

413th Forum on Research Works

21st Oct. 2013, Tokyo, Japan

A light gray silhouette of a world map is centered in the background of the slide, showing the outlines of continents and major landmasses.

Asia/World Energy Outlook 2013

—Analyzing Changes Induced by the Shale Revolution—

The Institute of Energy Economics, Japan (IEEJ)

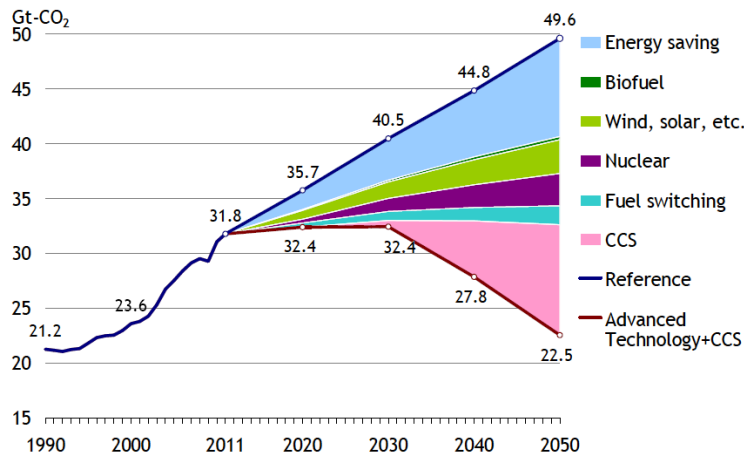
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Summary

I. World/Asia Energy Supply/Demand Outlook

- World energy demand will continue to grow, with most of the increase concentrated in Asian emerging countries.
- Energy conservation and climate change measures will greatly reduce emissions. Unfortunately, the diffusion of existing technologies will not be sufficient to achieve the target of "halving CO₂ emissions by 2050."
- Innovative technologies will have to be developed and deployed in order to limit the temperature rise to 2°C from pre-industrialization by the end of the 21st century.

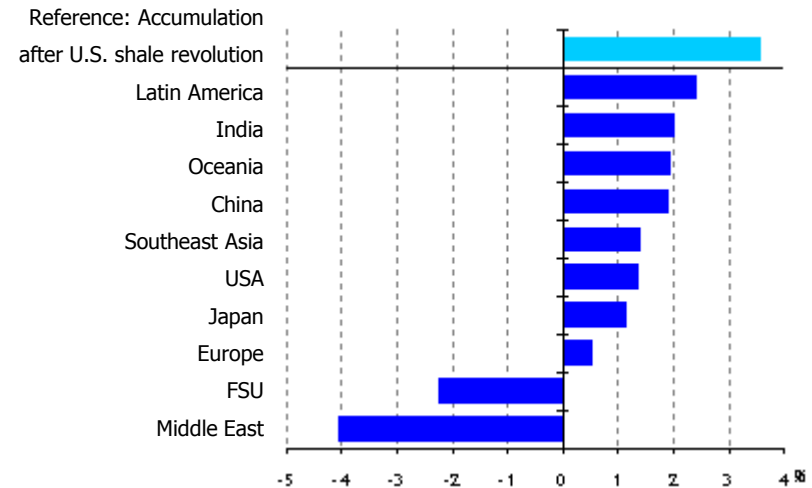
Global CO₂ Emission Growth and Projected Reduction



II. Analyzing Changes Induced by the Shale Revolution

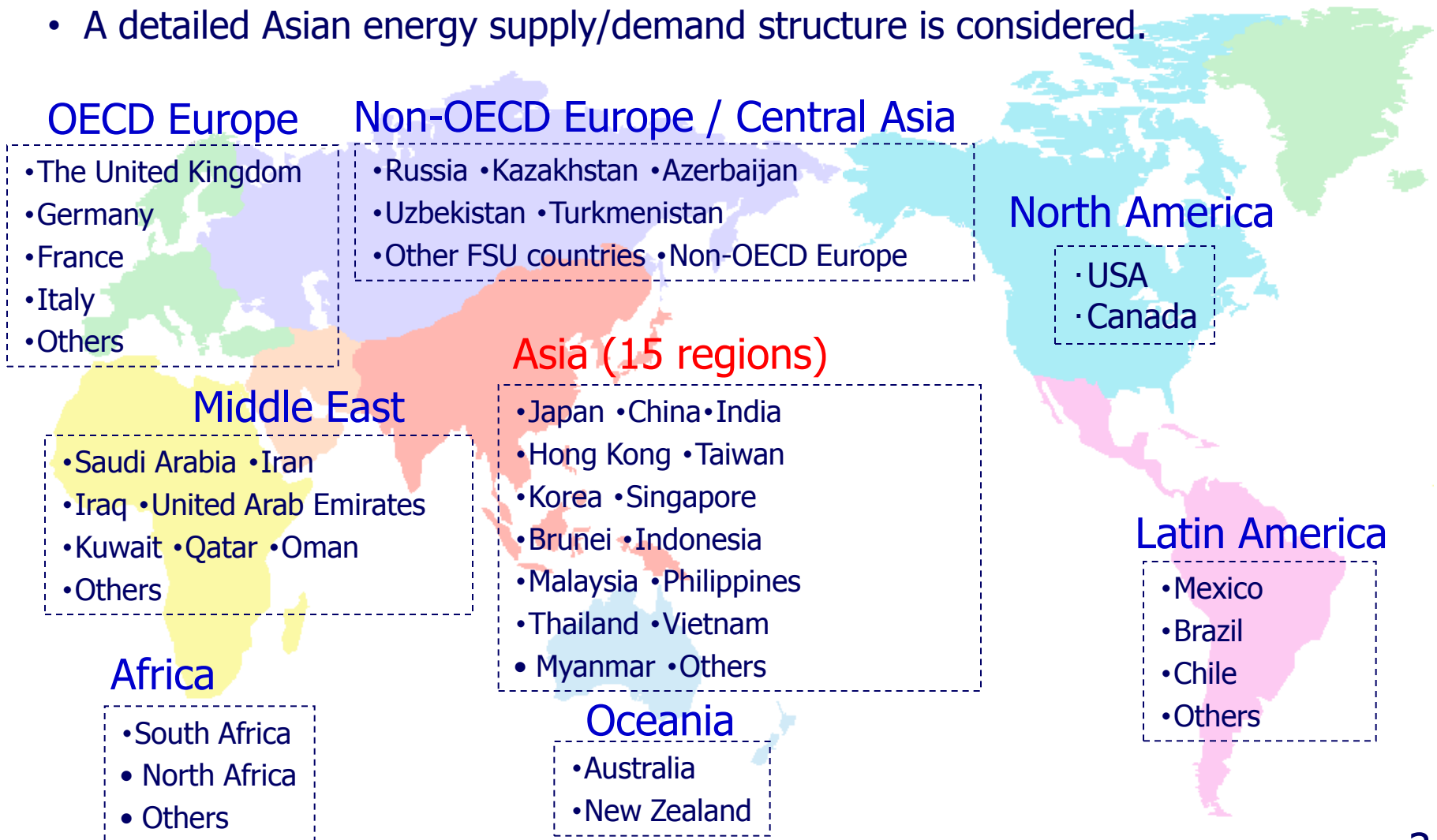
- Oil and gas prices will decline due to enhanced development of unconventional resources. The gas price decline will prompt fuel switching from coal to gas and will change the global primary energy structure.
- While net fossil fuel exports from such regions as North America will increase, those from the Middle East and the Former Soviet Union will decrease. Japan's oil and gas imports will increase in volume while decreasing in value due to the price decline.
- The shale revolution will translate into positive economic impacts for many countries such as the United States and Japan. It will, however, bring negative economic impacts for the Middle East and the Former Soviet Union.

Economic Impacts by 2040 of the Shale Revolution by Region (relative to the Reference Scenario)

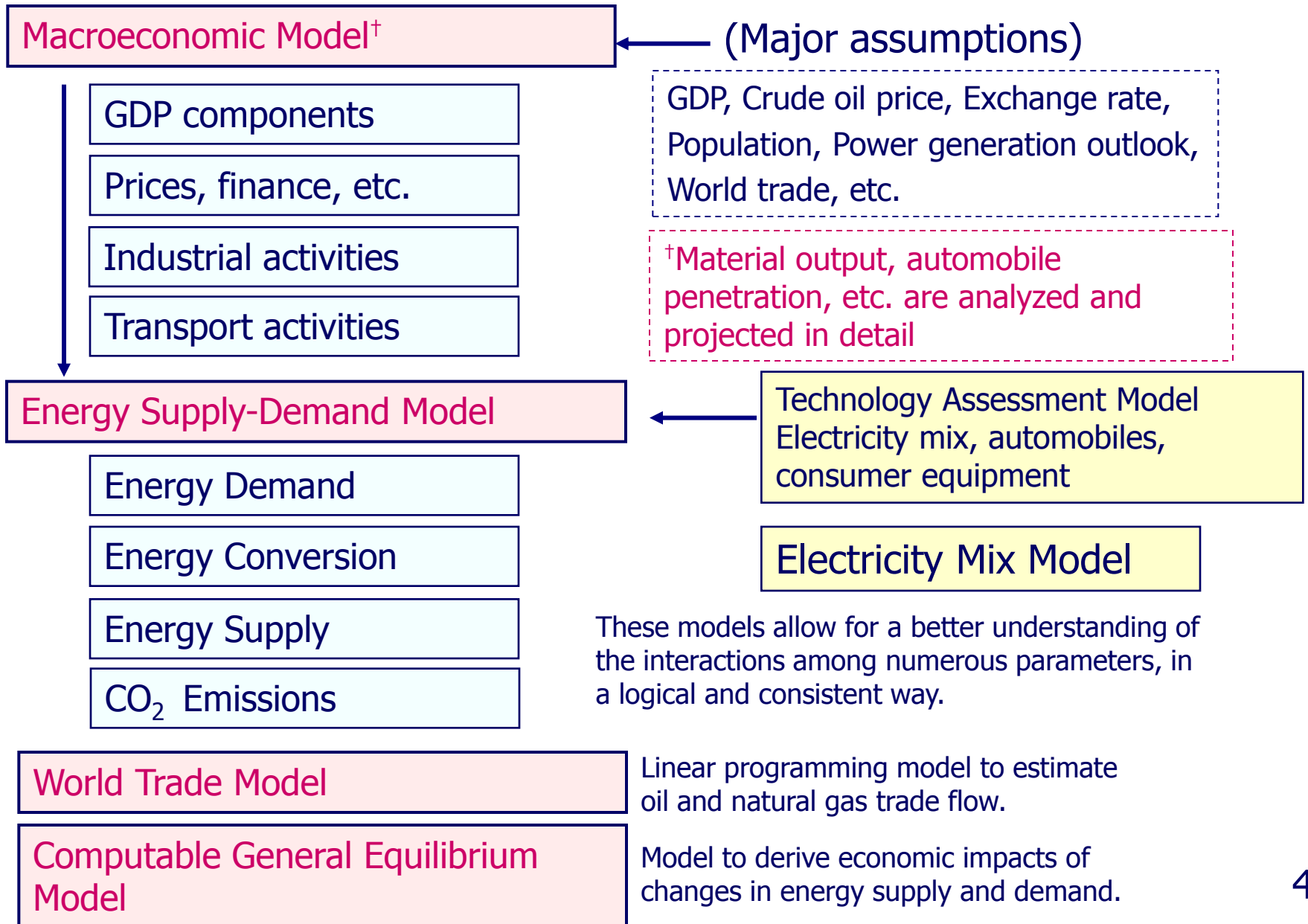


Geographical Coverage

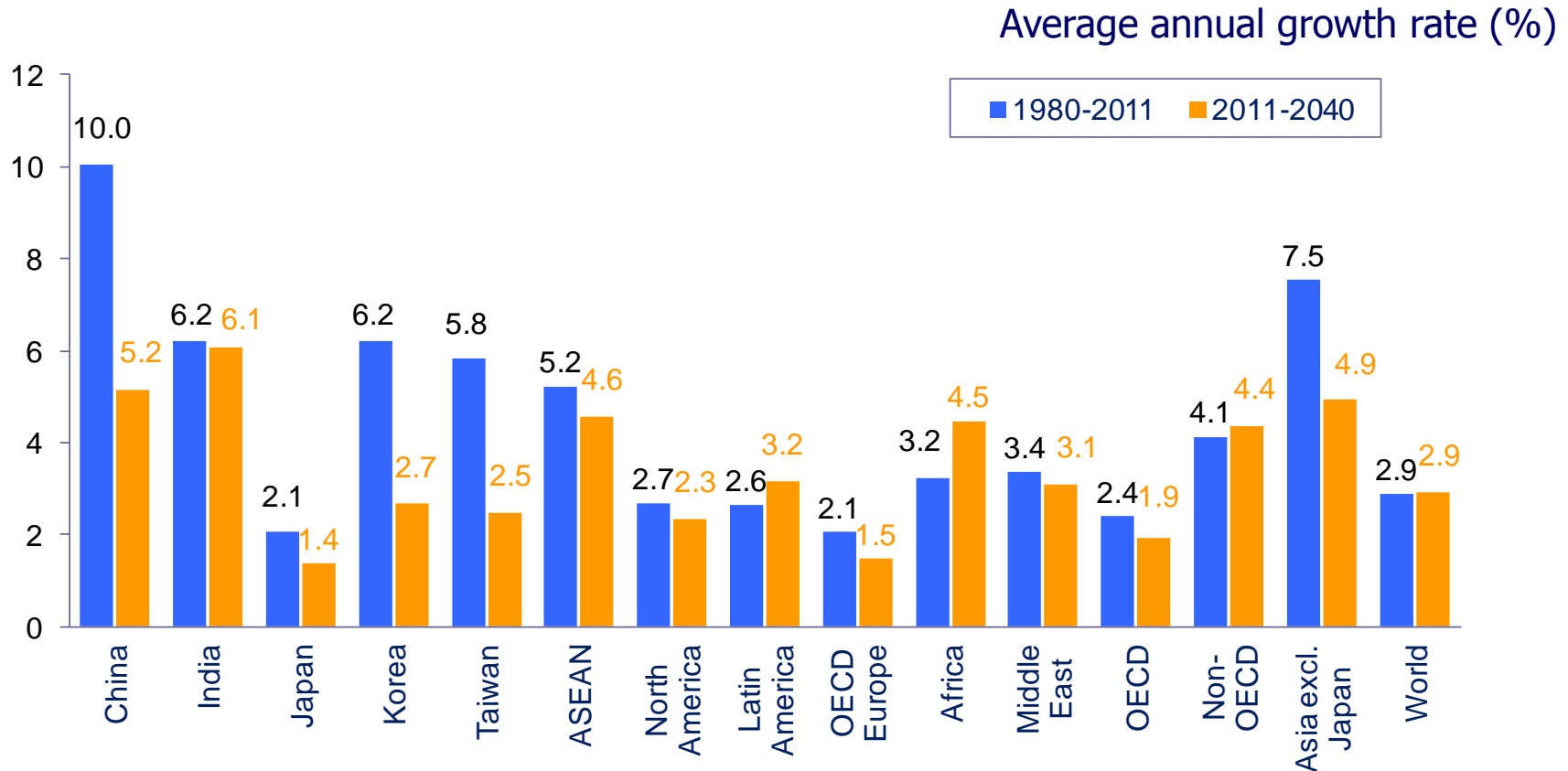
- The world is geographically divided into 46 regions, of which Asia represents 15 regions.
- A detailed Asian energy supply/demand structure is considered.



