



# **A Hybrid Modelling Framework to Incorporate Expert Judgment in Integrated Economic and Energy Models: The IEA WEM-ECO Model and the World Energy Outlook 2007**

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# Objective and approach

- Assess *global* implications of energy trends in China & India to 2030
- Co-operation with China's NDRC & ERI, India's TERI
- Scenario approach
  - *Reference Scenario*
  - *Alternative Policy Scenario*
  - *High Growth Scenario (China/India)*
- Use of IEA **WEM** model to project energy use by sector and country
  - *Co-operation with **CIREN** to assess economic implications of energy-environment scenarios*
  - *Development of **hybrid model coupling WEM with IMACLIM-R from CIREN***



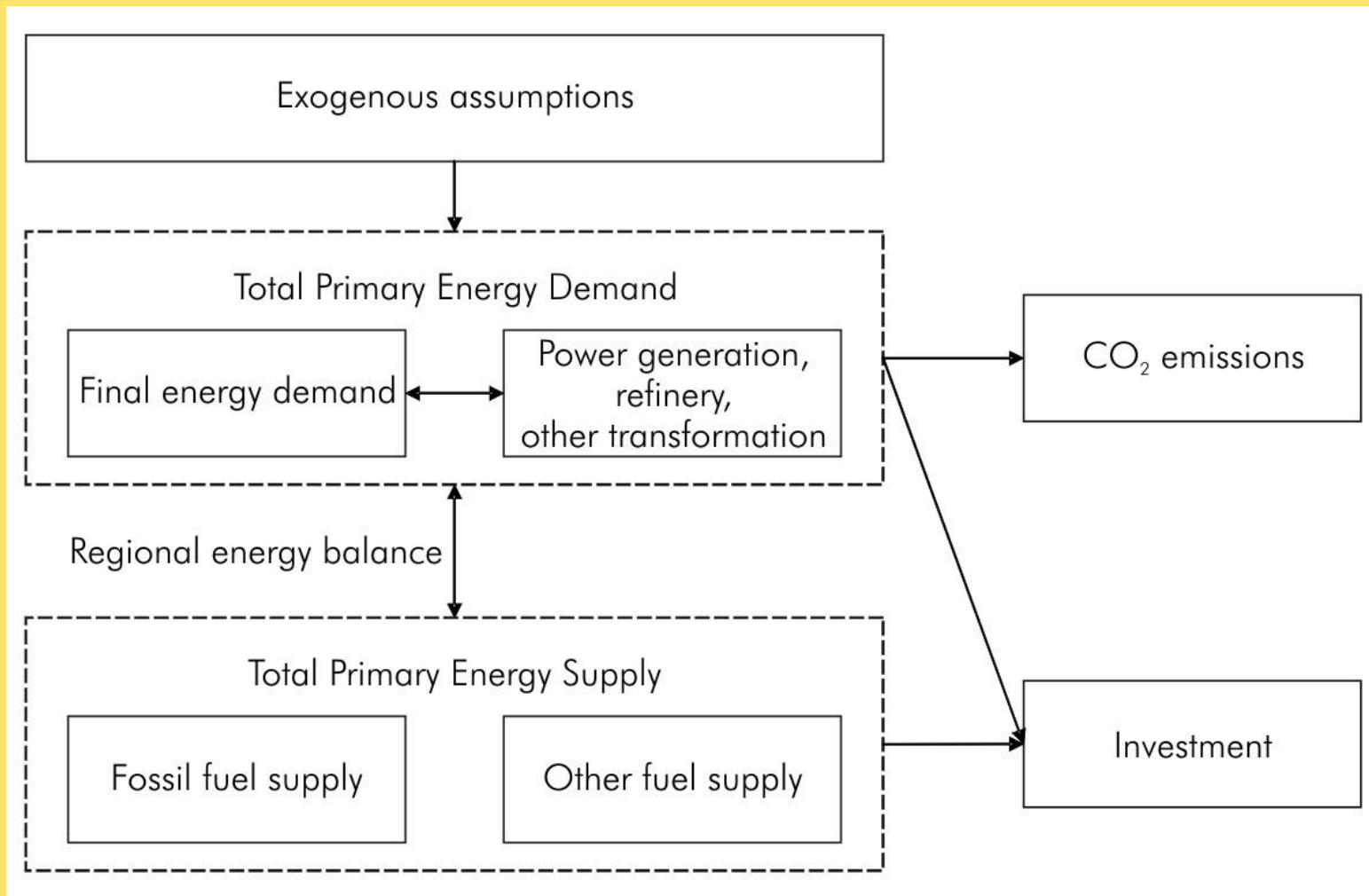
***Reference Scenario:  
bottom up WEM model***

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# World Energy Model Overview

