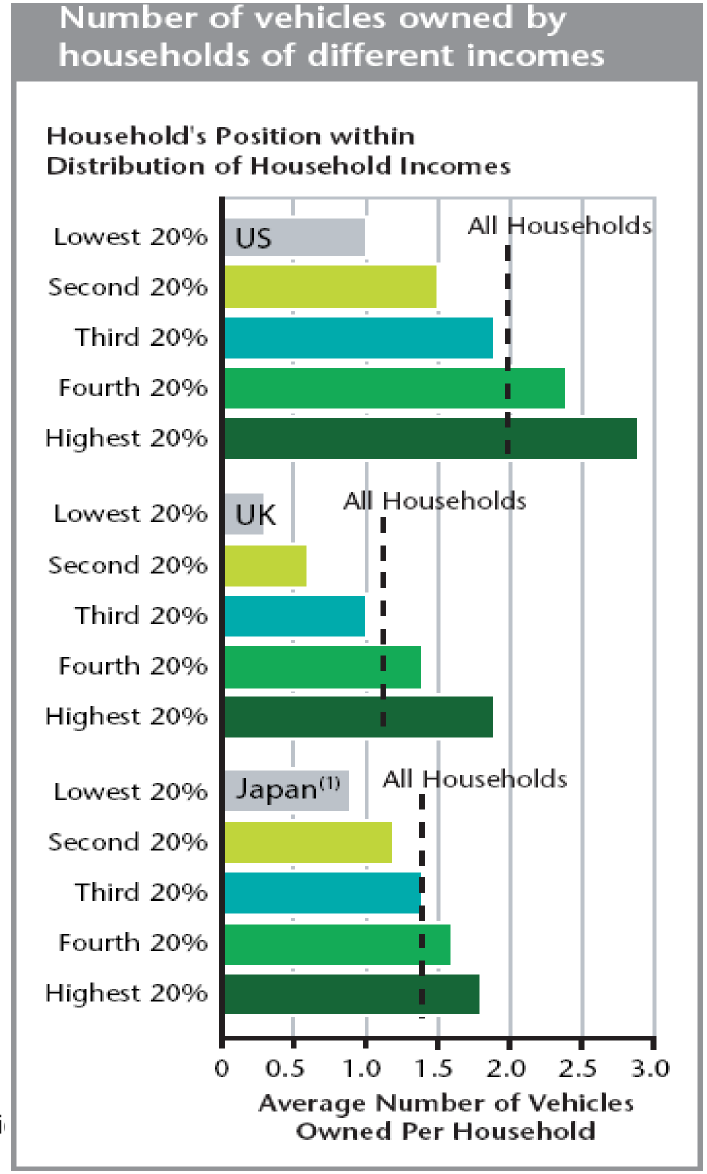
(WBCSD, 2004)

Other factors determining vehicle ownership

- Population density & population distribution / urbanization
  - a higher proportion of urban population and greater population density would encourage the availability and use of public transport systems, and could reduce the distances traveled by individuals and for goods transportation
- Income distribution
- Availability of rail network
  - A comprehensive rail network most likely decreases vehicle saturation levels
- Availability of road networks
  - A comprehensive road network most likely increases vehicle saturation levels

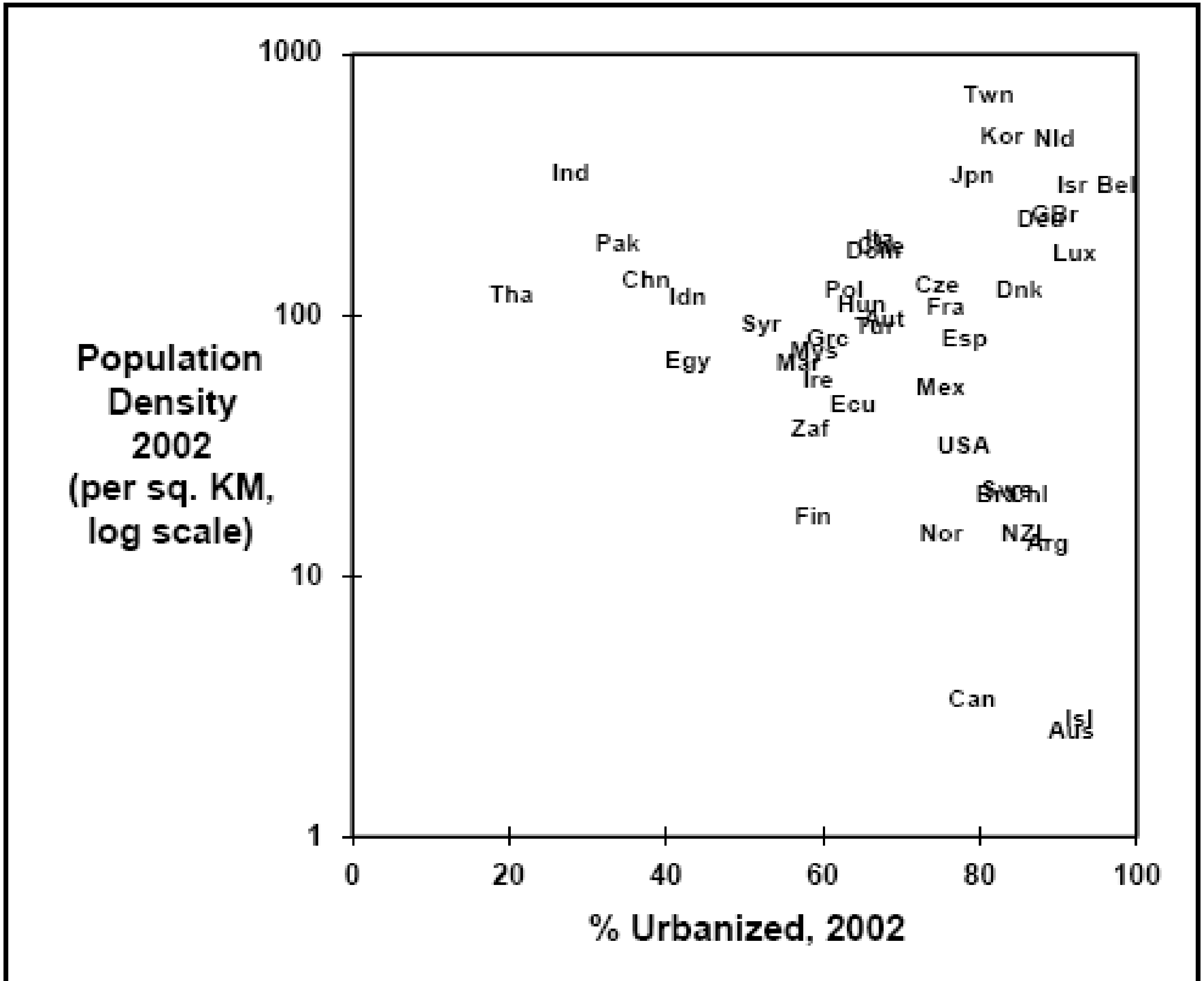
Vehicle ownership and income distribution

- households with lower incomes have a lower rate of vehicle ownership



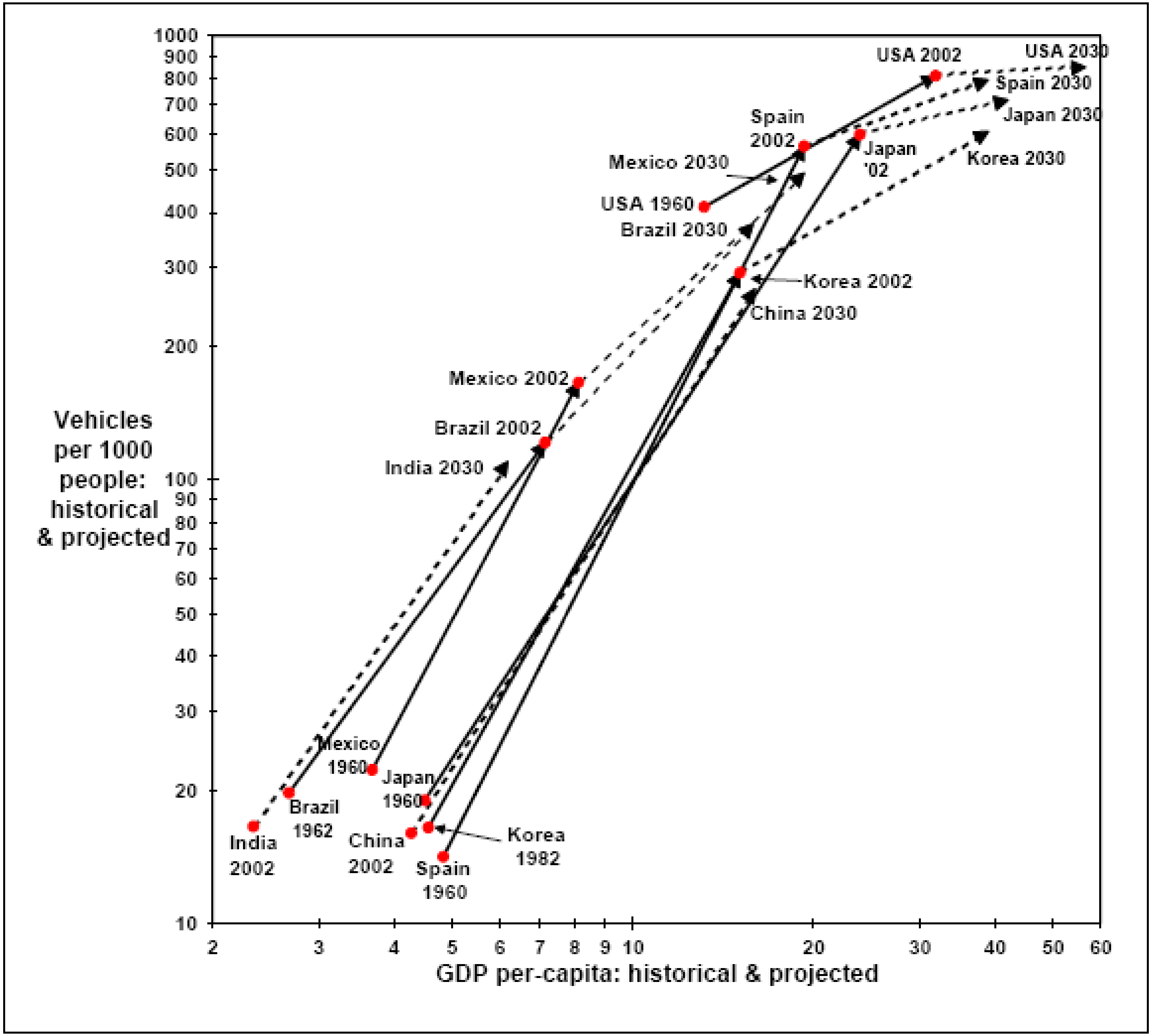
(WBCSD, 2004)

Country's population density and distribution (2002)



(Dargay, Gately, Sommer, 2006)

Figure 10. Projected Growth for China and India, compared with Historical and Projected Growth for USA, Japan, South Korea, Brazil, Mexico, and Spain.

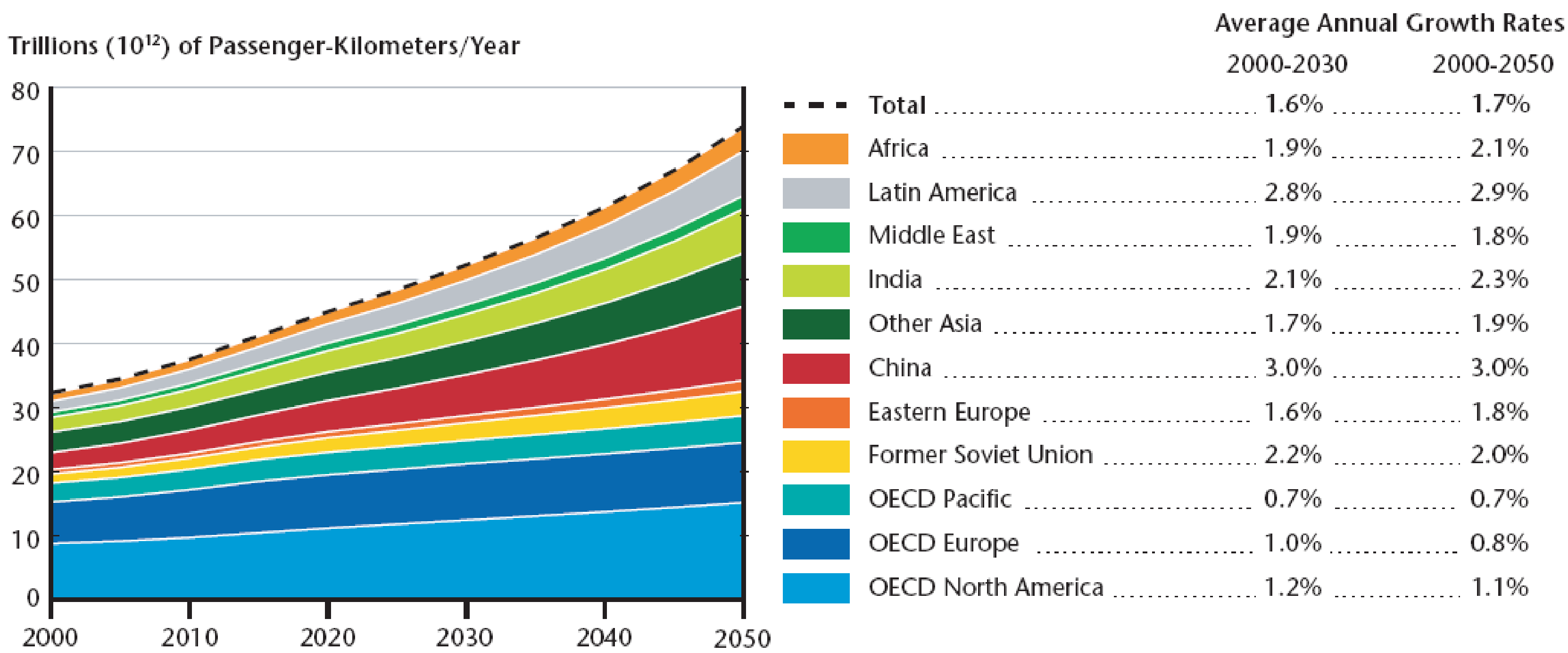


(Dargay, Gately, Sommer, 2006)

BUT: Are these trends replicable for South Asia with the 2500 US$ car ???

Transport demand scenarios

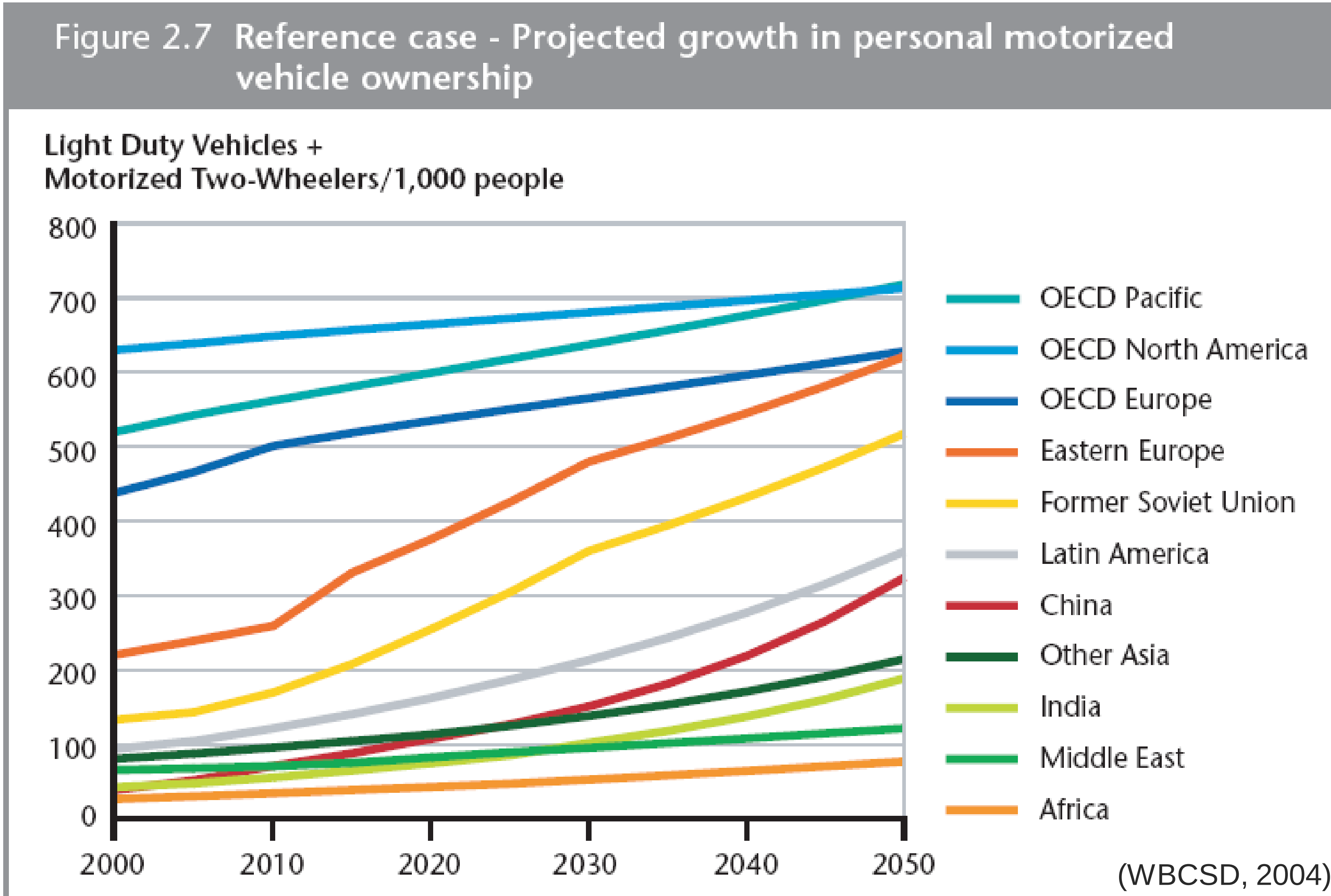
Figure 2.2 Personal transport activity by region



Source: Sustainable Mobility Project calculations.

(WBCSD, 2004)

Vehicle ownership scenarios

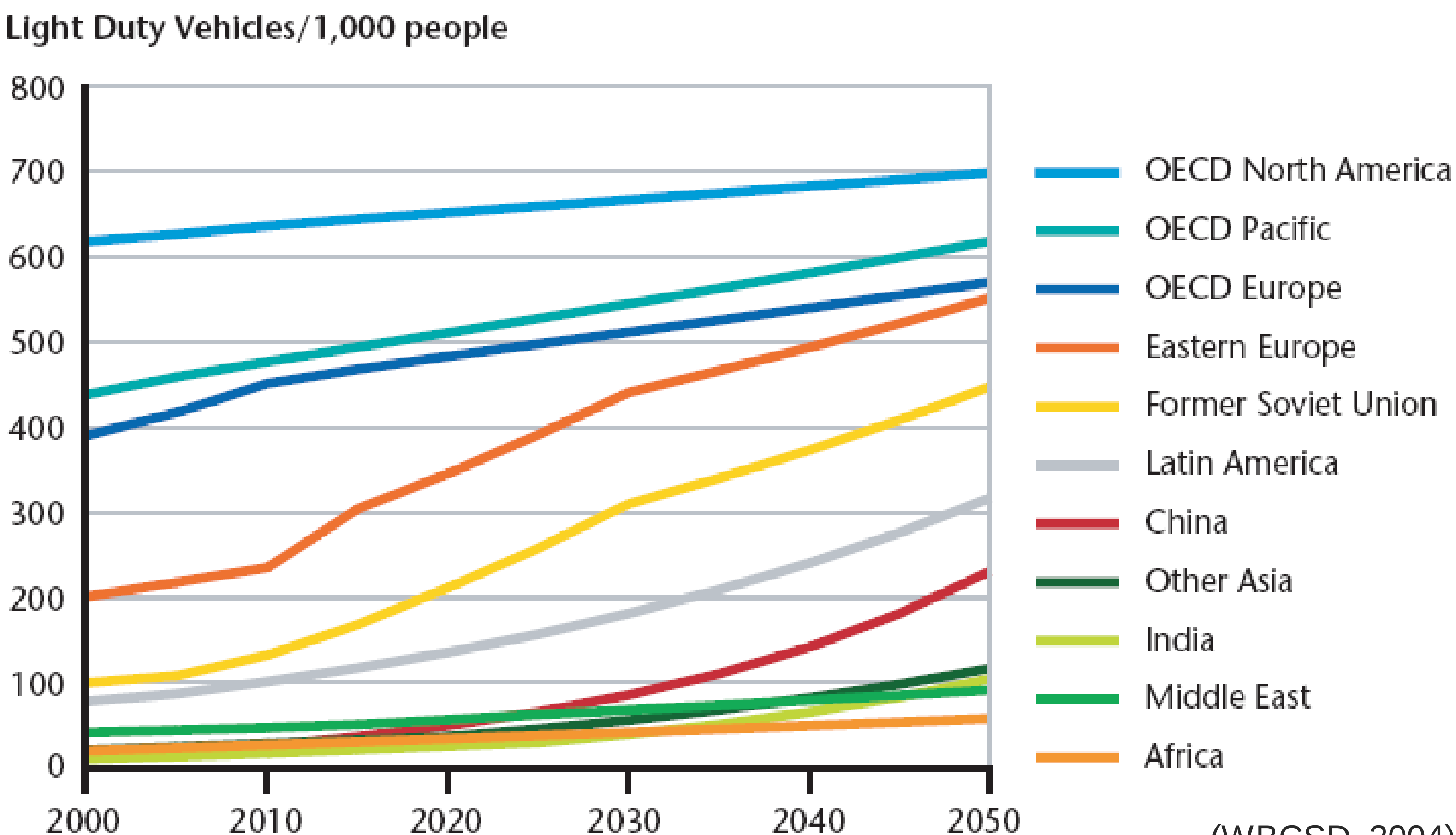


(WBCSD, 2004)

Source: Sustainable Mobility Project calculations.