Modeling Framework

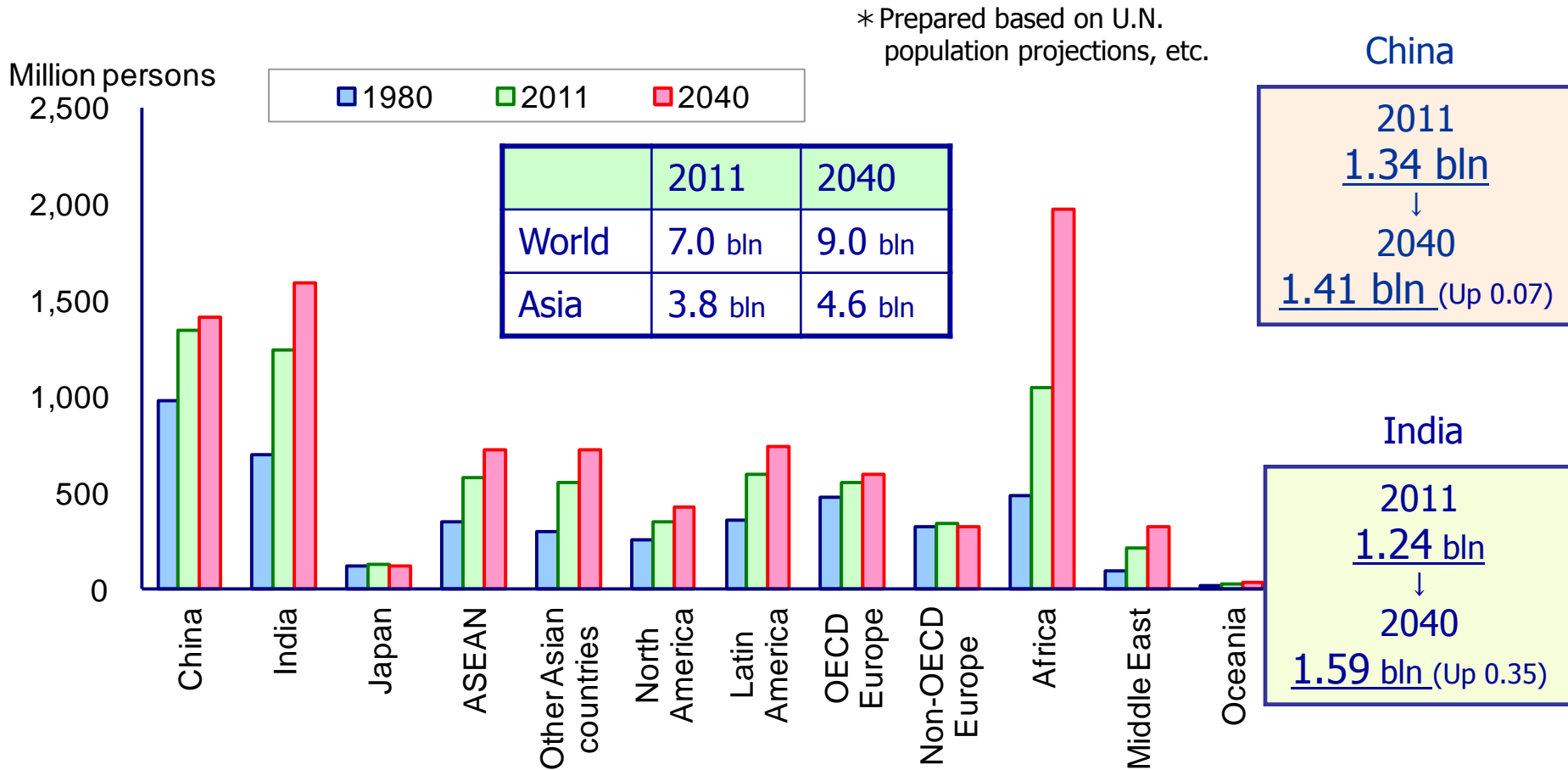


Major Assumptions: Gross Domestic Product



- The overall world economy is assumed to continue to grow steadily over the medium to long term by almost 3%.
- China's economic growth is anticipated to decelerate over time, primarily reflecting a decline in its currently abundant working population.
- Meanwhile, India and ASEAN countries with younger populations, are expected to benefit from a growing labor force and will achieve higher economic growth through 2040.

Major Assumptions: Population



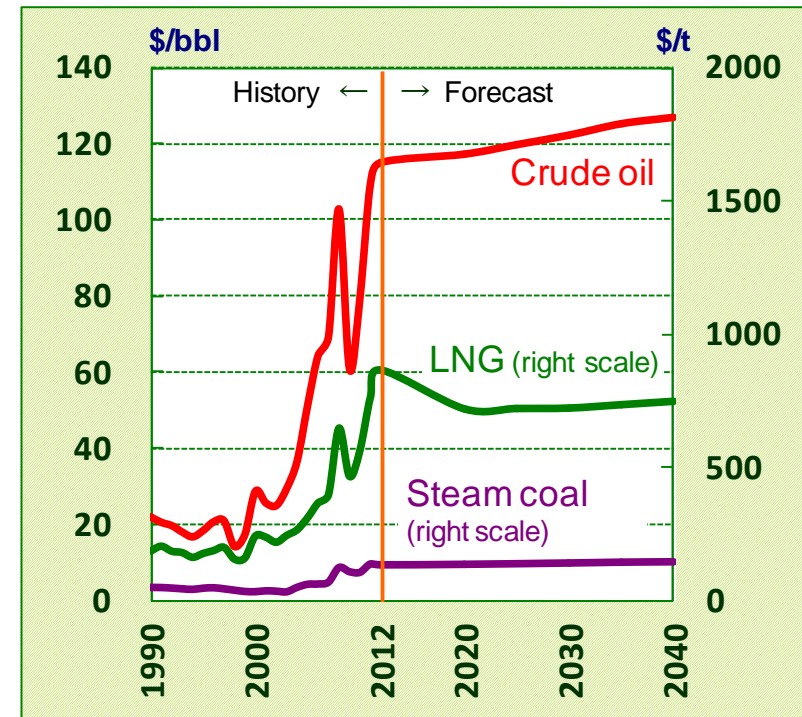
- Population is expected to increase mainly in developing (non-OECD) countries.
- China's population will gradually age and peak out around 2030. Meanwhile, population will rapidly increase in India and Africa, thanks to medical technology and food nutrition improvement.
- India will replace China as the most populated country in Asia (and the world) around 2025; population should reach 1.59 billion in 2040.

Major Assumptions: Primary Energy Price Outlook

			2012	2020	2030	2040
Crude oil	\$/bbl	Real	115	117	122	127
		Nominal	115	137	174	221
Steam coal	\$/t	Real	134	136	141	146
		Nominal	134	160	202	254
Natural gas	Japan	Real	864	719	722	747
		Nominal	864	842	1,031	1,301
	Japan	Real	16.7	13.9	14.0	14.4
		Nominal	16.7	16.3	19.9	25.1
	Europe	Real	10.5	11.1	12.0	12.8
		Nominal	10.5	13.0	17.2	22.3
USA	Real	2.8	4.3	5.6	8.0	
	Nominal	2.8	5.1	8.0	14.0	

(Note 1) Prices are for calendar years. Forecast prices are in 2012 dollars.

(Note 2) Japan's energy prices are on a CIF import basis.



- Crude oil prices (CIF import price for Japan) fell from a high of \$103 per barrel in 2008 to \$61/bbl in 2009 and turned upward later. While oil demand will remain robust mainly in Asia, oil supply constraints will emerge gradually reflecting rising depletion rates for oil fields in production and stagnant investments. In line with these developments, crude oil prices will soar gradually.
- As interregional gas trade expands, the existing interregional LNG price disparity will shrink.
- Coal prices will almost level off.

Scenarios

Reference Scenario

This scenario reflects past trends as well as energy and environment policies that have been introduced so far. This scenario does not reflect any aggressive policies for energy conservation or low-carbon measures.

Advanced Technology Scenario

In this scenario, energy conservation and low-carbon technologies are promoted for maximum impacts, as each country is assumed to implement powerful policies to enhance energy security and address climate change issues.

Enhanced Unconventional Resources Development Scenario

Using the Reference Scenario as a starting point, this scenario maximizes the development of unconventional fossil fuel resources, including shale oil and gas. This scenario identifies the global impacts of such development on energy supply and demand.

Advanced Technology Scenario Assumptions

In this scenario, each country will further enhance policies on energy security and address global warming. Technological developments and international technology transfers will be promoted to further expand the diffusion of innovative technologies.

Introducing and Enhancing Environmental Regulations and National Targets

Environment Tax, Emissions Trading, RPS, Subsidy Provisions, FIT, Efficiency Standards, Automobile Fuel Efficiency Standard, Low Carbon Fuel Standard, Energy Efficiency Labeling, National Targets, etc.

Promoting Technology Development and International Technology Cooperation

R&D Investment Expansion, International Cooperation on Energy Efficient Technology (steelmaking, cement and other areas), Support for Establishing Energy Efficiency Standards, etc.

【Demand Side Technology】

■ Industry

Under sectoral and other approaches, best available technologies on industrial processes (for steelmaking, cement, paper-pulp and oil refining) will be deployed globally

■ Transport

Clean energy vehicles (highly fuel efficient vehicles, hybrid vehicles, plug-in hybrid vehicles, electric vehicles, fuel cell vehicles) will diffuse further.

■ Building

Efficient electric appliances (refrigerators, TVs, etc.), highly efficient water-heating systems (heat pumps, etc.), efficient air conditioning systems and efficient lighting will diffuse further, with heat insulation enhanced.

【Supply Side Technology】

■ Renewable Energy

Wind power generation, photovoltaic power generation, CSP (Concentrated Solar Power) generation, biomass power generation and bio-fuel will diffuse further.

■ Nuclear Energy Promotion

Nuclear power plant construction will be accelerated with operating rates improved.

■ Highly Efficient Fossil-fired Power Plant Technology

Coal-fired power plants (USC, IGCC, IGFC) and natural gas MACC (More Advanced Combined Cycle) plants will diffuse further.

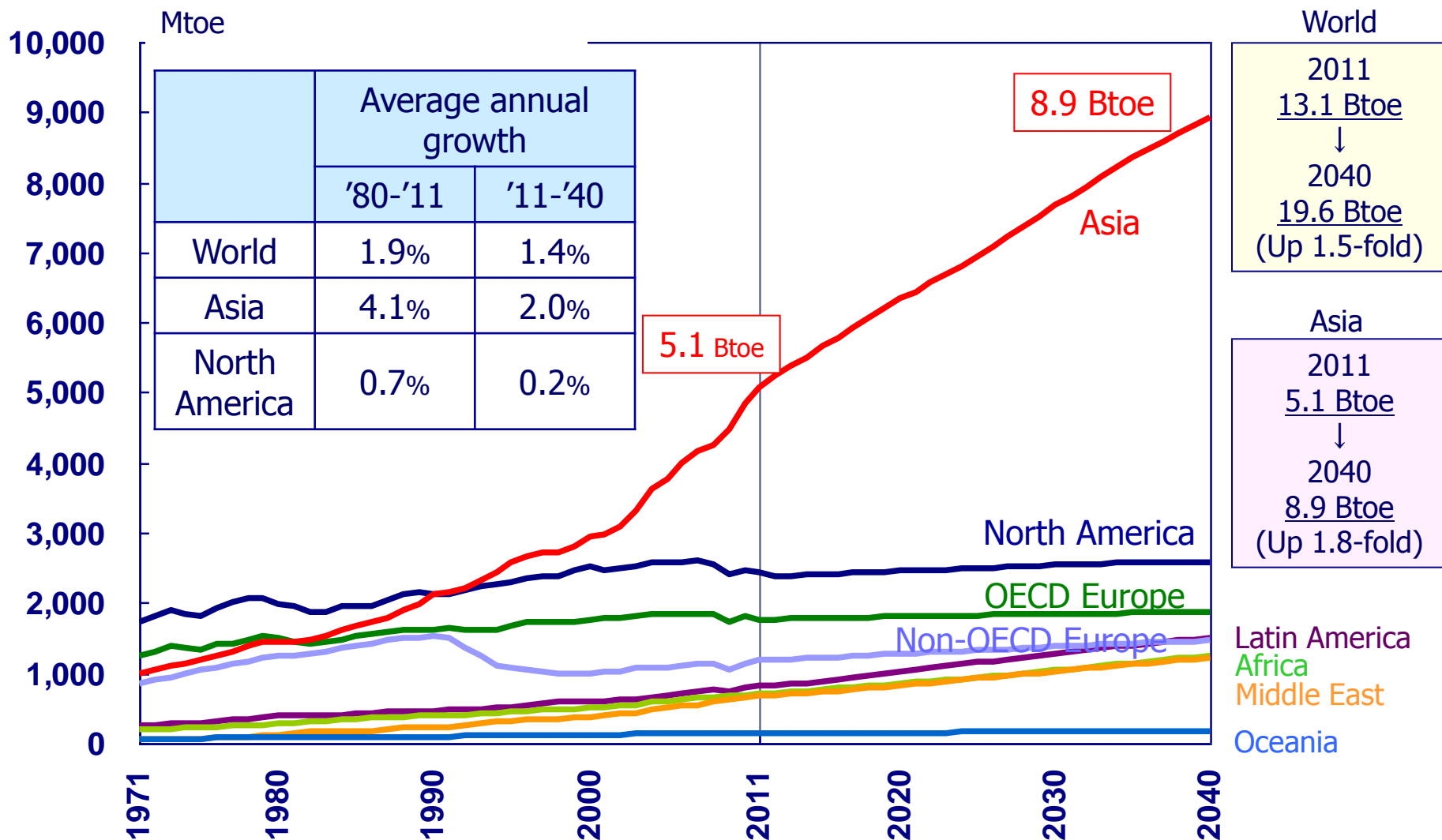
■ CCS

CCS deployment will expand in the power generation sector (new and old coal-fired and gas-fired plants) and the industrial sector (steelmaking, cement and other plants that emit massive GHGs).