WORLD  
ENERGY  
OUTLOOK  
2007

China  
and India  
Insights

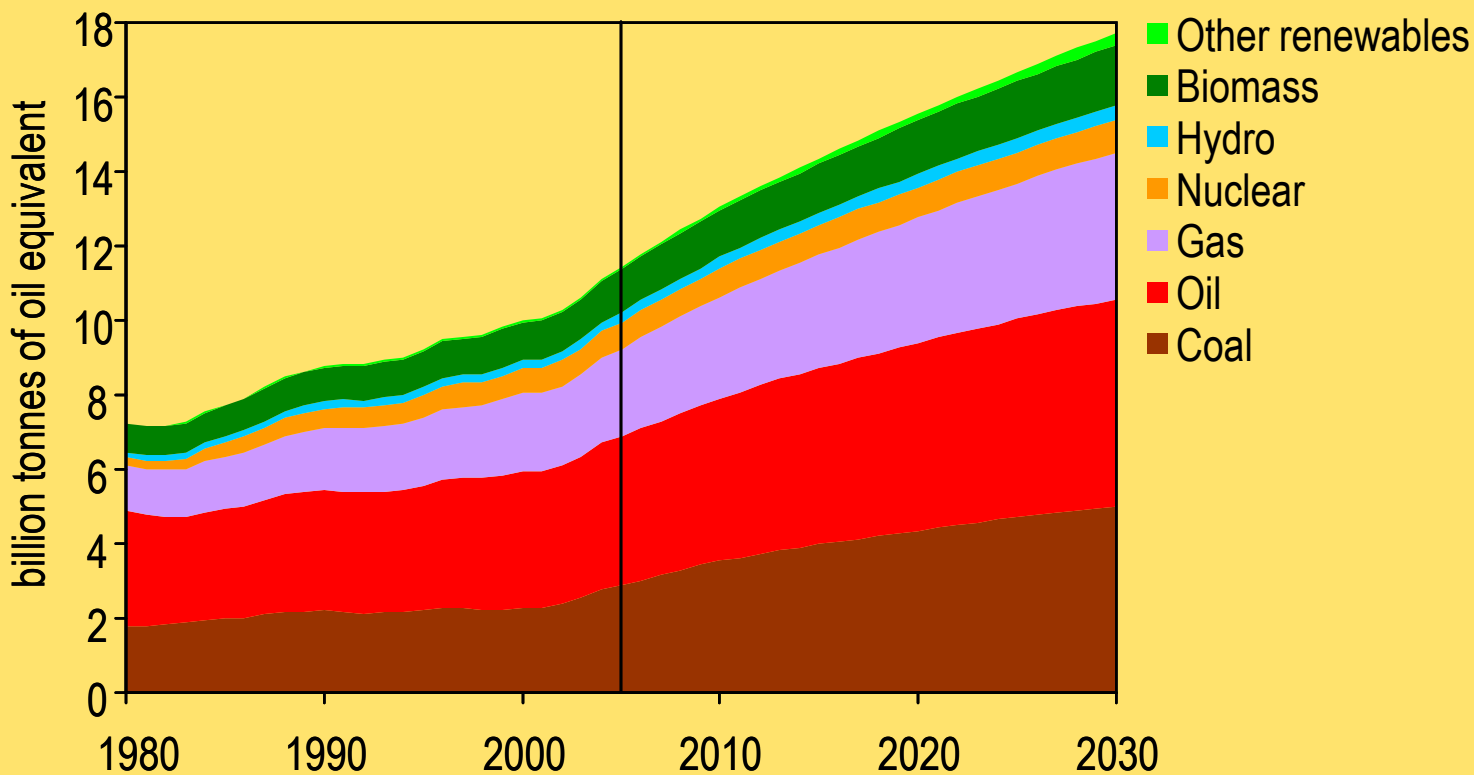




# Reference Scenario: World Primary Energy Demand

WORLD ENERGY OUTLOOK 2007

China and India Insights



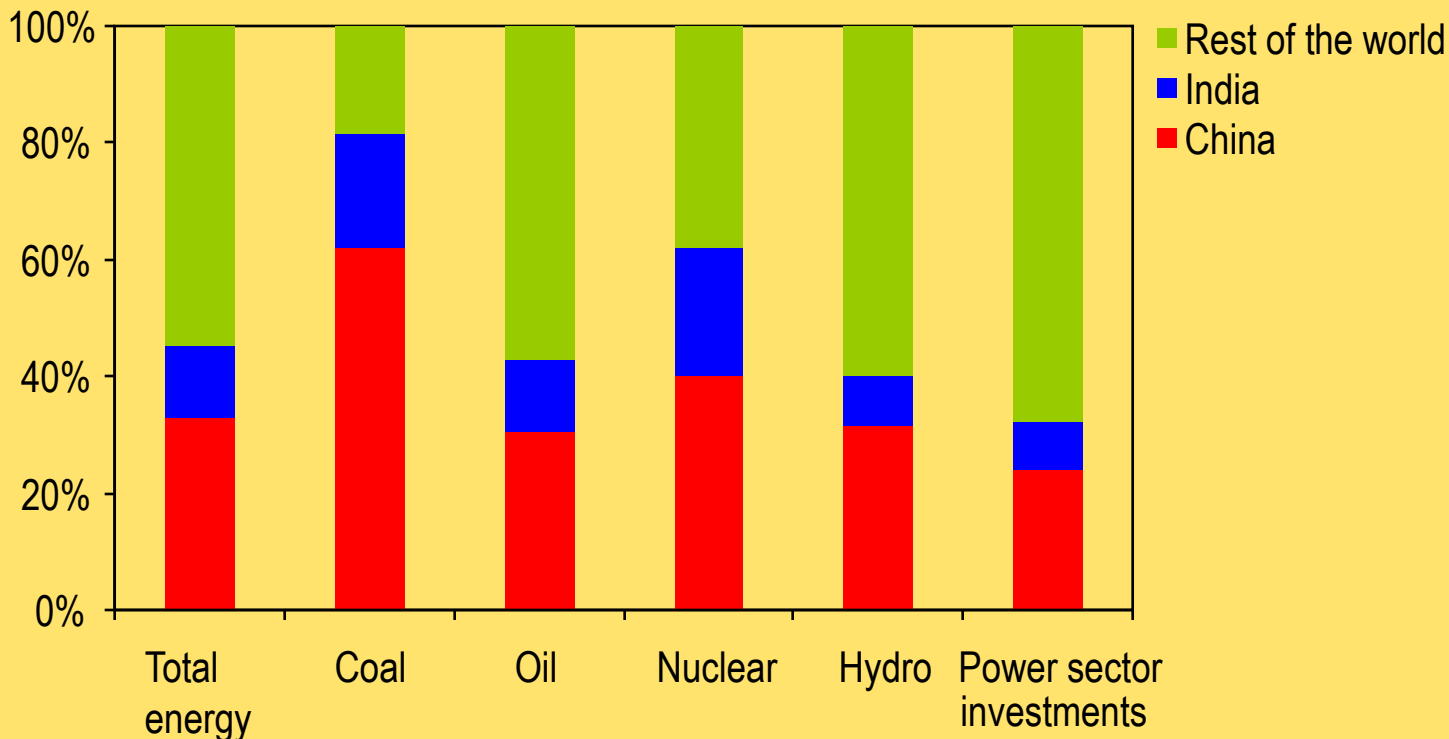
**Global demand grows by more than half over the next quarter of a century, with coal use rising most in absolute terms**

# The Emerging Giants of World Energy

**WORLD  
ENERGY  
OUTLOOK  
2007**

**China  
and India  
Insights**

**Increase in Primary Energy Demand & Investment  
Between 2006 & 2030 as Share of World Total**



***China & India will contribute more than 40% of the increase in global energy demand to 2030 on current trends***

A world map is shown in the background, rendered in a dark blue color. The map is overlaid with a grid of thin, light-colored lines. The background has a color gradient from dark blue on the left to bright yellow on the right. The text is centered in the upper half of the image.