Vehicle ownership scenarios

Figure 2.8 Reference case - Projected growth in light duty vehicle (LDV) ownership

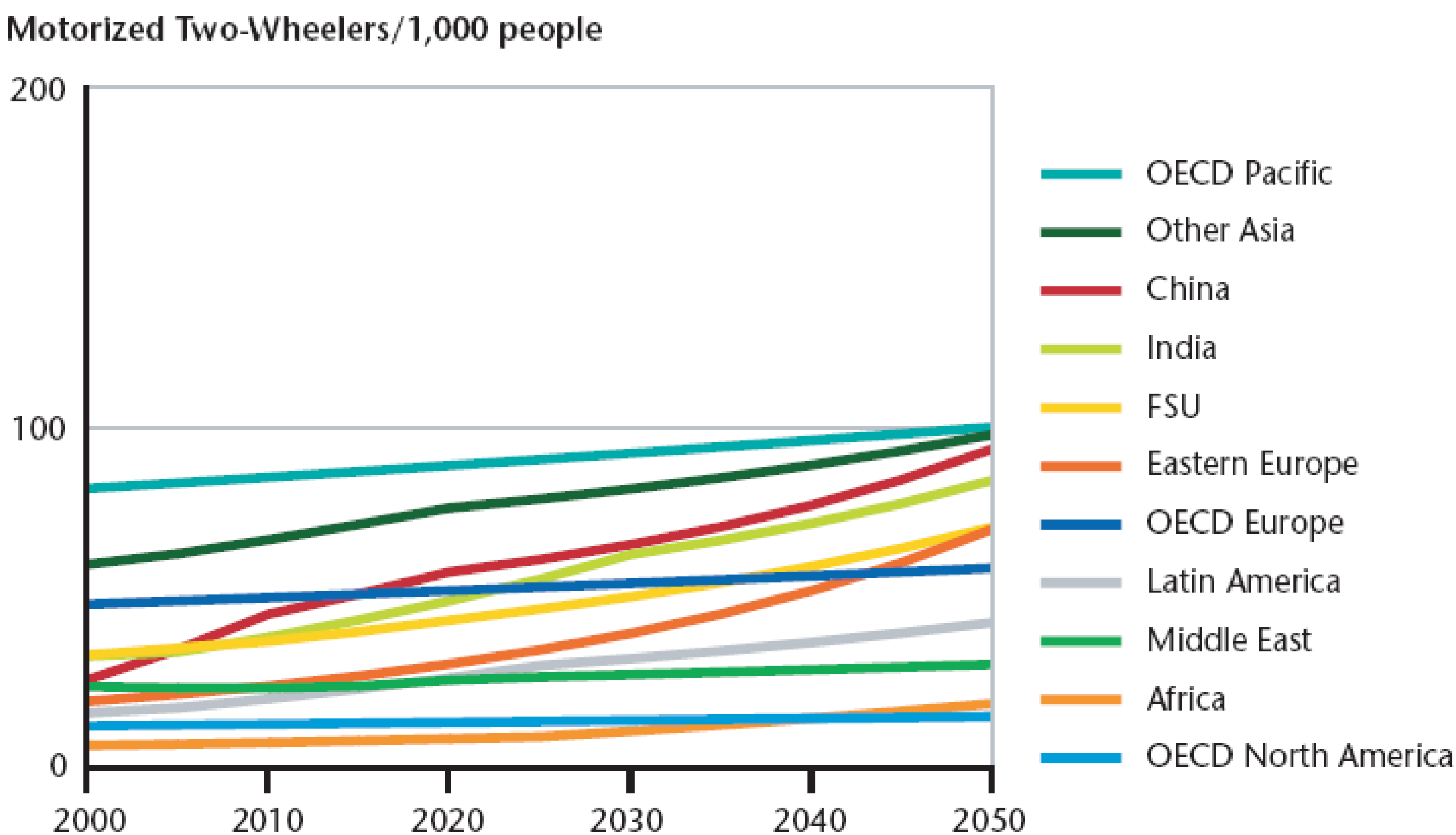


(WBCSD, 2004)

Source: Sustainable Mobility Project calculations.

Vehicle ownership scenarios

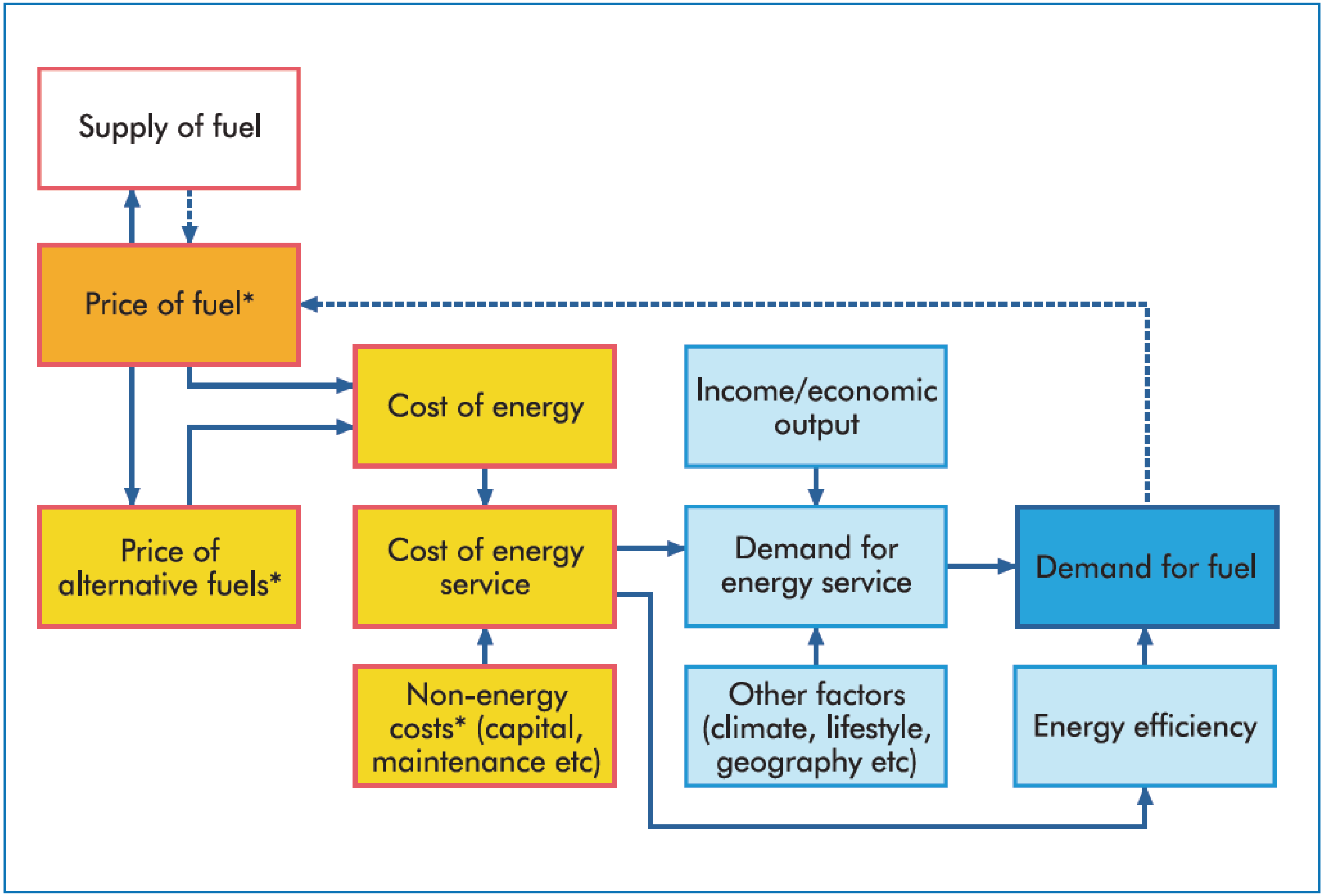
Figure 2.9 Reference case - Projected growth in motorised two-wheeler ownership



(WBCSD, 2004)

Source: Sustainable Mobility Project calculations.

2 Energy prices, energy demand, and fuel mix



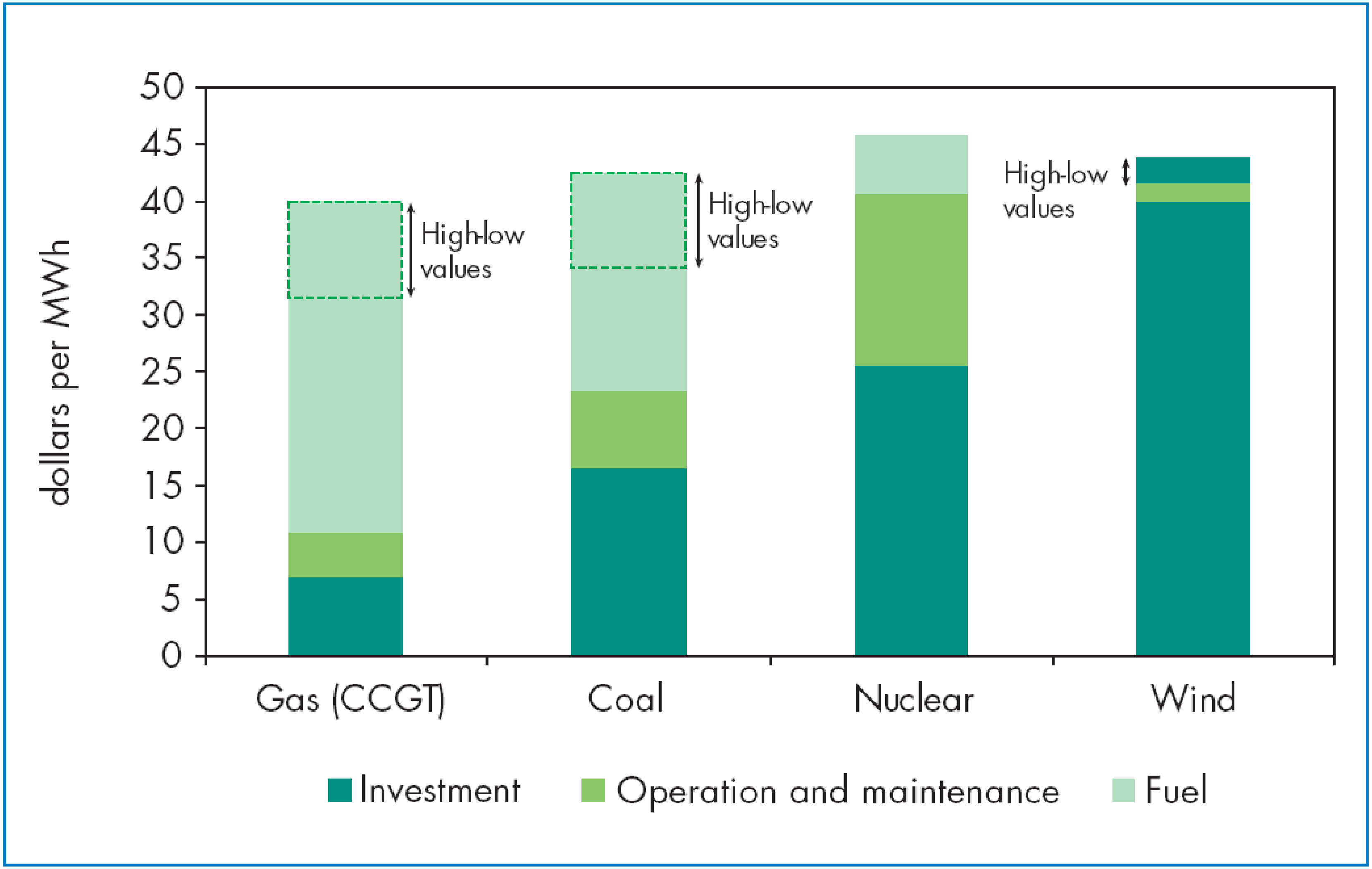
(IEA, 2006)

Energy prices and fuel mix

- Fuel mixes are strongly determined by the relative fuel prices
  - for example, higher oil and gas prices are making coal more competitive as a fuel for baseload power generation.
- Other factors
  - government policies on fuel diversification, climate change and air pollution
  - developments in technology

Energy prices and fuel mix

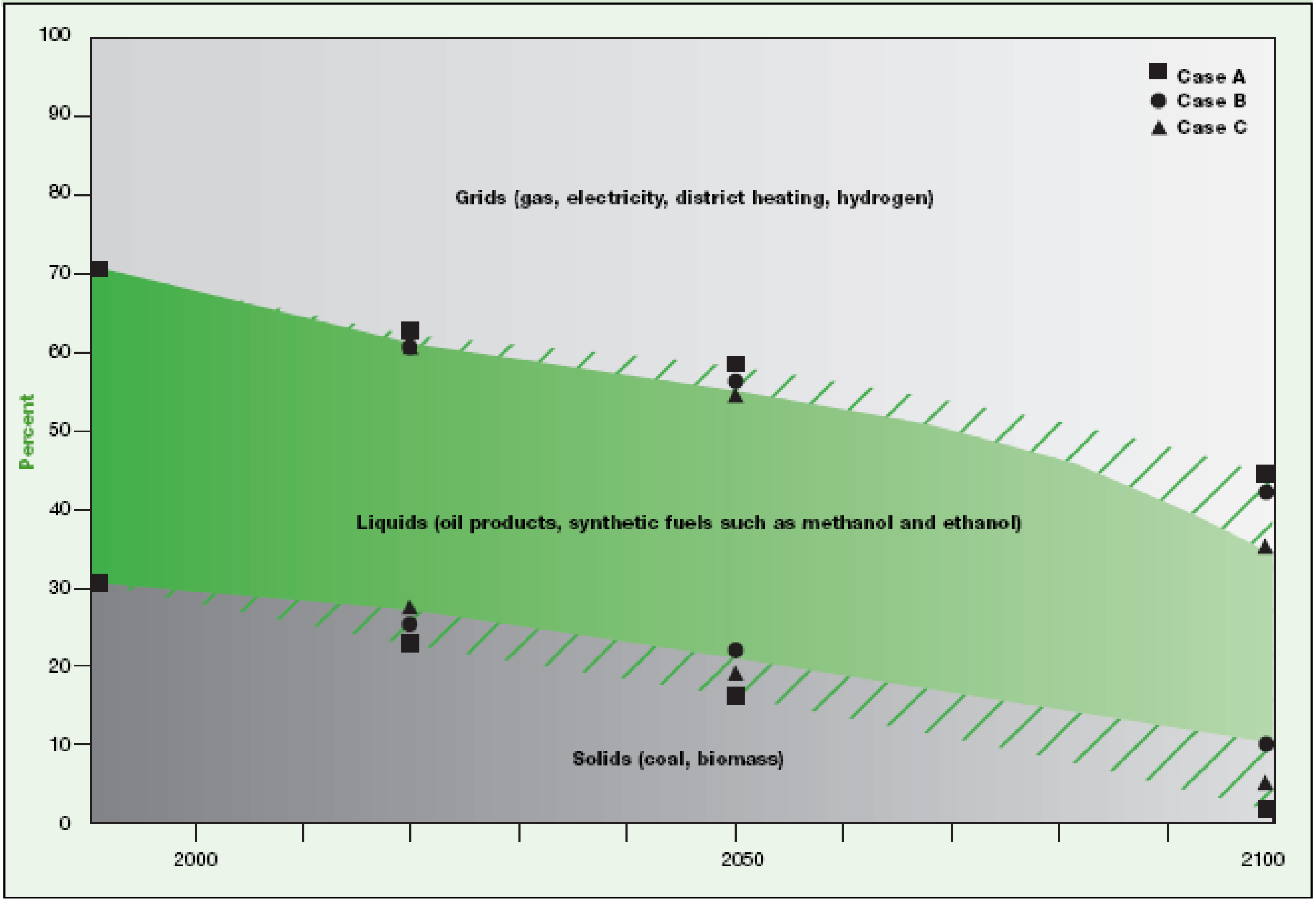
Figure 6.3: **Indicative Mid-Term Generating Costs of New Power Plants**



(IEA, 2004)

Changes in fuel consumption mix

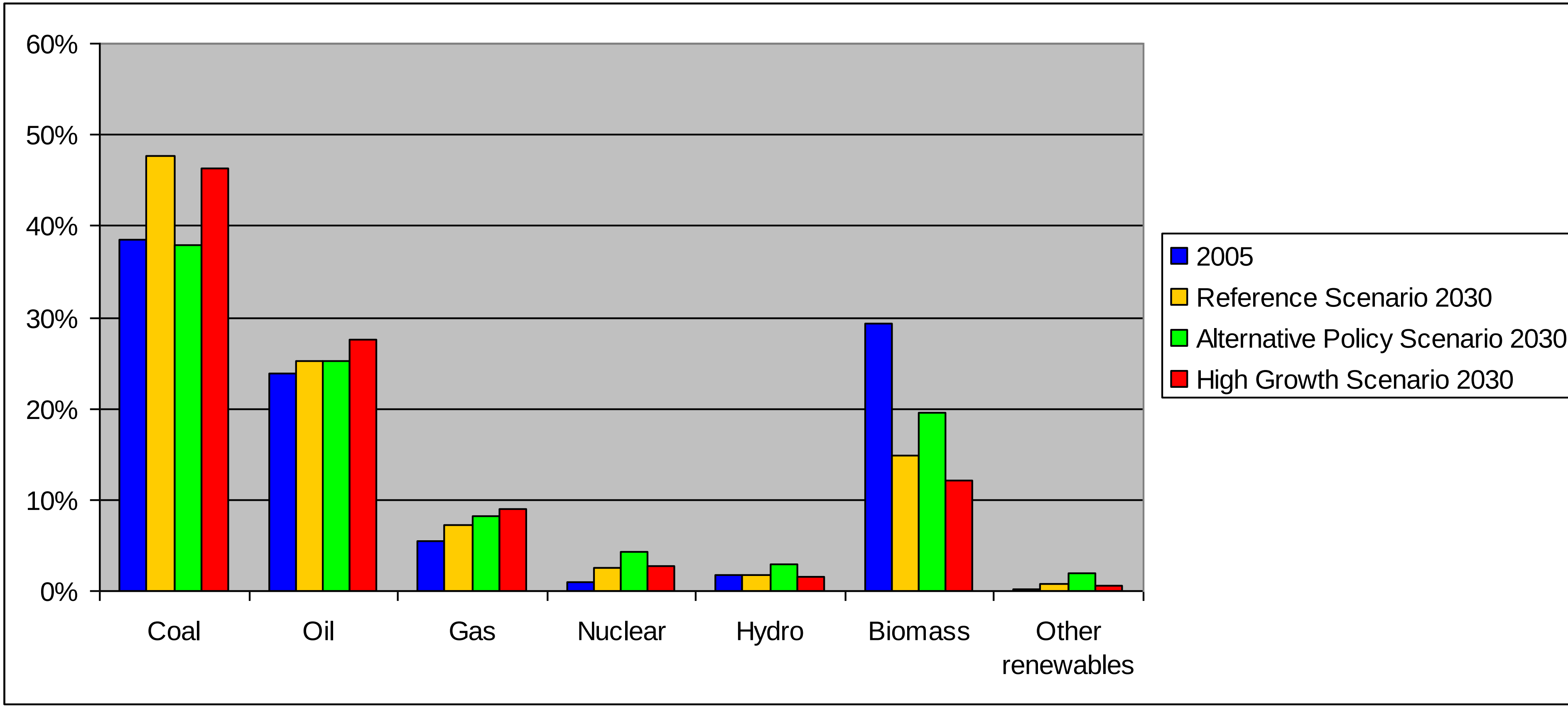
FIGURE 9.6 GLOBAL FINAL ENERGY SHARES BY FORM IN THREE CASES



Solids include direct delivery to end users. Overlapping areas indicate variations across the cases.

Source: Nakićenović, Grübler, and McDonald, 1998.

Fuel mix in IEA Energy Scenarios for 2030



(IEA, 2007)

3 Technology change

- Technology change is a major factor that determines future emissions of SOx, NOx and PM
  - Modern energy conversion technologies are cleaner and more efficient
  - End-of-pipe technology to clean flue gases from these pollutants is commercially available

3 Technology change

For energy and emission scenarios we need to model…

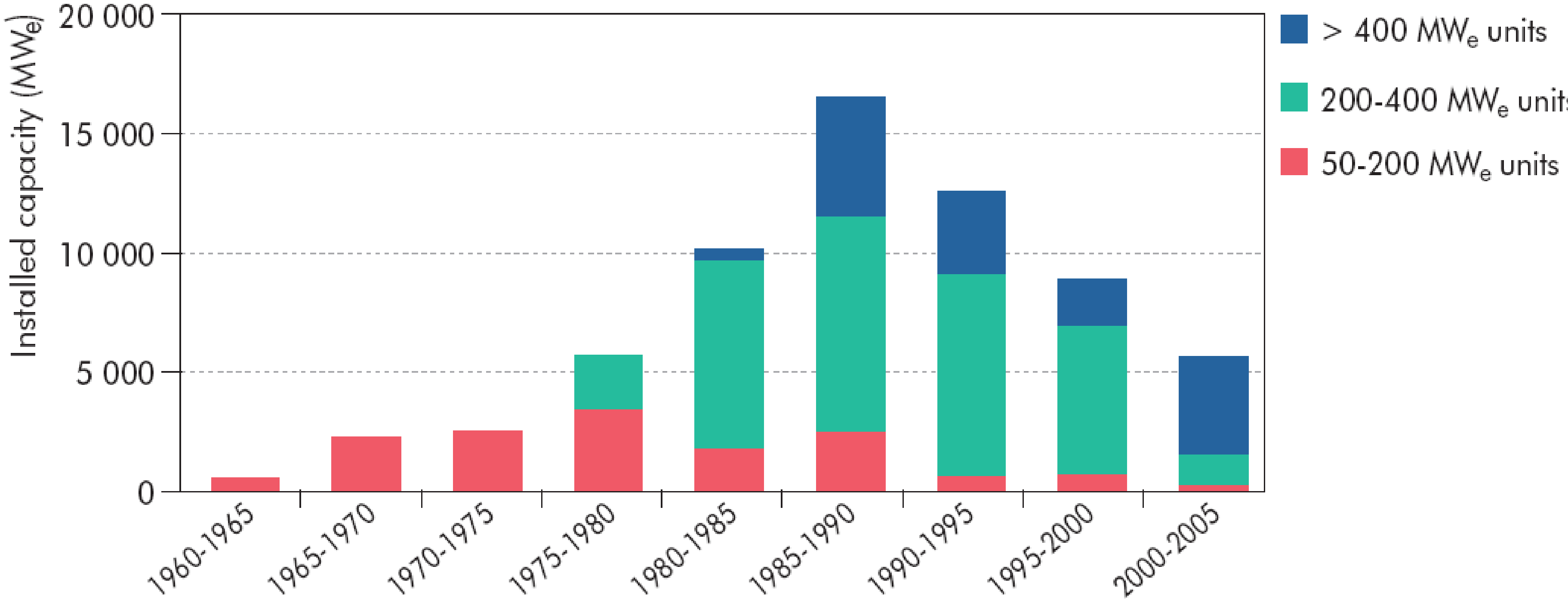
- the phase-out of old (polluting) technologies
  - as part of the replacement cycle
  - through policy intervention
- the retrofit and upgrade of old (polluting) technologies
  - especially power stations and industries
- the introduction of new (cleaner) technologies
  - technology availability
  - price
  - policy support

3.1 Power sector

- When will old power plants be phased-out?
- When will old power plants be retrofitted? How efficient and clean are they after a retrofit?
- When and how much new power generation capacity will be phased-in?
- What will be the performance of new power generation technologies with regard to air emissions? How clean will they be?

