

# IEA Energy Scenarios for India for 2030

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**Malé Declaration: Emission inventory preparation / scenarios / atmospheric transport modelling and soil acidification workshop  
UNEP RRCAP, Bangkok, Thailand. 28 January to 1 February 2008**

# Why building energy scenarios

- Energy sources contribute to a major share of the total emission load
  1. Combustion in the energy industries
  2. Combustion in manufacturing and constructing
  3. Transport
  4. Combustion in other sectors
  5. Fugitive emissions from fuels
  
- Questions to be answered by energy scenarios
  - Increase of energy demand
  - Change of fuel mix
  - Impact of technology change
  - Impact of policy intervention

# IEA Energy Scenarios for India

- Published in 2007
- Projection period: 2005 – 2030
- Identifying and quantifying the factors that will drive India's (and China's) energy balances and seeking to answer the question: how will their energy choices affect the world as a whole?
  - Energy prices
  - Energy security
  - Climate change issues

# IEA Energy Scenarios for India

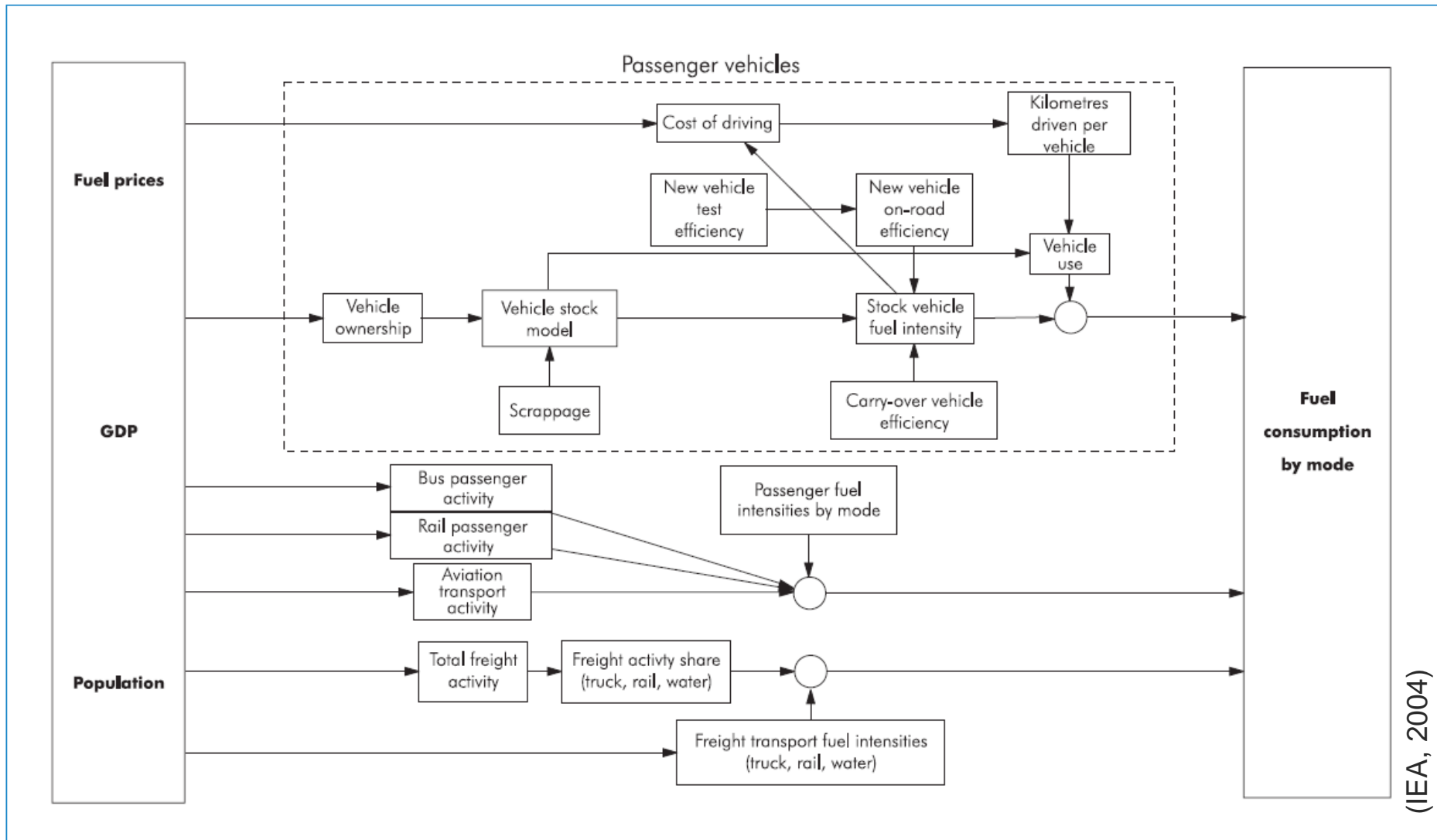
- Cooperation with the Energy and Resources Institute (TERI) in New Delhi and “other public and private bodies in India”

# The IEA World Energy Model (WEM)

- Large-scale mathematical model designed to replicate how energy markets function
- Incorporates detailed “bottom-up” sub-models of the energy system
- For India a rural urban breakdown in the residential sector has been introduced

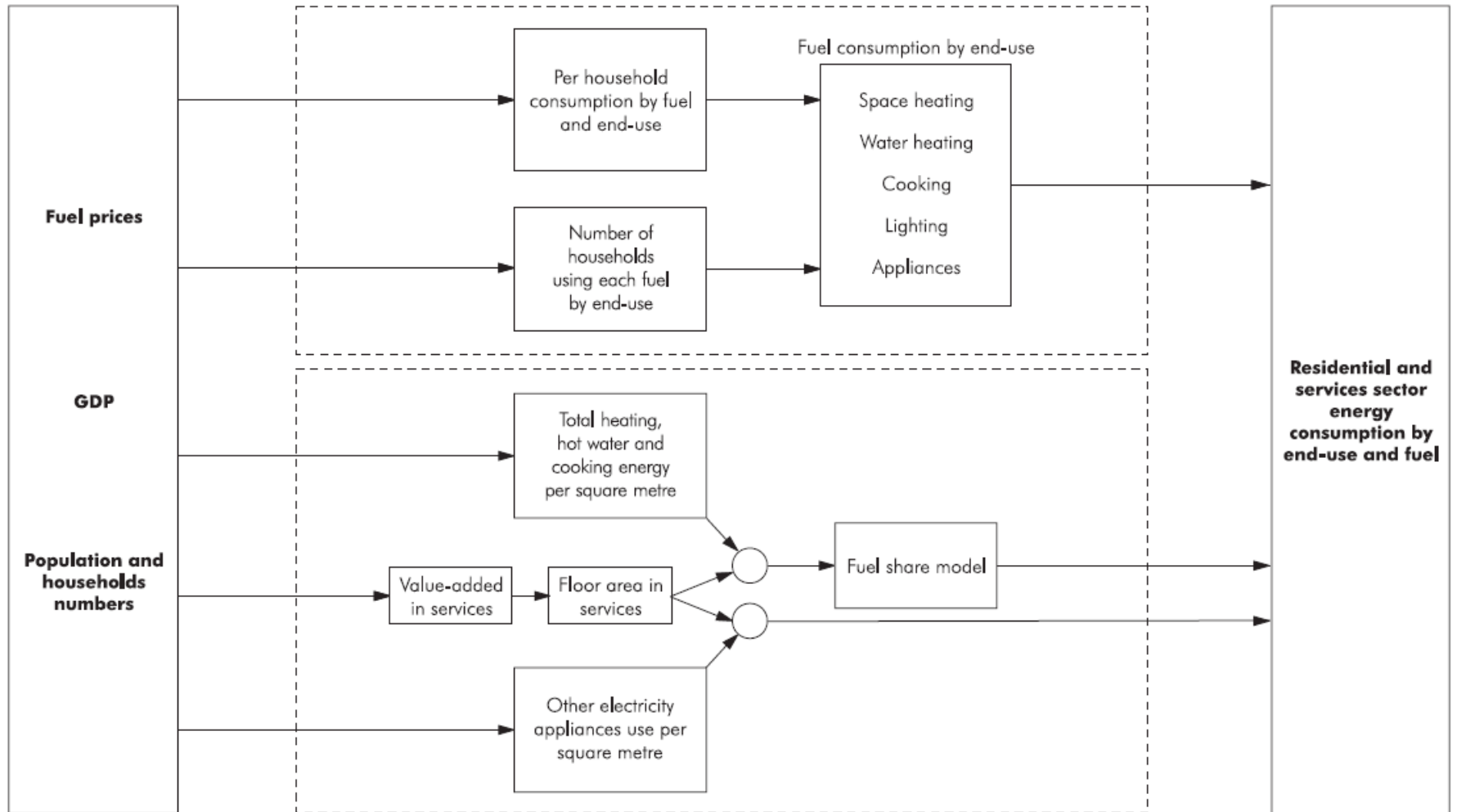
# WEM transport demand module

Figure C.3: Structure of the Transport Demand Module



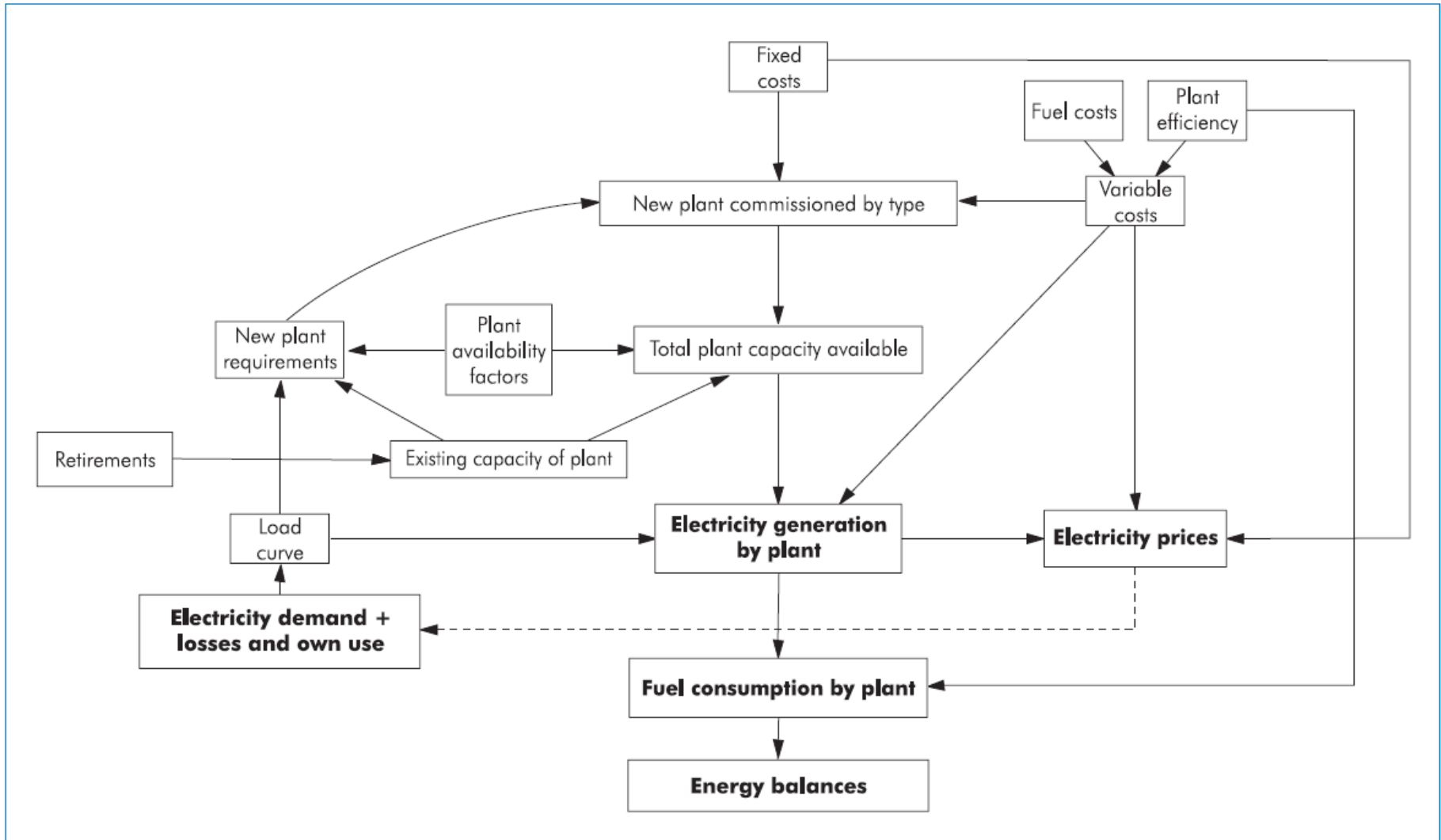
# WEM Residential and Services Sectors Demand Modules