***High Growth Scenario:  
Hybrid WEM-ECO model***





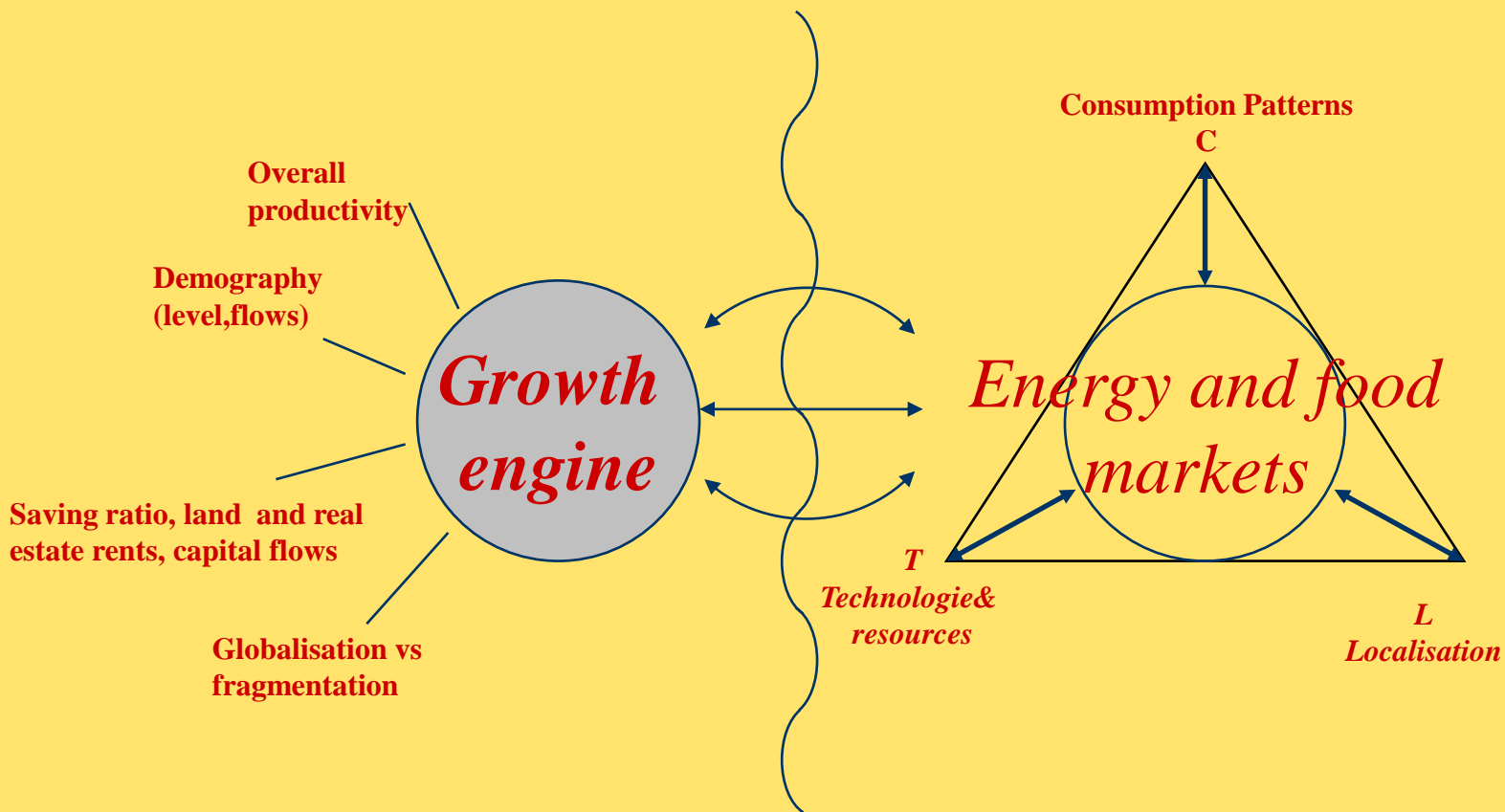
# Benefits of coupling WEM with a General Equilibrium Model

- Feedback on the **consistency** of macroeconomics/population/energy technology assumptions
- Assess the **macroeconomic impacts of energy policies**
- Introduce **consistent prices and energy flows**: useful to enrich analysis of costs/benefits of specific policies
- Identify **binding constraints in non-energy sectors** that are likely to make our energy scenarios unrealistic ?  
→ *e.g. available investment / trade and capital accounts*
- Complement WEM on **energy** issues by providing **new indicators**

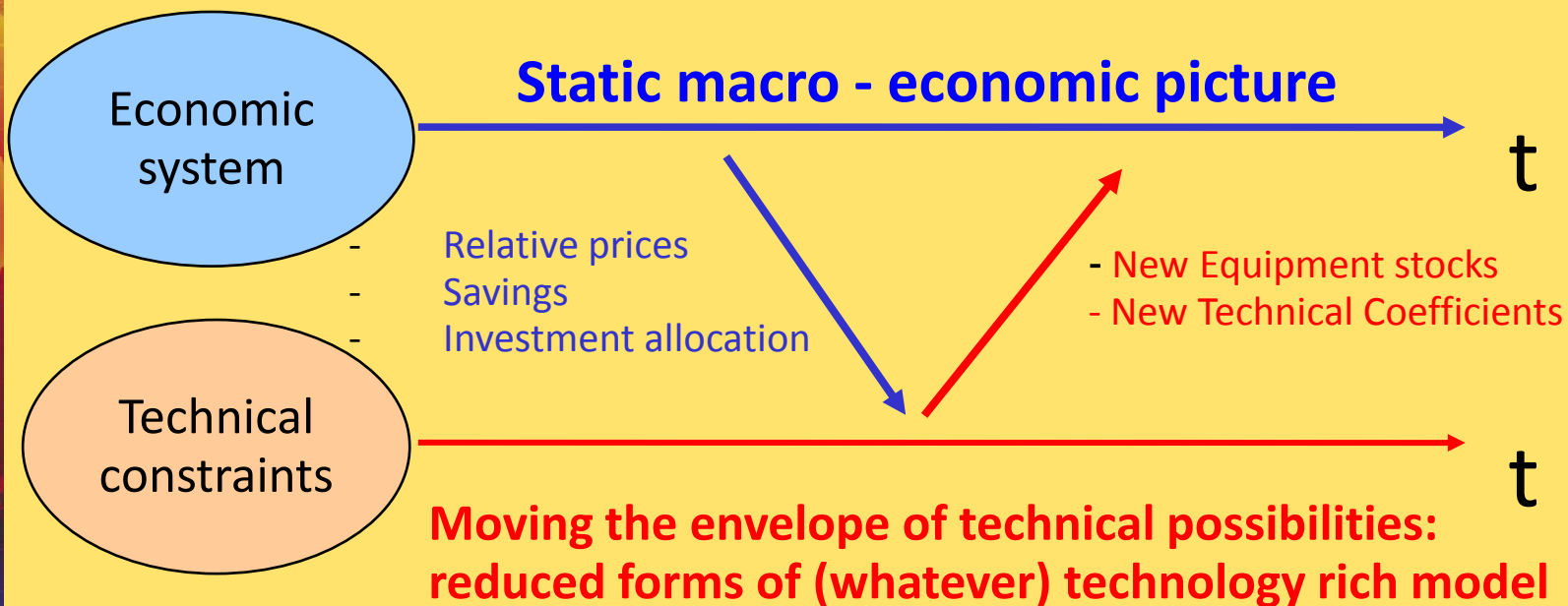
# What would we like to represent?