Age distribution of coal-fired capacity

Figure 4.9 ▶ Age distribution of coal-fired capacity by size in India

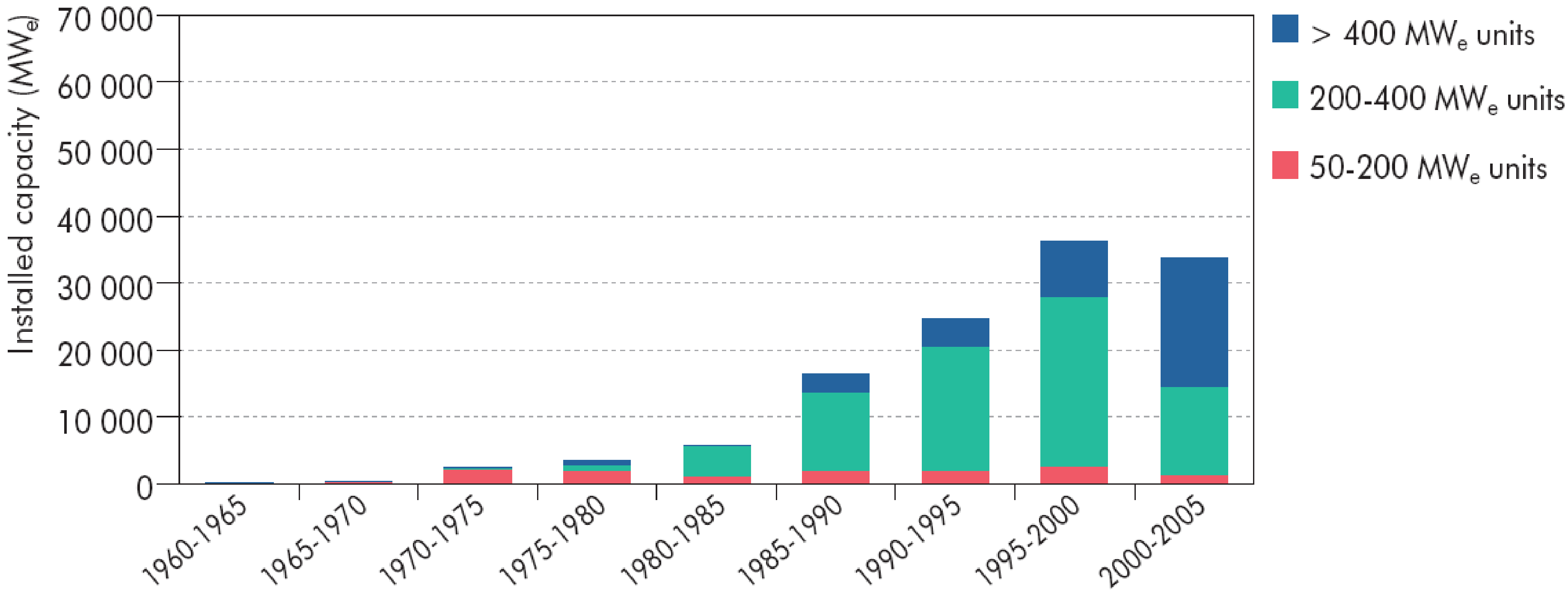


Source: IEA Clean Coal Centre, 2005b.

(IEA, 2006)

Age distribution of coal-fired capacity

Figure 4.5 ▶ Age distribution of coal-fired capacity by size in China

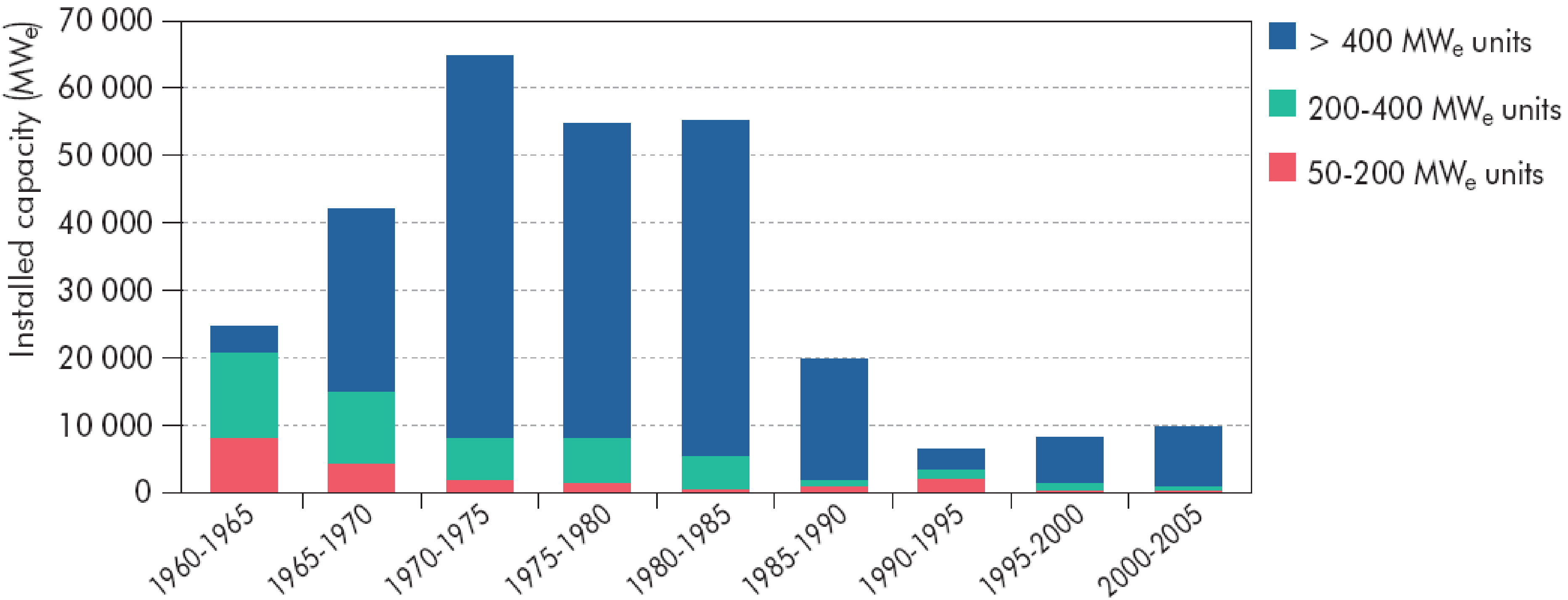


Source: IEA Clean Coal Centre, 2005b.

(IEA, 2006)

Age distribution of coal-fired capacity

Figure 4.4 ▶ Age distribution of coal-fired capacity by size in the United States

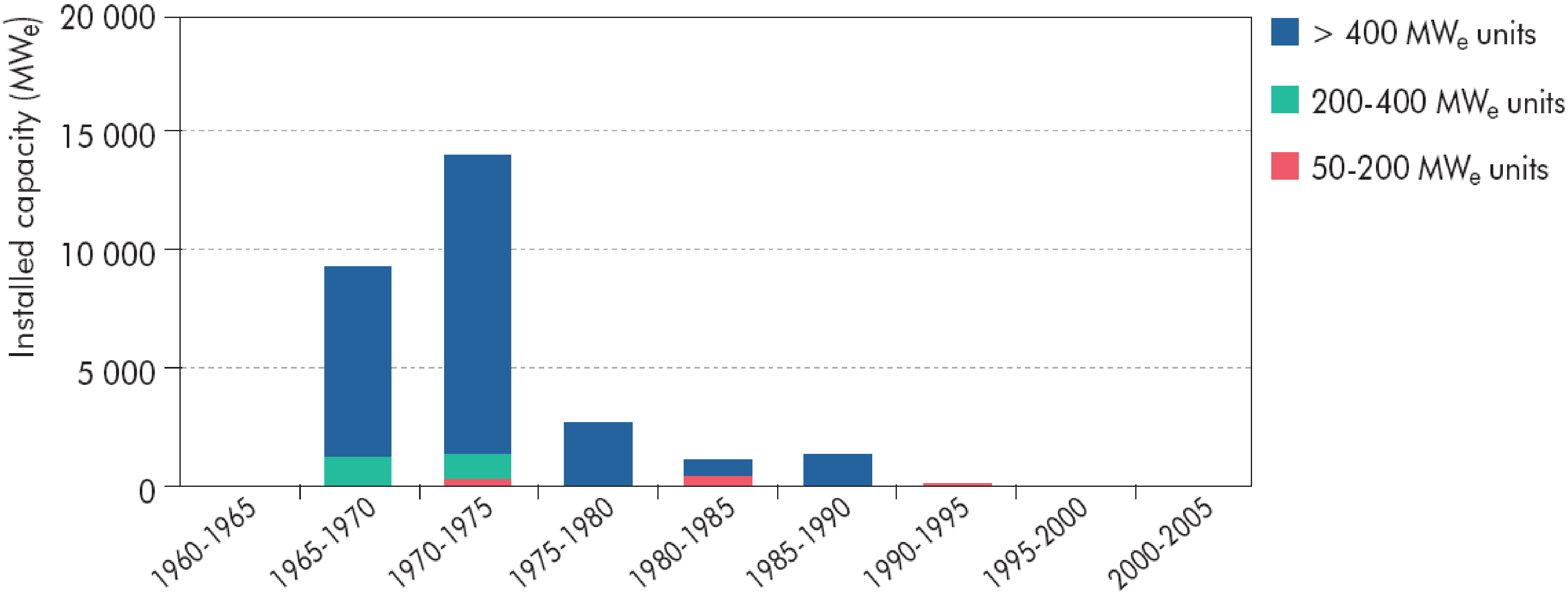


Source: IEA Clean Coal Centre, 2005b.

(IEA, 2006)

Age distribution of coal-fired capacity

Figure 4.8 ▶ Age distribution of coal-fired capacity by size in the United Kingdom



Note: No new plants in the 1995-2005 periods.

Source: IEA Clean Coal Centre, 2005b.

(IEA, 2006)

Current capacity installed

Table 4.4 ▶ **Current capacity of natural gas and coal-fired power plants world wide, 2003**

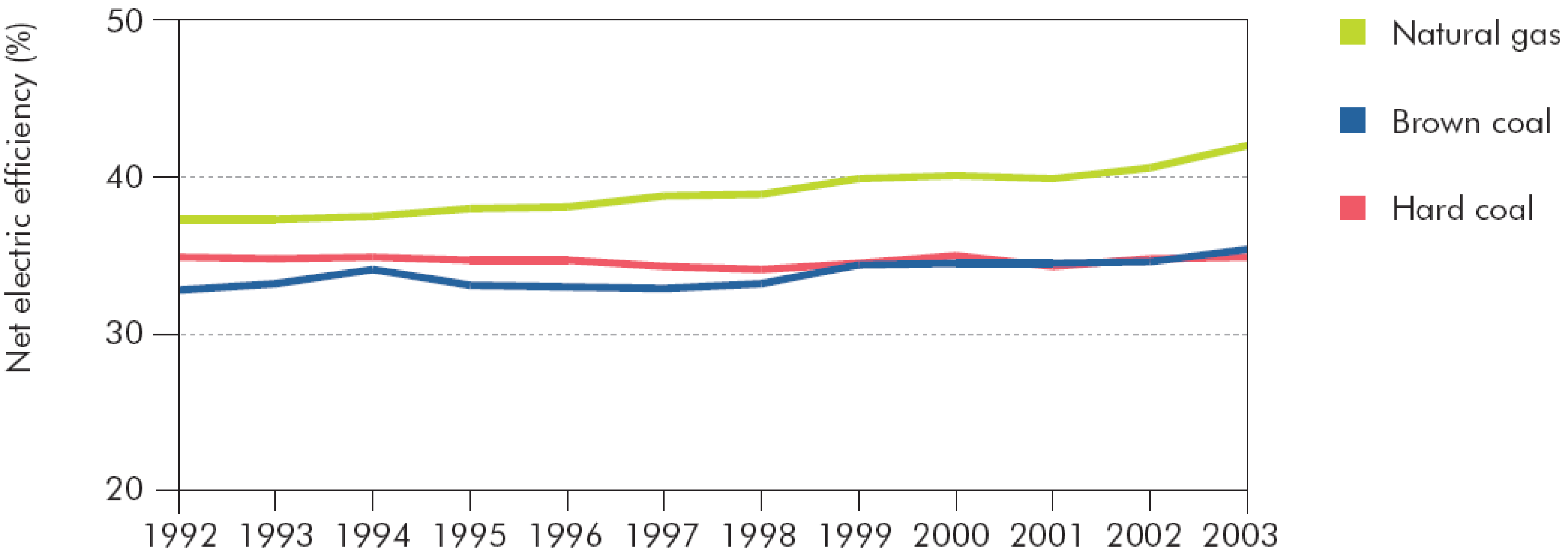
Natural gas	GW	Coal	GW
Combined-cycle	351	PCC subcritical	970
Natural gas turbine	225	PCC supercritical	138
Steam cycle	332	PCC ultra-supercritical	17
Internal combustion engine	7	Fluidised bed combustion subcritical	17
		Integrated gasification combined-cycle	1

Note: PCC – pulverised coal combustion. Supercritical plants are defined as those operating with steam temperatures above 540 °C. Ultra-supercritical plants are supercritical pressure units operating with temperatures above 580 °C.

Source: Natural gas-fired capacity from IEA, 2004b; coal-fired capacity from IEA Clean Coal Centre.

(IEA, 2006)

Global average power plant efficiencies (1992 – 2003)



(IEA, 2006)

Technology prospects for fossil-fuel power plants for baseload capacity

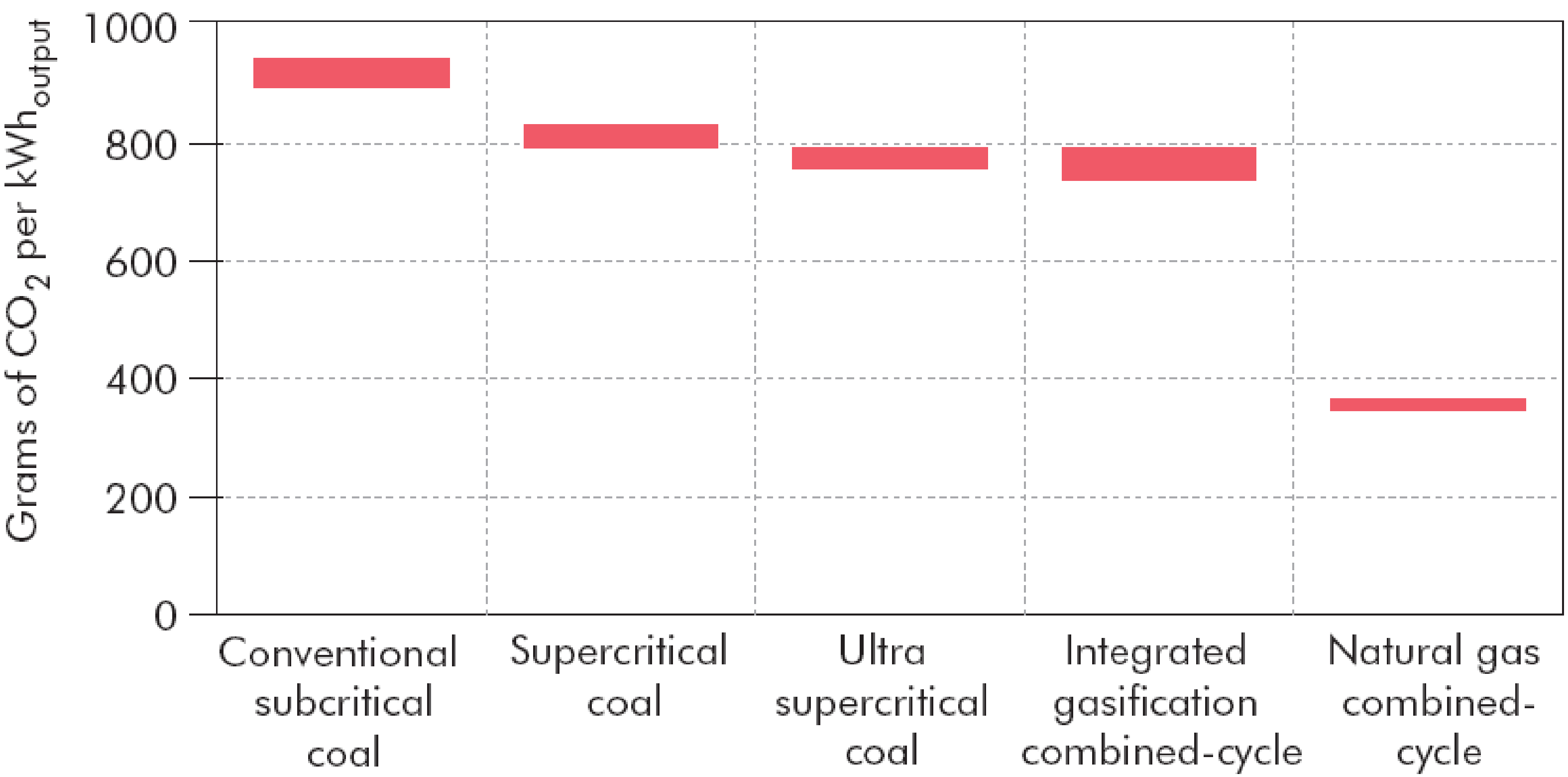
	Net electric efficiency, 2015-2030 (% LHV)	Investment cost, 2015-2030 (USD/kW)	2015 Electricity generation costs (USD/kWh)	2030 Electricity generation costs (USD/kWh)	2050 Electricity generation costs (USD/kWh)
Gas NGCC	>60	400-500	0.032 - 0.036	0.035 - 0.045	0.045 - 0.05
Coal PCC	>50	1 000-1 150	0.041	0.035 - 0.04	0.035 - 0.04
Coal FBC	>45	1 000	0.035 - 0.04	0.035 - 0.04	0.035 - 0.04
Coal IGCC	>50	1 250	0.04 - 0.05	0.035 - 0.04	0.035 - 0.04
Gas fuel cells	>50	1 250	0.15	0.10	0.05 - 0.08

Note: Using 10% discount rate. The natural gas price increases to USD 5/GJ in 2030 and USD 6.5/GJ by 2050, USD 2/GJ higher for decentralised fuel cells. The coal price is USD 2/GJ over the whole period. Because fuel cells are a decentralised technology, transmission costs are reduced by up to USD 0.05/kWh compared to technologies for centralised power plants. This has not been taken into account in this table. The actual global range is wider as discount rates, investment cost and fuel prices vary.

(IEA, 2006)

The potential for CO2 emission reductions

Figure 4.3 ▶ CO_2 emissions by type of plant[6]



(IEA, 2006)

Characteristics of power plants with CO_2 capture

Fuel & Technology	Starting year	Investment cost (USD/kW)	Efficiency (%)	Efficiency loss (%)	Additional fuel (%)	Capture efficiency (%)
Likely technologies						
Coal, steam cycle, CA	2010	1 850	31	-12	39	85
Coal, steam cycle, membranes + CA	2020	1 720	36	-8	22	85
Coal, USC steam cycle, membranes +CA	2030	1 675	42	-8	19	95
Coal, IGCC, Selexol	2010	2 100	38	-8	21	85
Coal, IGCC, Selexol	2020	1 635	40	-6	15	85
Gas, CC, CA	2010	800	47	-9	19	85
Gas, CC, Oxyfueling	2020	800	51	-8	16	85
Black liquor, IGCC	2020	1 620	25	-3	12	85
Biomass, IGCC	2025	3 000	33	-7	21	85
Technologies under development						
Coal, CFB, chemical looping	2020	1 400	39	-5	13	85
Gas, CC, chemical looping	2025	900	56	-4	7	85
Coal, IGCC & SOFC	2035	2 100	56	-4	7	100
Gas, CC & SOFC	2030	1 200	66	-4	6	100

(IEA, 2006)

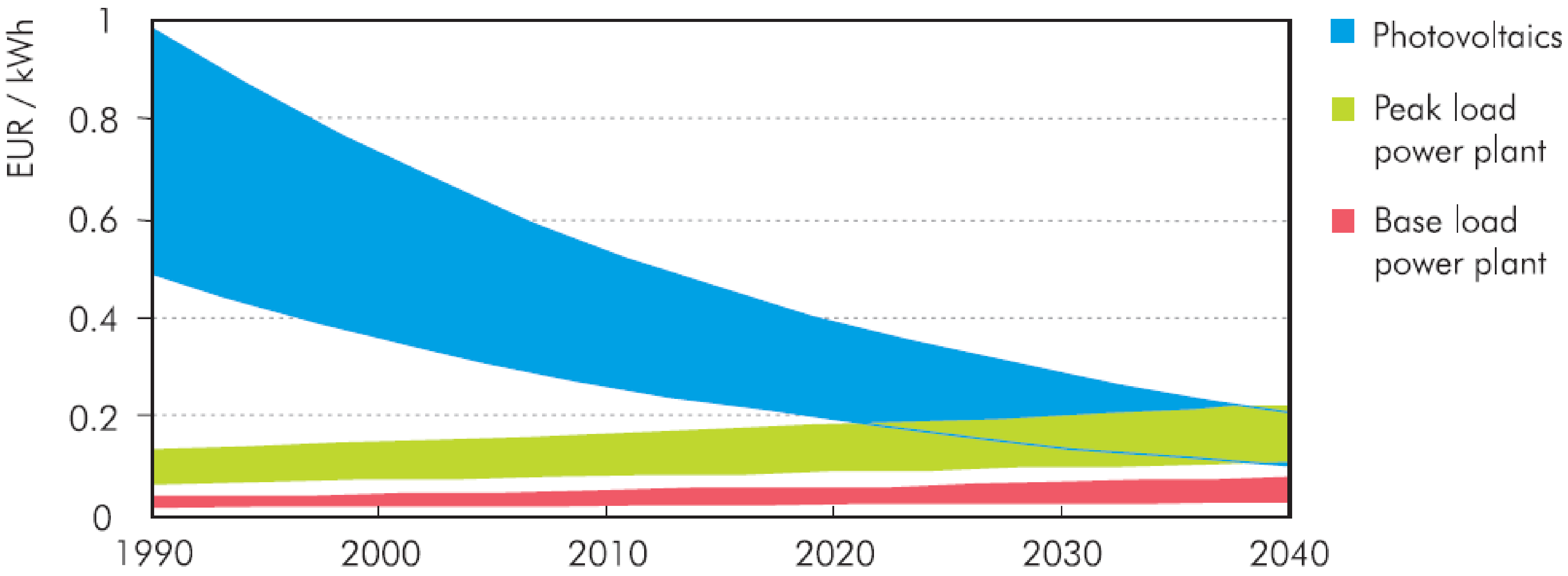
Characteristics of power plants with CO_2 capture

Fuel & Technology	Starting year	Investment cost (USD/kW)	Efficiency (%)	Efficiency loss (%)	Additional fuel (%)	Capture efficiency (%)
Likely technologies						
Coal, steam cycle, CA	2010	1 850	31	-12	39	85
Coal, steam cycle, membranes + CA	2020	1 720	36	-8	22	85
Coal, USC steam cycle, membranes +CA	2030	1 675	42	-8	19	95
Coal, IGCC, Selexol	2010	2 100	38	-8	21	85
Coal, IGCC, Selexol	2020	1 635	40	-6	15	85
Gas, CC, CA	2010	800	47	-9	19	85
Gas, CC, Oxyfueling	2020	800	51	-8	16	85
Black liquor, IGCC	2020	1 620	25	-3	12	85
Biomass, IGCC	2025	3 000	33	-7	21	85
Technologies under development						
Coal, CFB, chemical looping	2020	1 400	39	-5	13	85
Gas, CC, chemical looping	2025	900	56	-4	7	85
Coal, IGCC & SOFC	2035	2 100	56	-4	7	100
Gas, CC & SOFC	2030	1 200	66	-4	6	100

(IEA, 2006)

Learning curve for photovoltaics

Figure 4.12 ▶ Projected cost reductions for solar PV[17]



Source: Hoffmann, 2001.