I. World/Asia Energy Supply and Demand Outlook

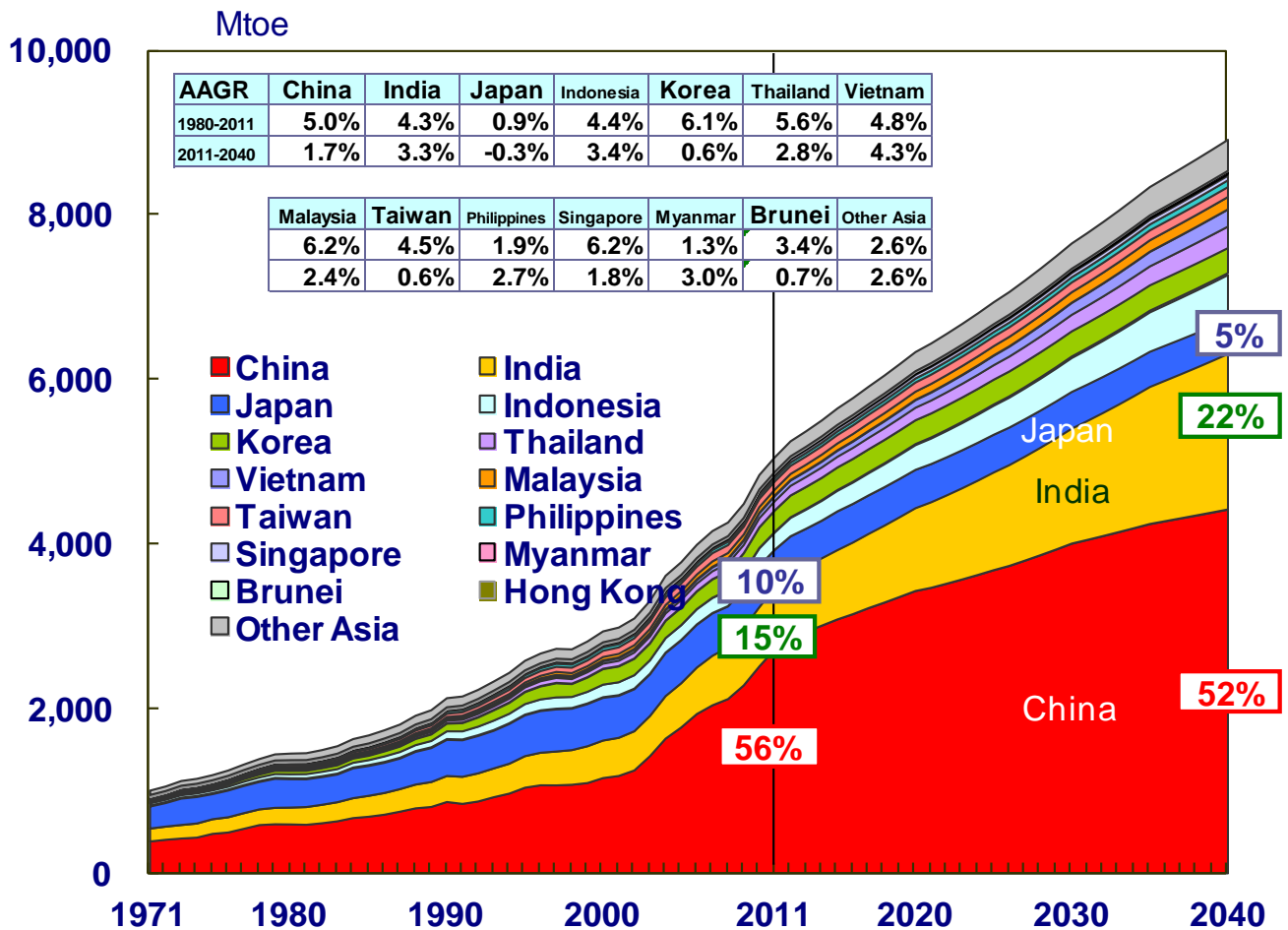
Primary Energy Demand by Region

Reference Scenario



Under steady economic growth assumptions, Asian energy consumption in 2040 will increase 1.8-fold from the present level (from 5.1 billion tons in 2011 to 8.9 billion tons in 2040). Non-OECD countries will account for about 90% of global energy consumption growth between 2011 and 2040.

Asian Primary Energy Consumption



Asia

2011
4.9 Btoe

↓

2040
8.5 Btoe
(Up 1.8-fold)

China, India

2011
2.7 Btoe 0.75 Btoe

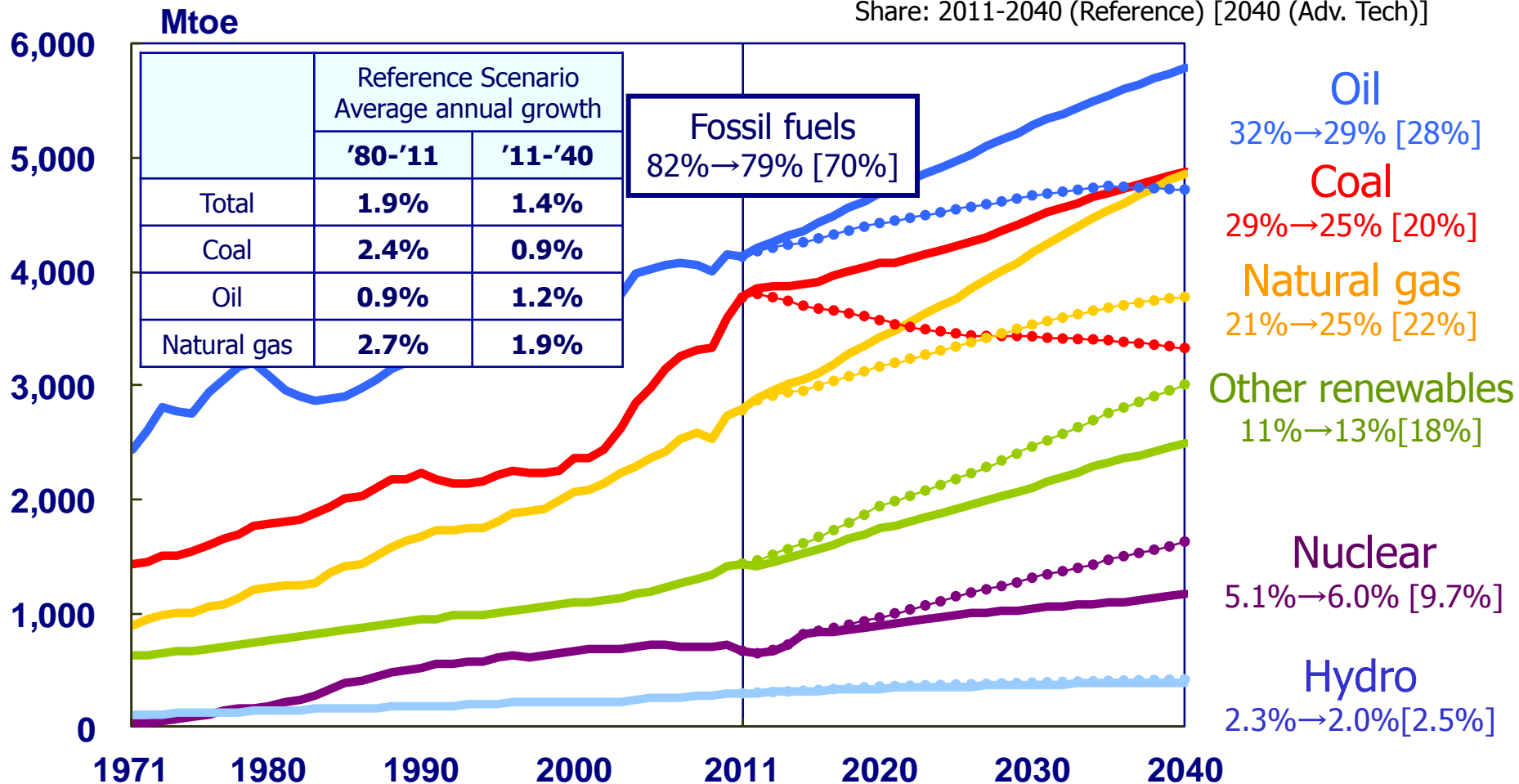
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2040
4.4 Btoe 1.9 Btoe
(Up 1.8-fold) (Up 2.6-fold)

- Energy demand in China and India will increase rapidly in line with economic growth. Their share of Asian energy demand will expand from 71 to 74% in 2040.
- Japan's energy consumption will decline as a result of progresses in energy efficiency combined with a maturing economy and a decreasing population. Its share of Asian energy consumption will shrink from 10% to 5%.

Global Primary Energy Consumption

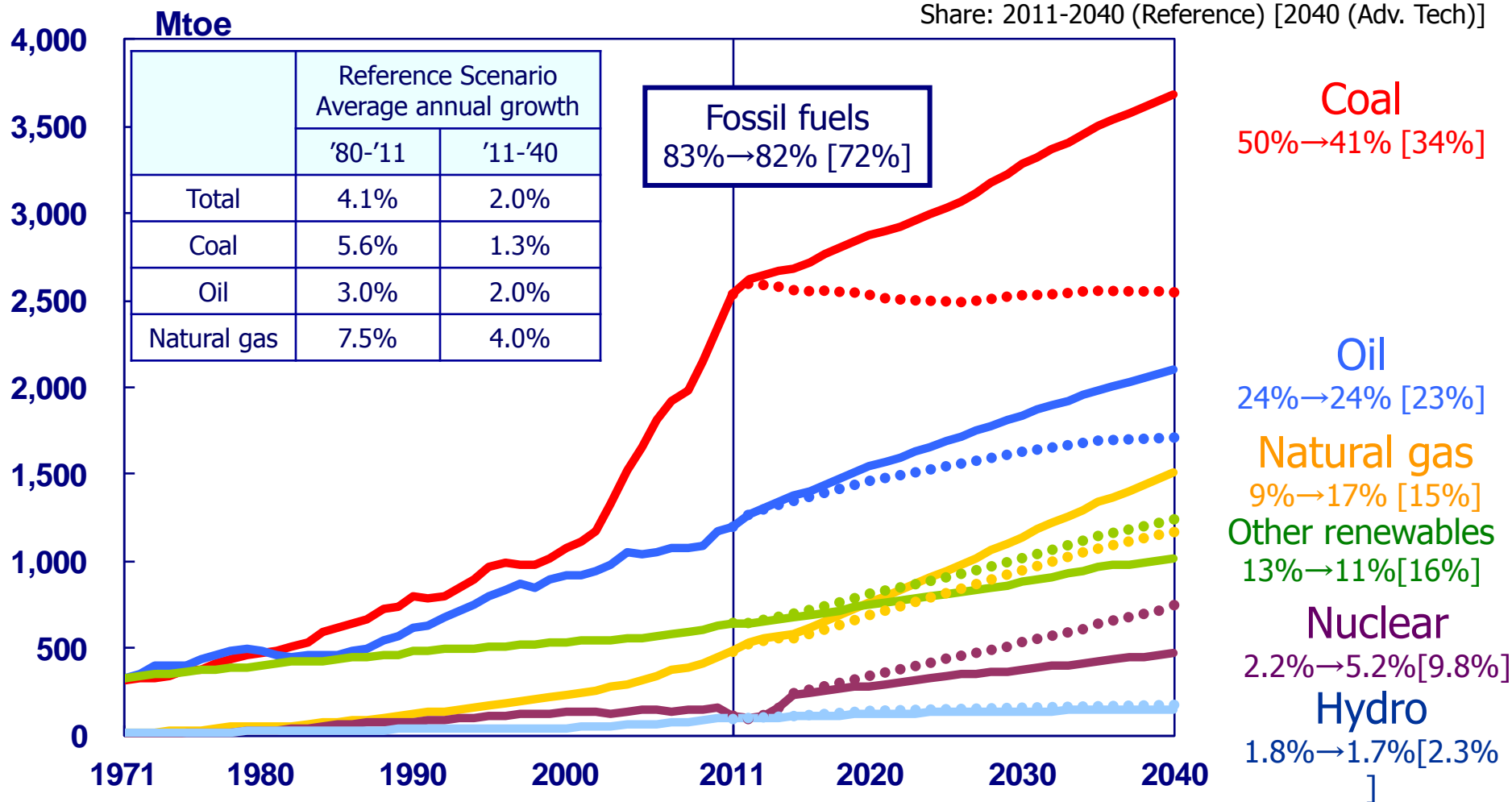
Solid line -----Ref. Scenario
Dotted line ····Adv. Tech.



- In both the Reference and the Advanced Technology Scenarios, oil will continue to capture the largest share of primary energy consumption and remain a major energy source until 2040. In the Advanced Technology Scenario, oil consumption will peak around 2030.
- Fossil fuels' share of primary energy consumption in 2040 will fall to 79% in the Reference Scenario and to 70% in the Advanced Technology Scenario. As such, fossil fuels will remain a major energy source.
- Natural gas will expand its share due to fuel switching from other fossil fuels to gas. Even in the Advanced Technology Scenario, natural gas consumption will continue to increase, instead of peaking out.

Asian Primary Energy Consumption

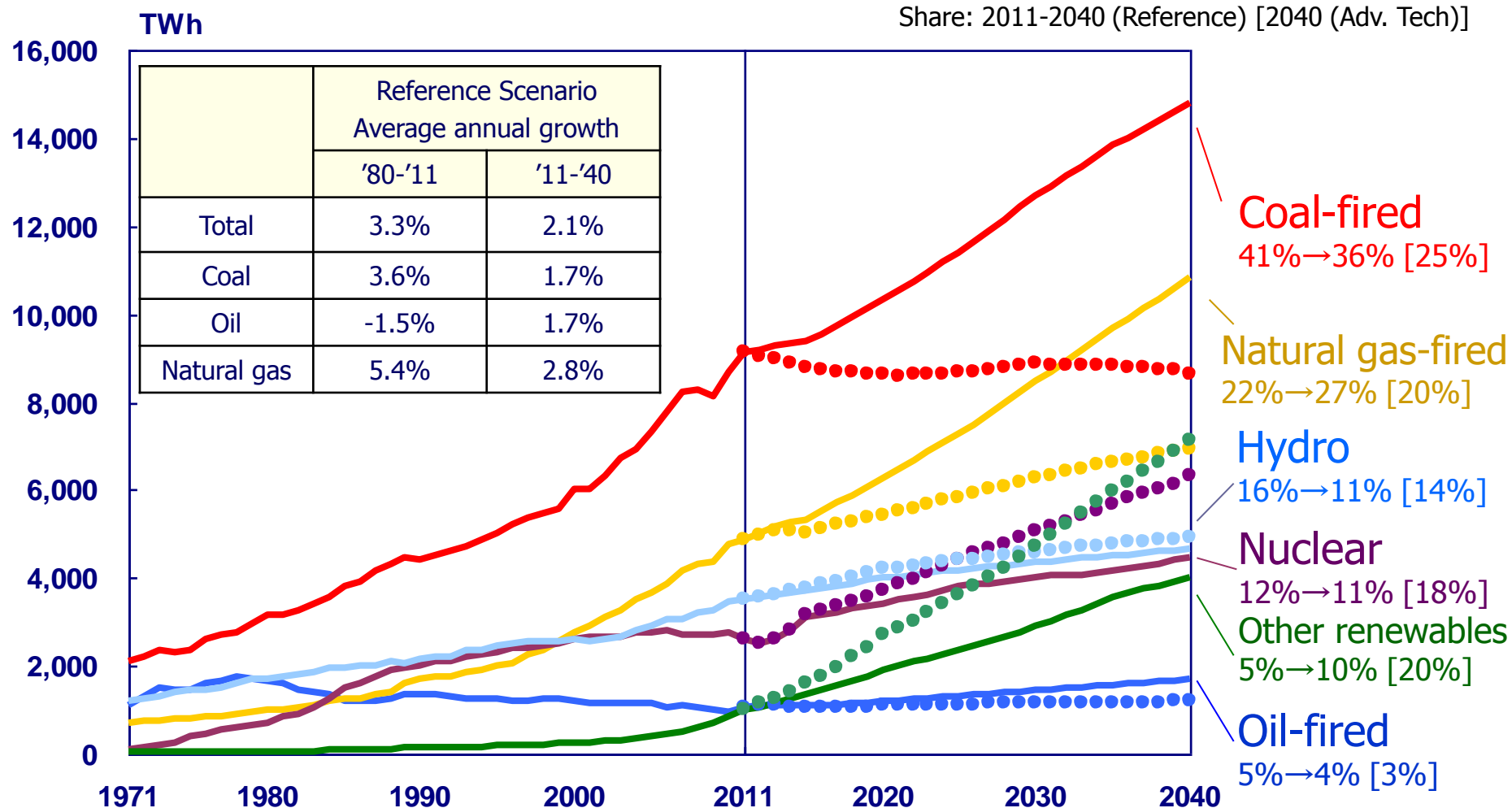
Solid line -----Ref. Scenario
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- In Asia, coal and oil will remain major energy sources with consumption increasing. Natural gas will also expand and increase its share to 17%, in line with demand from power generation sector.
- In the Technology Advanced Scenario, coal consumption will decline substantially while retaining the largest share among energy sources. Coal will still account for 34% of total energy consumption.

Power Generation Mix (World)

Solid line -----Ref. Scenario
Dotted line ····Adv. Tech.