WORLD  
ENERGY  
OUTLOOK  
2007

China  
and India  
Insights



# Consistency between economic and engineering based information





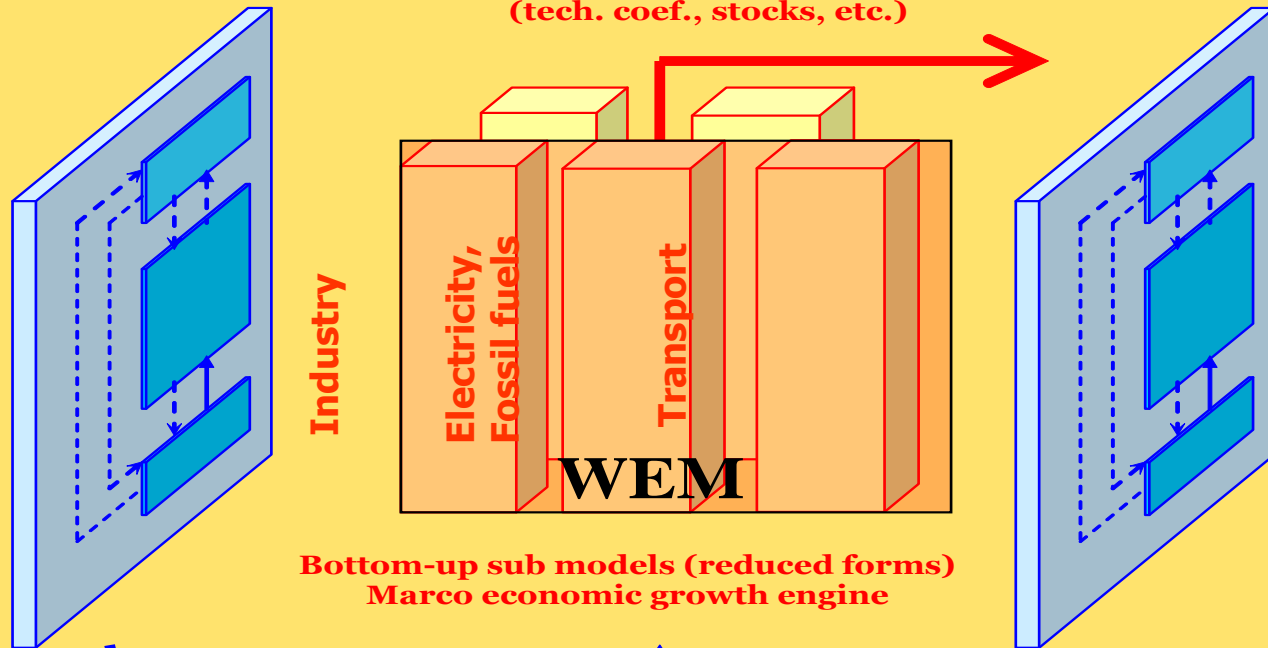
# Integrating the IEA energy sector model into IMACLIM-R general equilibrium framework



Static Equilibrium  $t$

Static equilibrium  $t+1$

Updated parameters  
(tech. coef., stocks, etc.)



Bottom-up sub models (reduced forms)  
Marco economic growth engine

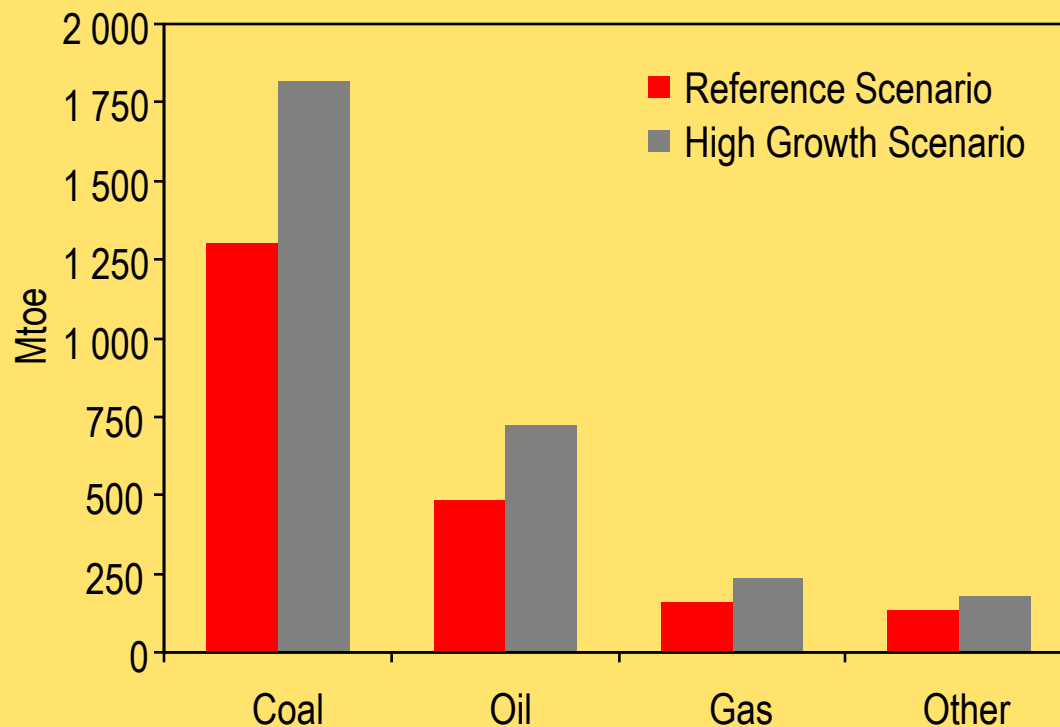
Price-signals, rate of return  
Physical flows

***A recursive and modular architecture:  
static equilibria + dynamic relations informed by the WEM model***

# High Growth Scenario

- Past projections have often significantly underestimated growth rates
  - *IMF: China's year ahead projection was 7.5% in 2003; actual 2004 growth 10.1%*
  - *India's year ahead projection was 6.7% in 2004; actual 2005 growth 9%*
  - *Chinese 11th Five-Year Plan targets 7.5% GDP growth over 2006-10; growing at >11% in 2007*
- Reference Scenario assumes 6% GDP growth in China, 6.3% in India (2005-2030)
- High Growth Scenario assesses implications for international trade (and energy)
  - *Assumes higher GDP growth by around 1.5%/year (7.5% for China; 7.8% for India)*

# High Growth Scenario: China's Additional Demand by Fuel



***Coal would see the biggest increase in demand in volume terms were China's economy to grow faster***



# Global Macroeconomic Impact of Higher GDP Growth in China and India

- Higher growth in China and India affects the rest of the world through its double impact on international commodity prices and on overall trade.
- Higher growth in energy demand, combined with supply-side constraints (limited investment response by major oil and gas producers), drives up international energy prices.
- WEM-ECO recalculates the global equilibrium for international trade in energy and non-energy goods and services, and for energy and other commodity prices in the rest of the world by major region.
  - The average IEA crude oil import price is 40% higher than in the Reference Scenario.
  - Natural gas prices rise in the same proportion.
  - Increased coal demand drives the price up by about 19% compared to the Reference Scenario.