Learning curve for windpower

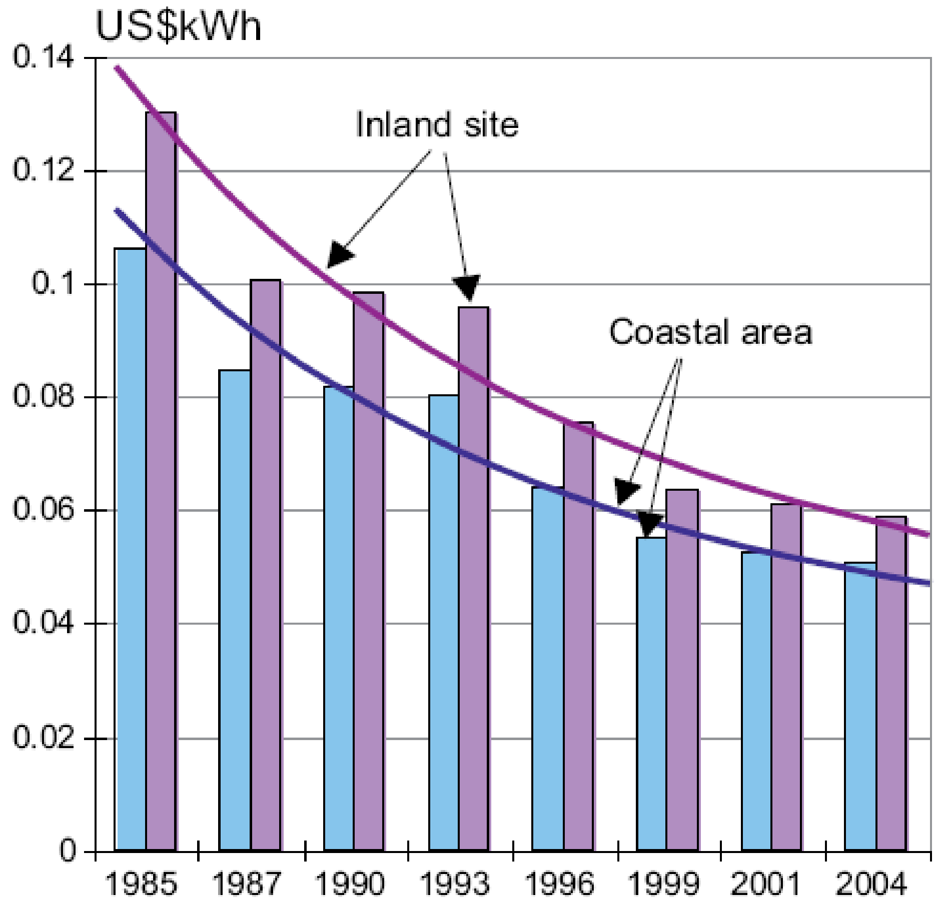
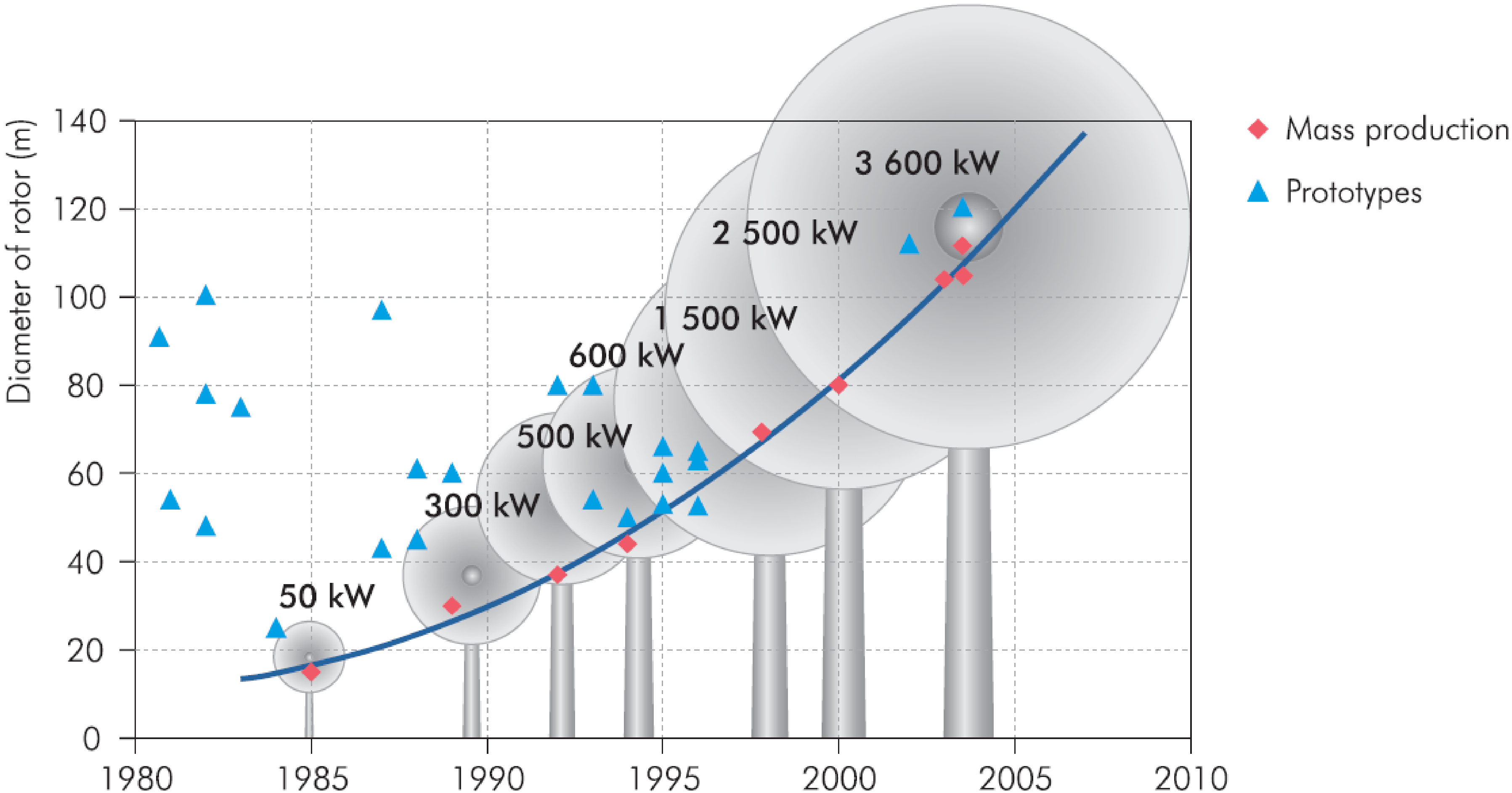


Figure 4.12: *Development of wind-generation costs based on Danish experience since 1985 with variations shown due to land surface and terrain variations (as indicated by roughness indicator classes which equal 0 for open water and up to 3 for rugged terrain).*

Source: Morthorst, 2004.

Development of wind turbine size



Source: German Wind Energy Institute (DEWI), 2004.

Learning curve: PV, wind, bioethanol

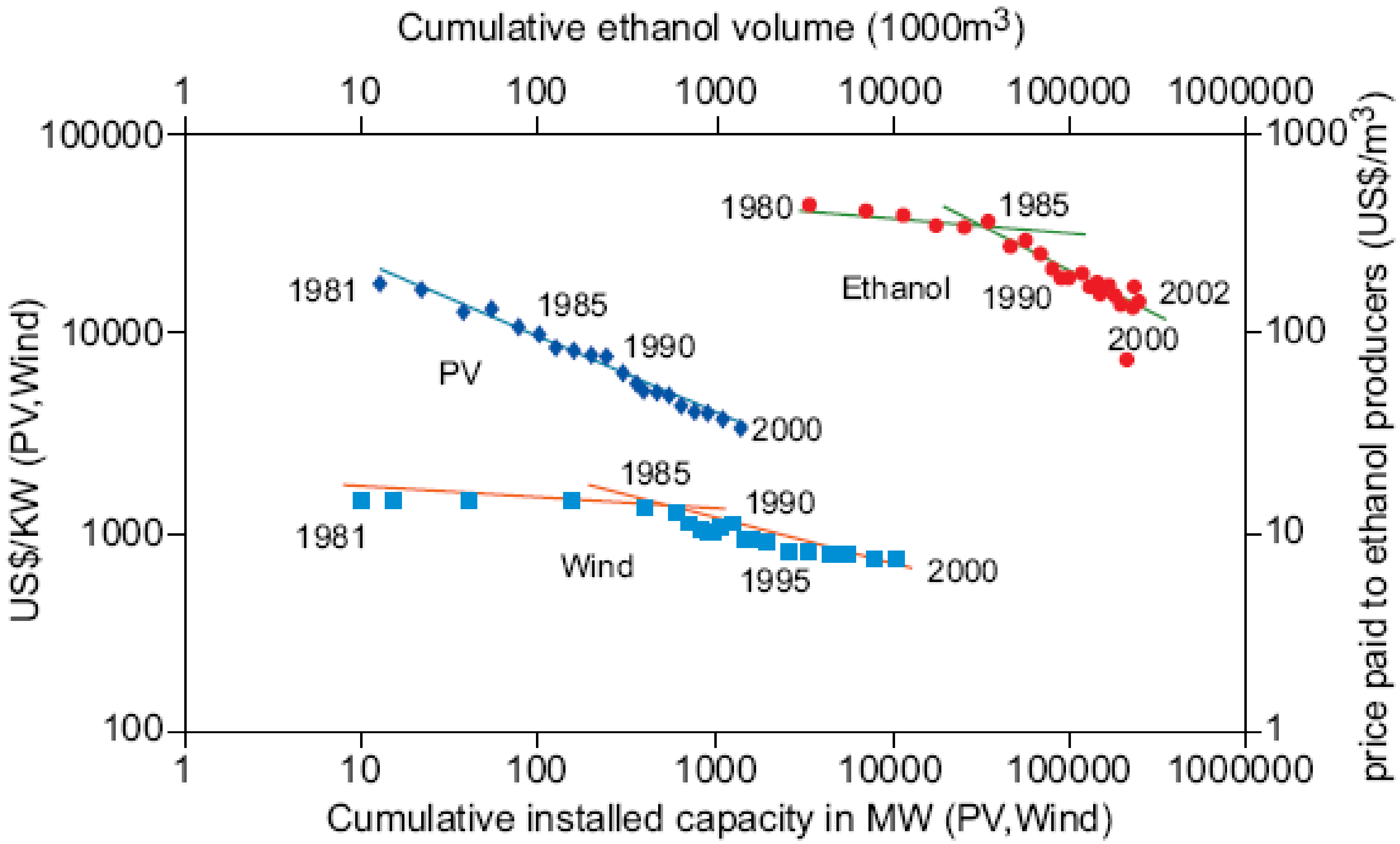


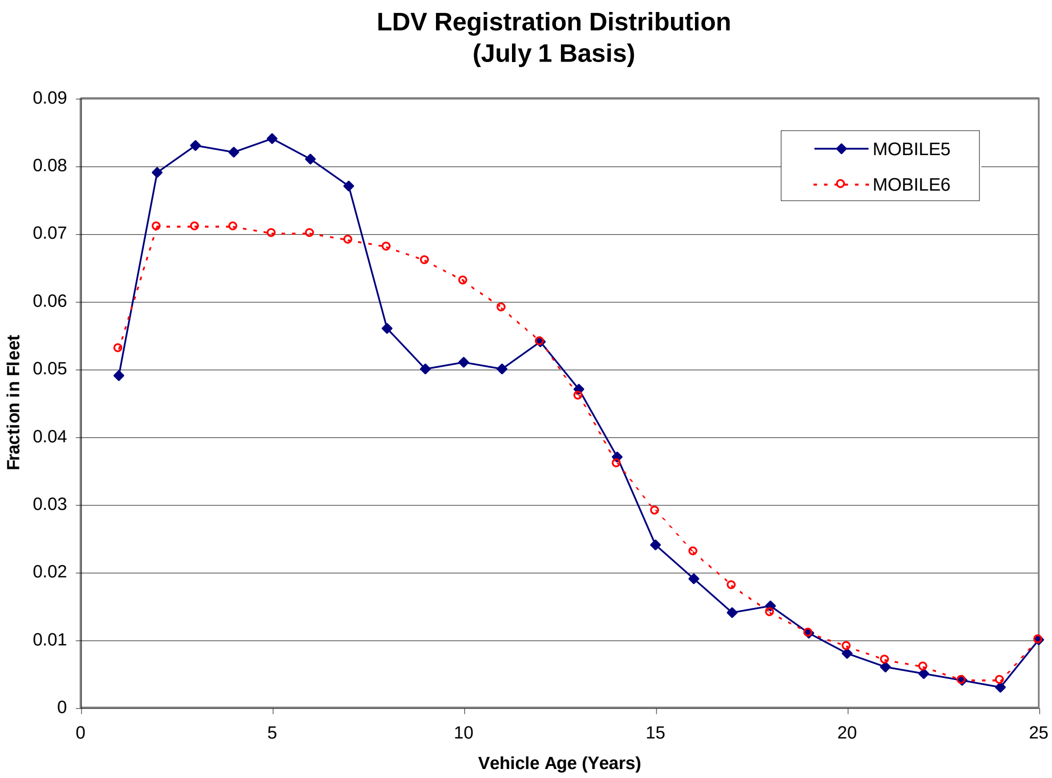
Figure 4.11: *Investment costs and penetration rates for PV, wind and bioethanol systems showing cost reductions of 20% due to technological development and learning experience for every doubling of capacity once the technology has matured.*

Source: Johansson et al., 2004.

3.2 Transport sector

- When will old vehicles disappear from the market?
- When will new vehicle technologies enter the markets?
- What will be the performance of new vehicle technologies with regard to air emissions? How clean will they be?

3.2 Vehicle age distribution



the international institute for
industrial environmental economics
Lund University, Sweden

Vehicle age distribution

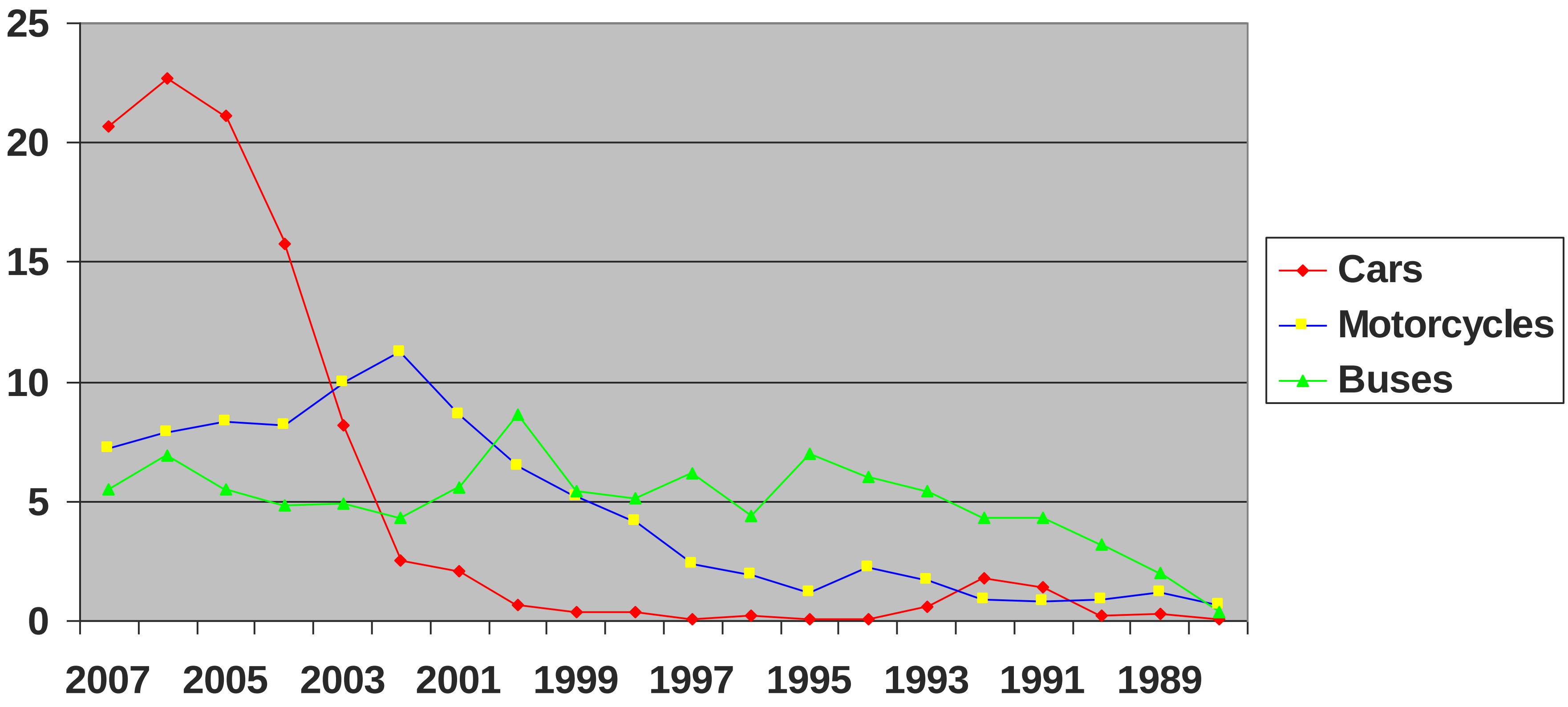
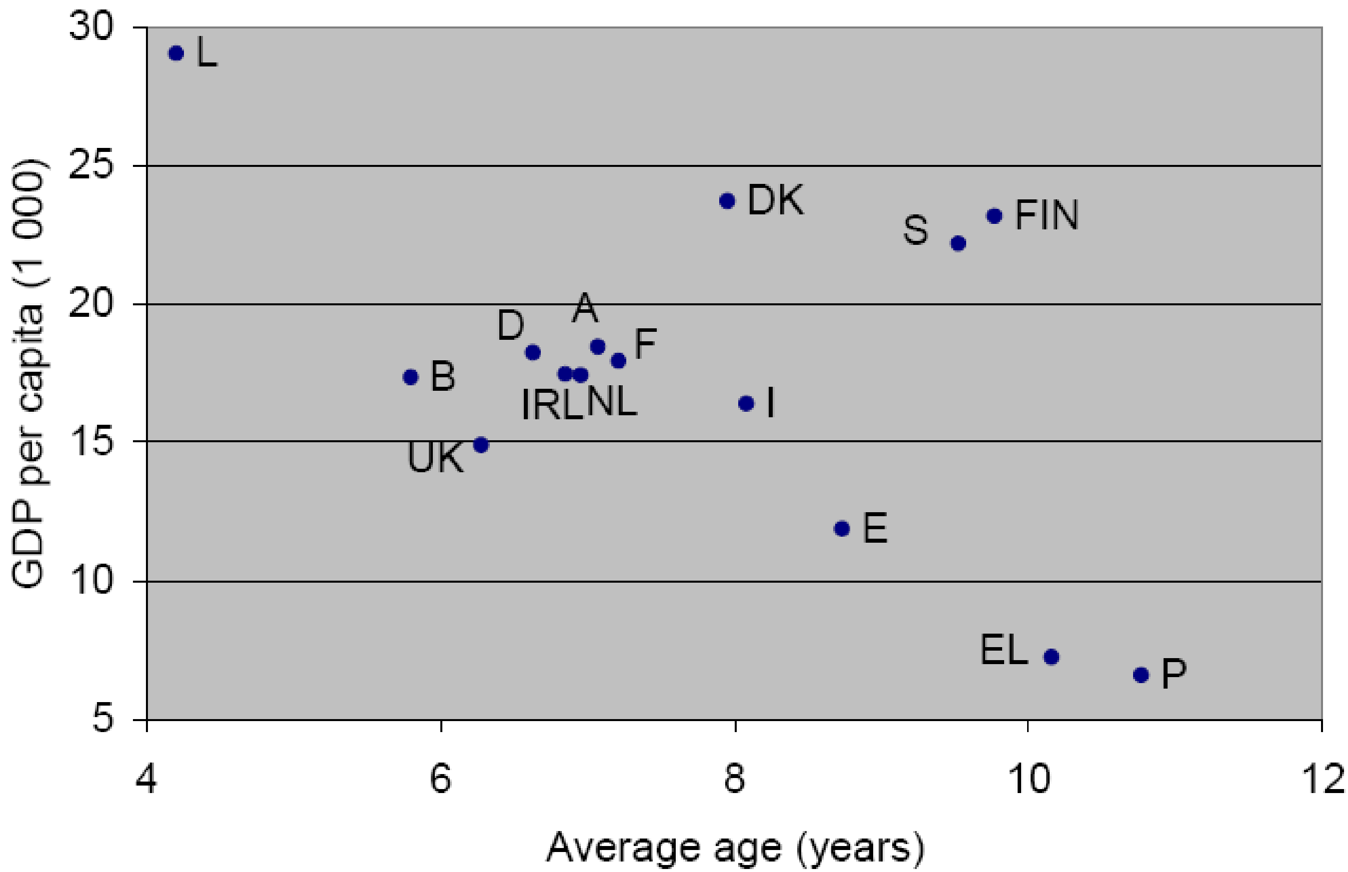


Figure: Age distribution of motor vehicles in Singapore as of 31 December 2007
(Land Transport Authority, 2008)