- In 2040, coal will still account for the largest share of power generation. Natural gas-fired power plants will globally increase on the introduction of natural gas combined cycle plants. Renewable energy sources including wind and solar energy will also expand their share of power generation.
- In the Advanced Technology Scenario, coal's share of power generation will decline to 25%, while nuclear, hydro and other renewable energy sources will expand their respective shares.

Photovoltaic and Wind Power Generation (World)

Photovoltaic (PV)

Wind Power

Photovoltaic (PV)

World

Asia

2011
89 GW

2011
9.0GW

2040

2040

Ref. Adv. Tech.
548 GW 1,458GW
(Up 6-fold) (Up 16-fold)

Ref. Adv.
Tech.
172 GW 453GW
(Up 19-fold) (Up 50-fold)

Wind Power

World

Asia

2011
229 GW

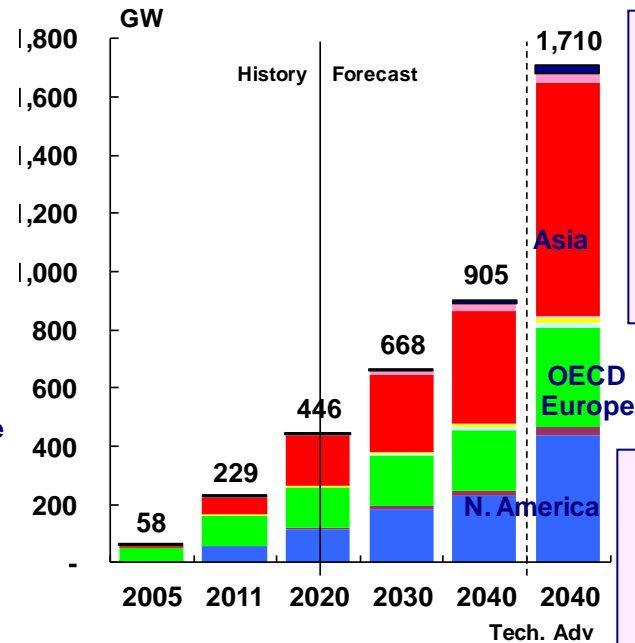
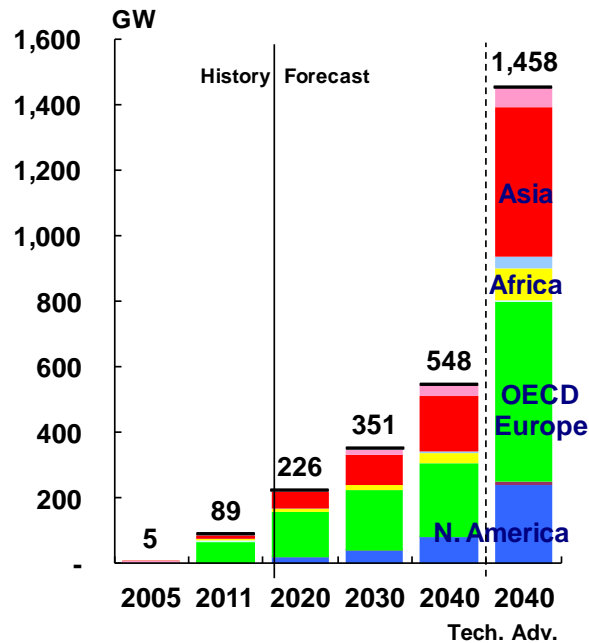
2011
61 GW

2040

2040

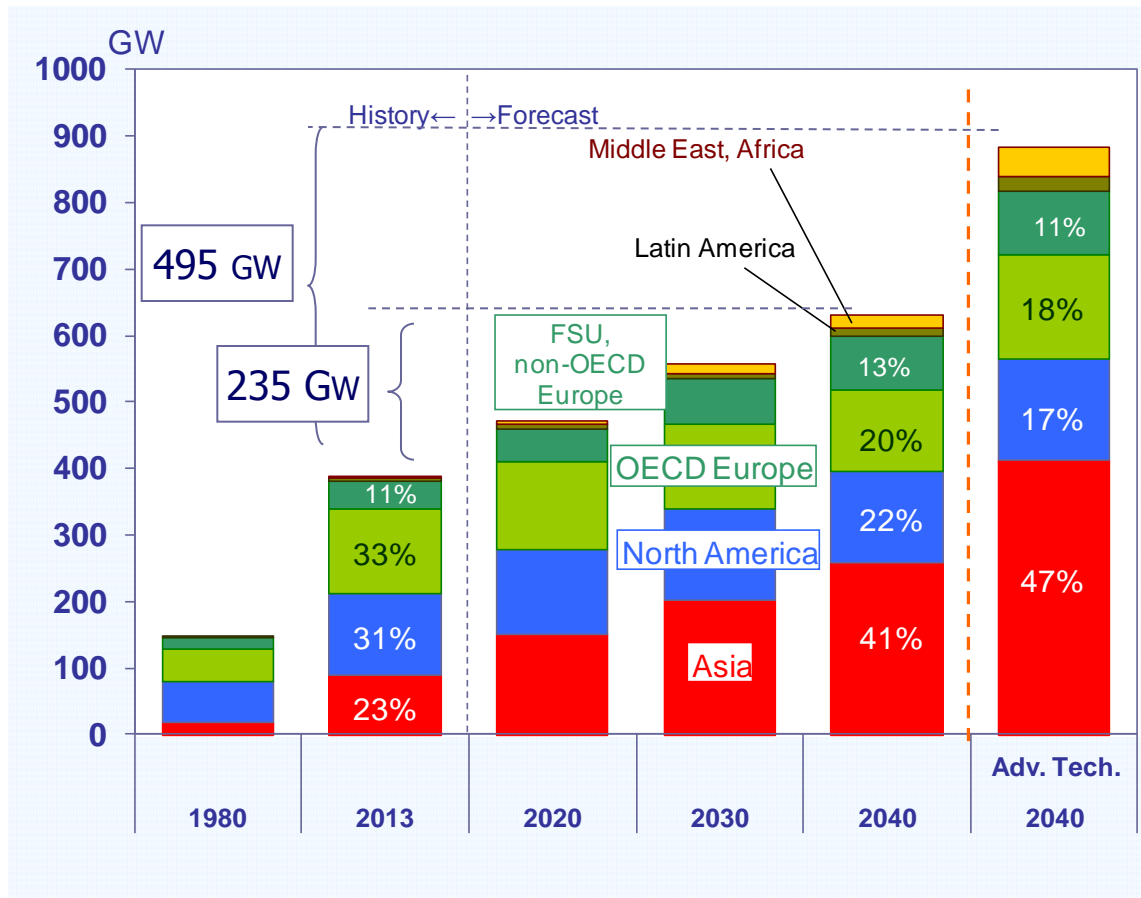
Ref. Adv.
Tech.
905 GW 1,710GW
(Up 4-fold) (Up 7-fold)

Ref. Adv.
Tech.
390 GW 801GW
(Up 6-fold) (Up 13-fold)

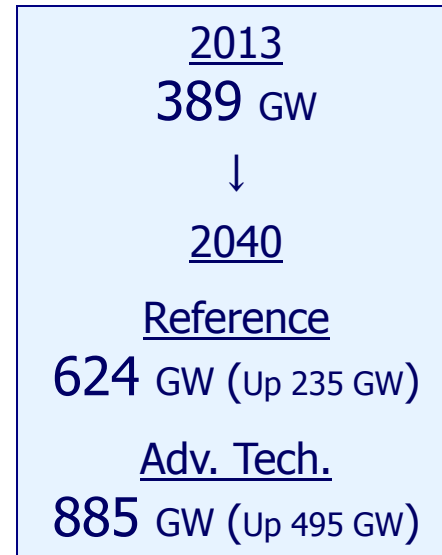


- Renewable energy power generation will expand due to technological development and supportive measures such as feed-in tariff systems and subsidization.
- In the Reference Scenario, global photovoltaic generation capacity will expand six-fold from 2011 to 548 GW in 2040 and wind power generation capacity will increase four-fold from 2011 to 905 GW in 2040. Photovoltaic and wind power generation's share of global generation will increase from 2.3% in 2011 to 5.9% in 2040.
- In the Advanced Technology Scenario, photovoltaic power generation capacity in 2040 will be 2.7-fold more than in the Reference Scenario, standing at 1,458 GW. Wind power generation capacity will be 1.9-fold more at 1,710 GW.

Global Nuclear Power Generation Capacity



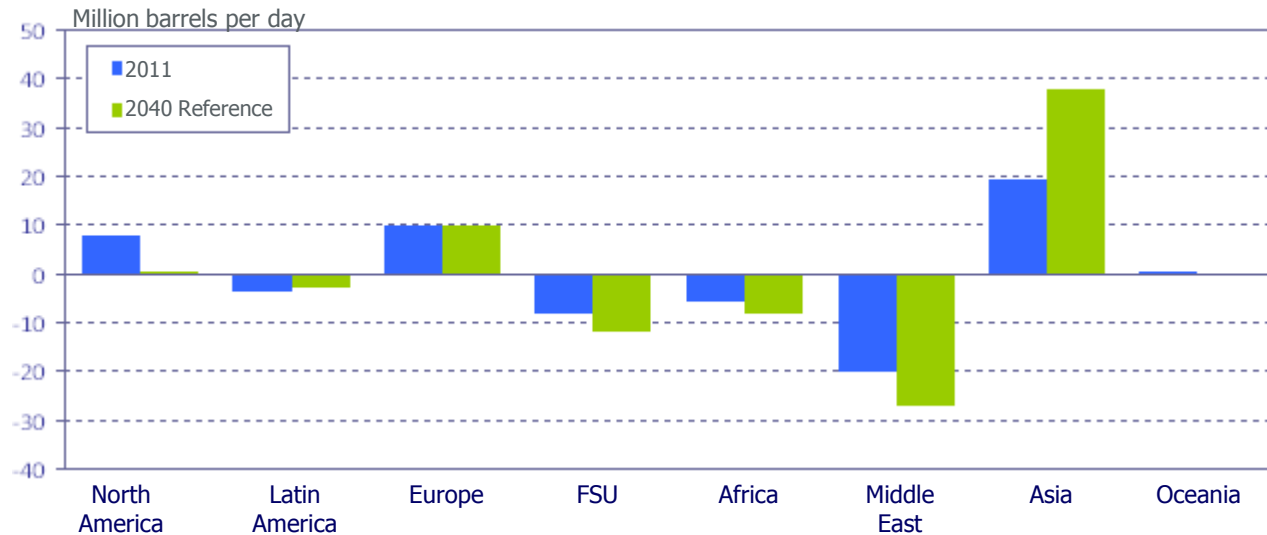
World



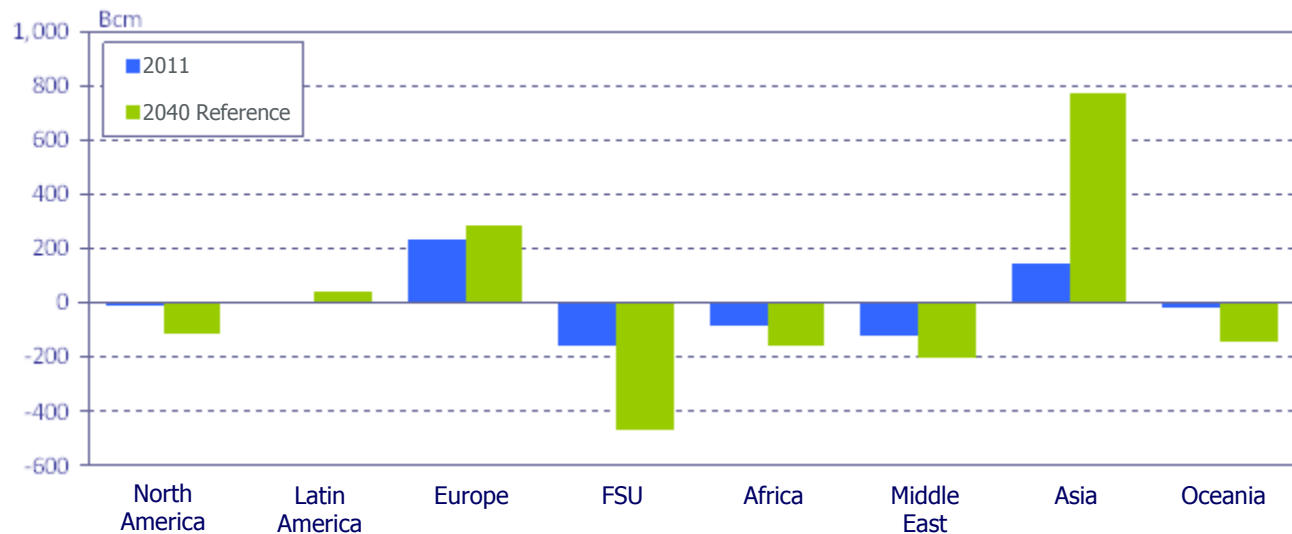
- Global nuclear power generation capacity in 2040 will grow by 235 GW in the Reference Scenario and by 495 GW in the Advanced Technology Scenario. Asia will lead the growth and account for nearly half of the global capacity in 2040 in the Advanced Technology Scenario.

Net Oil/Natural Gas Import Projections

Oil



Natural gas

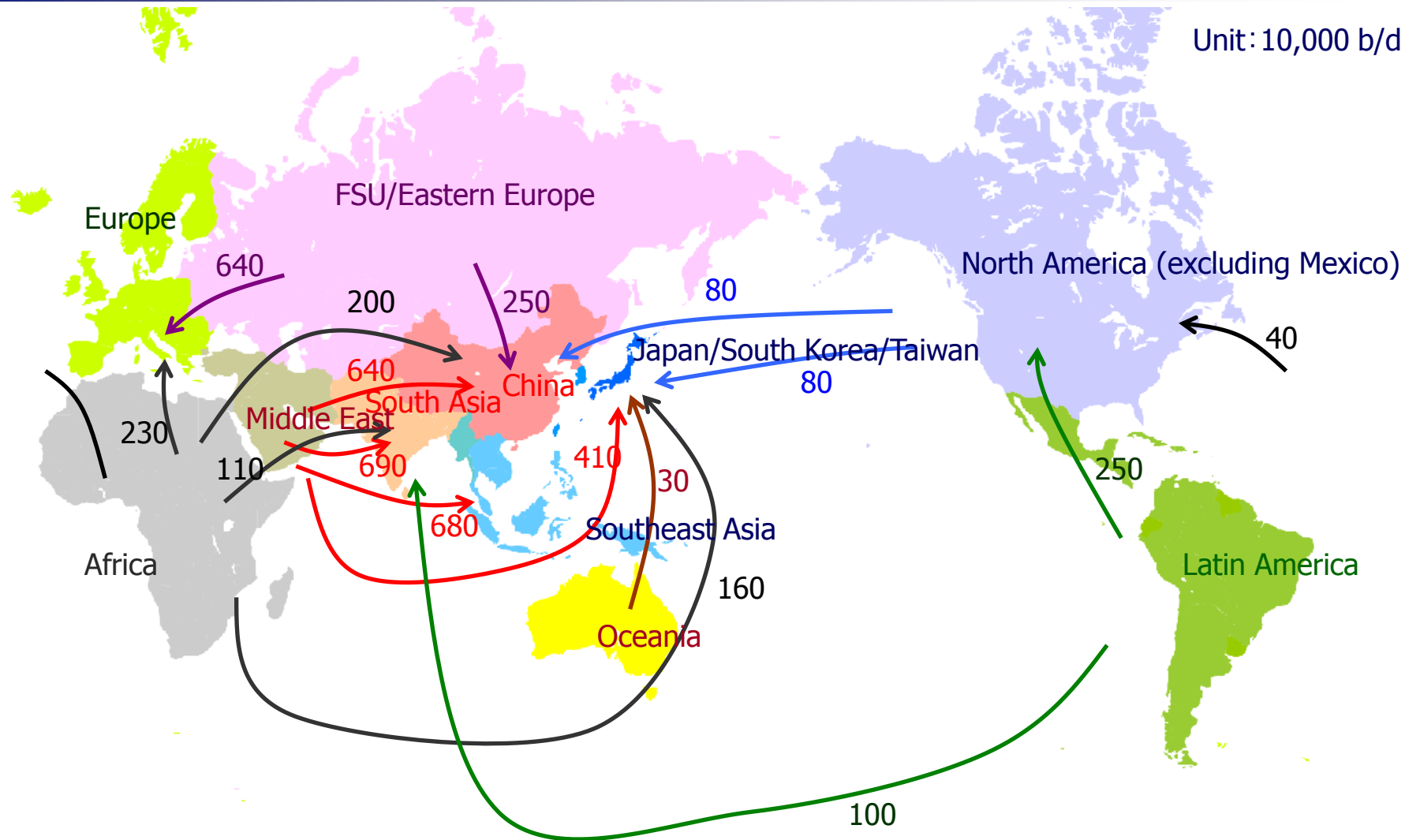


- While Asia will expand oil demand toward 2040, North America will go in the direction of oil self-sufficiency.