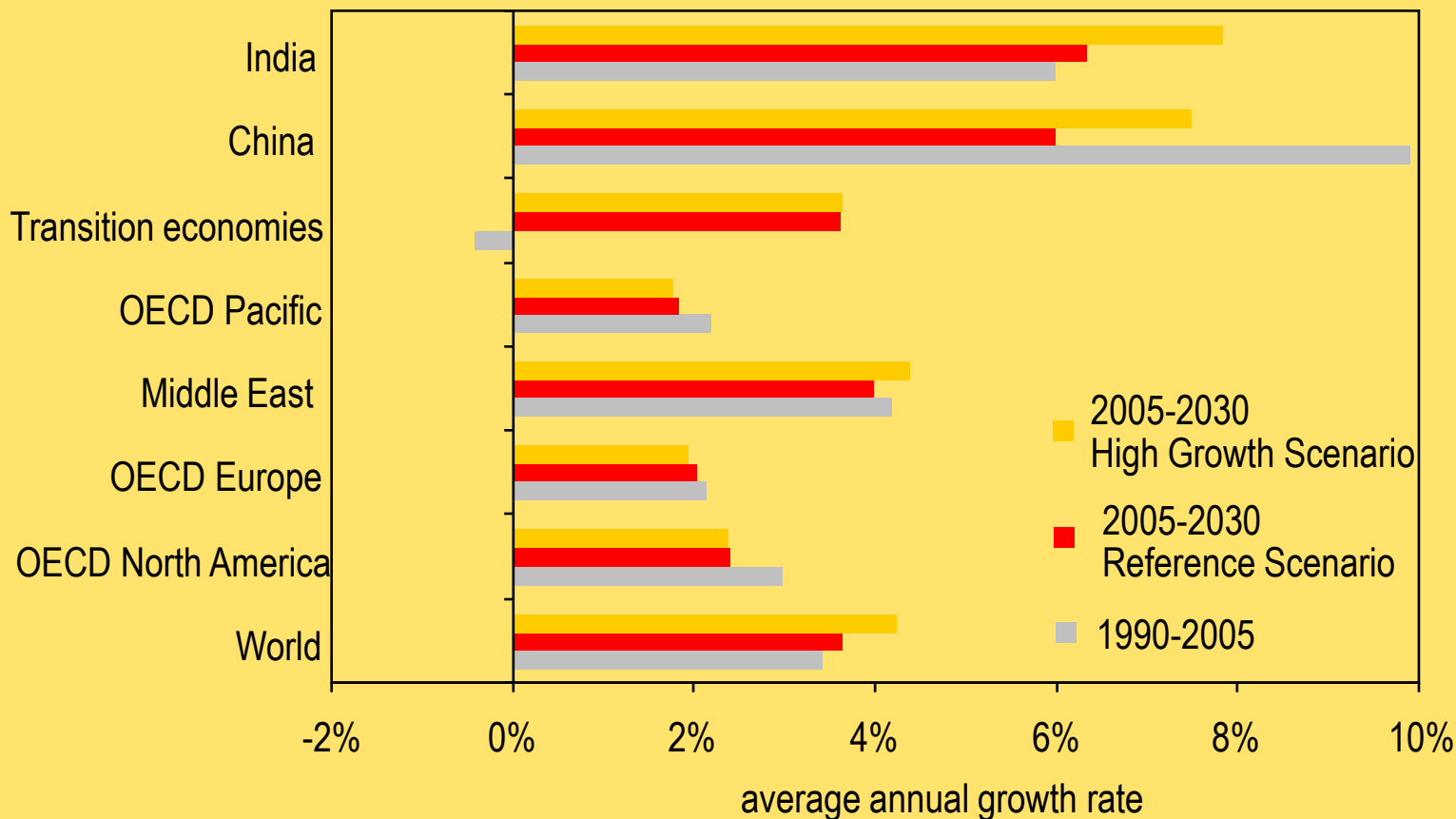
# Economic Growth in the Rest of the World

Table 3.1: World Real GDP Growth in the High Growth Scenario

	Average annual growth rate, 2005-2030	Difference from Reference Scenario	
		Average annual growth rate, 2005-2030	Level of GDP in 2030
<b>OECD</b>	<b>2.1%</b>	<b>-0.06%</b>	<b>-1.4%</b>
North America	2.4%	-0.02%	-0.4%
<i>United States</i>	2.3%	-0.04%	-1.0%
Europe	1.9%	-0.10%	-2.4%
Pacific	1.8%	-0.07%	-1.8%
<i>Japan</i>	1.3%	-0.07%	-1.7%
<b>Transition economies</b>	<b>3.6%</b>	<b>0.02%</b>	<b>0.4%</b>
Russia	3.5%	0.03%	0.6%
<b>Developing countries</b>	<b>6.2%</b>	<b>1.06%</b>	<b>30.2%</b>
Developing Asia	6.9%	1.28%	37.3%
<i>China</i>	7.5%	1.50%	45.2%
<i>India</i>	7.8%	1.50%	45.1%
Middle East	4.4%	0.41%	10.9%
Africa	4.0%	0.05%	1.4%
Latin America	3.3%	0.06%	1.4%
<i>Brazil</i>	3.1%	-0.00%	-0.1%
<b>World</b>	<b>4.3%</b>	<b>0.61%</b>	<b>16.3%</b>
<i>European Union</i>	1.9%	-0.10%	-2.4%

**Higher economic growth in China and India affects the world economy through larger volumes of trade but also higher energy and commodity prices**