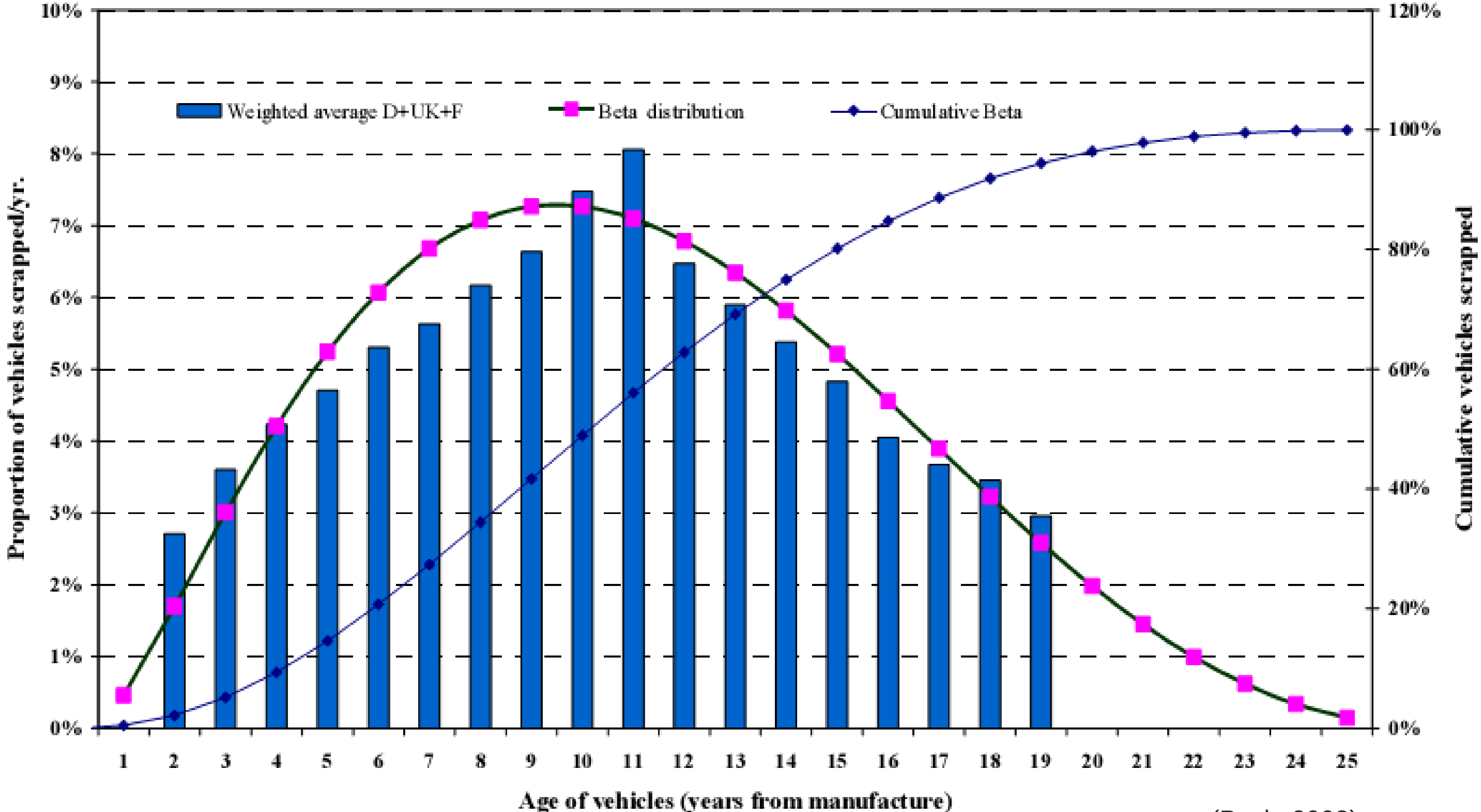
GDP and average vehicle age

Figure 2: The correlation between average age of vehicles in a country and GDP per capita (EU-15), 1998



(EEA, 2001)

Modelling the scrapping of old vehicles



(Peck, 2003)

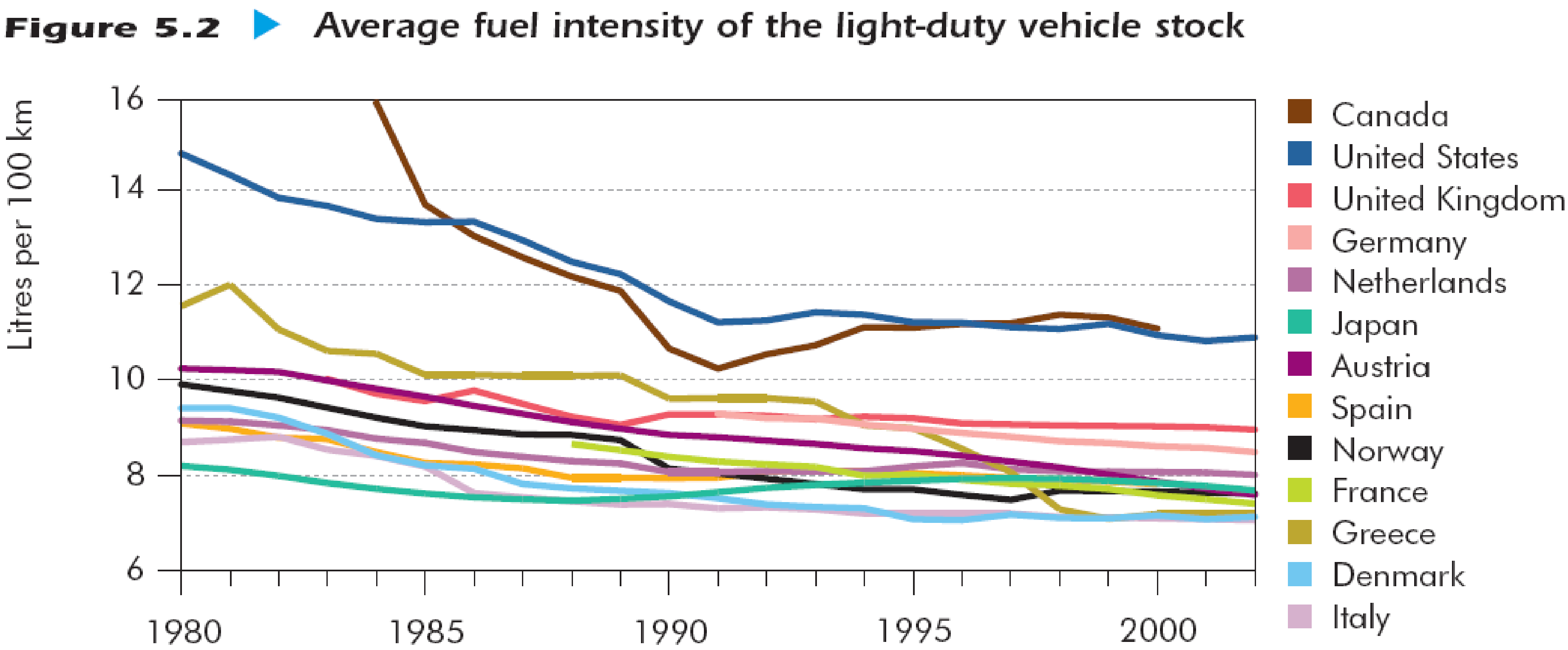
Emission standards for new vehicles (LDV)

Country	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14
European Union	E1	Euro 2					Euro 3				Euro 4				Euro 5				Euro 6	
Bangladesh[a]											Euro 2									
Bangladesh[b]											Euro 1									
Hong Kong, China	Euro 1		Euro 2				Euro 3					Euro 4								
India[c]							Euro 1				Euro 2					Euro 3				
India[d]					E1	Euro 2					Euro 3					Euro 4				
Indonesia											Euro 2									
Malaysia			Euro 1											*Euro 2*				*Euro 4*		
Nepal						Euro 1														
Pakistan	No conclusive information available																			
Philippines									Euro 1				*Euro 2*							
PRC[a]							Euro 1			Euro 2			Euro 3			Euro 4				
PRC[e]							Euro 1		Euro 2			Euro 3		Euro 4 Beijing only						
Singapore[a]	Euro 1						Euro 2													
Singapore[b]	Euro 1						Euro 2					Euro 4								
Sri Lanka									Euro 1				*Euro 2*[g]							
Taipei,China					US Tier 1								US Tier 2 for diesel[h]							
Thailand	Euro 1						Euro 2			Euro 3								Euro 4		
Viet Nam													Euro 2							

Notes: Italics – under discussion; a – gasoline; b – Diesel; c – Entire country; d – Delhi, Chennai, Mumbai, Kolkata, Bangalore, Hydrabad, Agra, Surat, Pune, Kanpur, Ahmedabad, Sholapur, Lucknow; Other cities in India are in Euro 2; e – Beijing and Guangzhou (as of 01 September 2006) have adopted Euro 3 standards; Shanghai has requested the approval of the State Council for implementation of Euro 3; f – Euro 4 for gasoline vehicles and California ULEV standards for diesel vehicles; g – As per government regulation 1295-11 from Ministry of Environment and Natural Resources http://www.cea.lk/acts/reg1295-11.pdf; h – Gasoline vehicles under consideration

CAI-Asia. 2008, January. Emission standards for new vehicles (light duty). Available: http://www.cleanairnet.org/caiasia/1412/articles-58969_new.pdf

Trends in fuel intensity of light-duty vehicles



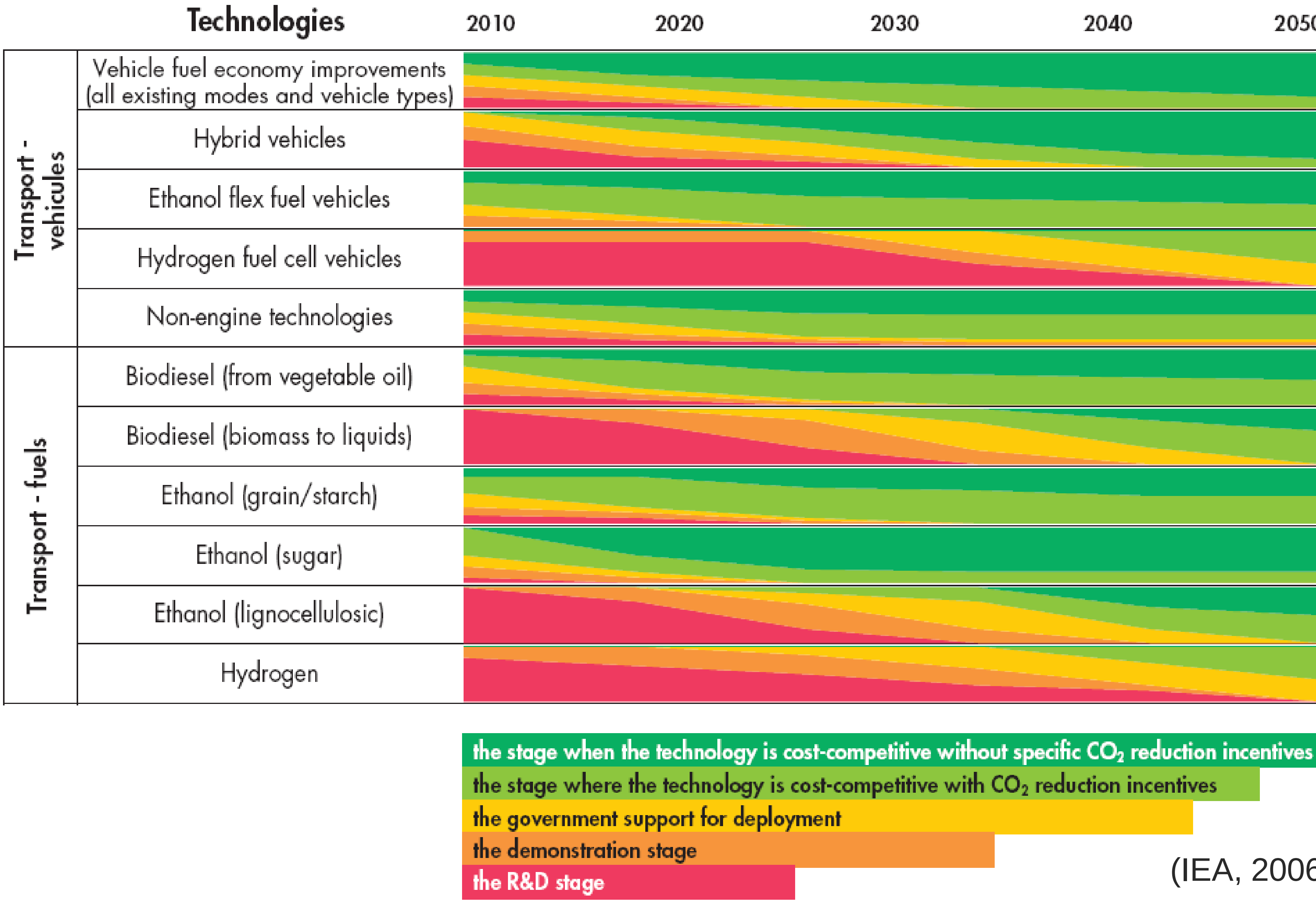
(WBCSD, 2004)

Points to consider

- The level of vehicle usage / mileage per year may differ significantly with different vehicle age groups
  - OECD: typically the younger the vehicle, the higher the annual mileage
  - What about South Asia?

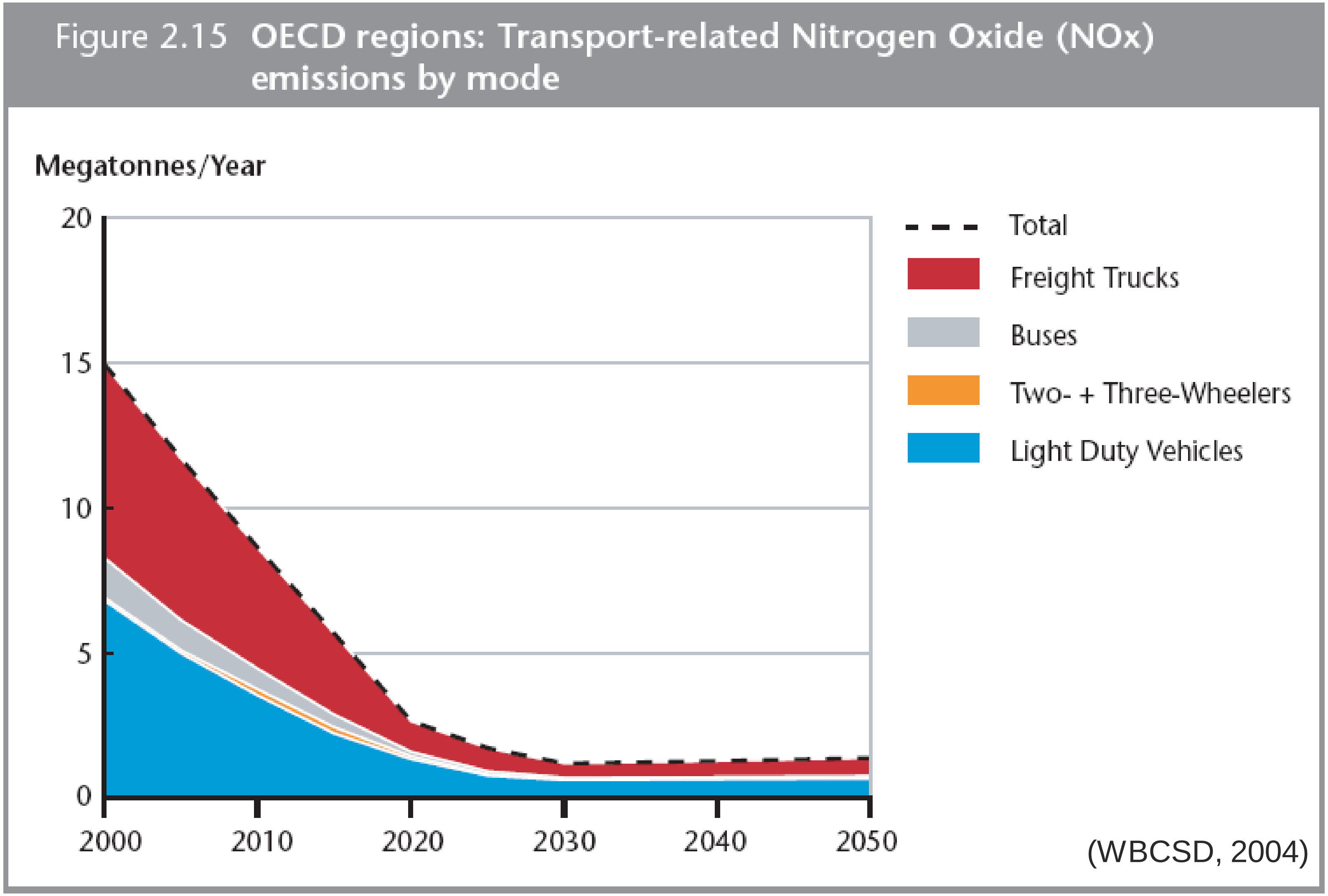
- The expected level of policy enforcement of emission standards and other policies for emission control will always be a critical factor when modeling future emission factors of vehicle fleets
  - What about South Asia?

Pathways towards cost-competitive transport technologies



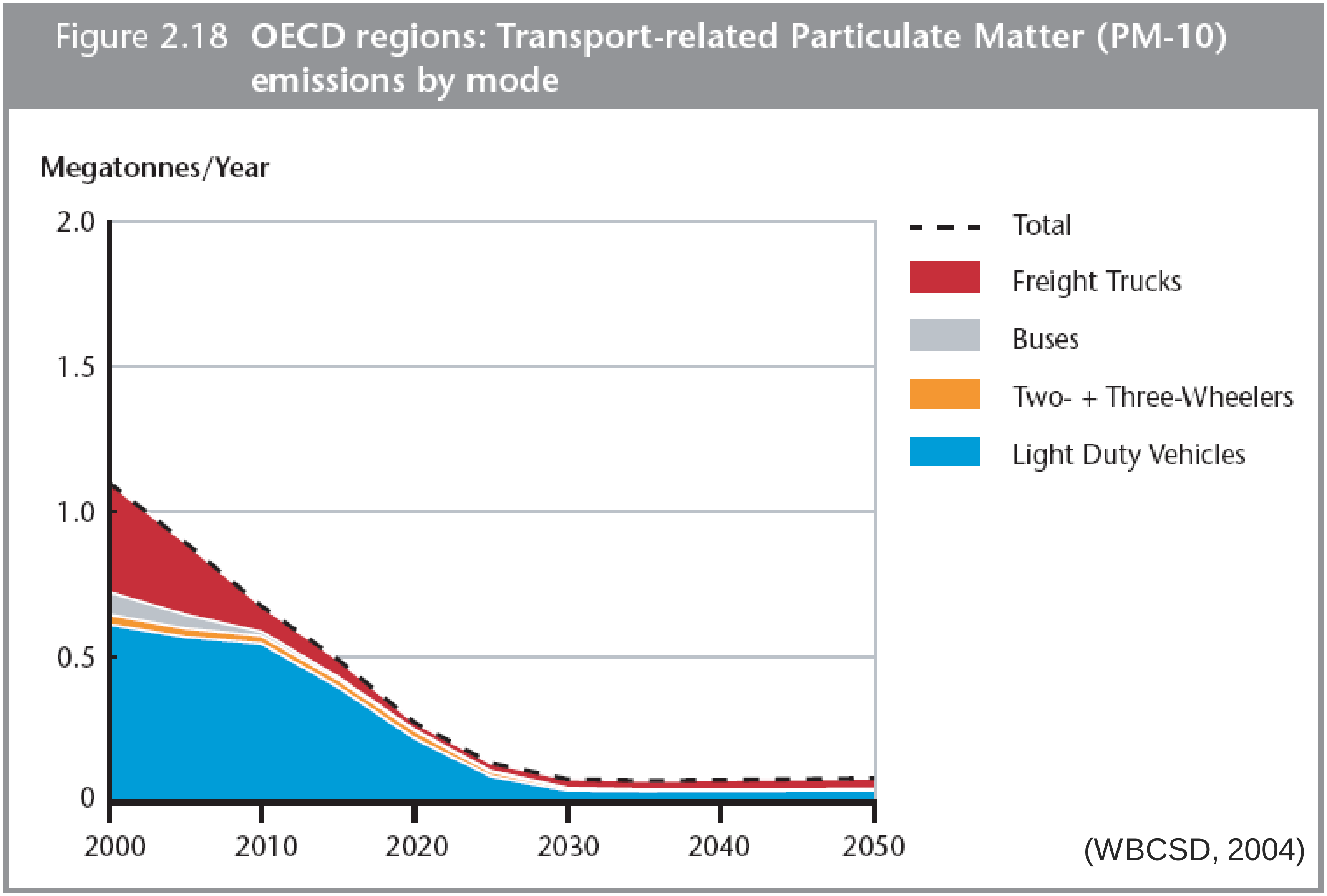
(IEA, 2006)

Transport emission scenarios (OECD)



Source: Sustainable Mobility Project calculations.

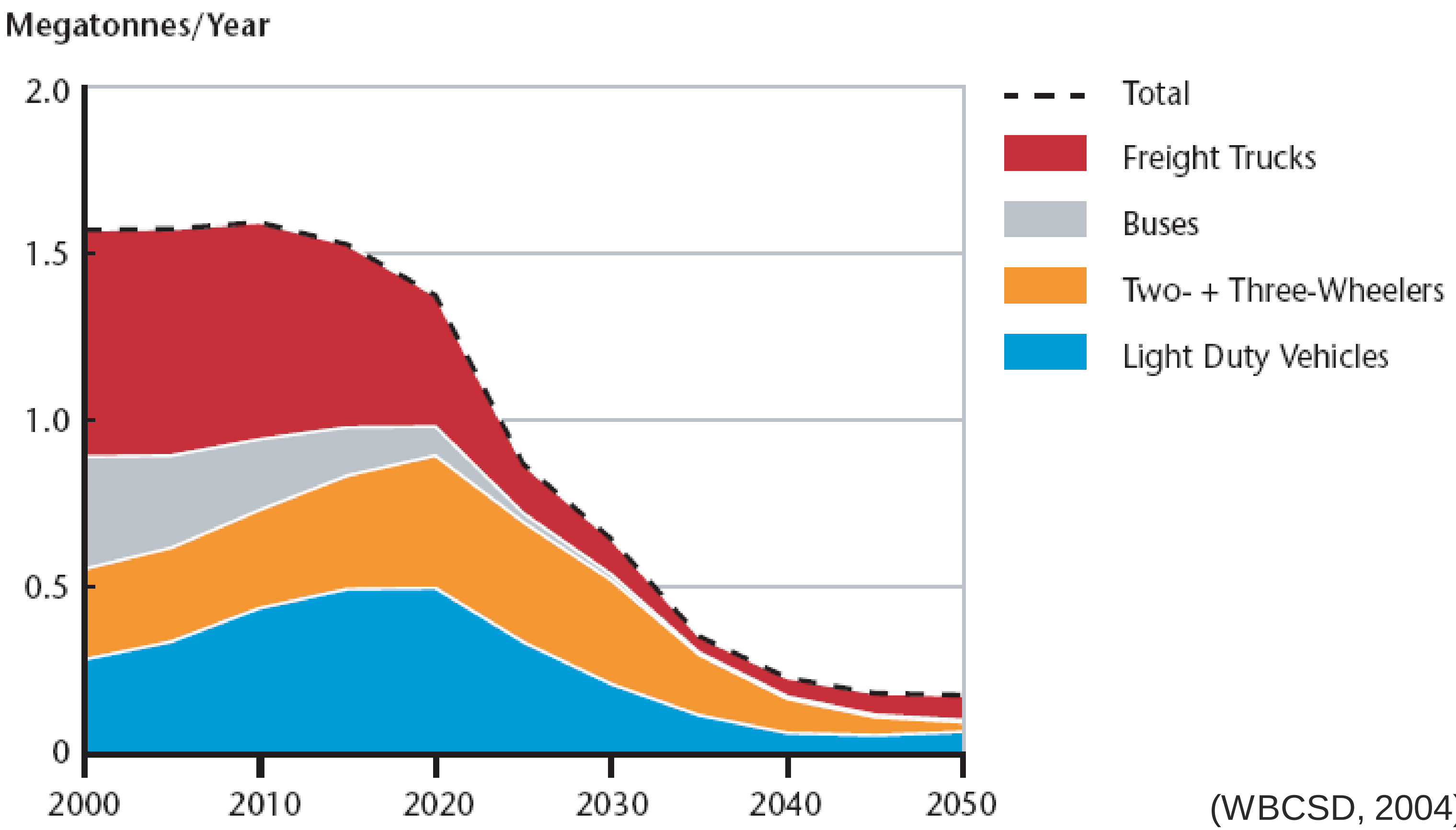
Transport emission scenarios (OECD)



Source: Sustainable Mobility Project calculations.