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



# WEM power generation module

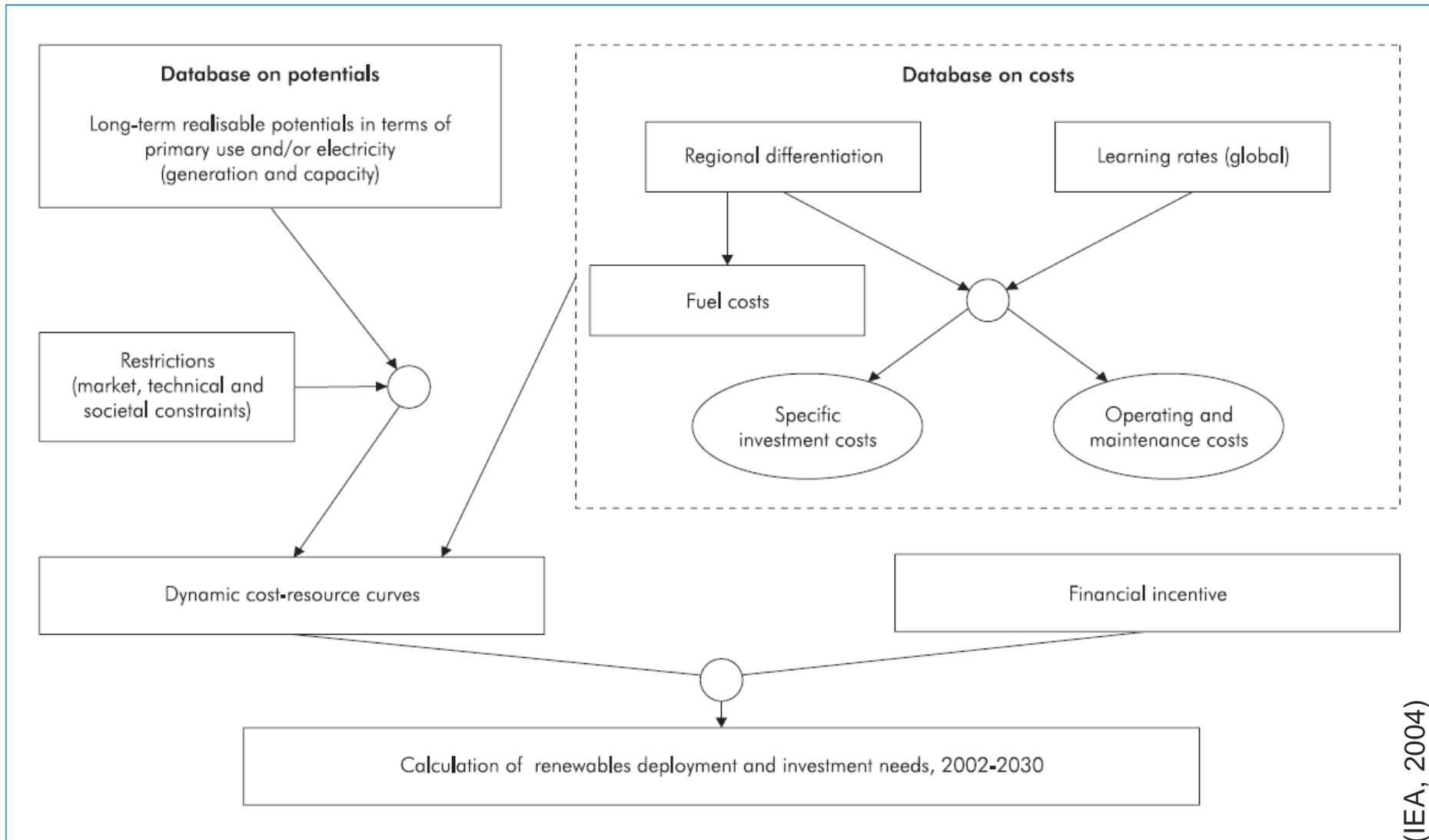
Figure C.5: Structure of the Power Generation Module





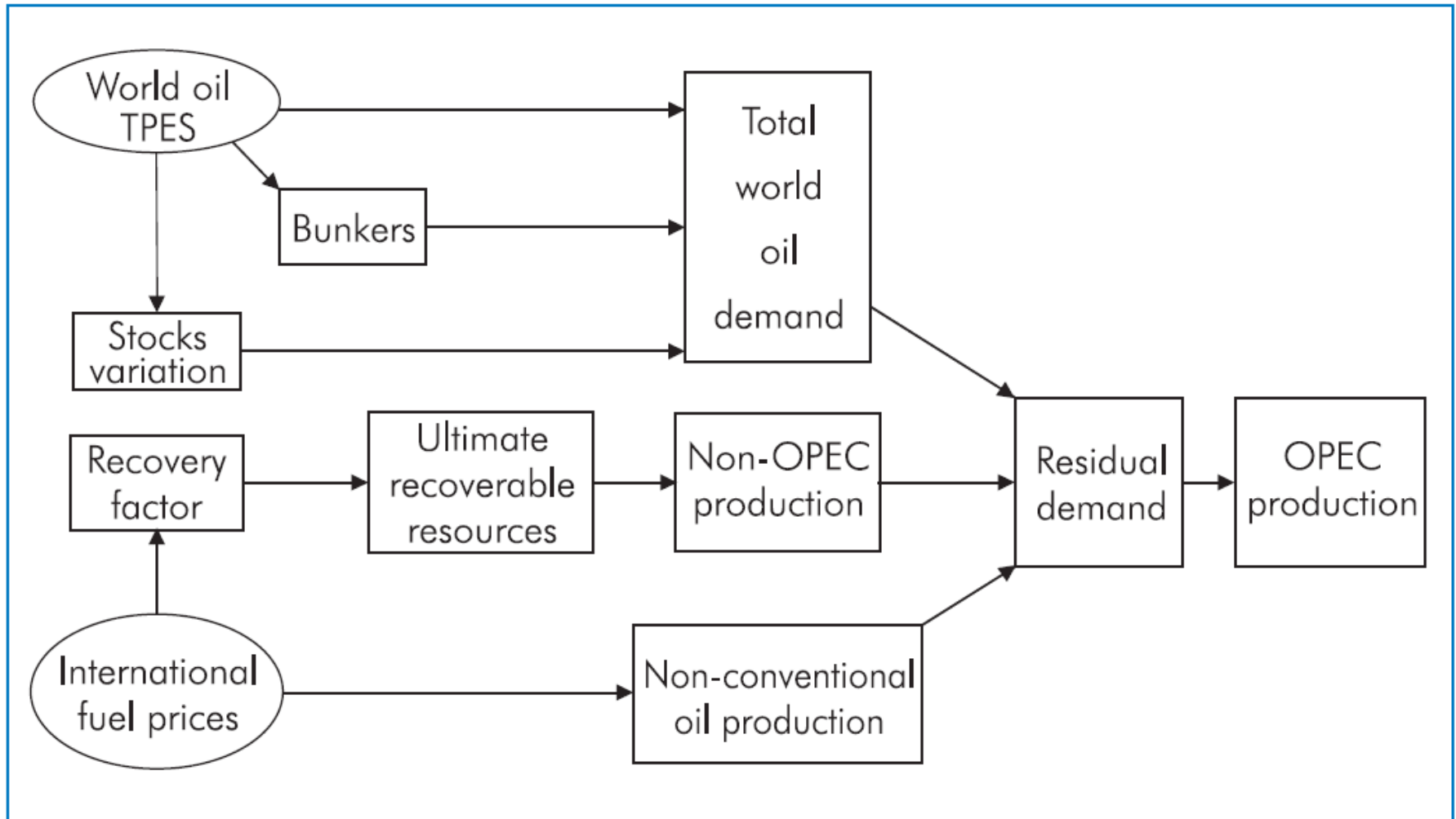
# WEM renewables module

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



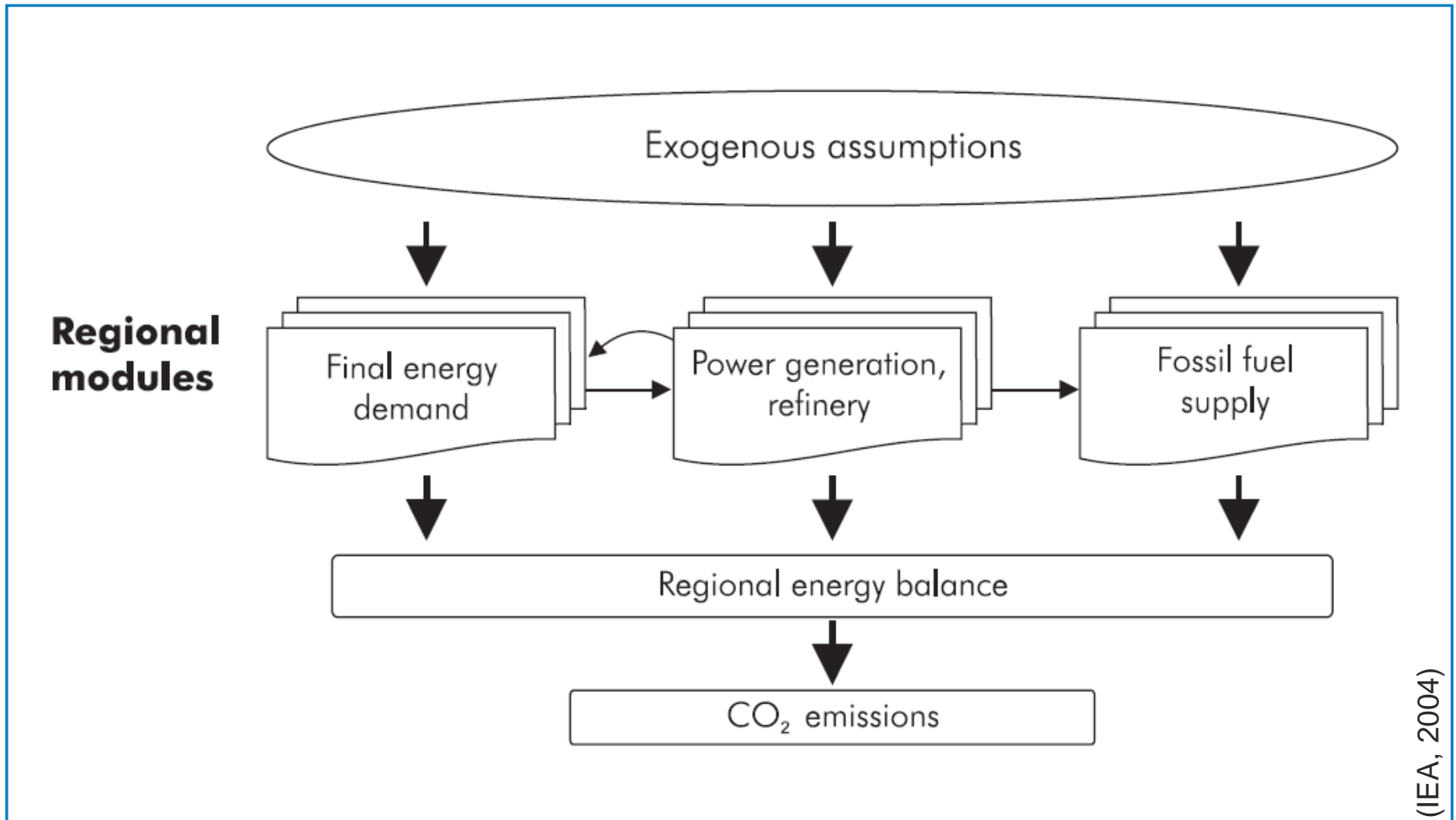
# WEM oil supply module

Figure C.7: Structure of Oil Supply Module



# The IEA World Energy Model (WEM)

Figure C.1: World Energy Model Overview



# Three scenarios

- **Reference Scenario 2030**
  - No new policy interventions by governments
  - Baseline vision of how global energy markets are likely to evolve if governments do nothing more to affect underlying trends in energy demand and supply
- **Alternative Policy Scenario 2030**
  - Analyses the impacts on global energy markets of a package of additional measures to address energy security and climate change-concerns
- **High Growth Scenario 2030**
  - Incorporates higher rates of economic growth in China and India, than those in the Reference Scenario