The Middle East will be required to expand its oil output to meet the Asian demand growth.

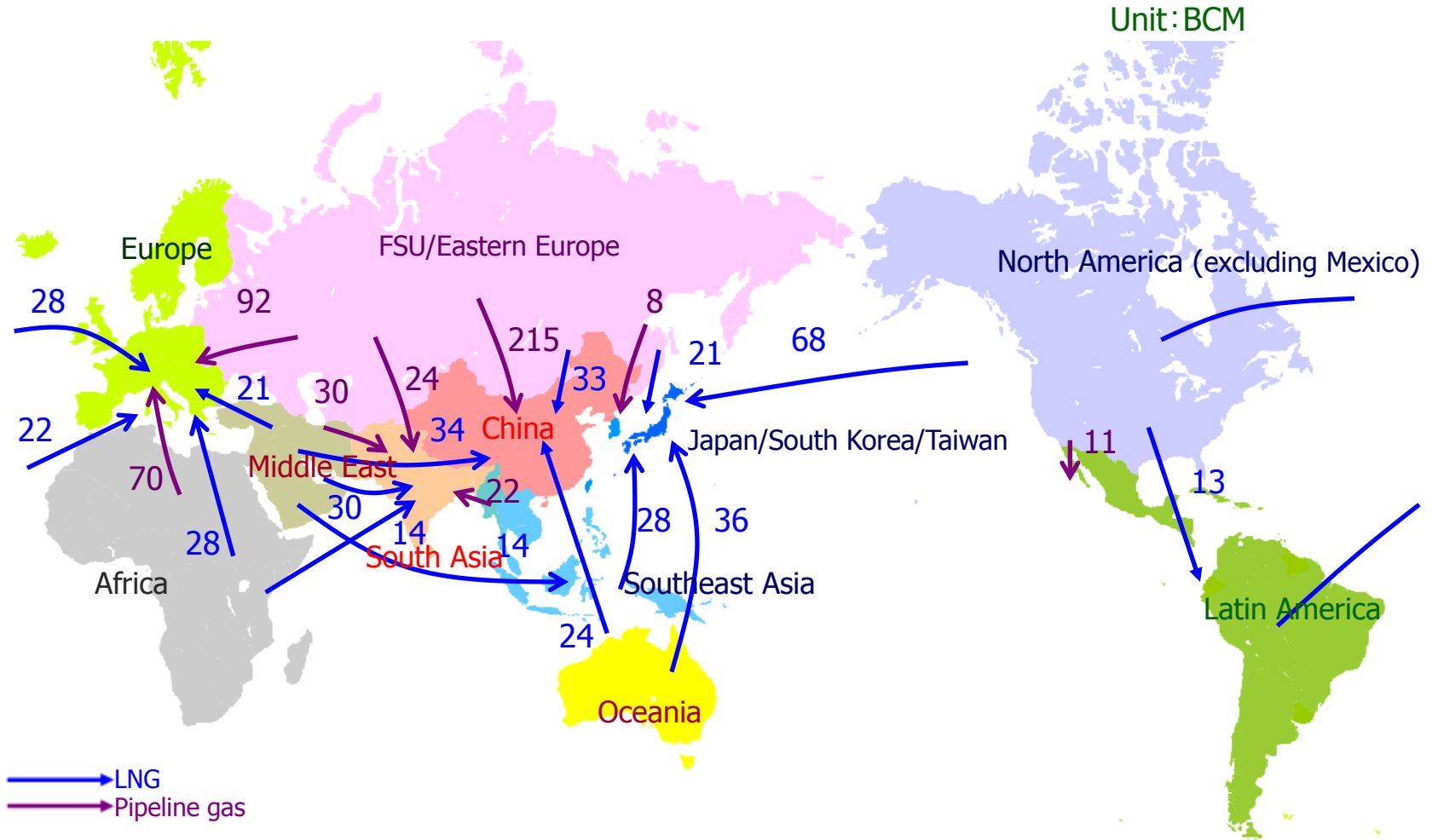
- While natural gas imports are increasing mainly in Asia, exports from North America are expanding.

Major Crude Oil Trade Flows (Ref. Scenario: 2040)



- By 2040, an export flow from North America to Asia will have been established.
- Crude oil imports into China, for a total of 12 Mb/d, will come from the Middle East, Africa, the Former Soviet Union and North America.

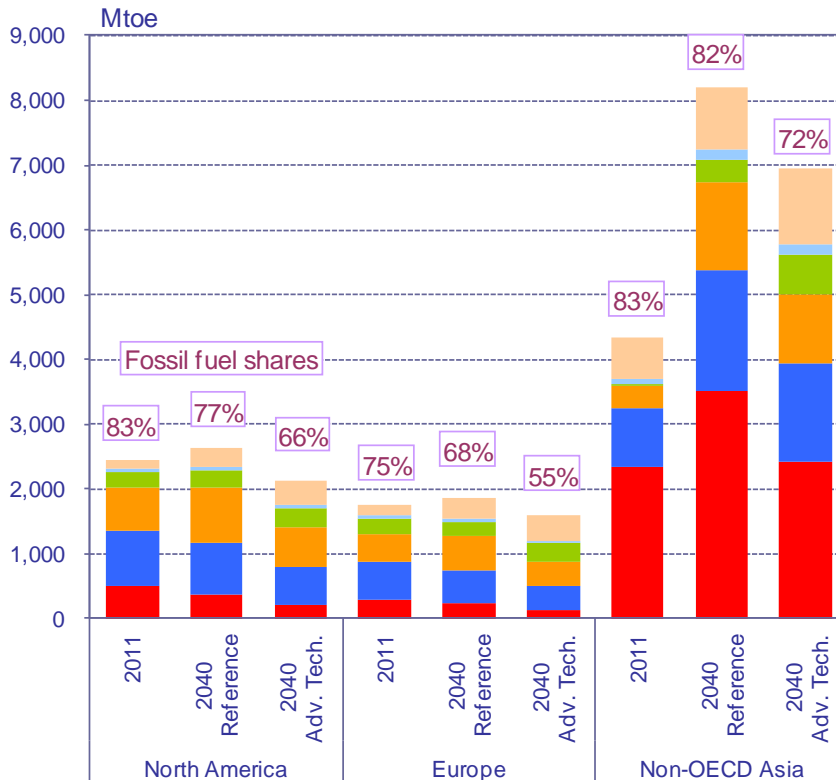
Major Natural Gas Flows (Ref. Scenario: 2040)



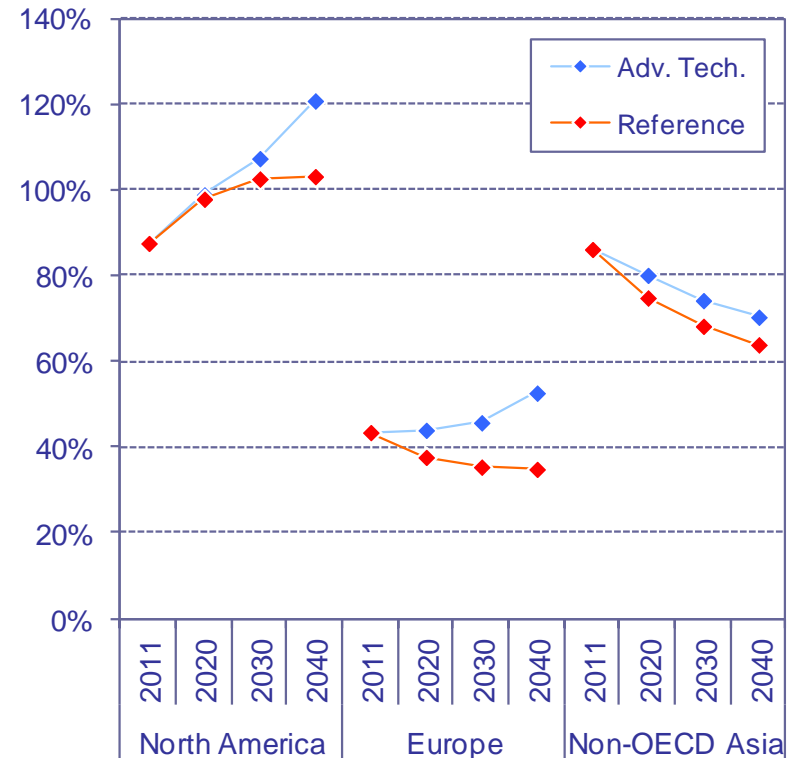
- Exports from North America, the Former Soviet Union and Australia will expand.
- Large export flows from North America will be established.
- Asia's imports will increase rapidly.

Fossil Fuel Self-Sufficiency Rates (North America, Europe, Asia)

Primary Energy Demand Mix



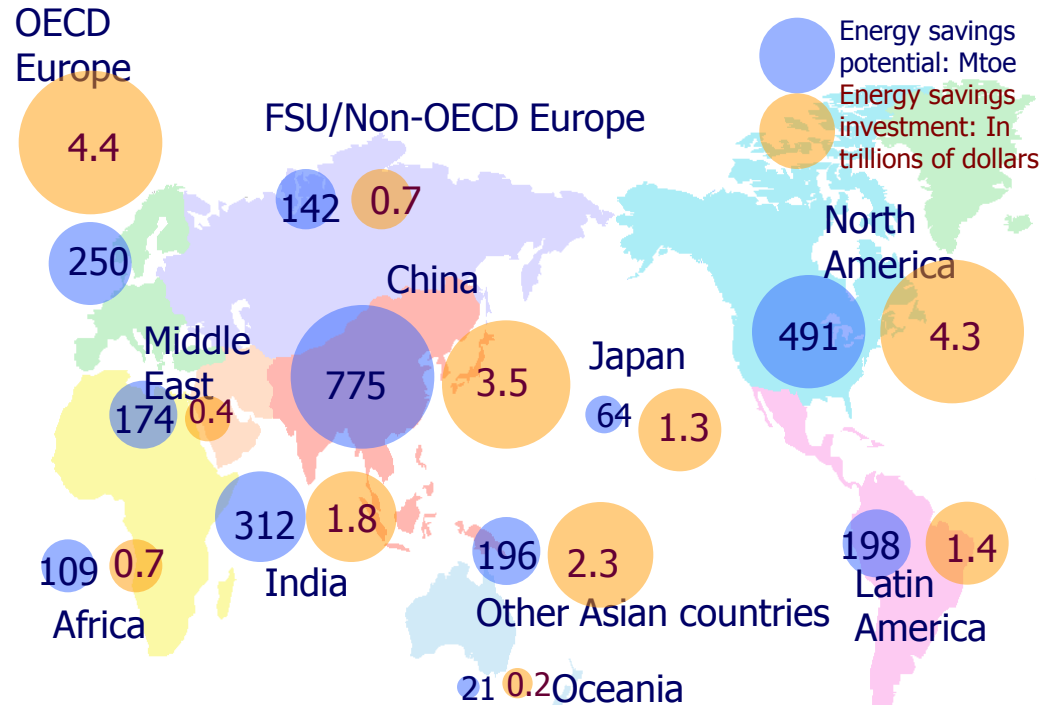
Fossil Fuel Self-Sufficiency Rates



- Even in the Advanced Technology Scenario, the fossil fuel self-sufficiency rate in non-OECD Asian countries will be as high as 72%.
- In North America, the fossil fuel self-sufficiency rate will rise above 100%. In the Advanced Technology Scenario, the self-sufficiency rate for Europe will increase slightly while the rate for Asia will continue to fall.

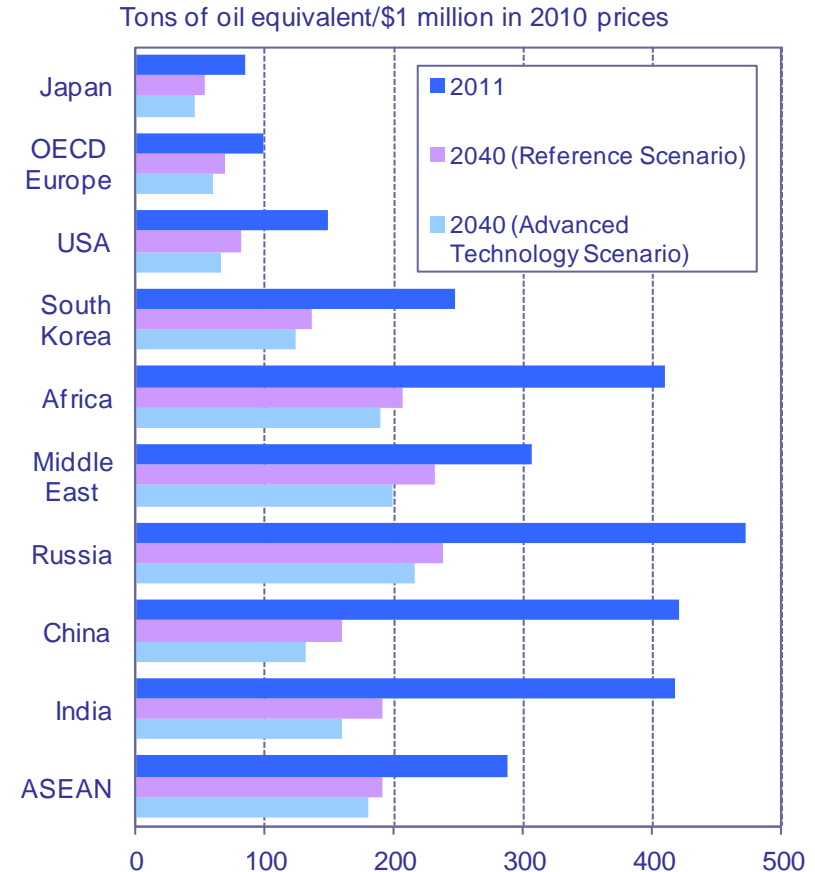
Energy Savings Potential by Region

Energy savings potential in 2040 and accumulated energy savings investment through 2040