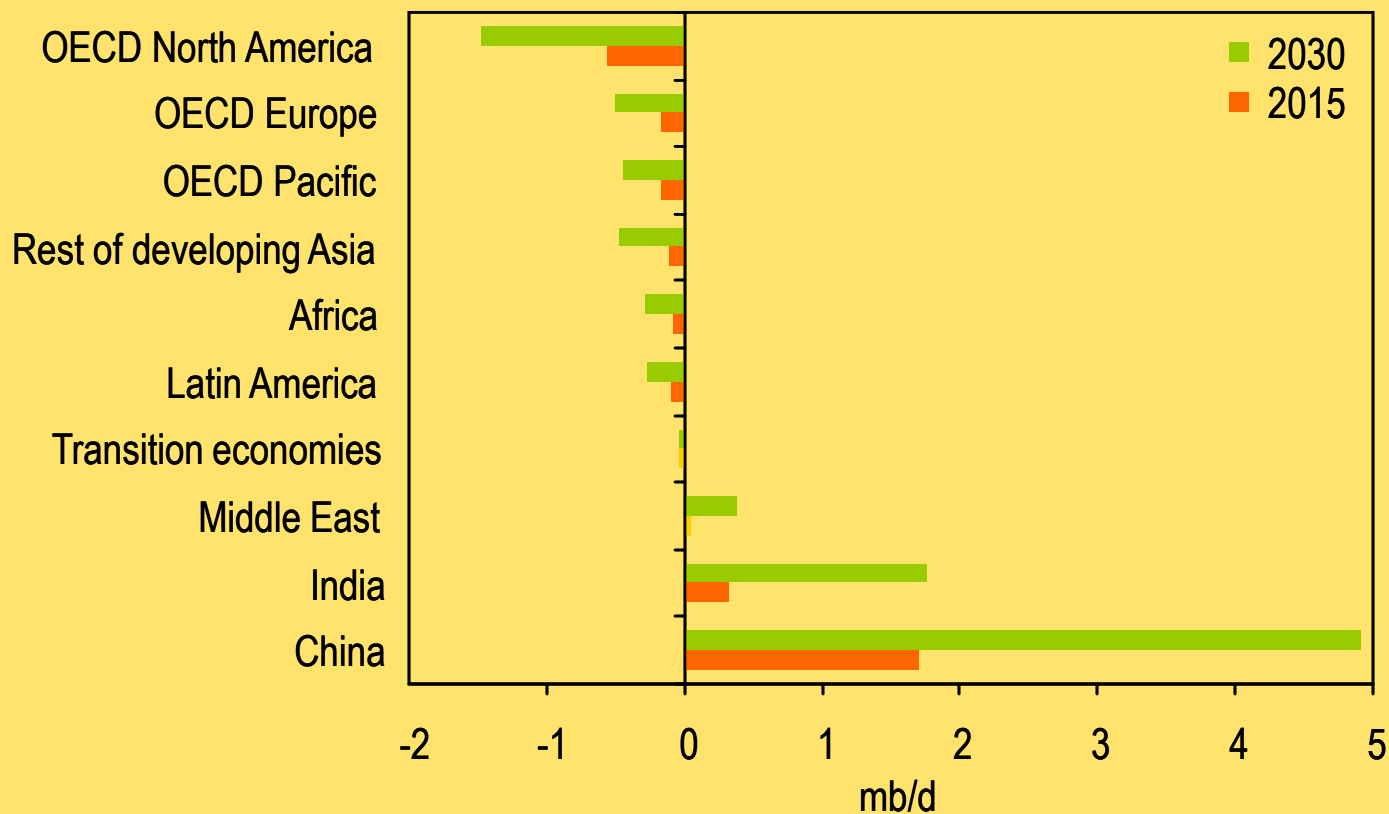
# Gross Domestic Product by Region



***OECD GDP drops marginally in the High Growth Scenario, but the uncertainties are very large***

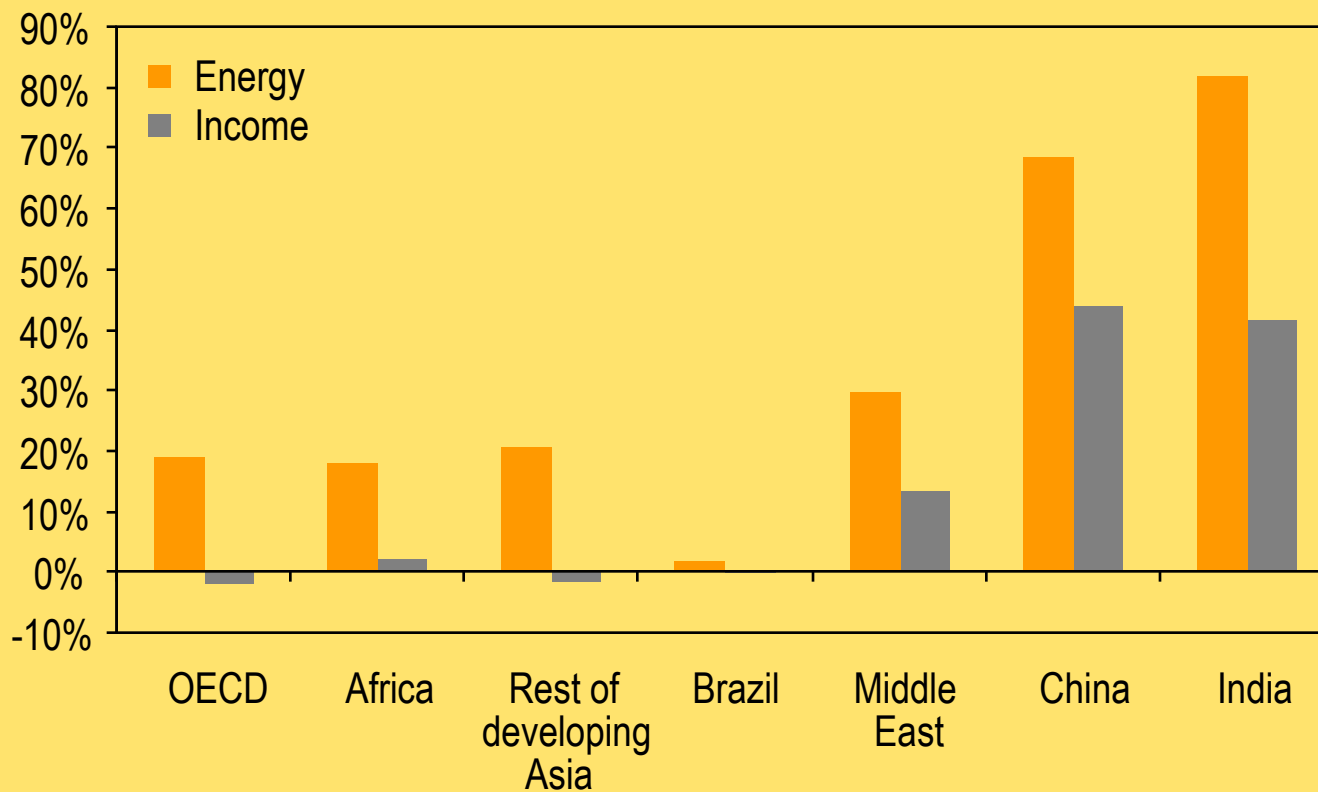


# High Growth Scenario: Change in Primary Oil Demand *vis-à-vis* the Reference Scenario



**World oil demand reaches 120 mb/d in 2030 – 4 mb/d higher than in the reference Scenario due to China, India & the Middle East**