# Three scenarios

	<b>Reference Scenario</b>	<b>Alternative Policy Scenario</b>	<b>High Growth Scenario</b>
Target year	2030	2030	2030
Average GDP growth	+ 6.3 % per year	+ 6.3 % per year	+ 7.8 % per year
New policy intervention	No	Yes	No

# GDP growth in Reference and Alternative Policy Scenarios

Table 2: World Real GDP Growth in the Reference Scenario  
(average annual growth rates, %)

	1980-1990	1990-2005	2005-2015	2015-2030	2005-2030
<b>OECD</b>	3.0	2.5	2.5	1.9	2.2
North America	3.1	3.0	2.6	2.2	2.4
<i>United States</i>	3.2	3.0	2.6	2.2	2.3
Europe	2.4	2.1	2.4	1.8	2.0
Pacific	4.2	2.2	2.2	1.6	1.8
<i>Japan</i>	3.9	1.3	1.6	1.3	1.4
<b>Transition economies</b>	-0.5	-0.4	4.7	2.9	3.6
Russia	n.a.	-0.5	4.3	2.8	3.4
<b>Developing countries</b>	3.9	5.8	6.1	4.4	5.1
Developing Asia	6.6	7.3	6.9	4.8	5.6
<i>China</i>	9.1	9.9	7.7	4.9	6.0
<i>India</i>	5.8	6.0	7.2	5.8	6.3
Middle East	-0.4	4.2	4.9	3.4	4.0
Africa	2.2	3.0	4.5	3.6	3.9
Latin America	1.3	3.0	3.8	2.8	3.2
<i>Brazil</i>	1.5	2.6	3.5	2.8	3.1
<b>World</b>	2.9	3.4	4.2	3.3	3.6
<i>European Union</i>	n.a.	2.0	2.3	1.8	2.0

(IEA, 2007)

Note: These assumptions also apply to the Alternative Policy Scenario.

# India: GDP and population growth rates in Reference and Alternative Policy Scenarios

*Table 16.1: GDP and Population Growth Rates in India in the Reference Scenario* (average annual rate of change)

	1980-2005	1990-2005	2005-2015	2015-2030	2005-2030
GDP	5.9%	6.0%	7.2%	5.8%	6.3%
Population	1.9%	1.7%	1.4%	1.0%	1.1%
GDP per capita	4.0%	4.2%	5.7%	4.7%	5.1%

(IEA, 2007)

# Fuel prices in Reference and Alternative Policy Scenarios

Table 3: Fossil-Fuel Price Assumptions in the Reference Scenario  
(in year-2006 dollars per unit)

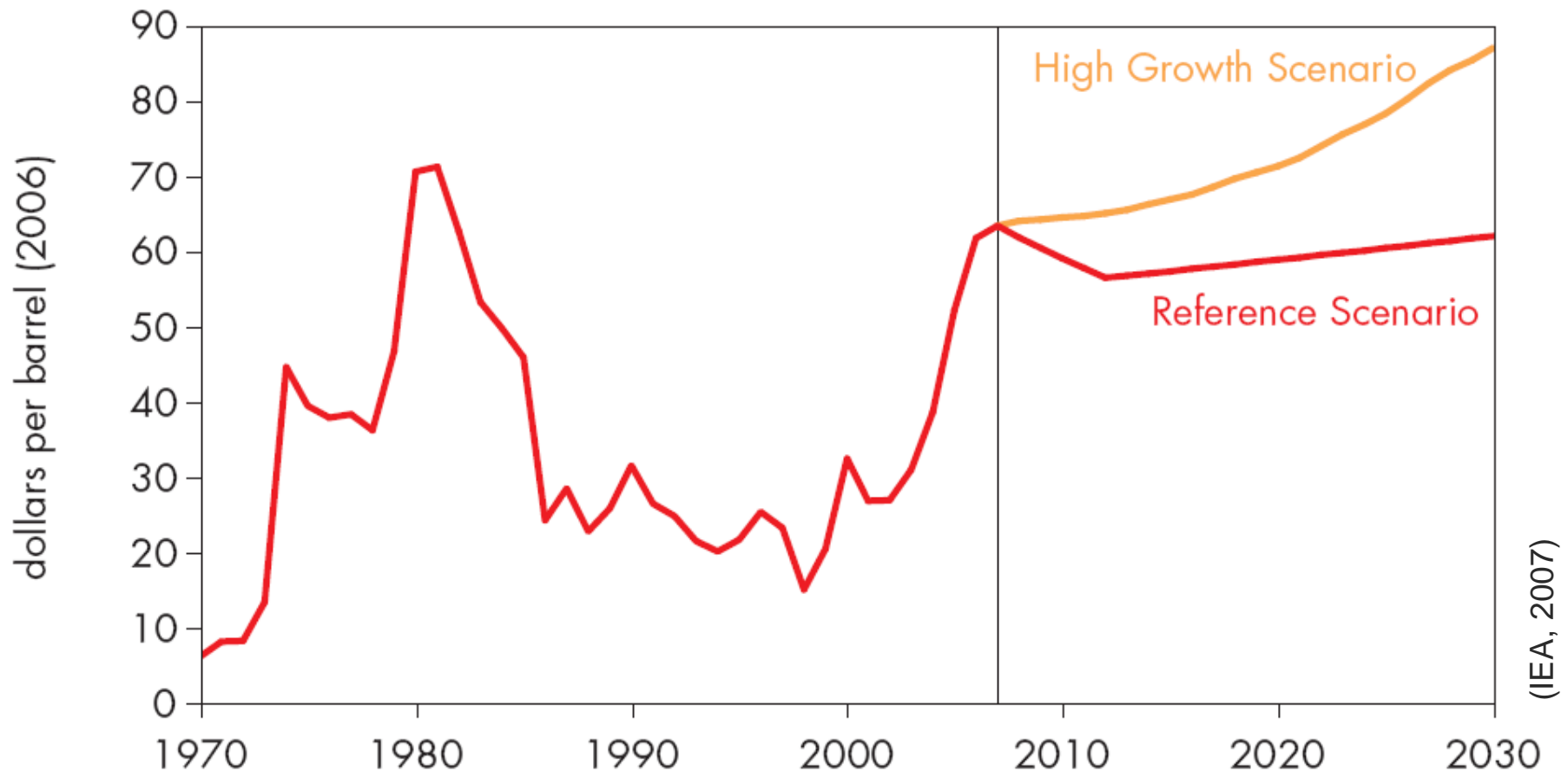
	unit	2000	2006	2010	2015	2030
<b>Real terms</b>						
<b>(year-2006 prices)</b>						
IEA crude oil imports	barrel	32.49	61.72	59.03	57.30	62.00
Natural gas						
<i>United States imports</i>	<i>MBtu</i>	<i>4.49</i>	<i>7.22</i>	<i>7.36</i>	<i>7.36</i>	<i>7.88</i>
<i>European imports</i>	<i>MBtu</i>	<i>3.27</i>	<i>7.31</i>	<i>6.60</i>	<i>6.63</i>	<i>7.33</i>
<i>Japanese LNG imports</i>	<i>MBtu</i>	<i>5.49</i>	<i>7.01</i>	<i>7.32</i>	<i>7.33</i>	<i>7.84</i>
OECD steam coal imports	tonne	39.05	62.87	56.07	56.89	61.17
<b>Nominal terms</b>						
IEA crude oil imports	barrel	28.00	61.72	65.00	70.70	107.59
Natural gas						
<i>United States imports</i>	<i>MBtu</i>	<i>3.87</i>	<i>7.22</i>	<i>8.11</i>	<i>9.08</i>	<i>13.67</i>
<i>European imports</i>	<i>MBtu</i>	<i>2.82</i>	<i>7.31</i>	<i>7.27</i>	<i>8.18</i>	<i>12.71</i>
<i>Japanese LNG imports</i>	<i>MBtu</i>	<i>4.73</i>	<i>7.01</i>	<i>8.06</i>	<i>9.05</i>	<i>13.61</i>
OECD steam coal imports	tonne	33.65	62.87	61.74	70.19	106.14

Note: Prices in the first two columns represent historical data. Gas prices are expressed on a gross calorific-value basis. All prices are for bulk supplies exclusive of tax. Nominal prices assume inflation of 2.3% per year from 2007.



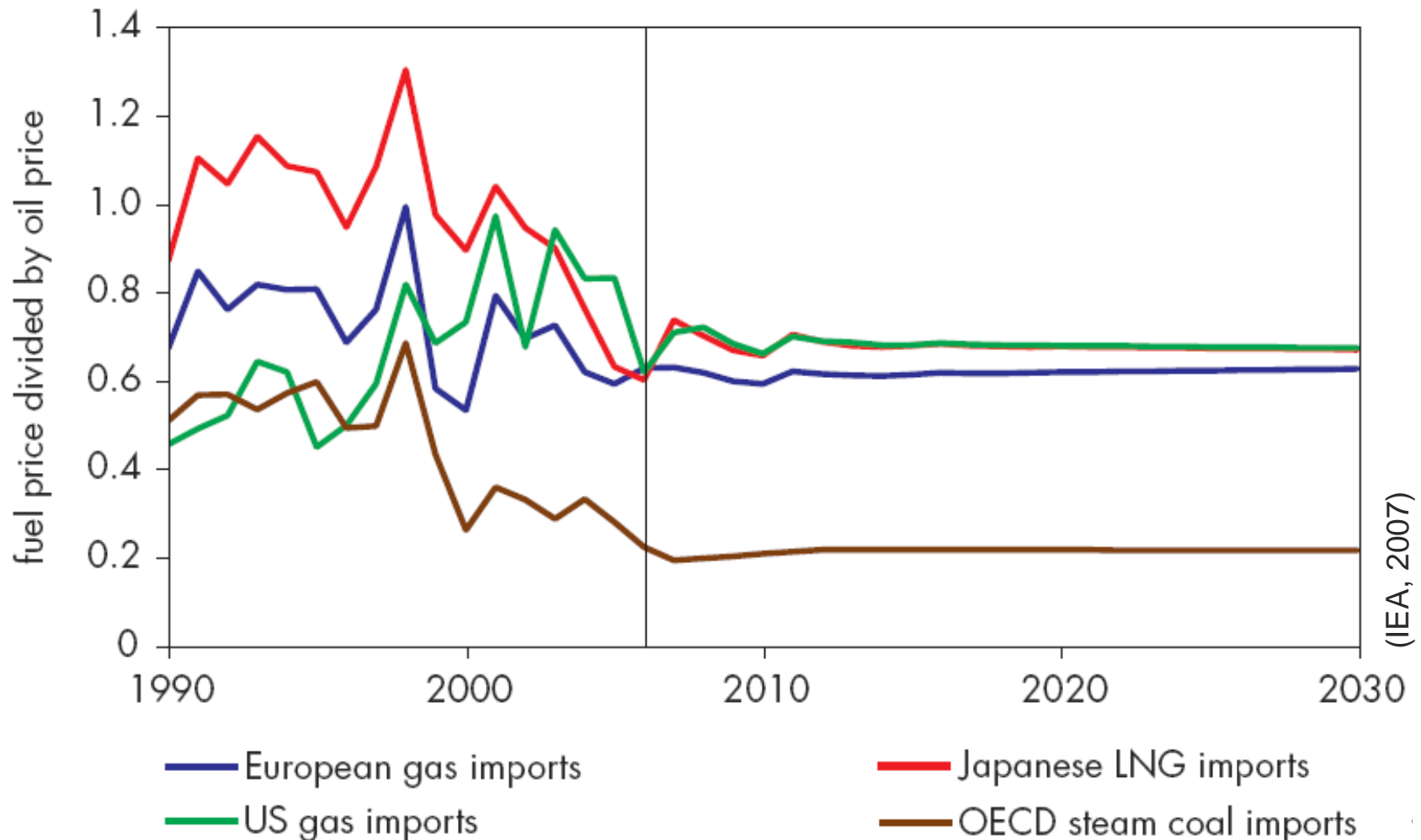
# Average IEA crude oil import price in the scenarios

Figure 4.9: Average IEA Crude Oil Import Price in the Reference and High Growth Scenarios



# Relative fuel price assumptions

Figure 2: Assumed Ratio of Natural Gas and Implied Relation of Coal Prices to Oil Prices in the Reference Scenario



# Alternative Policy Scenario

- Macroeconomic and population assumptions are the same as in the Reference Scenario
- Only policies aimed at enhancing energy security and/or addressing environmental problems including climate change are considered

# SCENARIO OUTCOMES

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# Scenario outcomes: energy demand

*Table 16.2: Indian Primary Energy Demand in the Reference Scenario (Mtoe)*

	1990	2000	2005	2015	2030	2005-2030*
Coal	106	164	208	330	620	4.5%
Oil	63	114	129	188	328	3.8%
Gas	10	21	29	48	93	4.8%
Nuclear	2	4	5	16	33	8.3%
Hydro	6	6	9	13	22	3.9%
Biomass	133	149	158	171	194	0.8%
Other renewables	0	0	1	4	9	11.7%
<b>Total</b>	<b>320</b>	<b>459</b>	<b>537</b>	<b>770</b>	<b>1 299</b>	<b>3.6%</b>
<i>Total excluding biomass</i>	<i>186</i>	<i>311</i>	<i>379</i>	<i>599</i>	<i>1 105</i>	<i>4.4%</i>

\* Average annual rate of growth.