Transport emission scenarios (non-OECD)

Figure 2.23 Non-OECD regions: Transport-related Particulate Matter (PM-10) emissions by mode

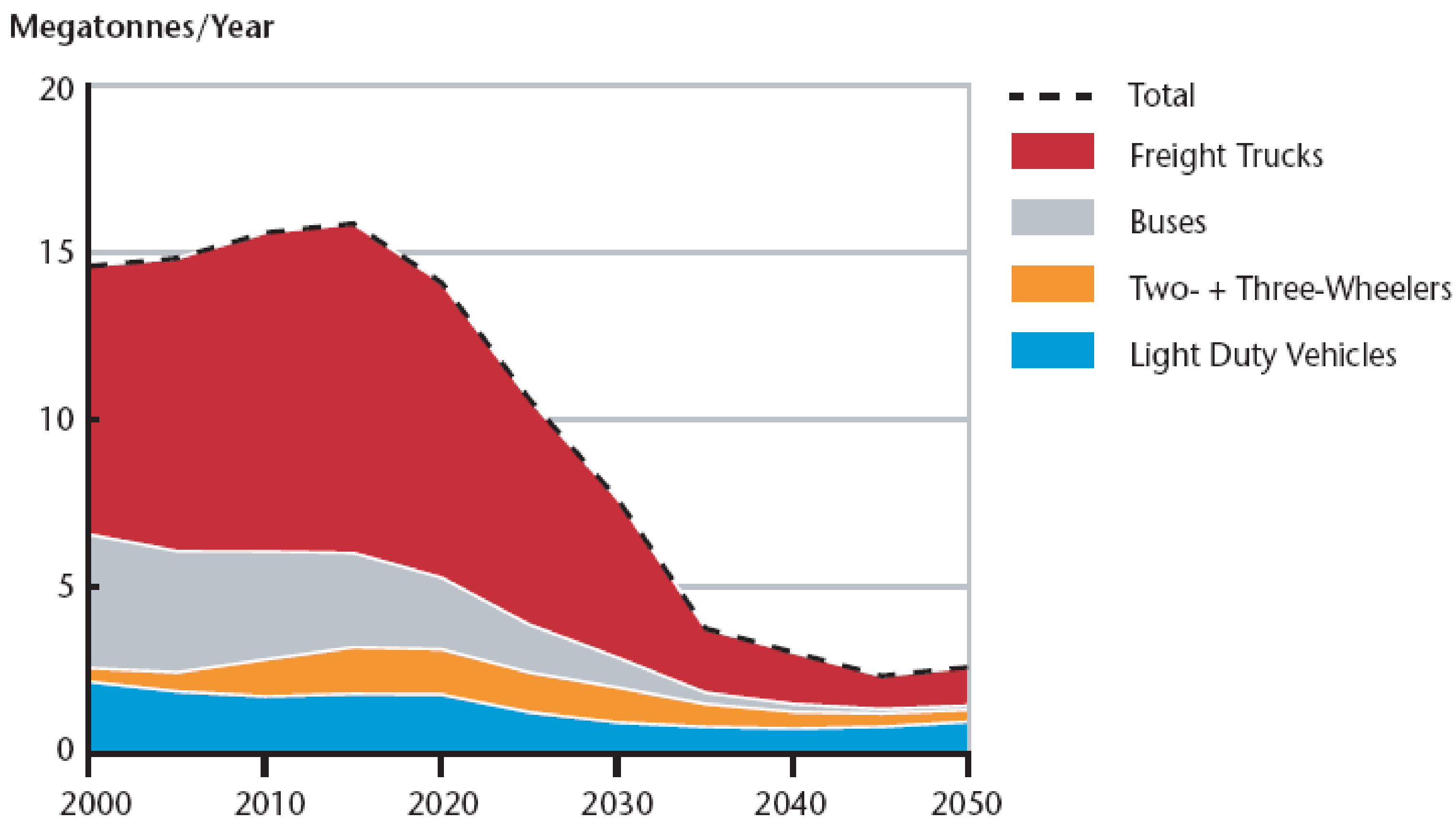


(WBCSD, 2004)

Source: Sustainable Mobility Project calculations.

Transport emission scenarios (non-OECD)

Figure 2.20 Non-OECD regions: Transport-related Nitrogen Oxide (NOx) emissions by mode



(WBCSD, 2004)

Source: Sustainable Mobility Project calculations.

4 Policy intervention

- Market developments will lead to some emission reductions per service unit in the future
  - New technologies are more energy-efficient and cleaner
  - BUT: the expected growth in energy demand / transport volume will outweigh these efficiency gains

- Additional technology ("end-of-pipe") and cleaner fuels will be required to cut NOx, SOx, PM emissions
  - Policy intervention will be required to implement this, as it is unlikely that "polluters" will install "filters" on their own initiative

Policy instrument for air pollution prevention and control

Command and control

- Emission standards
- Air quality standards
- Fuel quality standards
- Vehicle inspection programmes
- Technology standards
- Building codes

Economic instruments

- Emission taxes
- Fuel taxes
- Vehicle taxation
- Public procurement
- Subsidies
- Vehicle quota systems
- Emission trading schemes
- Liability and compensation schemes
- Parking fees
- Congestion pricing
- JI / CDM

Informative instruments

- Eco labelling
- Information disclosure
- Information and awareness raising campaigns

Infrastructure and public services

- Land-use planning
- Infrastructure for cleaner fuels
- R & D
- Infrastructure for public transport systems

Voluntary agreements

- Voluntary industry commitments
- Environmental Management Systems

4 Policy intervention

- The impact on emissions of some policy interventions are relatively easy to model…
  - Fuel quality standards
  - Emission standards
  - Banning of certain technologies
  - Mandatory technology standards

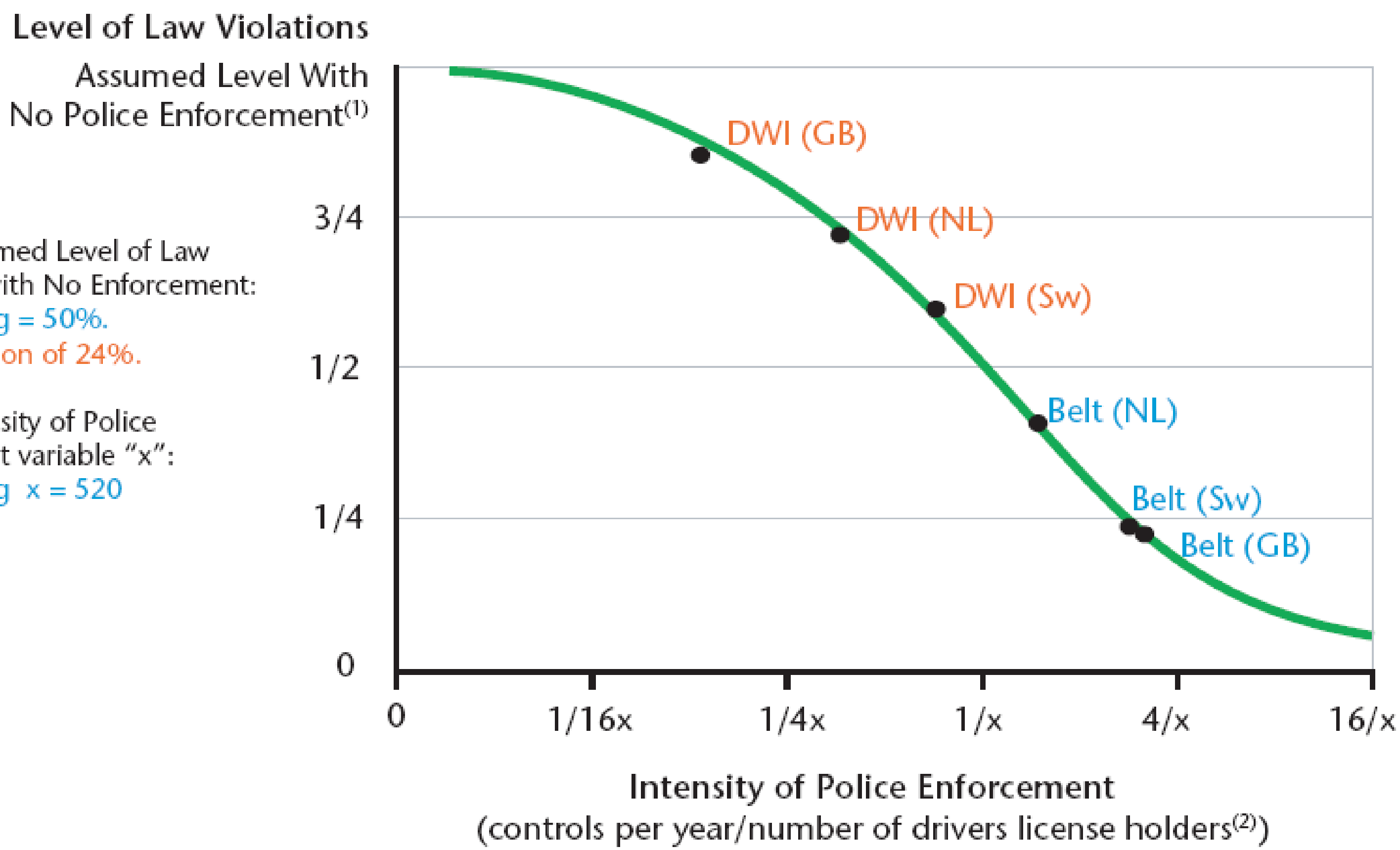
- The impact of other type of policy interventions are harder to forecast, e.g.
  - Economic instruments (fuel taxes, sulphur taxes, etc.)
  - Informative instruments
  - Voluntary agreements

4 Policy intervention

- It is not always clear how existing policies will be implemented in the future
- Often a degree of judgment is required in translating stated policies into formal assumptions for modelling purposes.
  - this requests especially to make assumptions about policy enforcement

The importance of effective policy enforcement

Figure 4.13 Police enforcement intensity and its effectiveness



(1) The Assumed Level of Law Violations with No Enforcement:
Belt Wearing = 50%.
DWI = fraction of 24%.

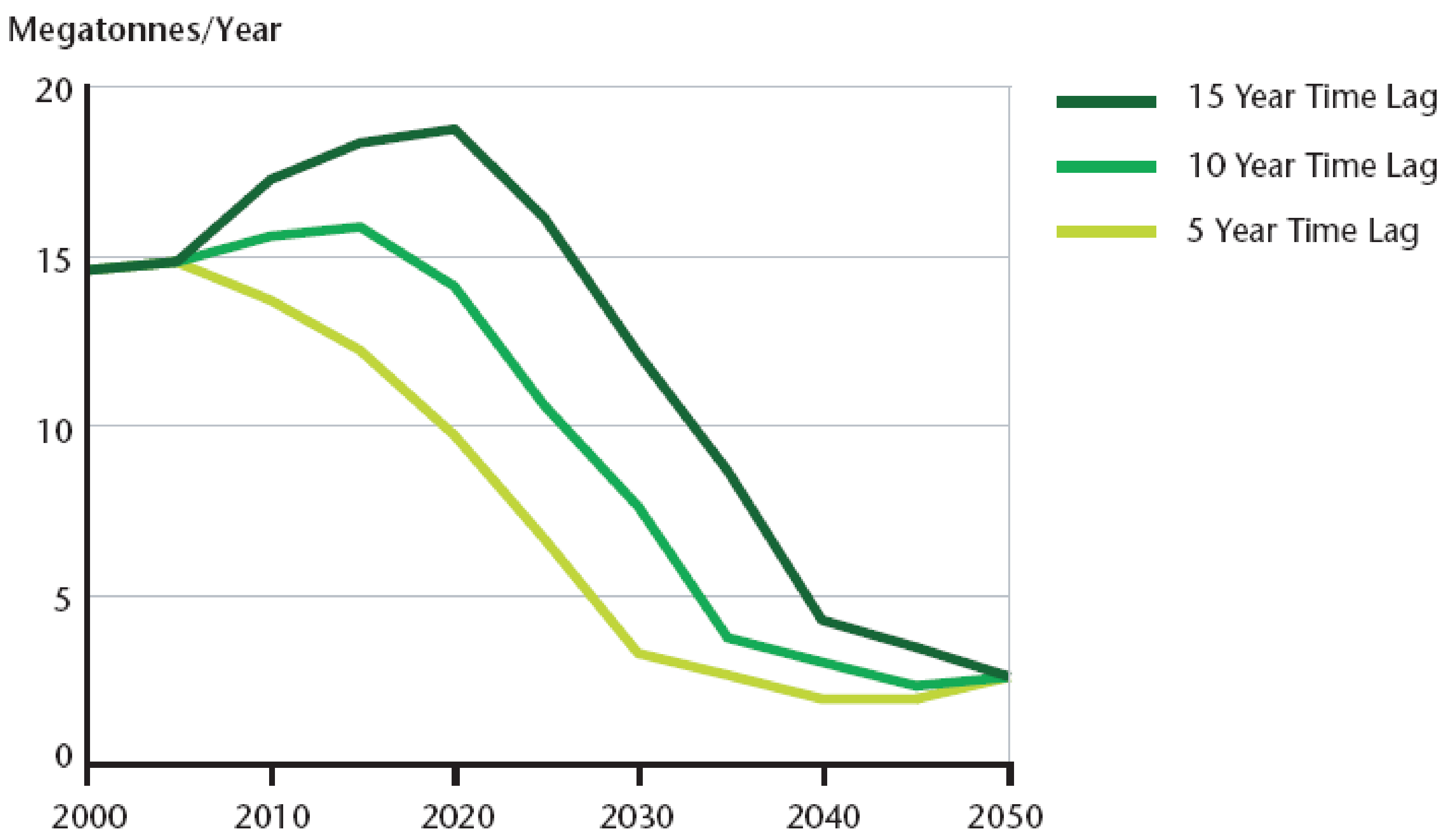
(2) The Intensity of Police Enforcement variable "x":
Belt Wearing x = 520
DWI x = 4

Source: Adapted from **Koornstra 2003**.

(WBCSD, 2004)

The timing of policy intervention (NOx)

Figure 4.3 Non-OECD regions: Nitrogen Oxide (NOx) emissions by year depending on the time lag in implementing developed world emissions standards

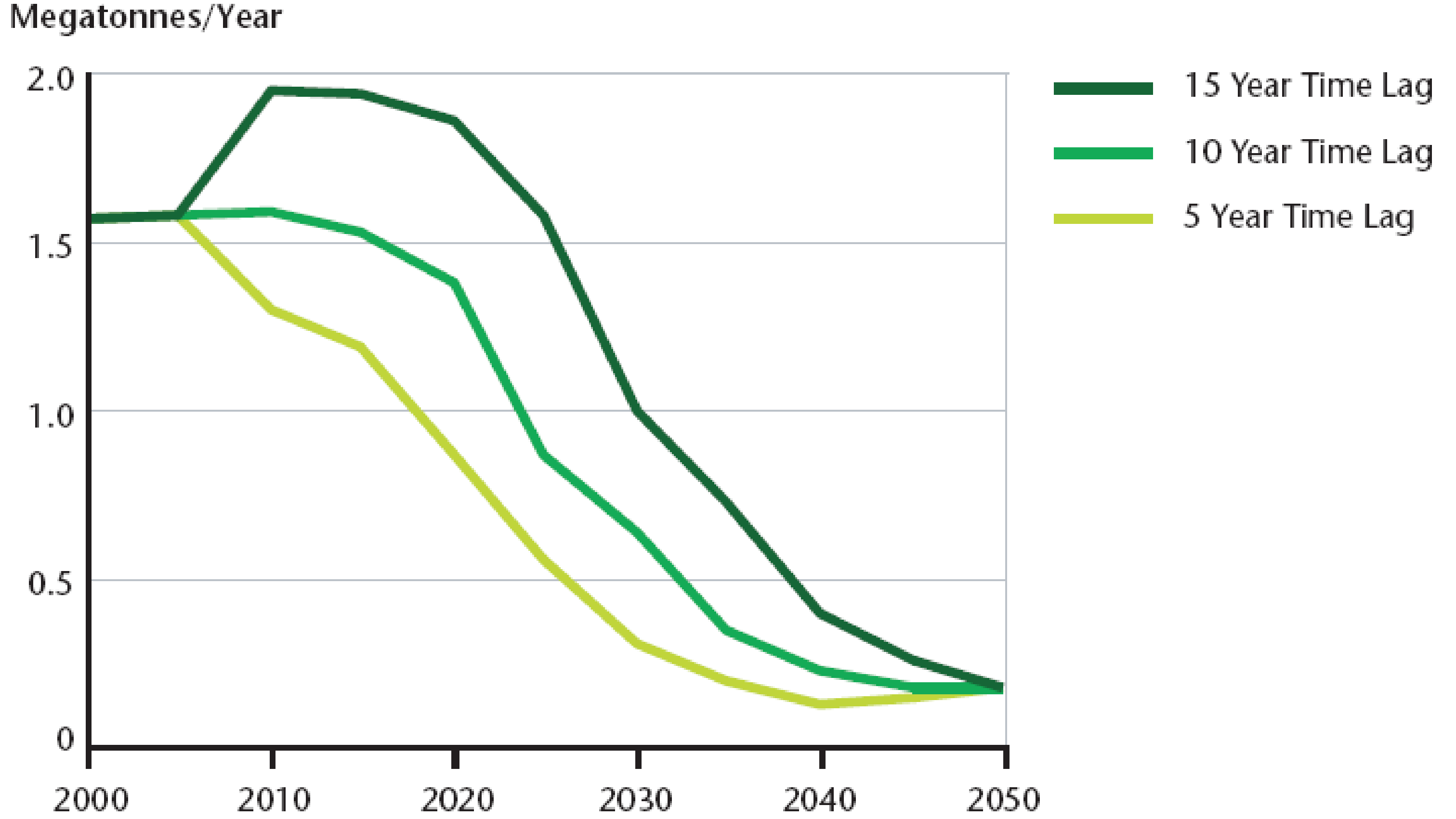


Source: Sustainable Mobility Project calculations.

(WBCSD, 2004)

The timing of policy intervention (PM10)

Figure 4.4 Non-OECD regions: Particulate Matter (PM-10) emissions by year depending on the time lag in implementing developed world emissions standards

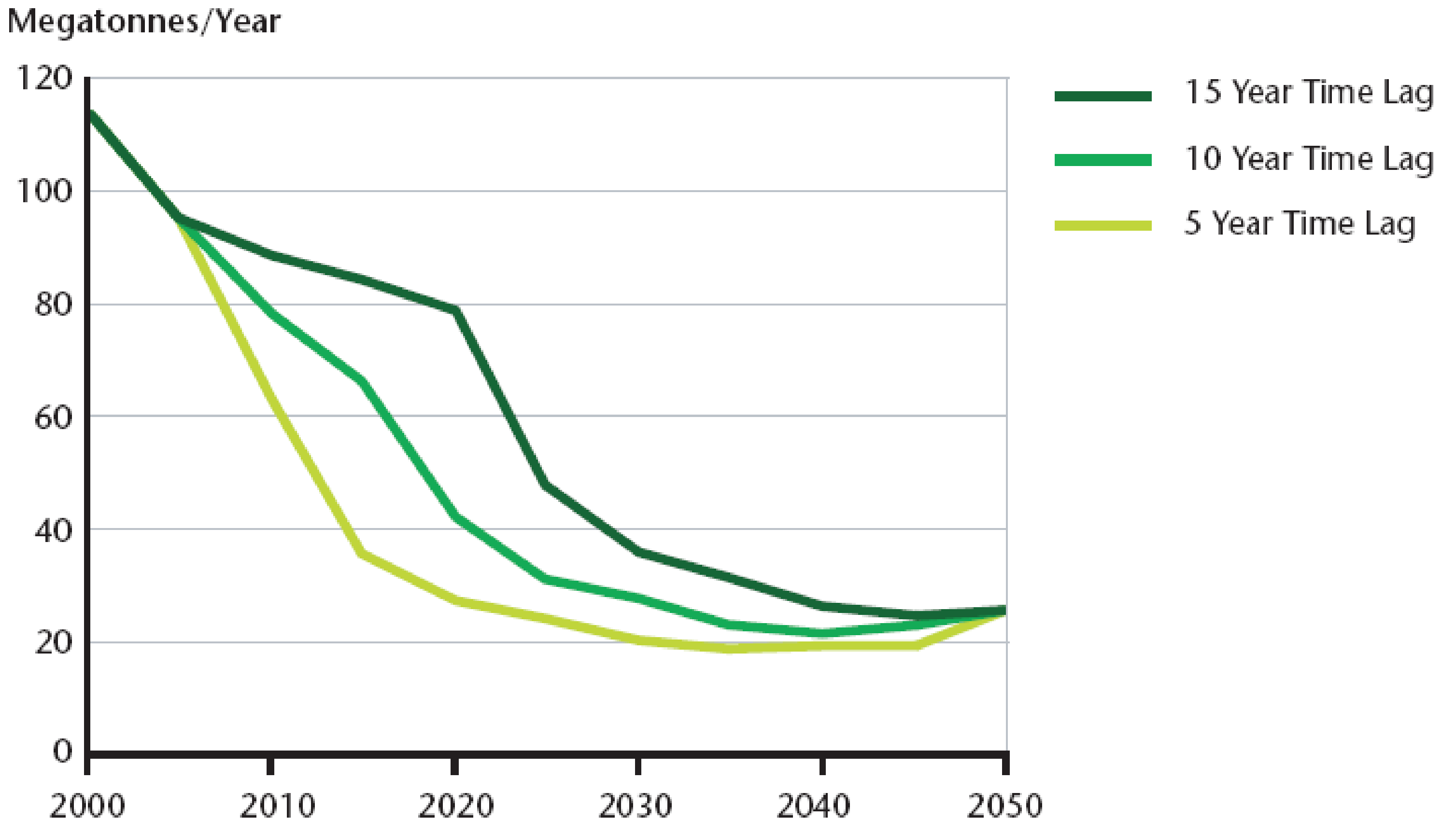


Source: Sustainable Mobility Project calculations.