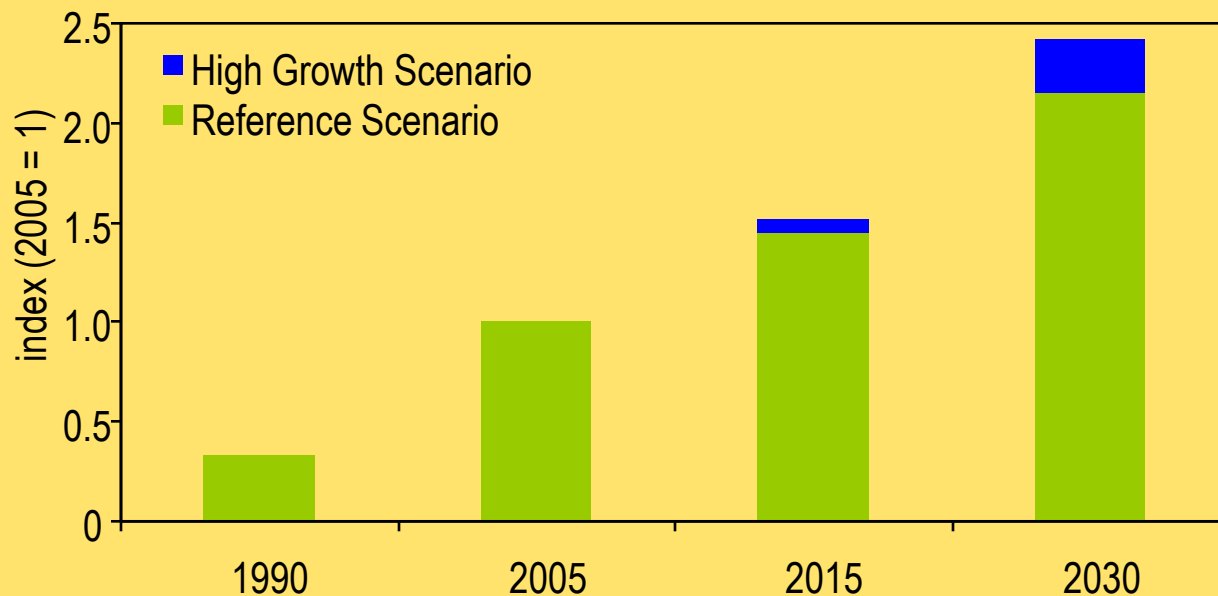
# High Growth Scenario: Change in Household Income and Energy Expenditures *vis-à-vis* the Reference Scenario



***Household energy expenditures increase as a result of higher commodity prices***



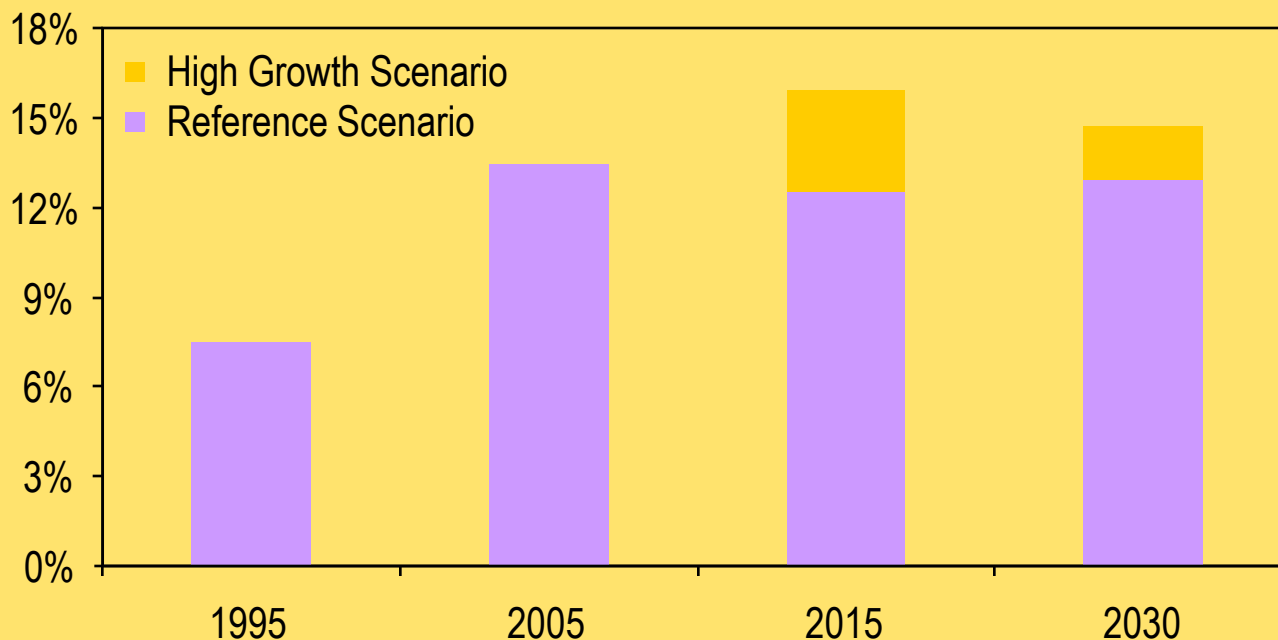
# Value of Worldwide Trade in Goods & Services



***In the High Growth Scenario, worldwide trade in goods & services expands much faster than in the Reference Scenario***