(IEA, 2007)

# Alternative Policy Scenario

- The Reference Scenario takes account of only those policies already enacted or in place.
- In the Alternative Policy Scenario, **80 additional polices and measures** for India covering all energy sectors are introduced.
  - Reflect the proposals under discussion in India in the current energy-policy debate.
- These policies result in a **reduction of dependence on coal and oil** and in the **faster deployment of more efficient and cleaner energy technologies**

# Key policies in India's power generation sector in the Alternative Policy Scenario

Policy/measure	Assumption
Integrated Energy Policy recommendation to increase coal plant efficiency from 30.5% to 39%	Two percentage points higher efficiency for new plant compared to Reference Scenario
Development of IGCC programme	More R&D, IGCC becomes available in 2020
Renovation of electricity networks, Accelerated Power Development and Reform Programme (APDRP)	Six percentage point decline in losses compared to Reference Scenario in 2030
R&M (renovation and modernisation) programme of power stations	One percentage point efficiency improvement of existing coal-fired power stations
Greater use of hydropower	Approaches full economic potential by 2030
New and Renewable Energy Policy Statement 2005 - Draft II, Rural Electricity Supply Technology (REST) Mission, Remote Village Electrification Programme (RVE)	Faster deployment of renewable energy technologies through incentives
Expand use of nuclear	24 GW by 2030

# Key policies in India's **industry sector** in the Alternative Policy Scenario

Policy/measure	Assumption
National Steel Policy – aims to reduce costs and improve efficiency and productivity in the iron and steel sector	Efficiency improves by 15% over Reference Scenario
Greater use of CHP	Increased use of biomass potential in CHP
Higher efficiency processes in energy-intensive industries, particularly cement	Reduction in energy intensity of cement industry of 3% per year
Energy Conservation Act 2001	Stricter enforcement; increased efficiency of motors by 15%

(IEA, 2007)



# Key policies in India's transport sector in the Alternative Policy Scenario

Measure	Description	Assumption
Fuel economy standards for LDVs	India has yet to enact fuel economy standards.	10% increase over all vehicles compared with Reference Scenario.
Vehicle emission standards	Following the European Vehicle Emission Standards (see Table 16.3 for details).	Impact on pollution and CO <sub>2</sub> emissions, secondary impact on fuel consumption.
Biofuels	5% ethanol blended gasoline was introduced in 9 states and 4 union territories in 2003, and was reintroduced and extended nationwide in 2006, although subject to availability.	Ethanol share in gasoline increases to 10% in 2012*. Biodiesel blending in diesel starts in 2009, increasing to 5% by 2015 and 8% share by 2018.
CNG	All commercial vehicles in Delhi, Mumbai and Kolkata run on CNG.	Doubling of CNG vehicles compared with Reference Scenario.
Public transport and infrastructure development	Construction of bus lanes and suburban and underground rail systems to ease road congestion.	5% increase in the number of buses (+200 000) compared with Reference Scenario in 2030.

(IEA, 2007)

# Key policies in India's residential and service sectors in the Alternative Policy Scenario

Measure	Description	Assumption
Building codes & standards	Set minimum requirements for the energy-efficient design and construction of commercial buildings or complexes with electricity load of 500 kW or capacity of 600 kVA or more.	Greater building stock efficiency improvements.
Energy efficiency labelling	Mandatory labelling covers frost-free refrigerators and tubular fluorescent lamps. Labelling for other products will be introduced in a phased manner.	50% of all light bulbs are CFLs in 2030; average appliance efficiency is 30% higher in 2030.
Improved cookstoves (chulhas)	Installation of improved chulhas in rural and semi-urban households.	120 million improved cookstoves by 2030, scale-up of the pilot programmes.
Biogas	Promote family type biogas units for recycling of cattle dung to harness its fuel value without destroying manure value.	12 million biogas plants by 2030.
Solar devices	Construction of solar water heating systems, solar air heating/steam generating systems for community cooking.	Increased penetration of solar water heaters.

(IEA, 2007)

# Alternative Policy Scenario

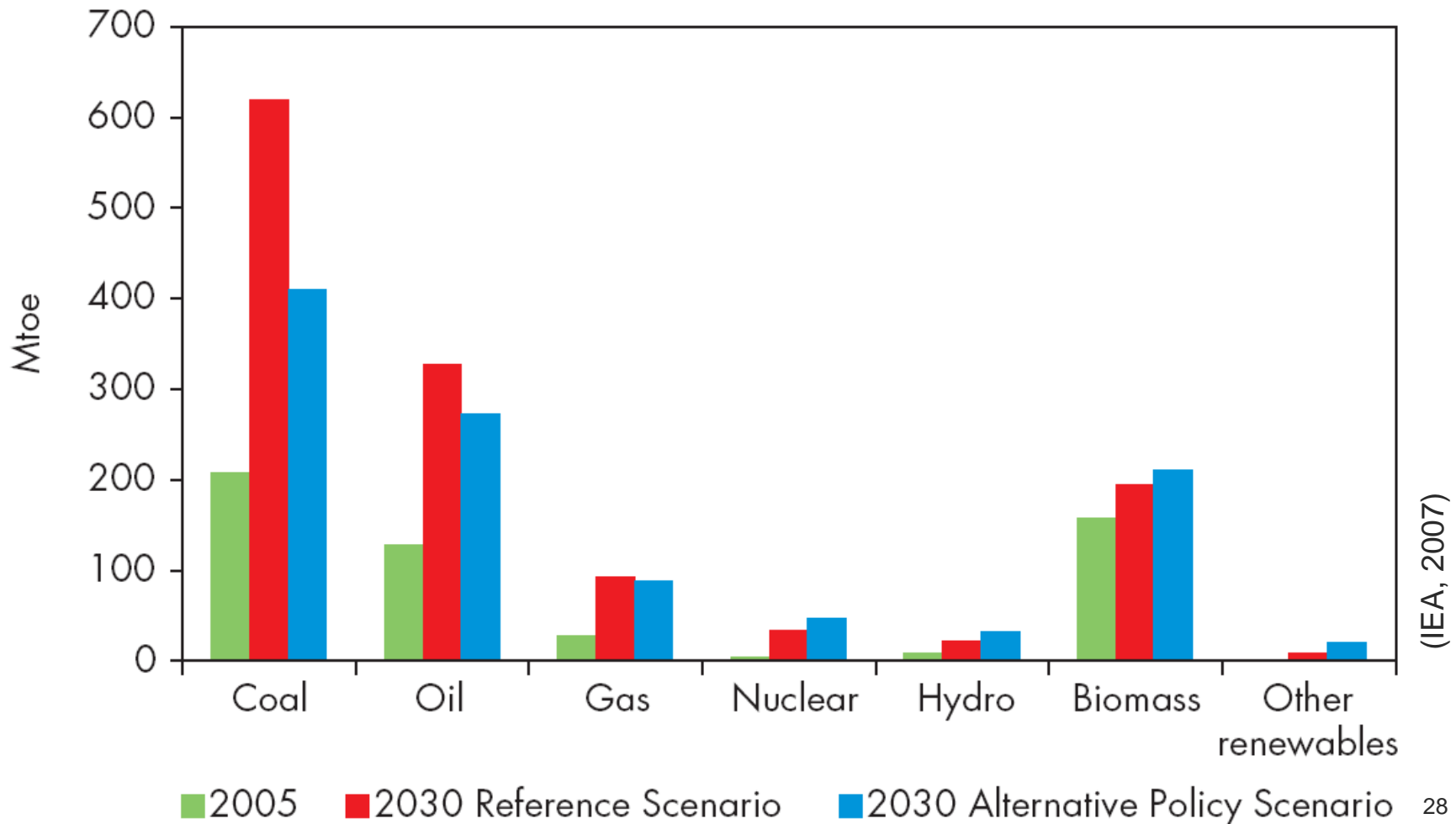
*Table 18.1: India's Primary Energy Demand in the Alternative Policy Scenario (Mtoe)*

	2005	2015	2030	2005-2030*	Difference from the Reference Scenario in 2030	
					Mtoe	%
Coal	208	289	411	2.8%	-209	-33.7
Oil	129	173	272	3.0%	-56	-17.1
Gas	29	47	89	4.6%	-4	-4.3
Nuclear	5	19	47	9.9%	14	41.9
Hydro	9	17	32	5.3%	9	42.3
Biomass	158	168	211	1.2%	17	8.5
Other renewables	1	6	21	15.8%	12	145.5
<b>Total</b>	<b>537</b>	<b>719</b>	<b>1 082</b>	<b>2.8%</b>	<b>-217</b>	<b>-16.7</b>

\* Average annual rate of growth.

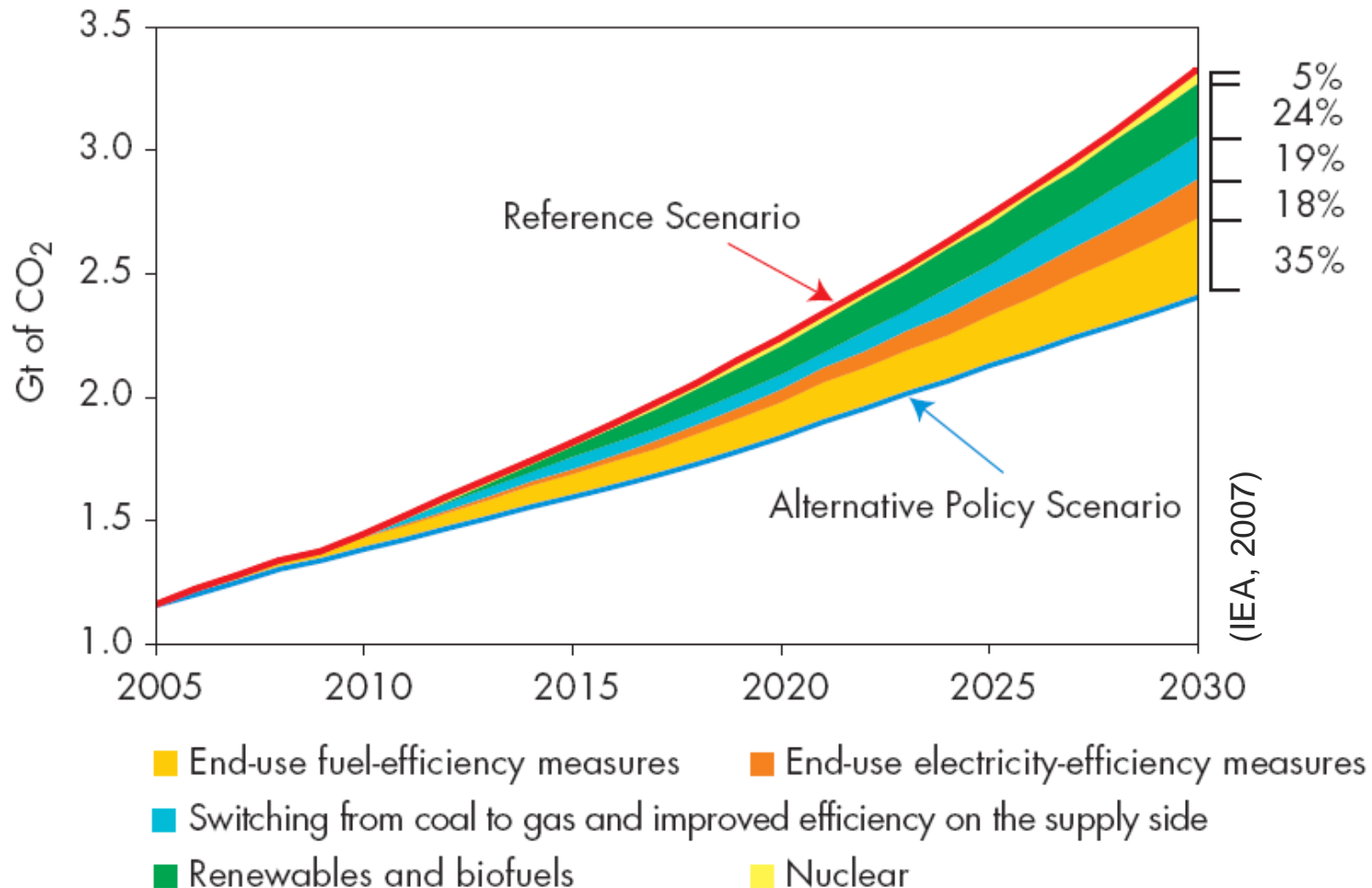
# Alternative Policy Scenario

Figure 18.1: India's Energy Demand in the Reference and Alternative Policy Scenarios