(WBCSD, 2004)

The timing of policy intervention (CO)

Figure 4.1 Non-OECD regions: Carbon Monoxide (CO) emissions by year depending on the time lag in implementing developed world emissions standards



Source: Sustainable Mobility Project calculations.

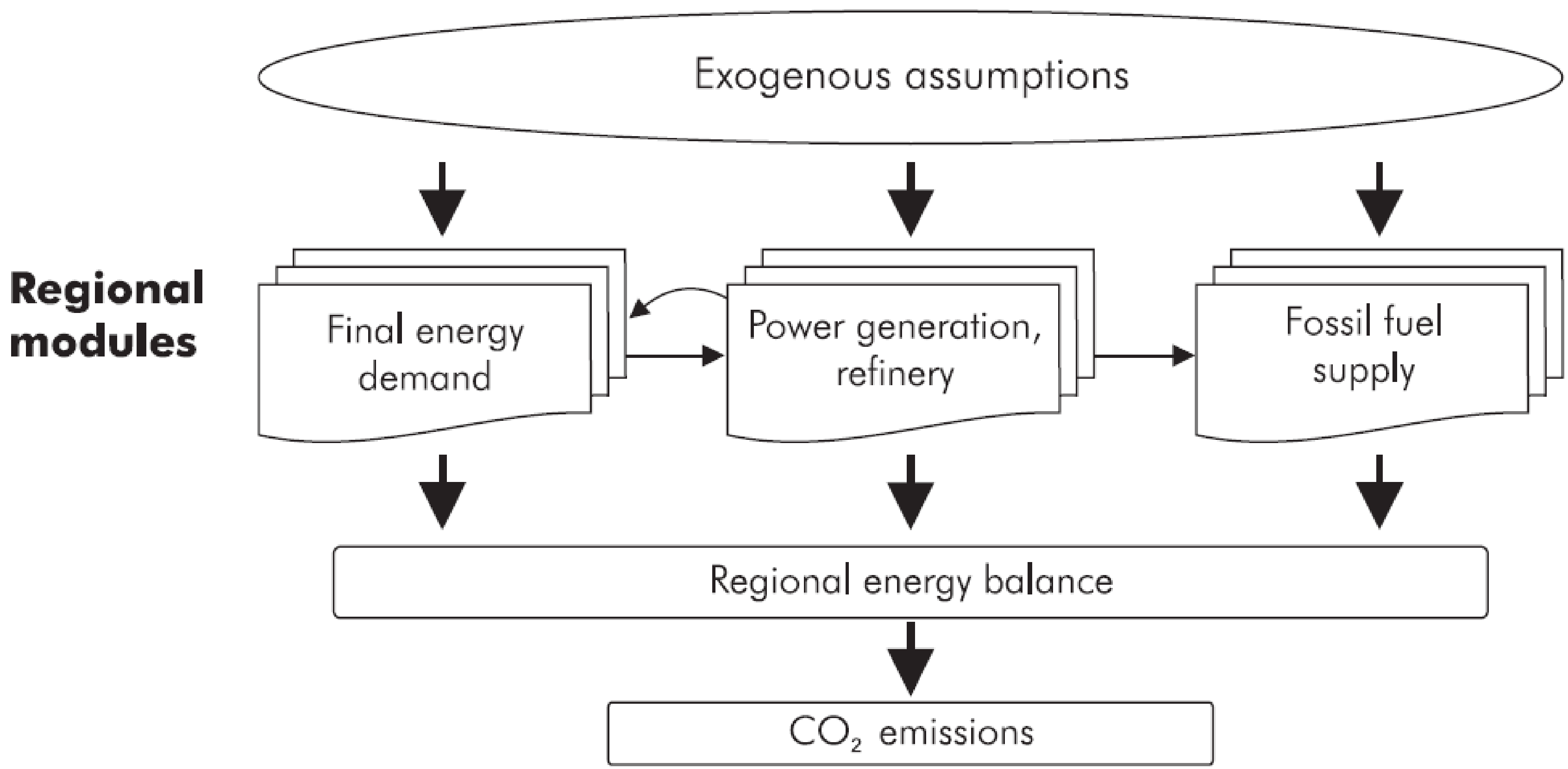
(WBCSD, 2004)

5 Models and tools

- Some established energy and emission models
  - the TREMOVE transport model
  - the TIMER energy demand and supply and emission model
  - the Long-range Energy Alternatives Planning tool (LEAP)
  - the MARKAL energy-economic-environmental model
  - GAINS - a model about Greenhouse Gas and Air Pollution Interactions and Synergies
  - and many more….

5 IEA World Energy Model (WEM)

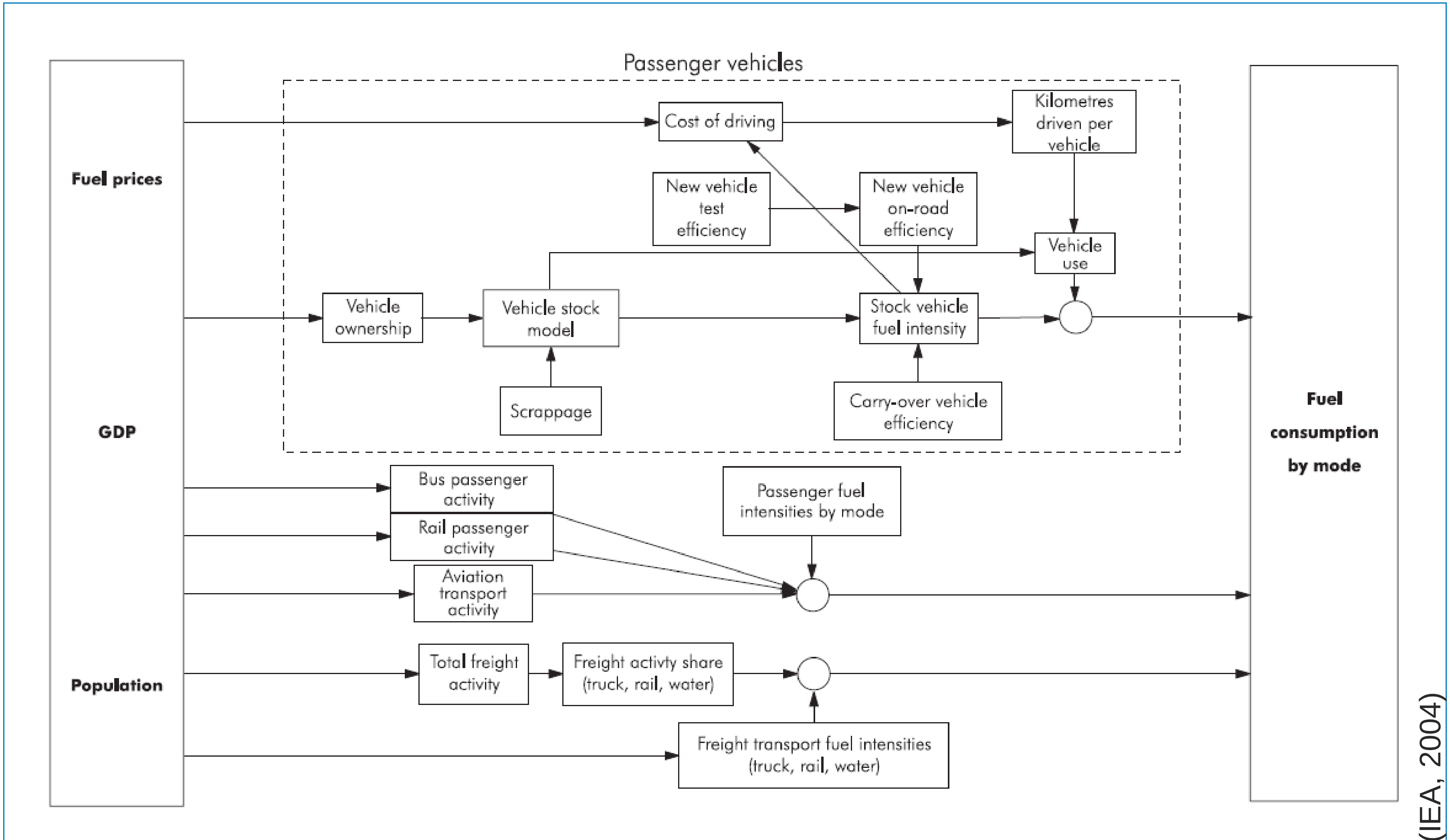
Figure C.1: **World Energy Model Overview**



(IEA, 2004)

5 IEA World Energy Model (WEM)

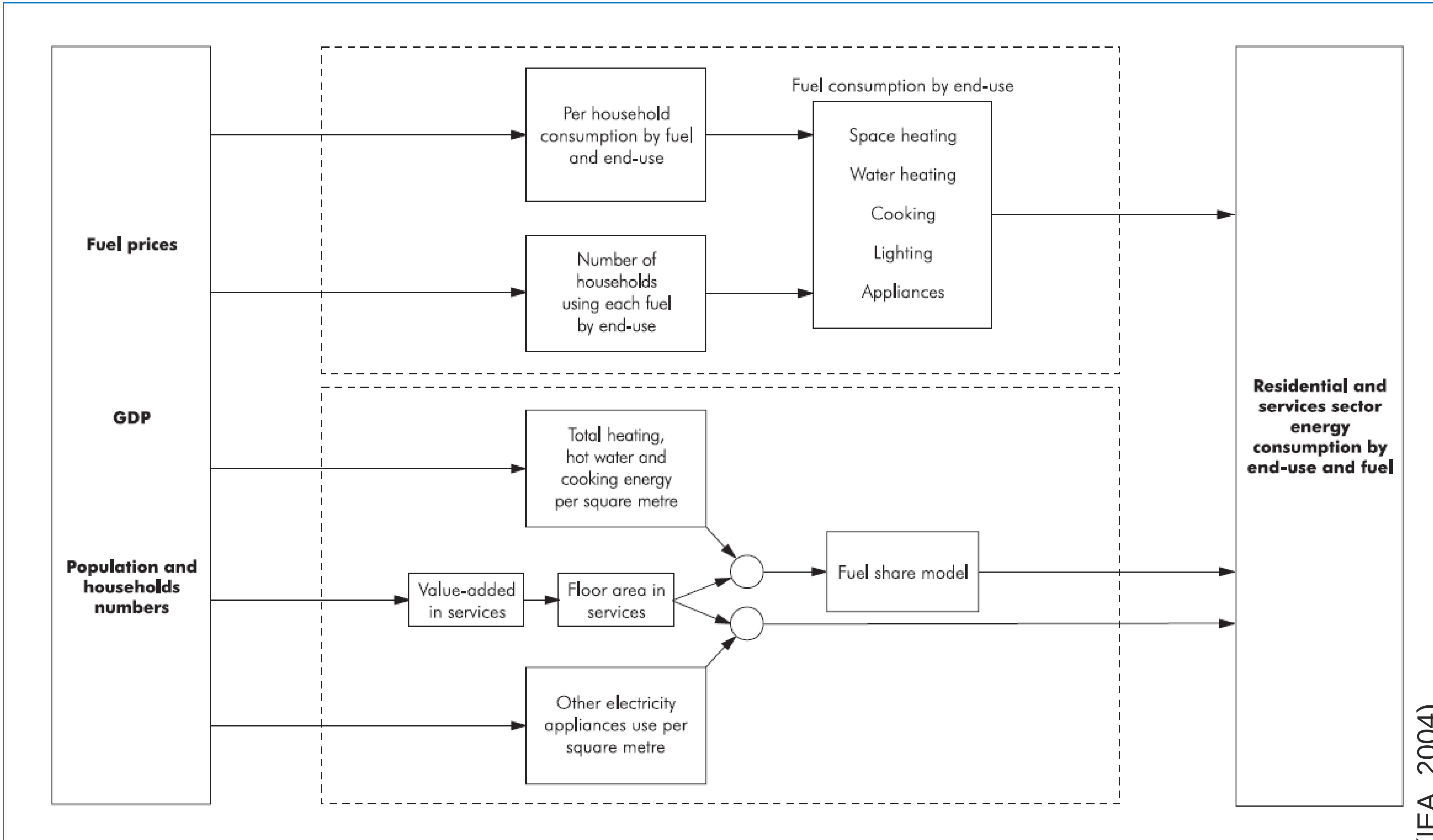
Figure C.3: **Structure of the Transport Demand Module**



(IEA, 2004)

5 IEA World Energy Model (WEM)

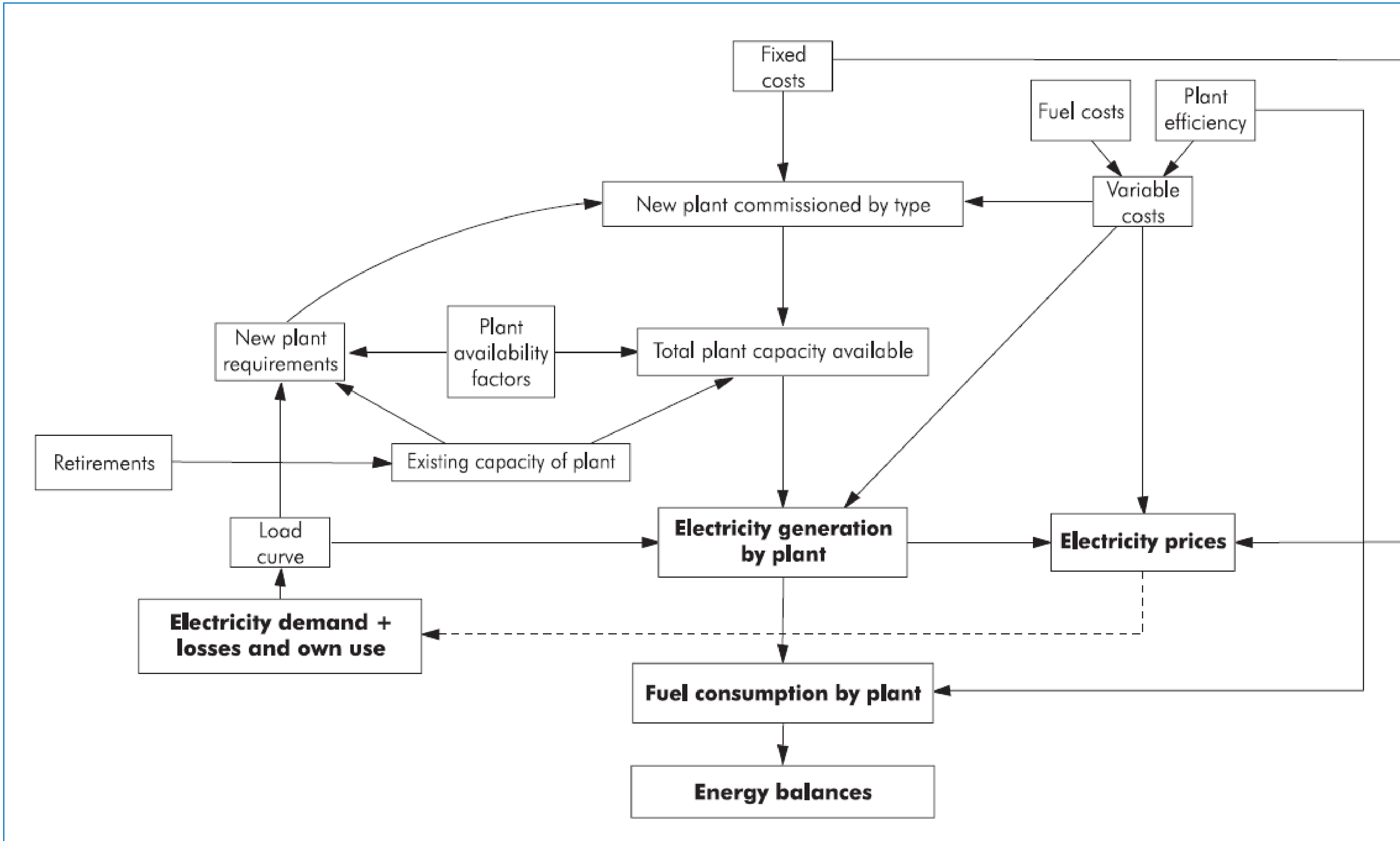
Figure C.4: **Structure of the Residential and Services Sectors Demand Modules**



(IEA, 2004)

5 IEA World Energy Model (WEM)

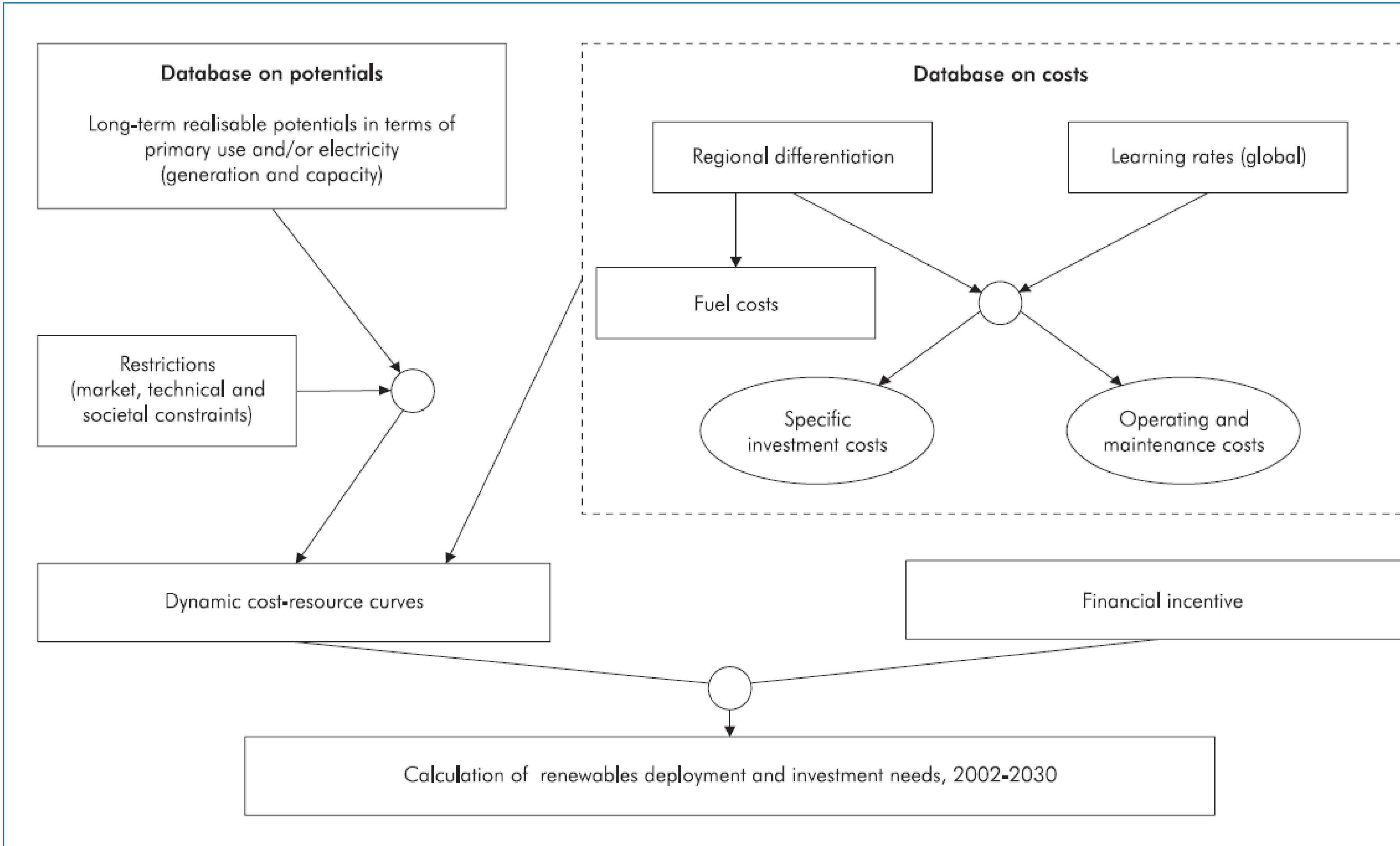
Figure C.5: **Structure of the Power Generation Module**



(IEA, 2004)

5 IEA World Energy Model (WEM)

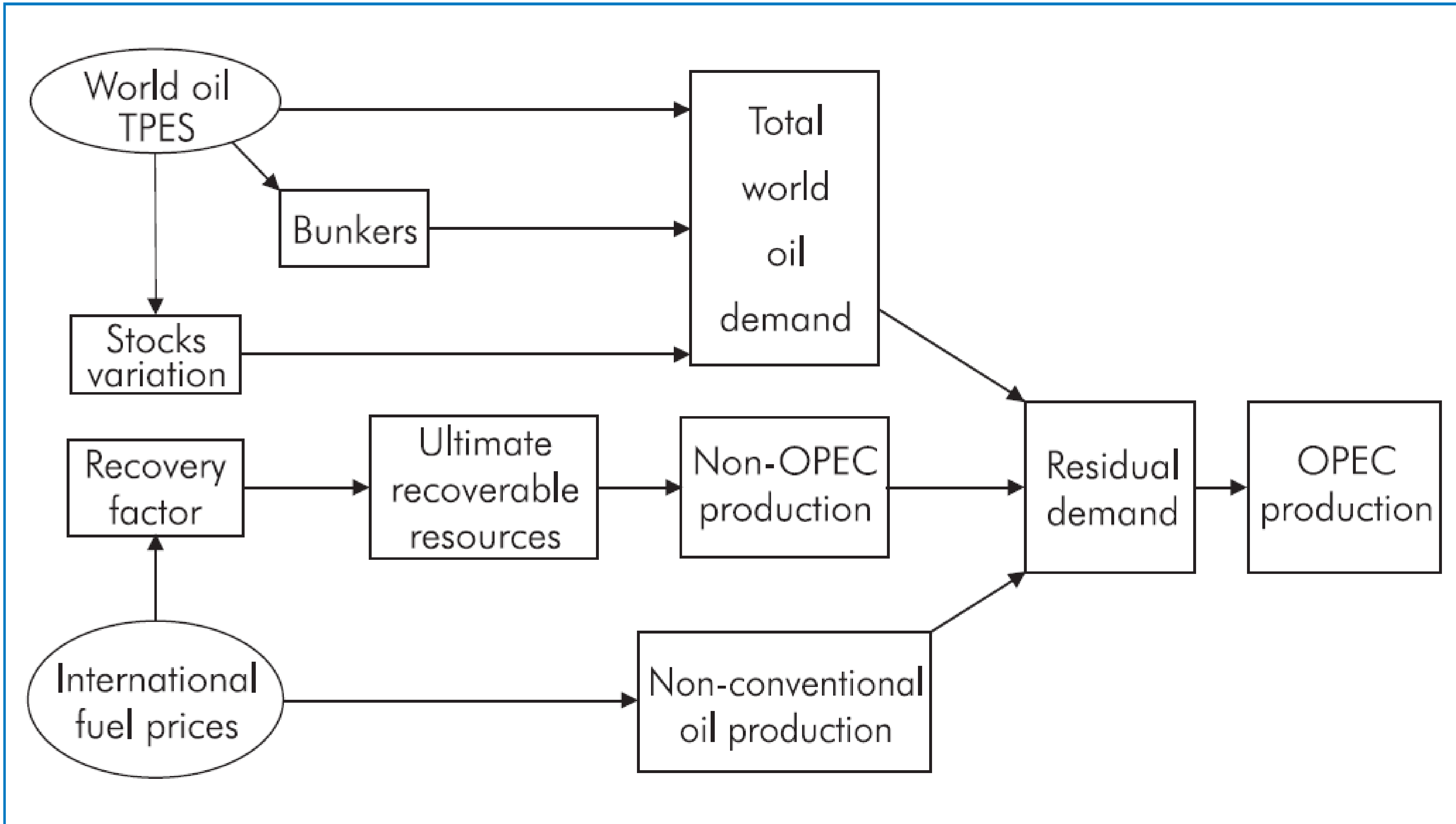
Figure C.6: Mehtod of Approach for the Renewables Module