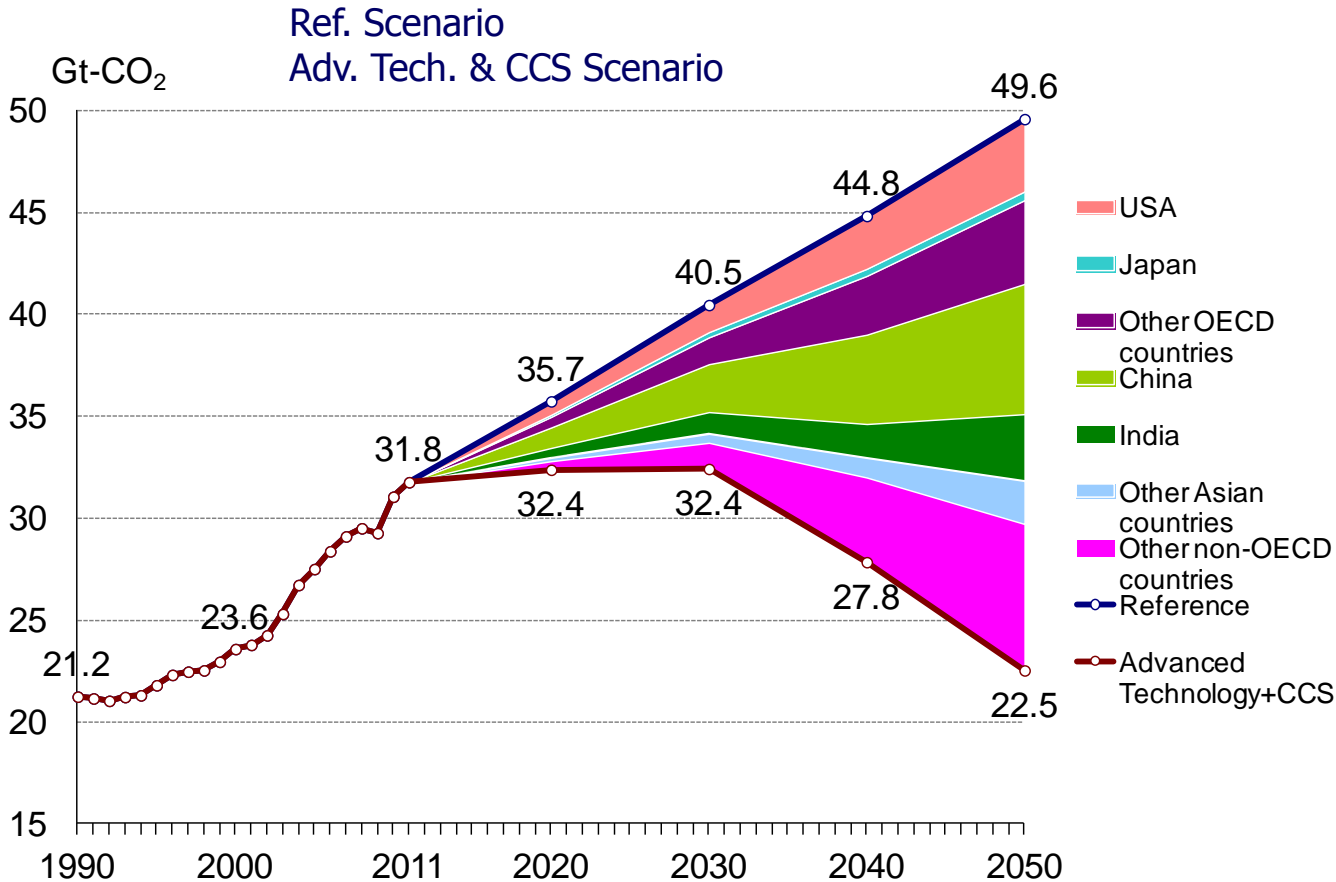
※ The energy savings potential is the primary energy consumption gap between the Advanced Technology and Reference Scenarios. Investment indicates an energy savings investment gap between the two scenarios through 2040.

Projected energy consumption per GDP (energy consumption rates)



- China, India and North America show the largest energy savings potential. Developed countries will be required to invest far more in energy savings.
- In line with economic growth and energy conservation progress through 2040, gaps in primary energy consumption per GDP will narrow. Even with the implementation of maximum energy conservation measures, there will be gaps between regions.

CO₂ Emissions (World: by Region)

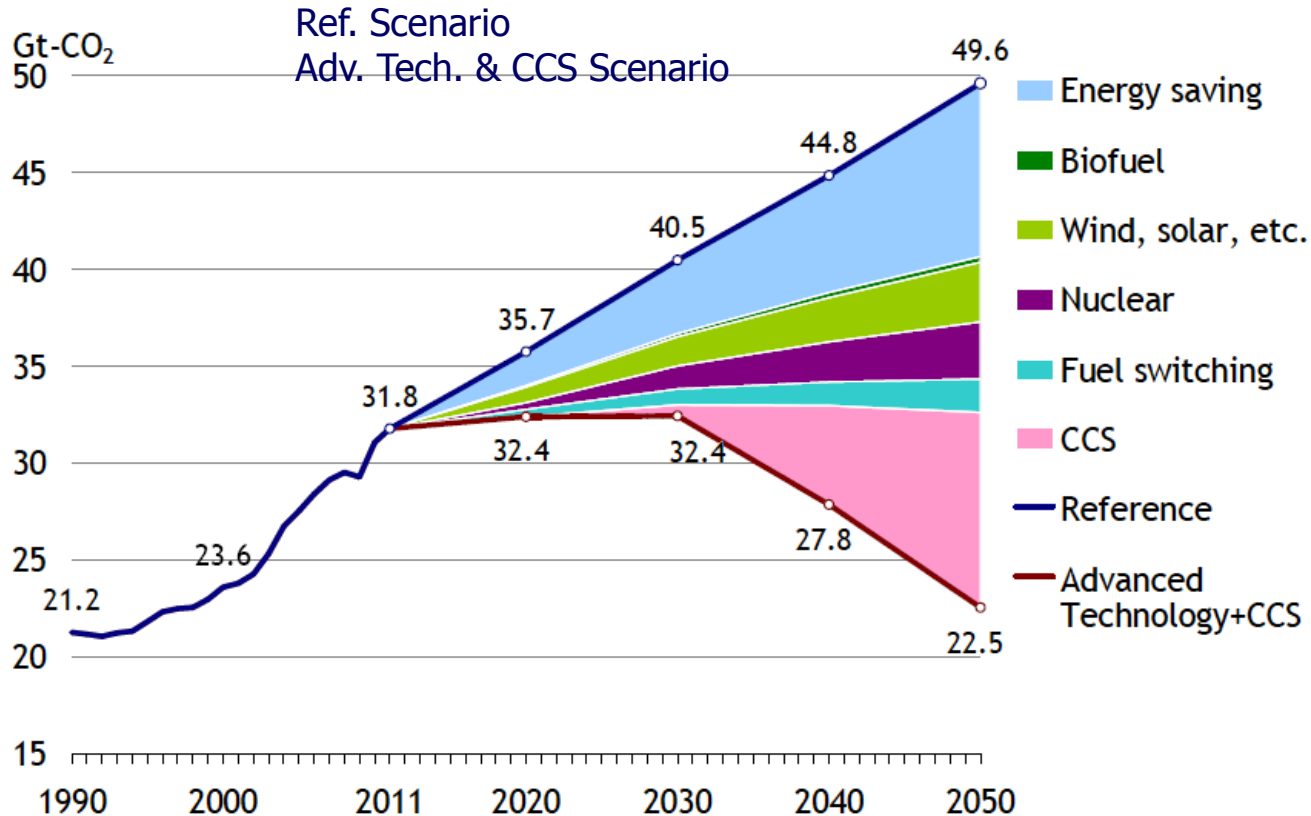


Breakdown of CO₂ Emissions Reduction in 2050

	Gt-CO ₂	Share
USA	3.5	13%
Japan	0.4	2%
Other developed countries	4.1	15%
China	6.4	24%
India	3.2	12%
Other Asian countries	2.1	8%
Other developing countries	7.2	27%
OECD	8.1	30%
Non-OECD	19.0	70%
Non-OECD Asia	11.8	43%
World total	27.1	100%

- CO₂ emission reduction potential in the Adv.Tech. Scenario, in non-OECD countries is larger than in OECD countries (non-OECD countries account for 19 gigatons CO₂ or 70% of the global potential).
- This indicates that it is important for non-OECD countries to enhance climate change measures.
- There exists great potential, particularly in non-OECD Asian countries (11.8 Gt- CO₂ or 43% of the global potential). China alone accounts for 24% of the global potential (6.4 Gt- CO₂).

CO₂ Emissions (World: by Reduction Measure)

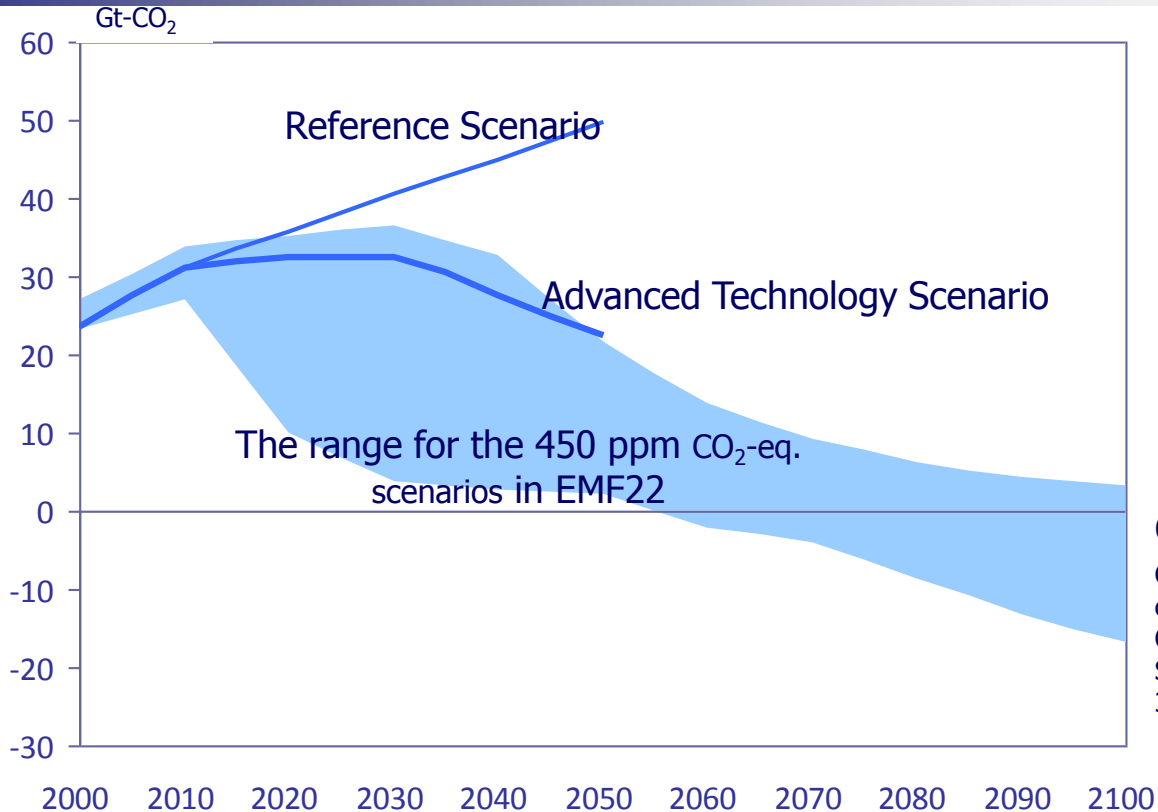


Breakdown of CO₂ Emission Cut through 2050

	Gt-CO ₂	Share
Energy saving	8.9	33%
Biofuel	0.3	1%
Solar, wind, etc.	3.1	11%
Nuclear	2.9	11%
Fuel switching	1.7	6%
CCS	10.1	37%
Total	27.1	100%

- CCS accounts for 10.1 Gt-CO₂ and represents the largest share of the 2050 CO₂ emission reduction potential (37%).
- Energy savings at 8.9 Gt-CO₂ represent the second largest share of the reduction potential (33%).
- The diffusion of renewable energy and fuel switching (from coal and oil to natural gas) can also play a major role equivalent to about 20% of the total.
- In order to halve global CO₂ emissions from present levels, additional measures will be required, including longer-term measures such as the development of innovative technologies and environment-friendly urban development.

CO₂ Emission Pathways for the Overshoot Scenario



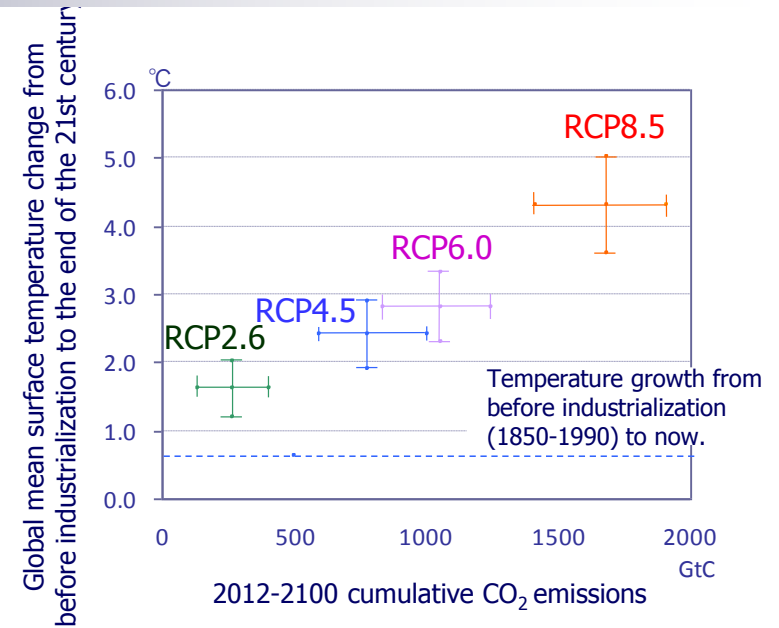
(Source)

Clarke et al. (2009), "International climate policy architectures: Overview of the EMF 22 International Scenarios", *Energy Economics*, vol. 31, pp. 64-81.

- At the 22nd Working Group of the EMF (Energy Modeling Forum), the world's 10 major integrated assessment models participated in considering long-term GHG concentration and the presence or absence of an overshoot.
- CO₂ emission cuts for the Advanced Technology Scenario by 2050 are close to the upper-bound estimate in the 450 ppm scenario, indicating that the 2°C target could fail to be achieved unless CO₂ emissions are substantially further reduced in the second half of the 21st century. To achieve the target, drastic and innovative technologies including bioenergy with CCS (BECCS) and carbon capture and use (CCU) technologies like artificial photosynthesis will have to be developed and diffused.
- We may have to keep close watch on uncertain factors, including the future expansion and deepening of scientific knowledge, the timing for China and India to take part in an international emission reduction framework, and the reduction of GHG emissions other than energy-related CO₂.

5th IPCC Assessment Report

- The Intergovernmental Panel on Climate Change held its 36th general conference and the 12th meeting of its Working Group I in Stockholm on September 23-26, 2013, where the working group's report as part of the IPCC's Fifth Assessment Report under preparation was adopted.
- Projections of future global mean surface temperature and sea level rise are given for four RCP (Representative Concentration Pathway) scenarios, developed for specific radiative forcing levels.