# CO<sub>2</sub>-emissions

Figure 18.4: India's CO<sub>2</sub> Emissions in the Alternative Policy Scenario Compared with the Reference Scenario



# SO<sub>2</sub>, NO<sub>x</sub> and PM<sub>2.5</sub> emissions

*Table 16.5: Local Air Pollutant Emissions in India  
in the Reference Scenario (kilotonnes)*

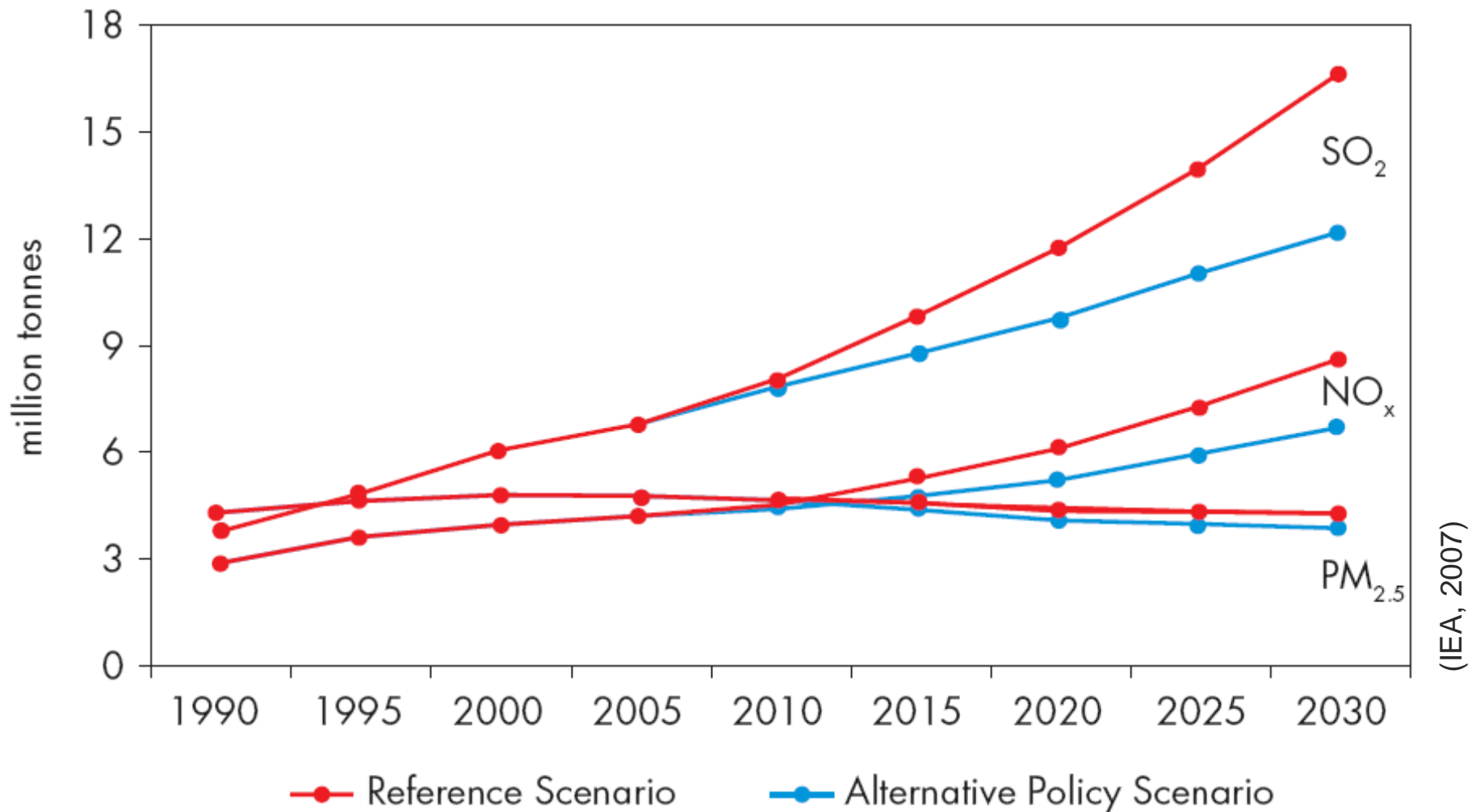
	1990	2005	2015	2030	2005- 2030*
SO <sub>2</sub>	3 668	6 699	9 759	16 546	3.7%
NO <sub>x</sub>	2 791	4 109	5 165	8 528	3.0%
PM <sub>2.5</sub>	4 206	4 681	4 469	4 192	-0.4%

\* Average annual rate of growth.

(IEA, 2007)

# SO<sub>2</sub>, NO<sub>x</sub> and PM<sub>2.5</sub> emissions

Figure 18.3: Local Air Pollutant Emissions in India in the Reference and Alternative Policy Scenarios



# A more detailed look at some sectors

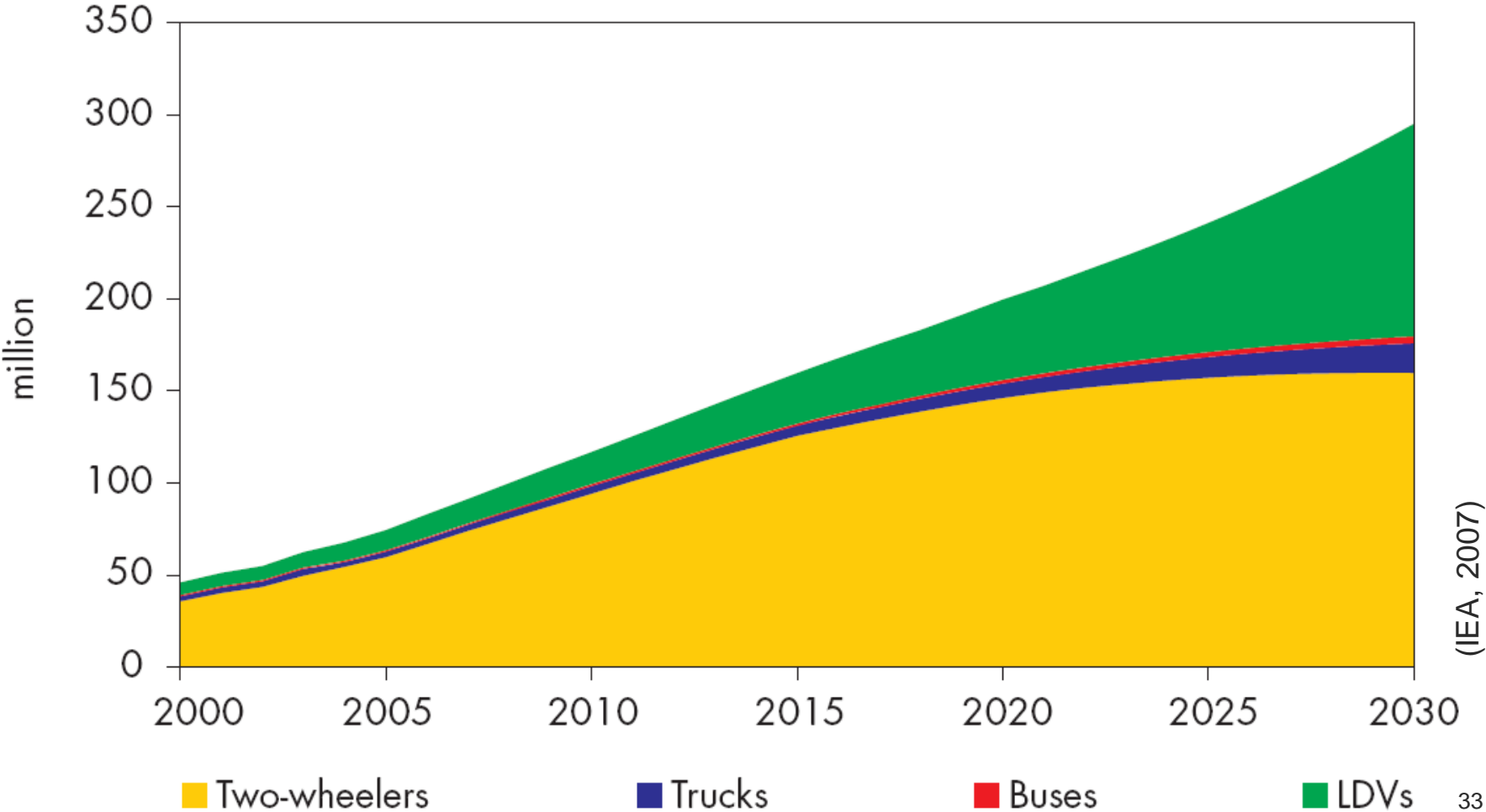
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- Transport sector
- Power sector



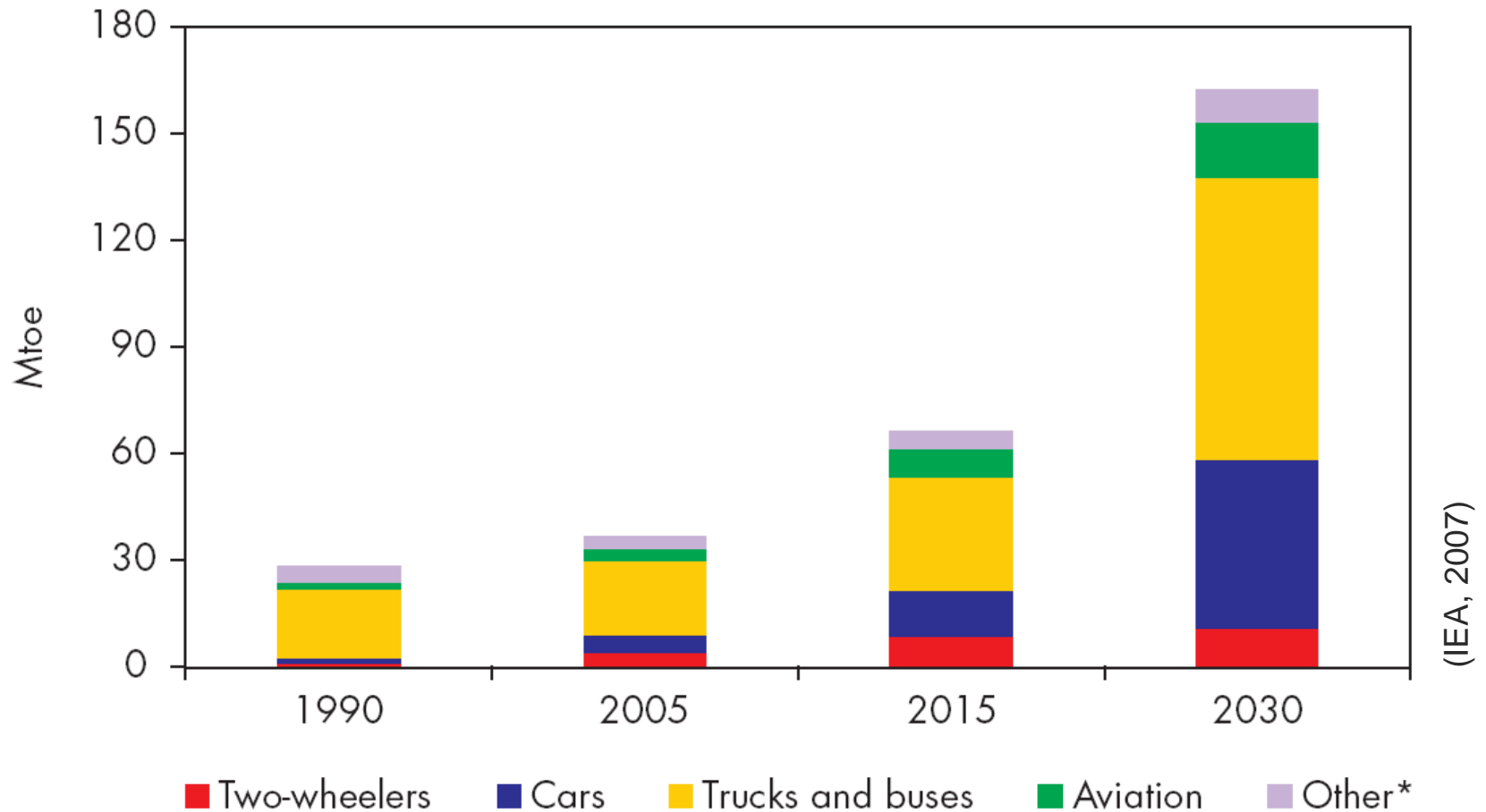
# India's vehicle stock in the Reference Scenario