(IEA, 2004)

5 IEA World Energy Model (WEM)

Figure C.7: **Structure of Oil Supply Module**



(IEA, 2004)

ADDITIONAL SLIDES

Market exchange rates vs purchasing power parities

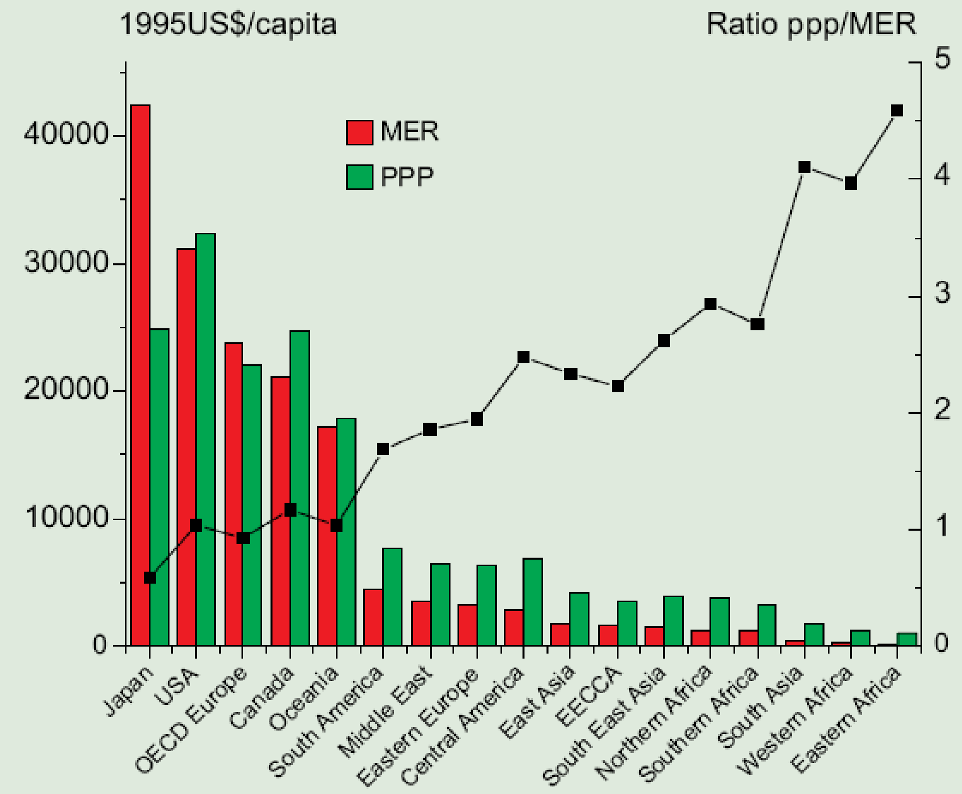


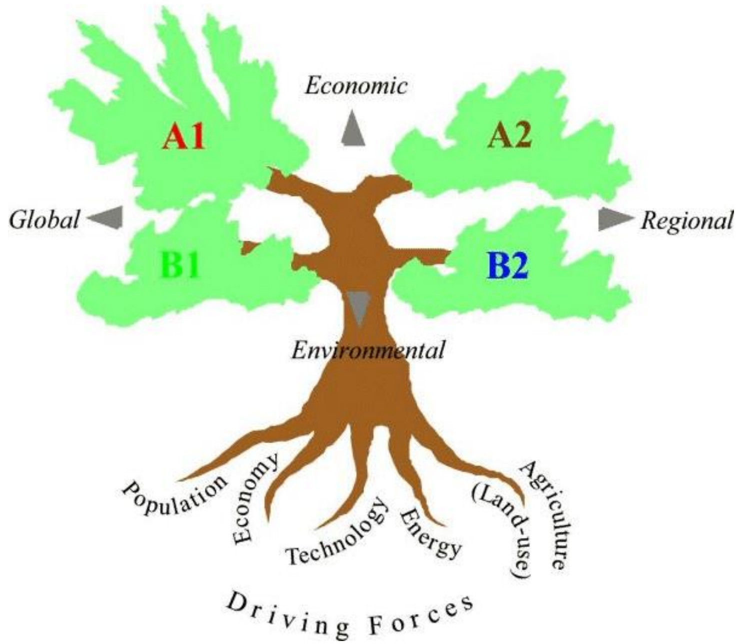
Figure 3.4: *Regional GDP per person, expressed in MER and PPP on the basis of World Bank data aggregated to 17 global regions.*

Note: The left y-axis and columns compare absolute data, while the right y-axis and line graph compare the ratio between PPP and MER data. EECCA = countries of Eastern Europe, the Caucasus and Central Asia.

Source: Van Vuuren and Alfsen, 2006.

What are emission scenarios?

- *A plausible quantitative description of how emissions in the future may develop, based on a coherent and internally consistent set of assumptions (“scenario logic”) about key relationships and driving forces.*
- *Emission scenarios are neither predictions nor forecasts.*



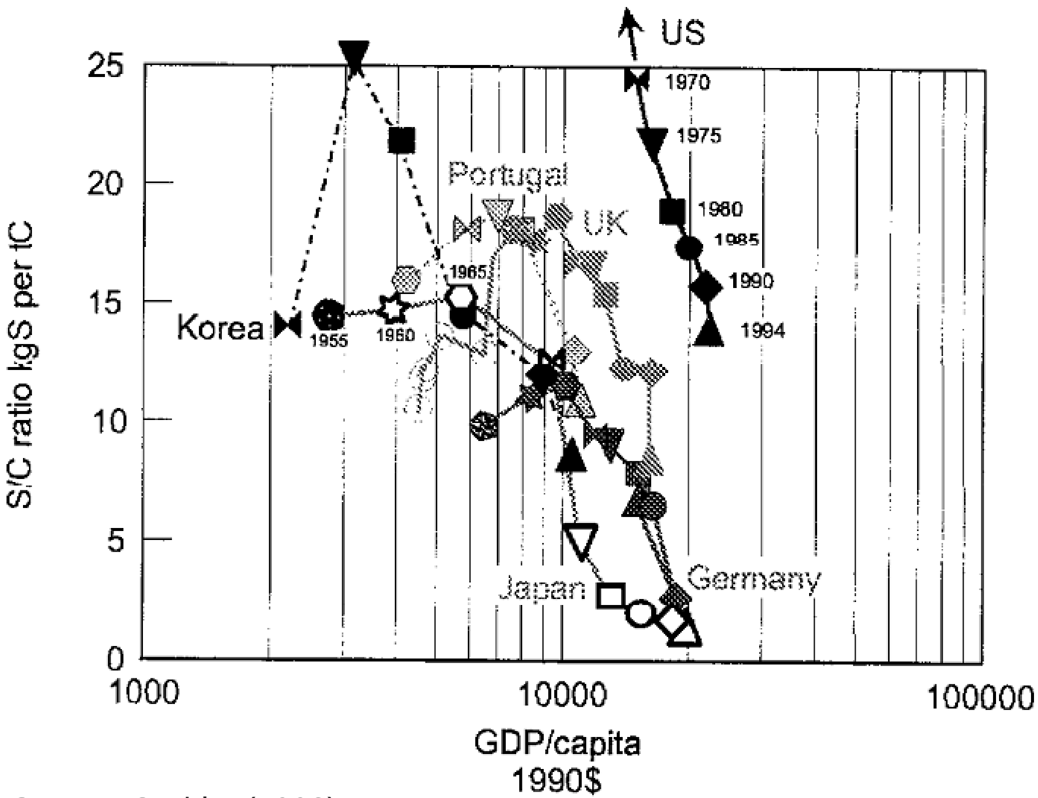
(adapted from IPCC)

General approaches for emission scenarios

- **socio-economic**
  - correlate emissions with socio-economic time series, such as GDP development, without accounting in detail for technological change
  - top-down approach
- **technology based**
  - considers explicitly technological change
  - emission factor approach is widely used, mainly due to the fact that technological change became a prevailing parameter
  - bottom-up approach, can be rather detailed and resource-intensive

Socio-economic, top-down approach

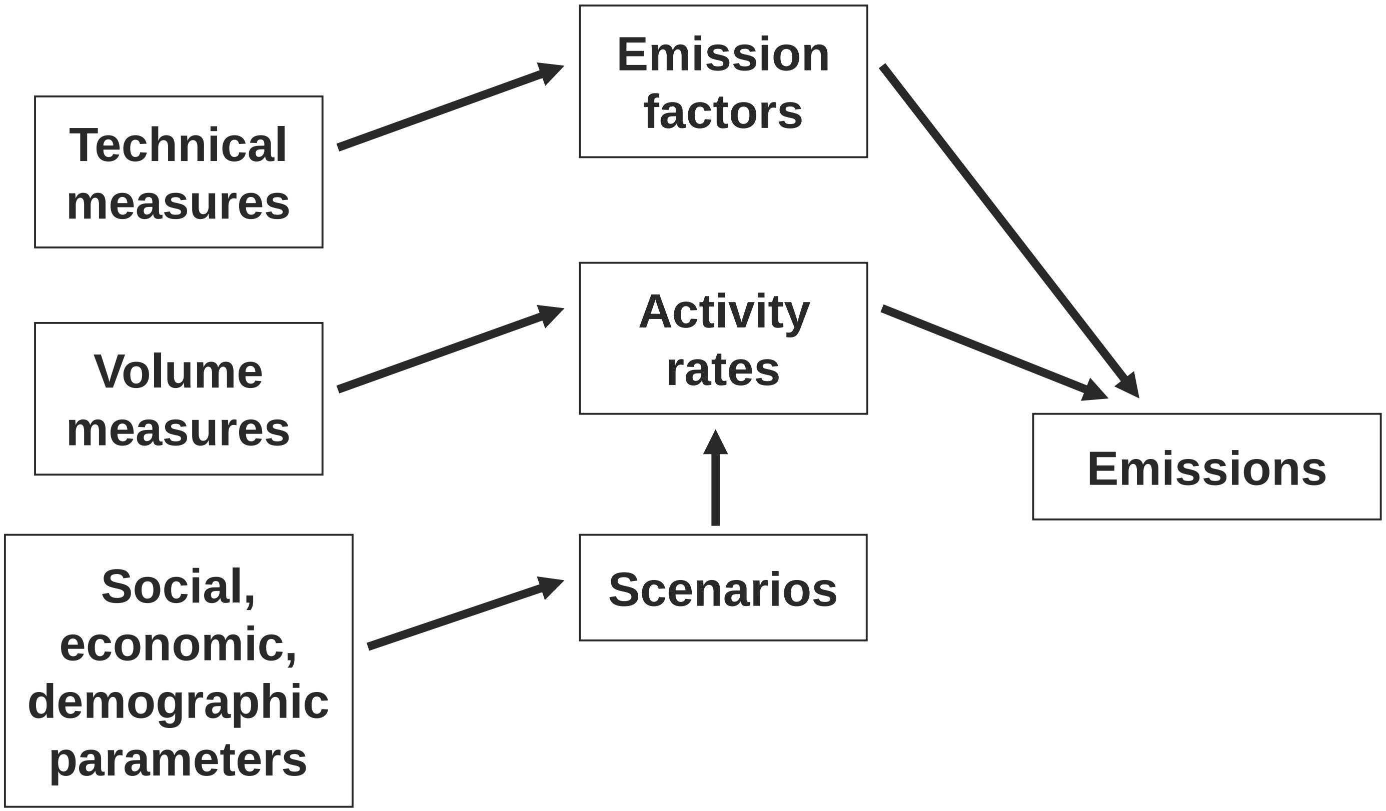
- **Ratio of sulphur to carbon emissions (in kg per ton C) as a function of GDP per capita**



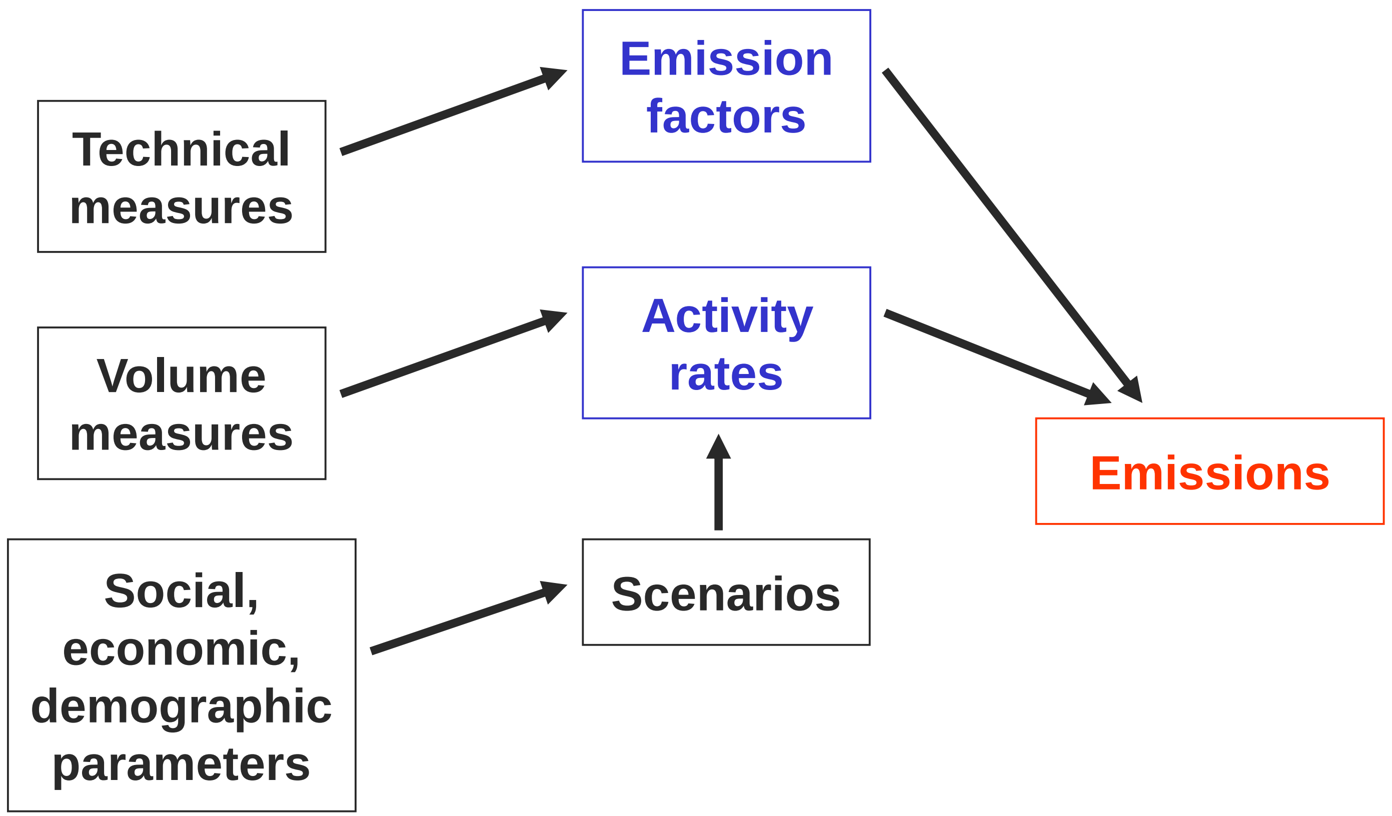
Source: Grübler (1998)

- Peak of sulphur to carbon emissions for early industrializing countries (UK, US, Germany) at around 10,000 $/capita
- Later industrializing countries experiences the peak at lower income levels, e.g. Japan at 6,000 $/capita and Korea at 3,000 $/capita

Technology-based, bottom-up approach



Technology-based, bottom-up approach



The fundamental formula

$$E = A \times \sum_{k=1}^{n} (F_k \times P_k)$$

E: emissions

A: activity rate

F: process level emission factors

P: activity share or penetration rate of a technology within a sector

k: technology type

Source: EEA

ne

Activity rate, e.g.

- electricity consumption (kWh)
- transport volume (Pkm / tkm)
- steel production (tons)

Process level emission factor, e.g.

- g_{SO2} / kWh_{el}
- g_{NOx} / tkm
- g_{SO2} / ton_{steel}

Activity shares or **penetration rates** of a technology (k) within a sector

- eventually determined by the behaviour of people
- legislative requirements
- technology acceptance
- etc.

$$E = A \times \sum_{k=1}^{n} (F_k \times P_k)$$

Sectoral emission factor

The fundamental formula

Data sources for emission inventories (PAST)

- A: national statistics
- F_k: measurements
- P_k: - national statistics - expert judgements

$$E = A \times \sum_{k=1}^{n} (F_k \times P_k)$$

E: emissions

A: activity rate

F: process level emission factors

P: activity share or penetration rate of a technology within a sector

k: technology type

The fundamental formula

Data sources for emission inventories (PAST)

national statistics

measurements

- national statistics
- expert judgements

$$E = A \times \sum_{k=1}^{n} (F_k \times P_k)$$

economic scenarios

technological investigation

- technological investigation
- financial economic basic assumptions
- behaviour projections

Data sources for emission projections / scenarios (FUTURE)

E: emissions

A: activity rate

F: process level emission factors

P: activity share or penetration rate of a technology within a sector

k: technology type

Key assumptions & data quality

- Some aspects of the future are relatively easy to predict
  - e.g. a 20 year old consumer of 2025 is already born
  - economic growth can be derived from the experience of other comparable economies in the past
  - long planning and investment horizons in the energy sector make this sector transform at slow rates
- In other fields, uncertainty is much higher
  - political stability and overall policy directions
  - energy and world oil prices
  - technological innovation

Emission scenarios…

- …are an important tool to design and assess emission reduction strategies, which aim at achieving given emission reduction targets in the future
- …help to evaluate alternative abatement options to achieve these targets within given scenarios of societal trends
- …help to allocate emission abatement measures in a temporal and spatial frame and to assess the future efficiency of a large variety of measures

The link between inventories and projections / scenarios

- Each emission projection must be based on an existing emission inventory as a starting point.

Data sources for emission inventories (PAST)

national statistics

measurements

- national statistics
- expert judgements

$$E = A \times \sum_{k=1}^{n} (F_k \times P_k)$$

economic scenarios

technological investigation

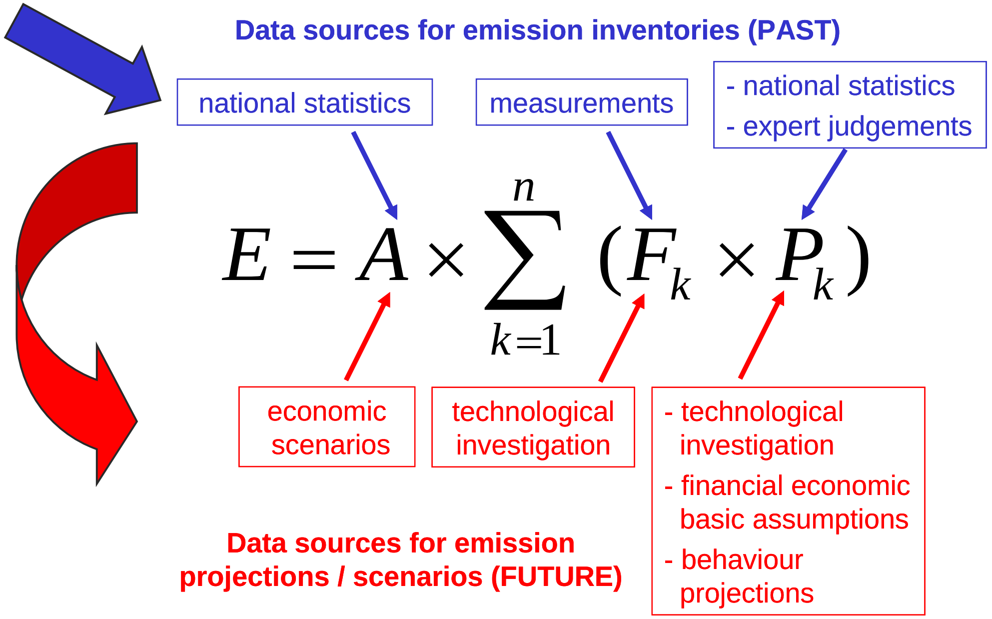
- technological investigation
- financial economic basic assumptions
- behaviour projections

Data sources for emission projections / scenarios (FUTURE)

The link between inventories and projections / scenarios

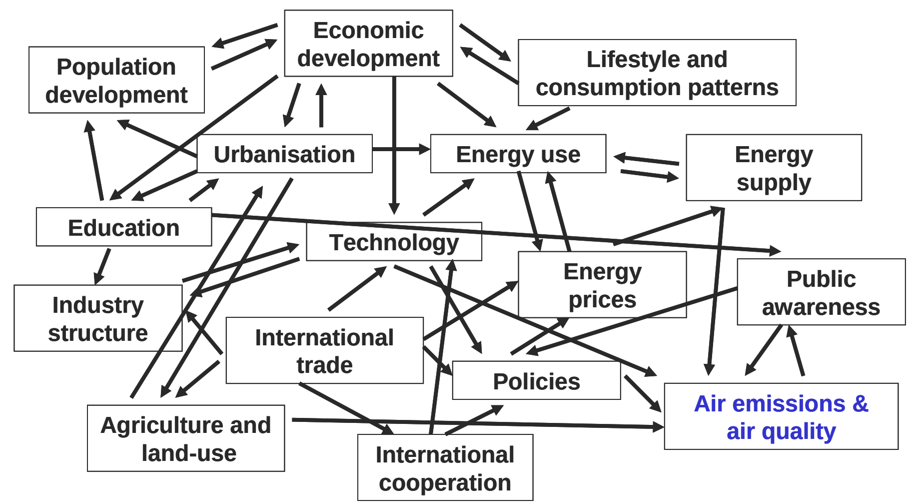
- Each emission projection must be based on an existing emission inventory as a starting point.

- The main difference between an emission inventory and an emission projection / scenario is the <u>time reference</u>.



There are many driving forces behind future emissions…

- Population
- Economic and social development
- Energy
- Technology
- Agriculture and land-use
- Policies



Data collection and modeling of causal interrelations is a big task!