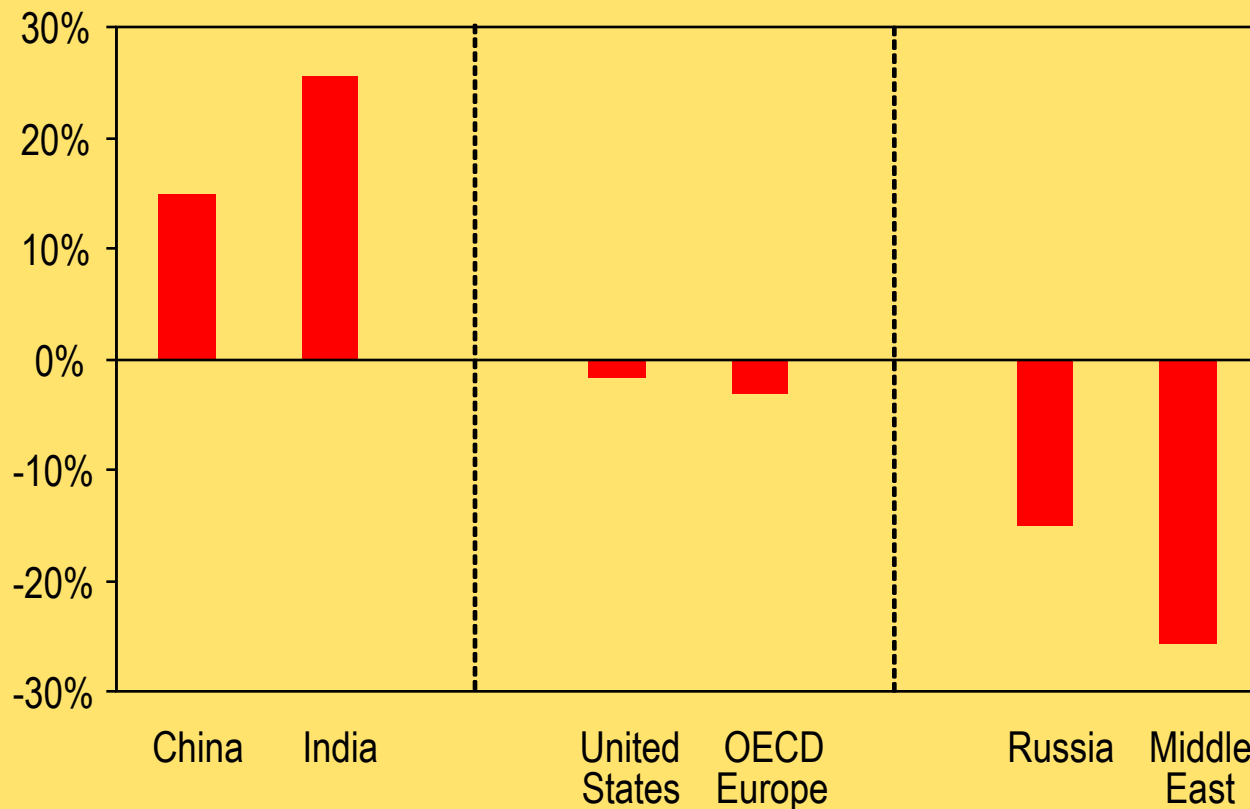


# Share of Energy in World International Trade Value



***The share of energy in international trade continues to grow with higher prices in the High Growth Scenario***

# Change in Competitiveness Index in 2030 in the High Growth Scenario Compared with the Reference Scenario



***Resource-rich countries such as Russia & Middle Eastern oil exporters suffer losses in competitiveness in non-resource sectors***

# Conclusions: Research and Methodological challenges

- Benefits of coupling WEM with a General Equilibrium Model (IMACLIM-R from CIRED)
  - **Consistency** of macroeconomics/population/energy technology assumptions
  - **Macroeconomic impacts of energy policies**
- Pursuing the effort in direction to “hybrid” models
  - **Physical and Economic** account of energy and materials (steel, cement, etc.)
  - ‘Open the box’ of economic models to embark **sector-based expertise**
  - Describe infrastructures dynamics, inertia and technical **lock-ins**
- Define the right signals to each energy sector in any future climate and energy policy framework
  - Energy price signals, other price signals, capital costs
  - Regulations, R&D cooperation and spill-overs



***Thank you***

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# ***Methodology and Assumptions***

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# World Population Growth (average annual growth rates, %)

	1980-1990	1990-2005	2005-2015	2015-2030	2005-2030
<b>OECD</b>	<b>0.8</b>	<b>0.8</b>	<b>0.5</b>	<b>0.3</b>	<b>0.4</b>
North America	1.2	1.3	1.0	0.7	0.8
<i>United States</i>	0.9	1.1	0.9	0.7	0.8
Europe	0.5	0.5	0.3	0.2	0.2
Pacific	0.8	0.5	0.1	-0.2	-0.1
<i>Japan</i>	0.6	0.2	-0.1	-0.5	-0.3
<b>Transition economies</b>	<b>0.8</b>	<b>-0.2</b>	<b>-0.2</b>	<b>-0.3</b>	<b>-0.2</b>
Russia	0.6	-0.2	-0.5	-0.6	-0.6
<b>Developing countries</b>	<b>2.1</b>	<b>1.6</b>	<b>1.4</b>	<b>1.1</b>	<b>1.2</b>
Developing Asia	1.8	1.4	1.1	0.8	0.9
<i>China</i>	1.5	0.9	0.6	0.3	0.4
<i>India</i>	2.1	1.7	1.4	1.0	1.1
Middle East	3.6	2.3	2.0	1.5	1.7
Africa	2.9	2.3	2.2	1.9	2.0
Latin America	2.0	1.6	1.2	0.9	1.0
<i>Brazil</i>	2.1	1.5	1.2	0.8	0.9
<b>World</b>	<b>1.7</b>	<b>1.4</b>	<b>1.1</b>	<b>0.9</b>	<b>1.0</b>
<i>European Union</i>	0.3	0.3	0.1	0.0	0.0



# 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>	<b>3.0</b>	<b>2.5</b>	<b>2.5</b>	<b>1.9</b>	<b>2.2</b>
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>	<b>-0.5</b>	<b>-0.4</b>	<b>4.7</b>	<b>2.9</b>	<b>3.6</b>
Russia*	n.a.	-0.5	4.3	2.8	3.4
<b>Developing countries</b>	<b>3.9</b>	<b>5.8</b>	<b>6.1</b>	<b>4.4</b>	<b>5.1</b>
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>	<b>2.9</b>	<b>3.4</b>	<b>4.2</b>	<b>3.3</b>	<b>3.6</b>
<i>European Union</i>	2.4	2.0	2.3	1.8	2.0



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

	unit	2000	2006	2010	2015	2030
<b>Real terms (year-2005 prices)</b>						
IEA crude oil imports	barrel	32.49	61.72	59.03	57.30	62.00
Natural gas						
<i>US imports</i>	<i>MBtu</i>	4.49	7.22	7.36	7.36	7.88
<i>European imports</i>	<i>MBtu</i>	3.27	7.31	6.60	6.63	7.33
<i>Japanese LNG imports</i>	<i>MBtu</i>	5.49	7.01	7.32	7.33	7.84
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>US imports</i>	<i>MBtu</i>	3.87	7.22	8.11	9.08	13.67
<i>European imports</i>	<i>MBtu</i>	2.82	7.31	7.27	8.18	12.71
<i>Japanese LNG imports</i>	<i>MBtu</i>	4.73	7.01	8.06	9.05	13.61
OECD steam coal imports	tonne	33.65	62.87	61.74	70.19	106.14



# Resources

## Description of the World Energy Model

<http://www.worldenergyoutlook.org/model.asp>

## Description of WEM-ECO General Equilibrium Model

[http://www.worldenergyoutlook.org/docs/weo2007/WEM-ECO\\_Description.pdf](http://www.worldenergyoutlook.org/docs/weo2007/WEM-ECO_Description.pdf)

## List of policies and measures of the Alternative Policy Scenario

<http://www.iea.org/textbase/pm/?mode=weo>

## Download past WEO's:

<http://www.worldenergyoutlook.org/older.asp>