Figure 16.5: India's Vehicle Stock in the Reference Scenario



# Transport energy demand in the Reference Scenario

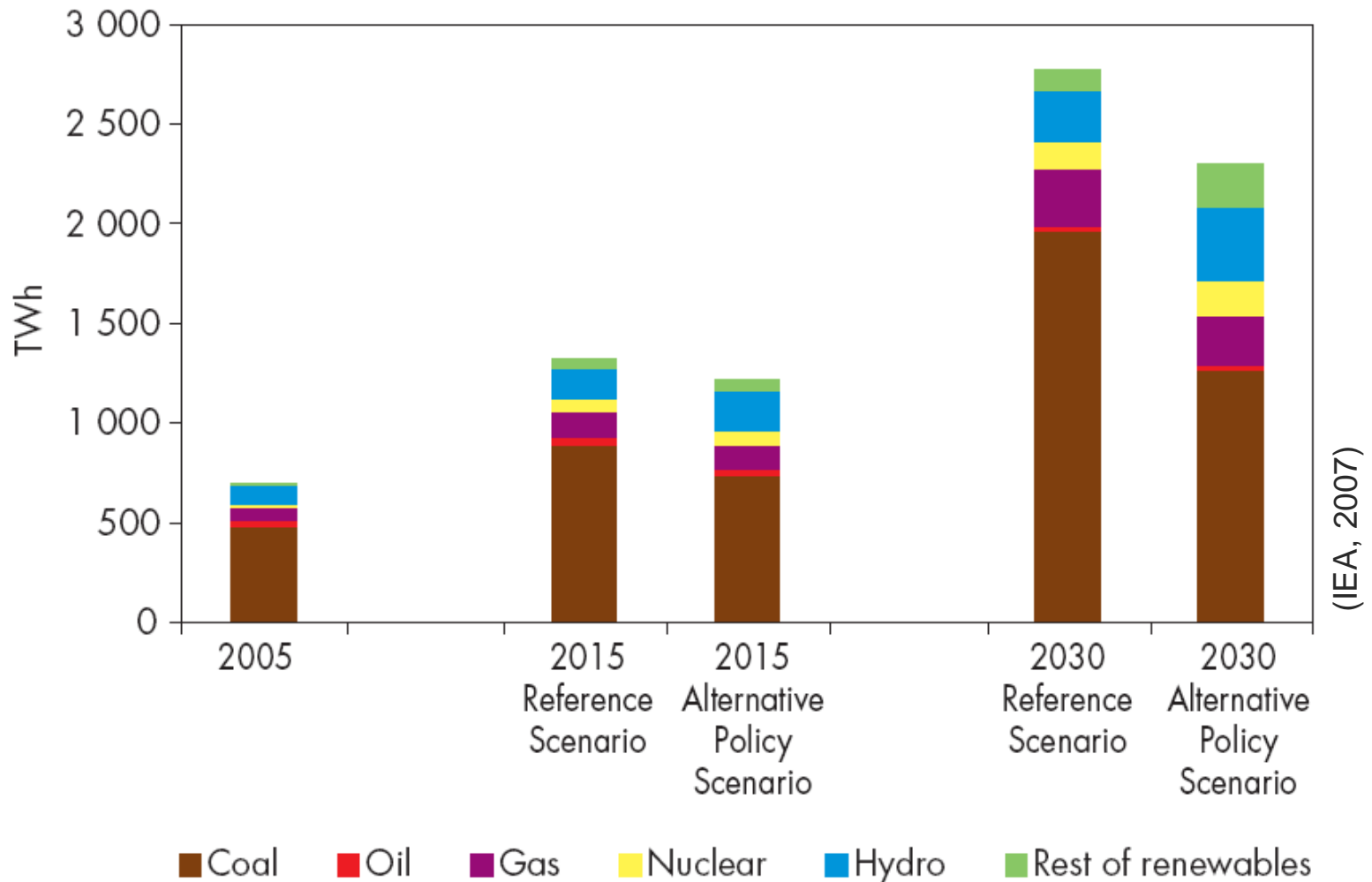
Figure 16.4: India's Transport Energy Demand by Mode in the Reference Scenario



\* Refers to rail, pipeline and navigation.

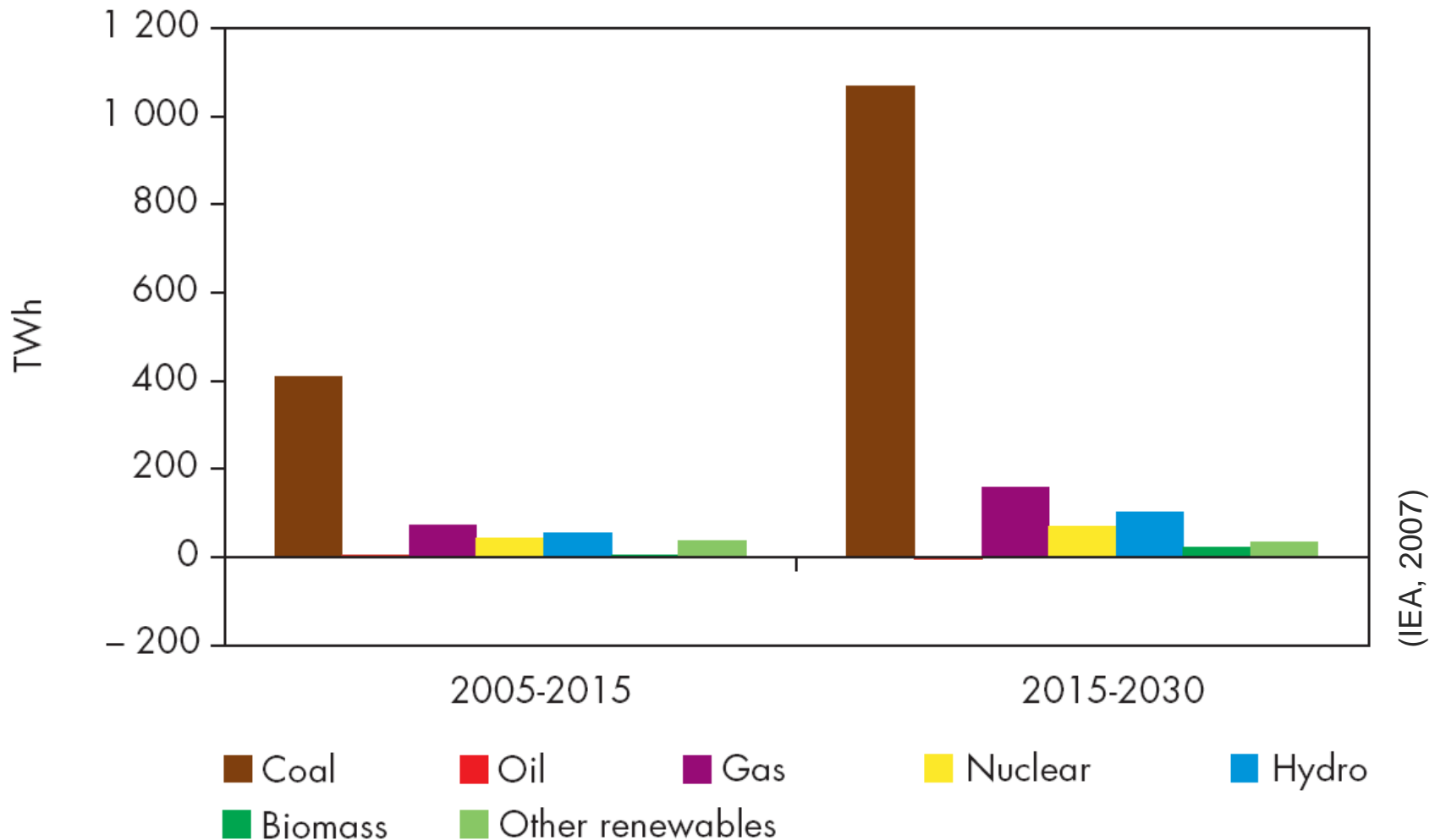
# India's power generation mix

Figure 18.6: India's Power Generation Fuel Mix in the Reference and Alternative Policy Scenarios



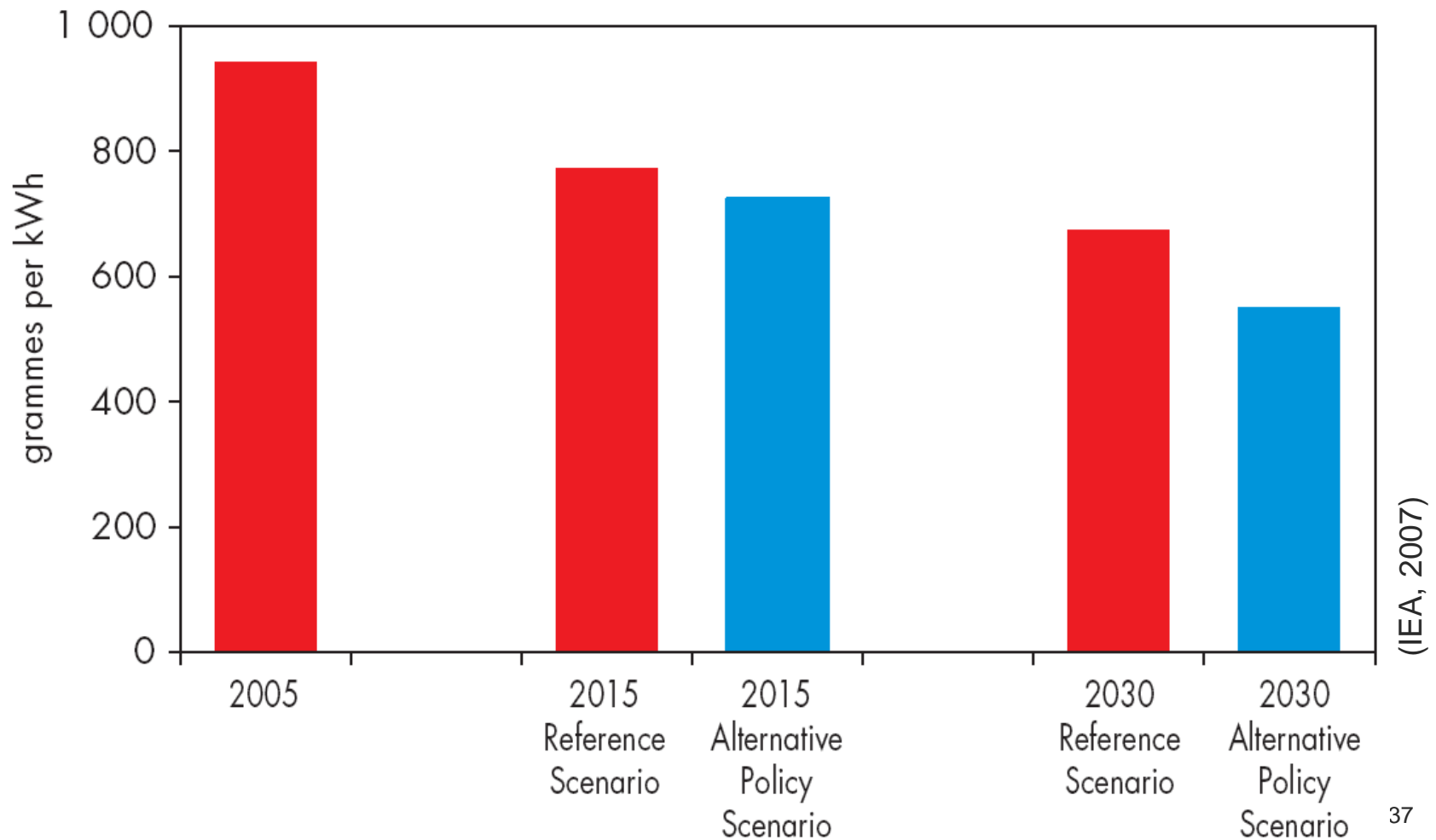
# Changes in power generation mix

Figure 17.11: Changes in India's Electricity Generation Mix in the Reference Scenario