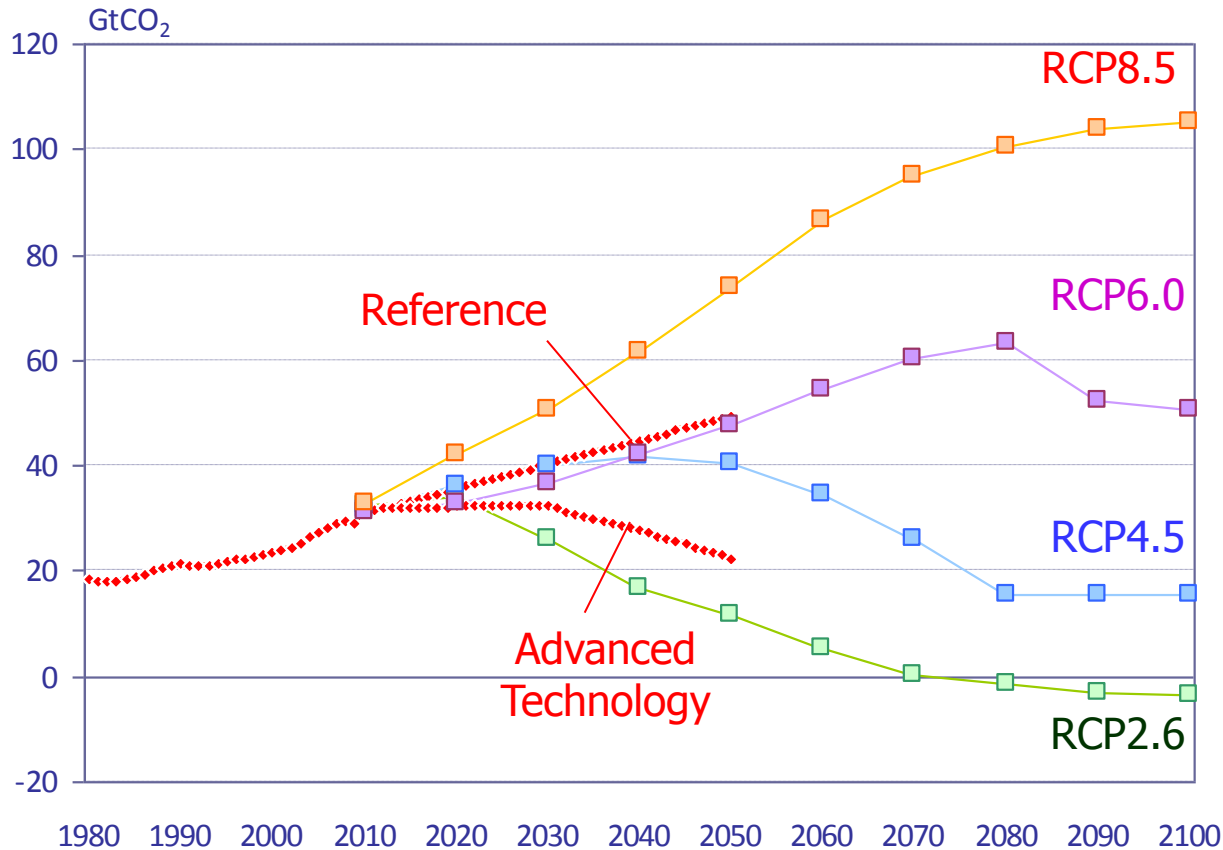
GHG concentration to be reached by 2100 (ppm)

Mean surface temperature change from before industrialization to the end of 21st century (°C)

Sea Level rise through the end of 21st century (m)

RCP Scenario	GHG concentration to be reached by 2100 (ppm)	Mean surface temperature change from before industrialization to the end of 21st century (°C)	Sea Level rise through the end of 21st century (m)
RCP2.6	475	1.6±0.4	0.26~0.55
RCP4.5	630	2.4±0.5	0.32~0.63
RCP6.0	800	2.8±0.5	0.33~0.63
RCP8.5	1,313	4.3±0.7	0.45~0.82

Comparing RCP Scenarios with the Reference/Advanced Technology Scenarios



(Source) RCP Database

CO₂ emissions for RCP scenarios are from fossil fuels and industry and those for the IEEJ scenarios are energy related.

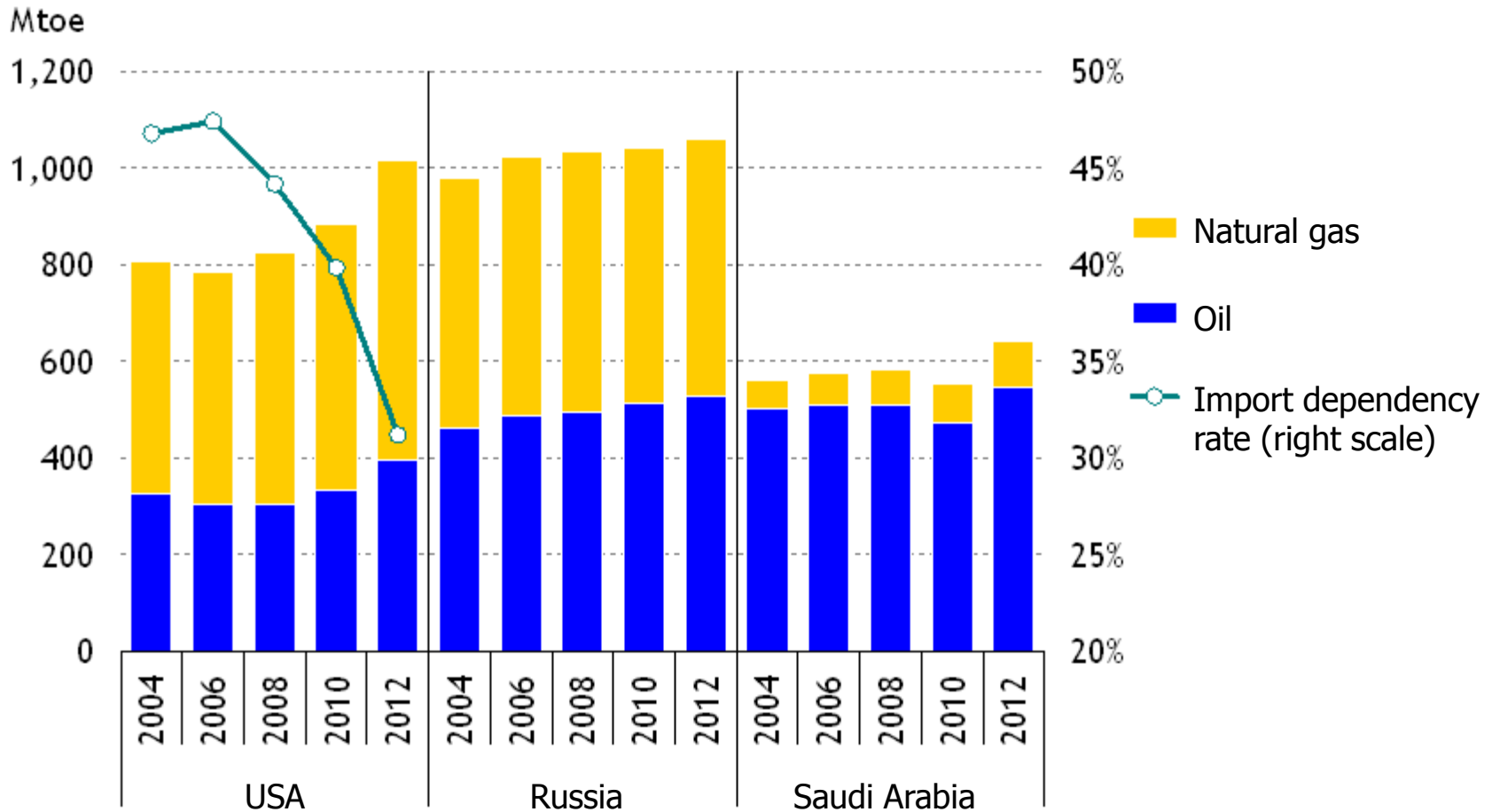
- CO₂ emissions in the Reference Scenario exceed those in the RCP 6.0 scenario. In the Reference Scenario, the temperature rise from before industrialization is very likely to exceed 2°C.
- CO₂ emissions in the Advanced Technology Scenario will fail to be halved in 2050 but will follow a pathway that will be between the RCP 4.5 and 2.6 scenarios and closer to the RCP 2.6 scenario.

Conclusion

- Global primary energy consumption will increase 1.5-fold through 2040. The increase will be concentrated in Asia. As energy demand expands rapidly, Asia's energy self-sufficiency rate will continue to fall and that change may destabilize the world energy market.
- As unconventional resources are developed, North America is expected to expand fossil fuel exports. The Middle East will still hold the key to meeting Asia's robust oil demand and it will become even more important for Asia (as a great energy consumer) to enhance relations with the Middle East.
- Asian emerging countries, including China and India, hold the key to reducing energy-related CO₂ emissions. Without their cooperation, the international community will not be able to address the climate change problem. Although costs for energy conservation and low-carbon measures may differ from country to country or from region to region, all countries or regions will have to adopt maximum measures of efficiency, while maintaining their sustainable economic growth.
- Long-term measures will have to be taken beyond 2050 to accomplish the 2°C target. In addition to existing technologies, innovative technologies including CCS and CCU technologies will have to be developed to accomplish the target.

II. Analyzing Changes Induced by the Shale Revolution

Trends of 3 Largest Oil/Natural Gas Producing Countries



BP "Statistical Review of World Energy 2013"

- U.S. oil and natural gas production is recovering rapidly under the shale revolution scenario. The United States will very soon become the world's largest oil and natural gas producer.
- The United States' net oil imports are also declining due to a combination of energy conservation and fuel switching.
- In a not-so-distant future, China will replace the United States as the world's largest oil importer.

Changes in the Enhanced Development Scenario

Energy prices

- Crude oil and natural gas prices will decline in line with expanding production. Coal and electricity prices will also fall through competition and fuel cost reduction efforts.
- In response to the price decline, consumption will increase.

Fossil fuel use

- Shift from coal-fired power generation to natural gas-fired generation, diffusion of natural gas vehicles will reduce oil requirements, etc.

Nuclear/renewable energy

- While some regions will decelerate the deployment of nuclear and renewable energy power plants due to a decline in their competitiveness, other regions will maintain their deployment pace from the viewpoints of energy security and climate change measures.

Energy trade

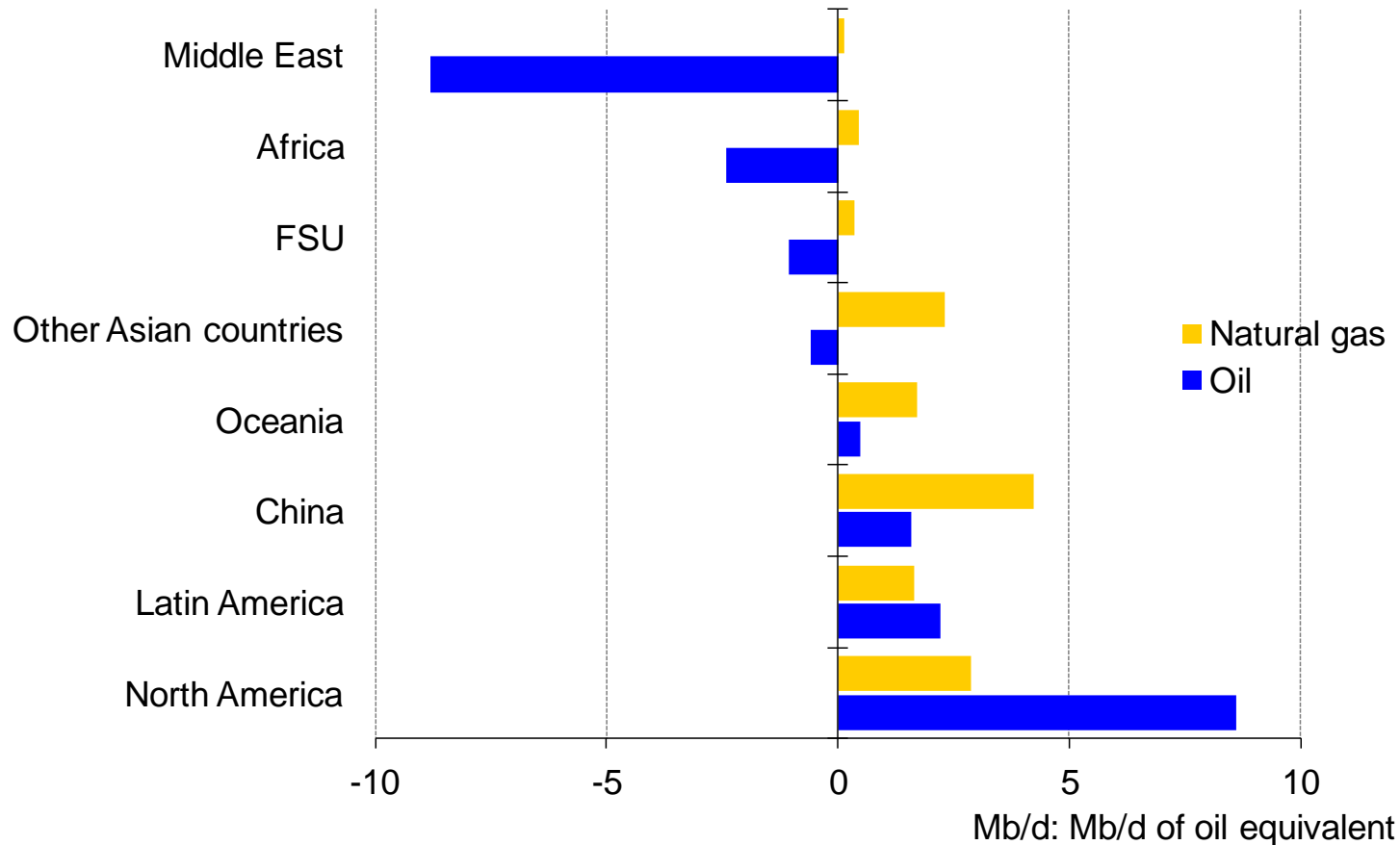
- Growth in net oil and natural gas exports from the Middle East and the Former Soviet Union will decelerate.

Economy

- Changes in oil and natural gas related activities, in energy prices, in energy imports and exports and in overall demand will impact all economies.