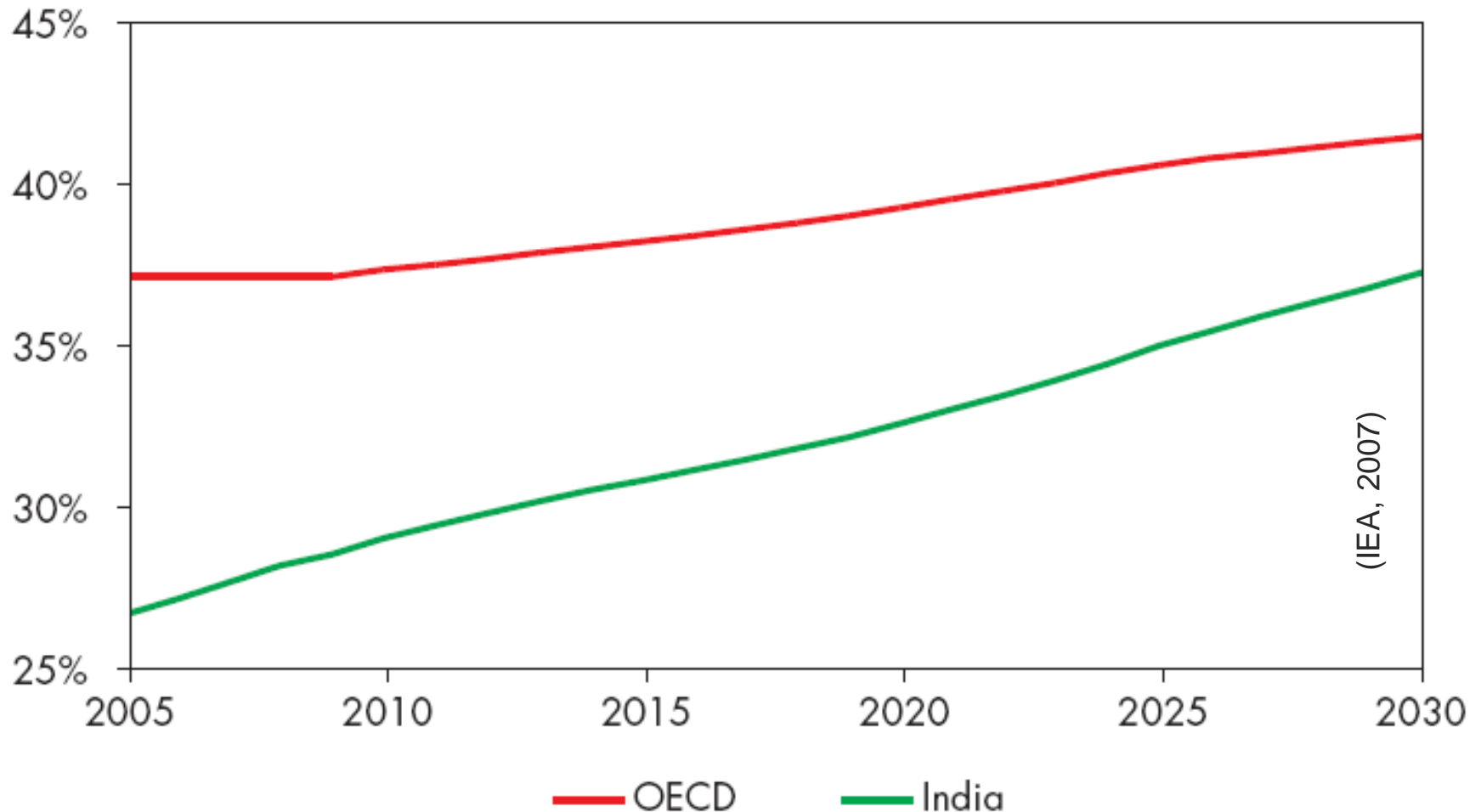
# CO<sub>2</sub>-intensity of India's power generation

Figure 18.5: CO<sub>2</sub> Intensity of India's Electricity Generation in the Reference and Alternative Policy Scenarios



# Power plant efficiency in Alternative Policy Scenario

Figure 18.7: Average Coal-Fired Power Plant Efficiency in India Compared with the OECD in the Alternative Policy Scenario



# Coal-fired power plant technology in India

- Efficiency of India's coal fired power plants is in the range of 27% - 30%, considerably lower than the OECD average of 37%
- On average, efficiency is expected to increase from 27% now to 38% in 2030 (compared to OECD average of 42% in 2030)
- In the Reference Scenario, no integrated gasification combined cycle (IGCC) plants nor Carbon Capture and Storage (CSS) facilities are expected to be built before 2030

# Coal-fired power plant technology in India

- The main supplier of coal-fired power plants in India is Bharat Heavy Electricals Ltd. (BHEL)
  - “it is likely to maintain its dominant position in the future” (IEA, 2007)
  - manufacturers from industrialised countries are more prominent in the provision of gas turbines and hydro plants.
- BHEL's R&D expenditure is around 1% of sales, while internationally this ratio is between 1.8 and 6%.
  - “Many uncertainties exist as to the rate at which BHEL will be able to expand its manufacturing capacity and when it will be in a position to produce far more efficient power plants, notably supercritical ones.”
- With increasing demand for coal-fired power stations, it is likely that more plant purchases will have to be made from other manufacturers.
  - “**Competition between manufacturers** is likely to encourage innovation” (IEA, 2007)
  - Doosan Heavy Industries of Korea has been selected as supplier of five boilers for the 4 GW Mundra project



# Electricity losses in transmission and distribution (T&D)

- losses in electricity transmission and distribution and internal power plant consumption account to 32% in India (2005)
- insufficient investments in, and poor maintenance of, networks
- electricity theft



# High Growth Scenario

- In the **High Growth Scenario**, GDP growth in India is assumed to average **7.8% per year** in 2005-2030
  - compared with 6.3% in the Reference Scenario
- Illustrates the potential impact on energy demand and energy related emissions of higher economic growth than in the Reference Scenario

# High Growth Scenario

*Table 19.2: India's Energy Demand in the High Growth Scenario (Mtoe)*

	2005	2015	2030	2005-2030*	Difference from the Reference Scenario in 2030	
					Mtoe	%
Coal	208	337	700	5.0%	79.9	12.9
Oil	129	204	416	4.8%	88.3	26.9
Gas	29	61	136	6.4%	43.2	46.7
Nuclear	5	17	40	9.2%	6.9	20.7
Hydro	9	14	24	4.1%	1.4	6.3
Biomass and waste	158	167	183	0.6%	-11.6	-6.0
Other renewables	1	5	10	12.3%	1.1	13.2
<b>Total</b>	<b>537</b>	<b>804</b>	<b>1 508</b>	<b>4.2%</b>	<b>209.2</b>	<b>16.1</b>

\* Average annual rate of growth.

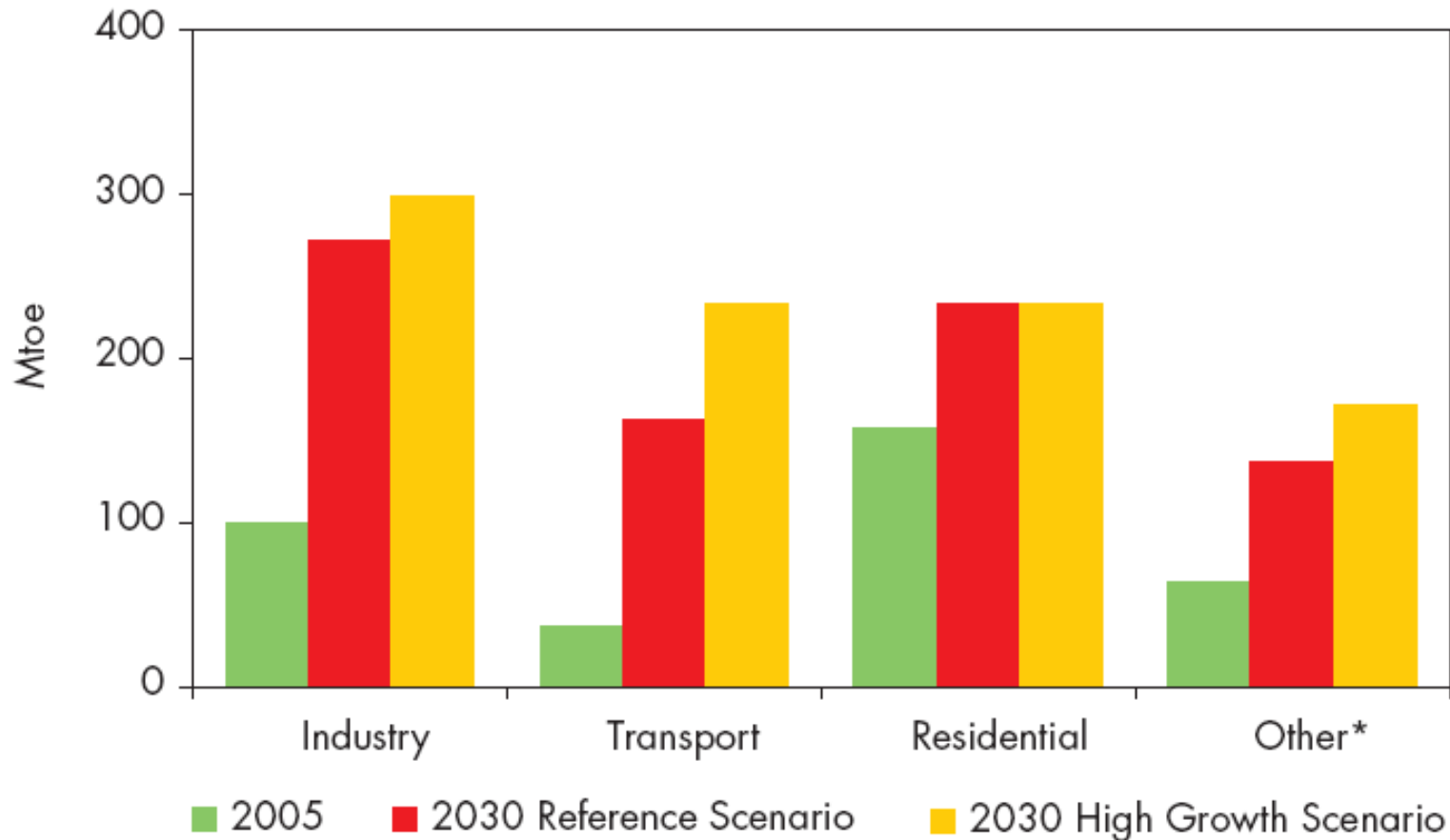
# High Growth Scenario projections

- per-capita GDP is 42% higher than in the Reference Scenario
- energy demand is 16% higher than in the Reference Scenario
- The transport sector accounts for 74% of the additional final oil demand in the High Growth Scenario
- energy prices, particularly for oil and gas, are higher in the High Growth Scenario partly due to higher demand
- biomass use is lower than in the Reference Scenario, mainly due to fuel switching in the residential sector

# High Growth Scenario: environmental implications

- CO<sub>2</sub>-emissions are 19% higher than in the Reference Scenario
- Greater reliance on coal, oil and gas compared with the Reference Scenario results in **higher emissions of SO<sub>2</sub> and NO<sub>x</sub>**  
(assumed that no new government measures are introduced to control air pollution)
- Emissions from transport rise most in percentage terms > air quality especially in urban areas worsen
- **PM emissions** from burning biomass for cooking and heating **decline more rapidly** than in the Reference Scenario

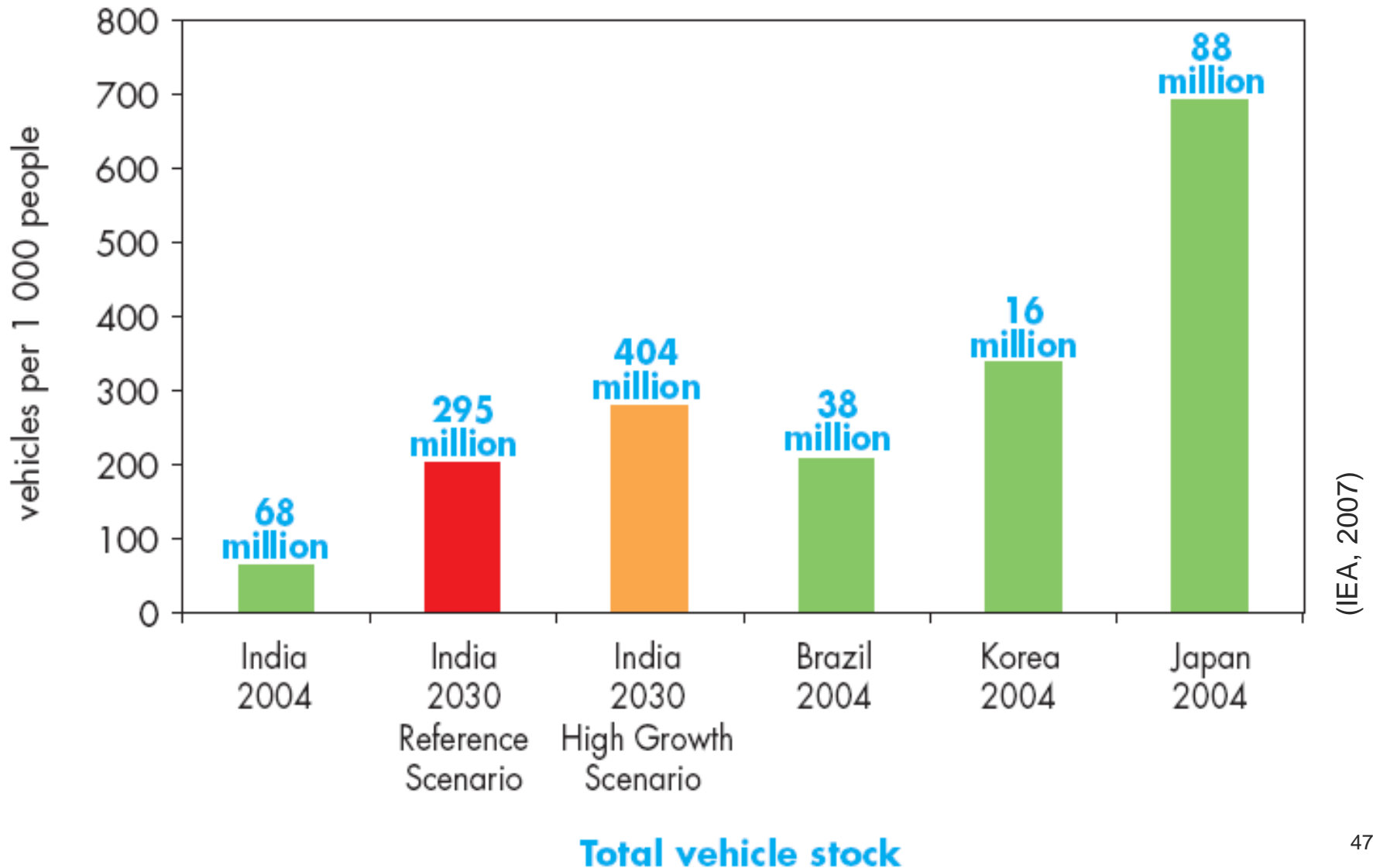
# India's final energy demand by sector in the Reference and High Growth Scenarios



\* Includes services, agriculture and non-energy use.

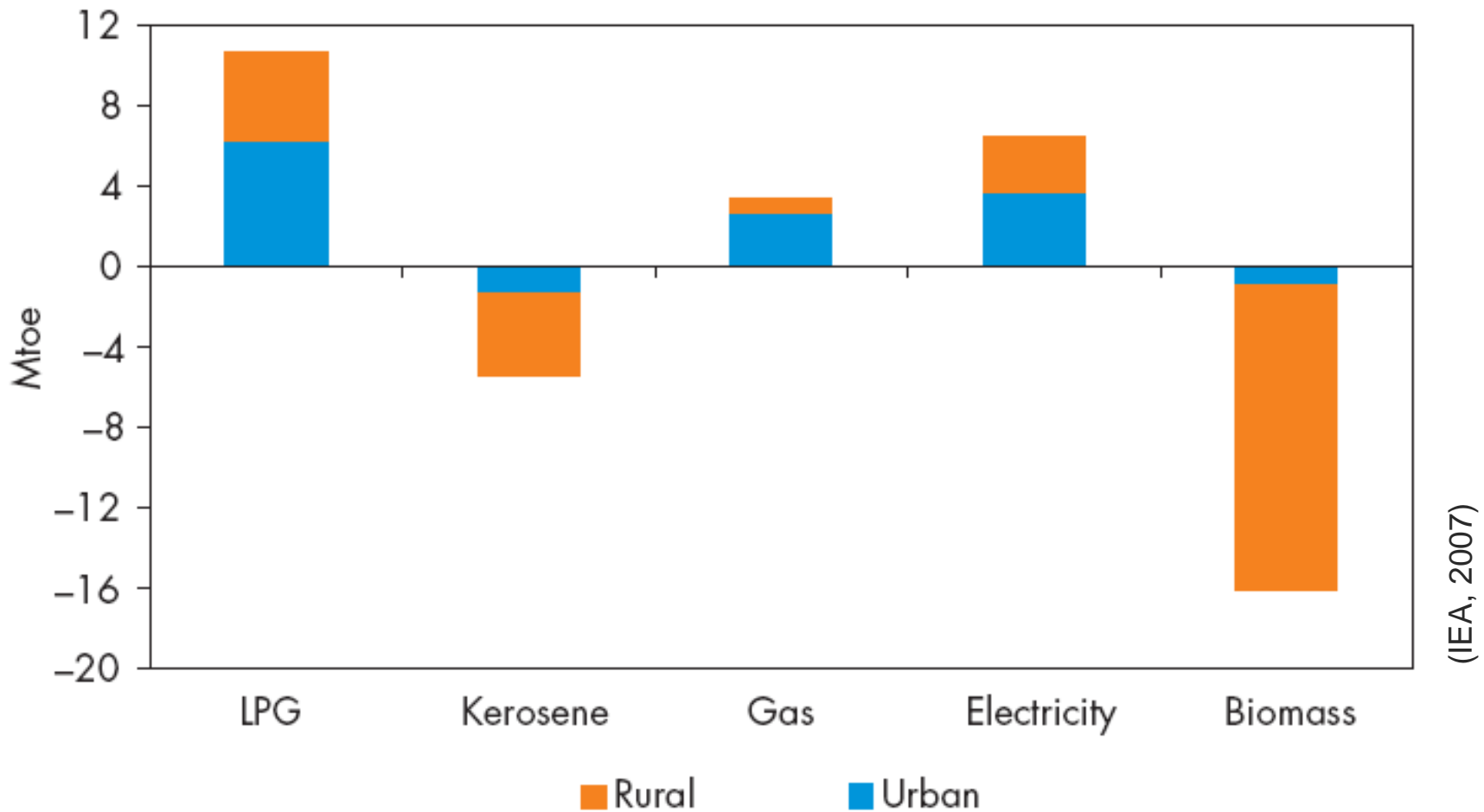
(IEA, 2007)

# India's vehicle ownership and stock in the Reference and High Growth Scenarios



# Use of cleaner, more efficient fuels in the residential sector

Figure 19.8: Change in India's Residential Energy Demand in the High Growth Scenario Relative to the Reference Scenario in 2030

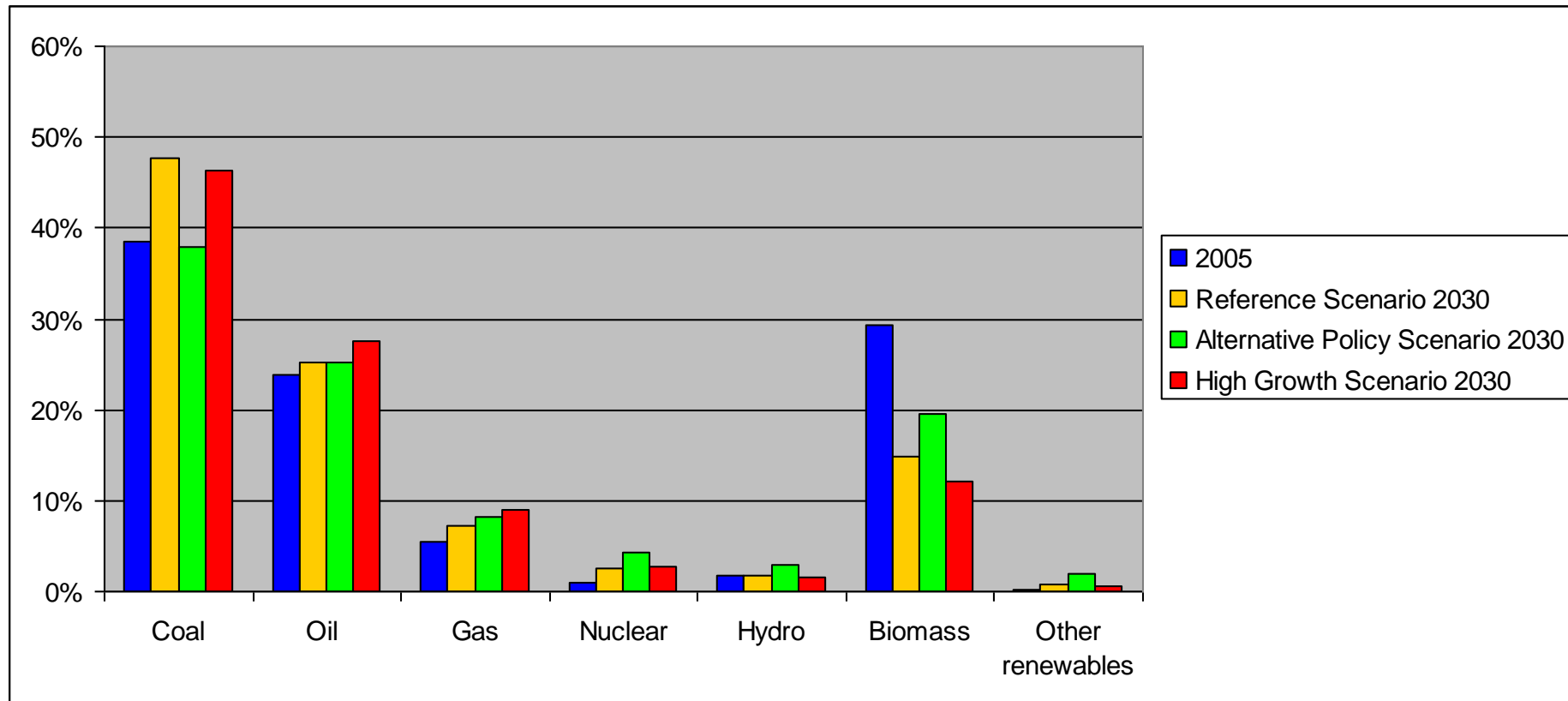


(IEA, 2007)

Note: Coal and renewables other than biomass are not shown as the change is negligible.



# Fuel mix in IEA Energy Scenarios for 2030



(IEA, 2007)

# Economic growth and energy demand

- Economic growth is by far the most important driver of energy demand.
- Future rates of economic growth are extremely uncertain, especially towards the end of the projection period.
- Energy projections are highly sensitive to the underlying assumptions about GDP growth.
  - In the High Growth Scenario, the cumulative effect of even a marginally annual higher rate of GDP growth means that the level of energy demand in 2030 could be substantially higher than in the Reference Scenario.

# Some final comments

- The **resources for modeling** spent into the IEA scenarios are **significant**
- Regional / country scenarios are linked to World Energy Scenarios