Changes in Oil/Natural Gas Output

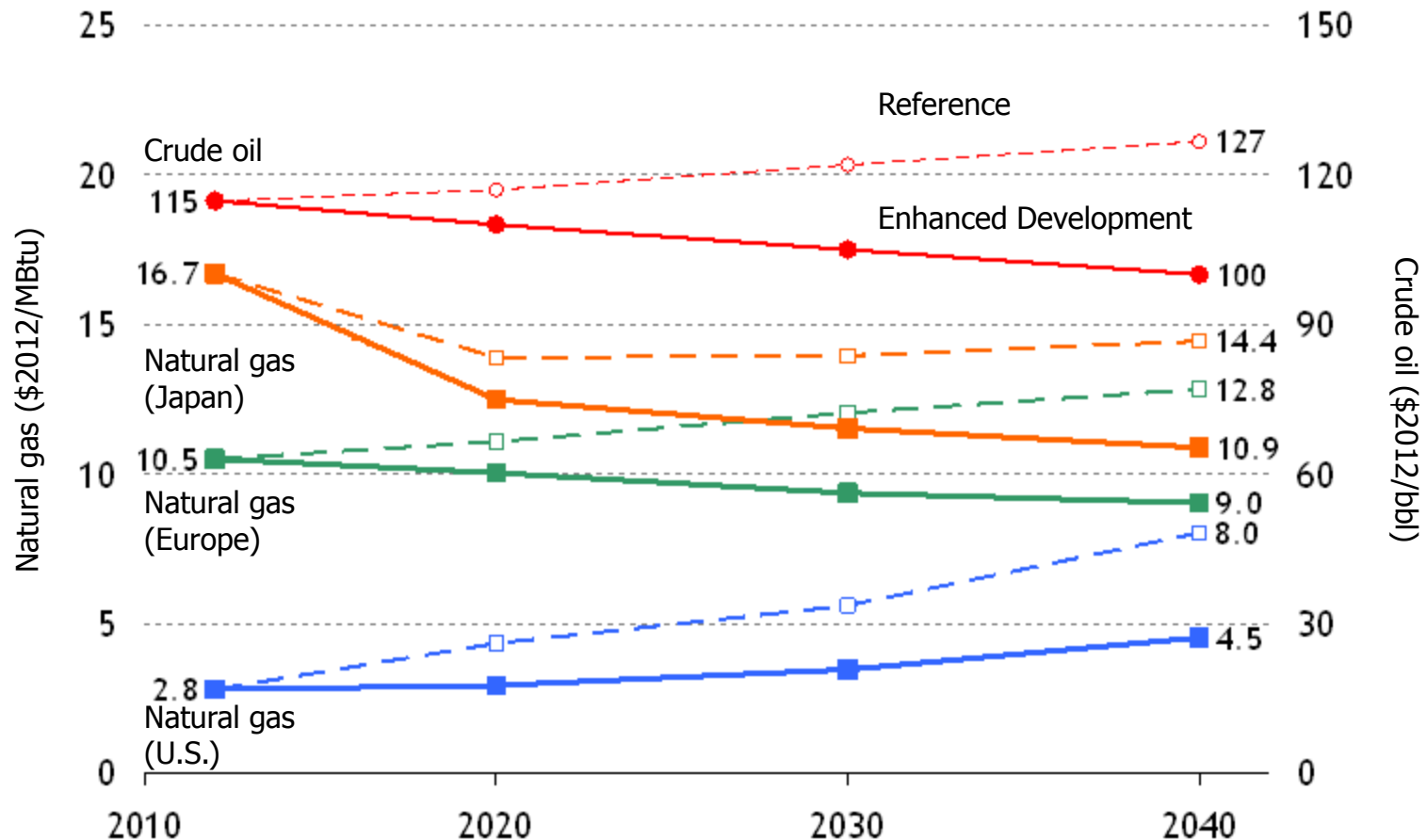
2040 Changes in the Enhanced Development Scenario from the Reference Scenario



- In the Reference Scenario, global natural gas production will increase from current levels of 3,384 Bcm/y to 5,411 Bcm/y. In the Enhanced Development Scenario, natural gas output will further expand to 6,180 Bcm. Unconventional gas production will account for 36% of total natural gas output.
- In the Reference Scenario, oil production will increase from 85 Mb/d (present level) to 115 Mb/d. In the Enhanced Development Scenario, total output will remain almost unchanged at 114 Mb/d, but unconventional oil production mainly from North America, Latin America and China will almost double to account for 29 Mb/d of the total.

Assumed Crude Oil/Natural Gas Prices

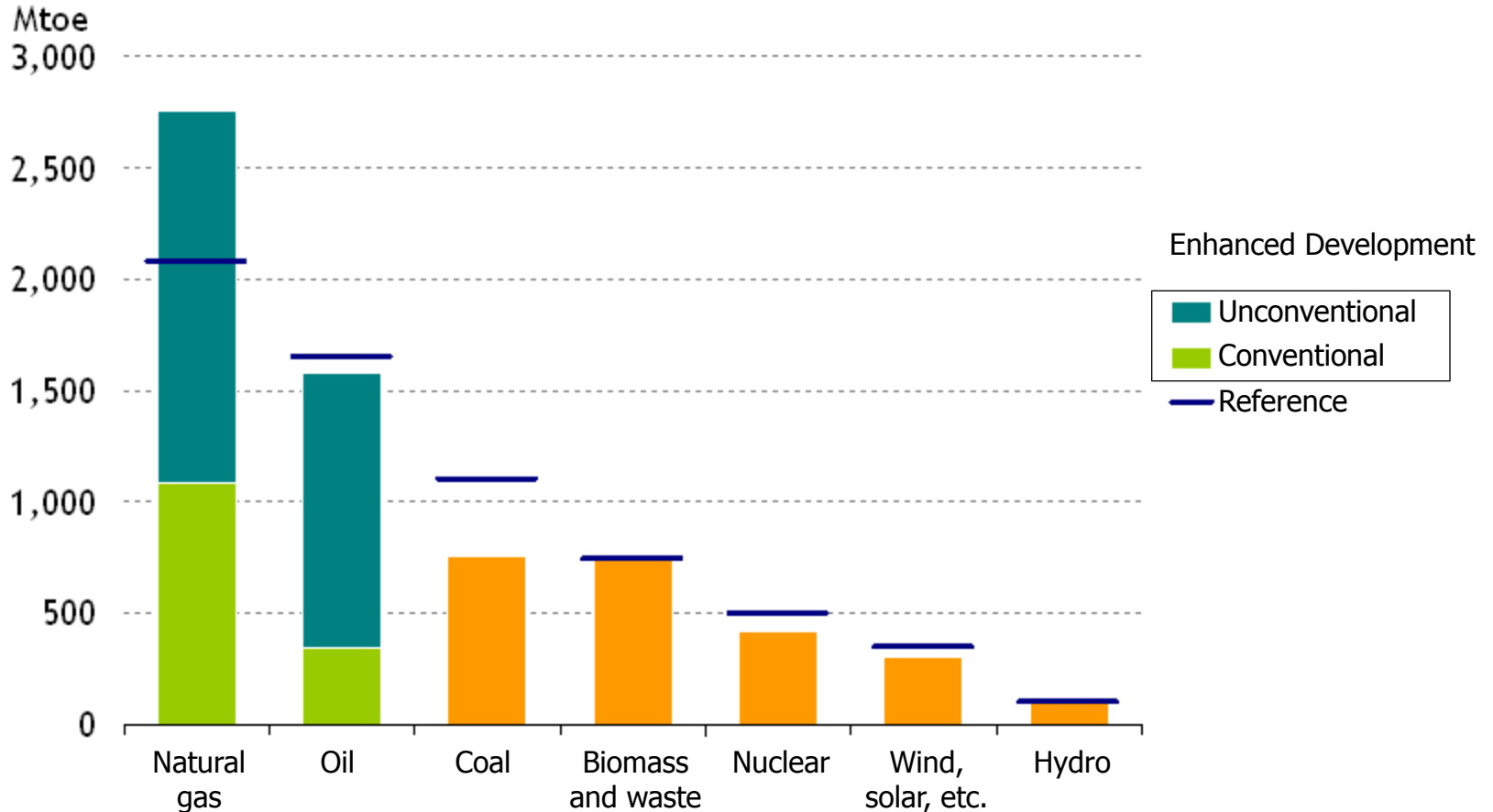
Enhanced Development and Reference Scenarios



- As energy supply expands in line with unconventional resources development, primary energy prices will fall.
- The crude oil price in 2040 in the Enhanced Development Scenario will fall from \$127/bbl in the Reference Scenario to \$100/bbl, slipping below the present level. Japan's CIF import price for LNG will drop from \$14.4/MBtu (\$747/t) in the Reference to \$10.9/MBtu (\$563/t).

Primary Energy Consumption Growth

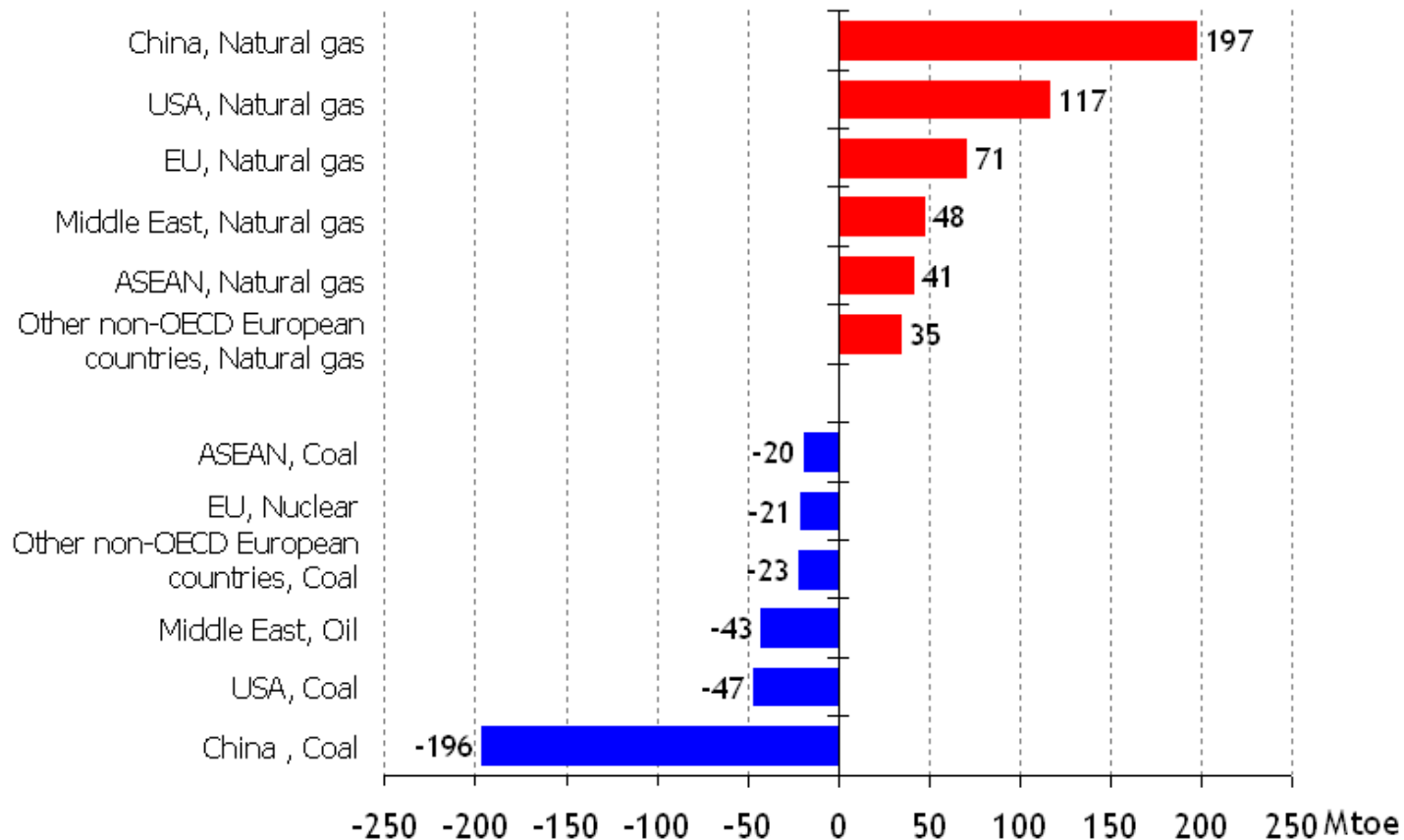
2011-2040 in the Enhanced Development Scenario



- Natural gas consumption will double from the present level exceeding 6,000 Mtoe by 2040. In the second half of the 2030s, natural gas will become the second largest energy source after oil. The change will result from demands for power generation. The power generation sector will account for two-thirds of the increase, with coal consumption being affected.
- While unconventional oil production will increase, consumption will fall short of expanding and cause conventional oil production cuts in the Middle East and other traditional oil producing regions. Oil consumption will be held down with natural gas replacing oil for some purposes.

Primary Energy Consumption Growth

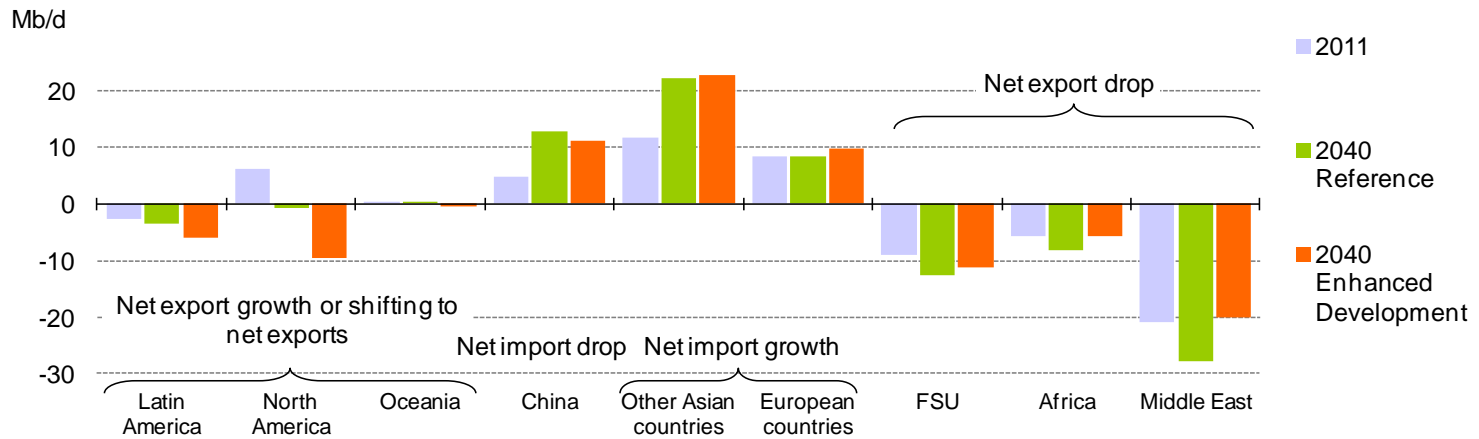
Changes in 2040 From the Reference Scenario to the Enhanced Development Scenario



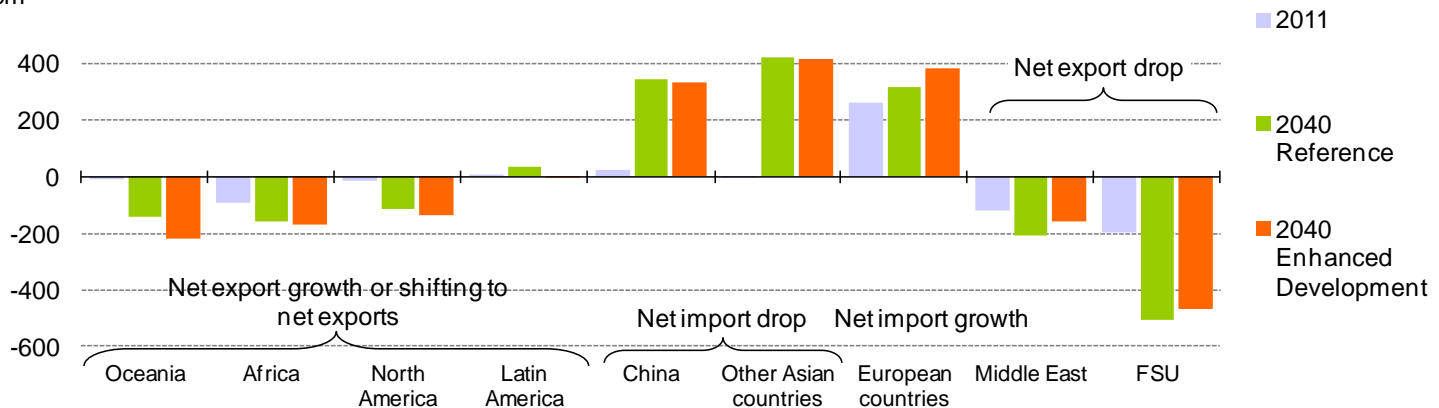
- A shift from the Reference Scenario to the Enhanced Development Scenario will bring about the largest change in China. China's additional natural gas demand will be equivalent to double the present Japanese consumption, with coal consumption being reduced by almost the same amount.
- In the United States and Europe, a great impact will be imposed not only on coal but also on other energy sources.
- The Middle East will see an oil consumption decline of 0.9 Mb/d as gas replaces oil in the power generation sector.

Changes in Net Oil/Natural Gas Imports

Oil

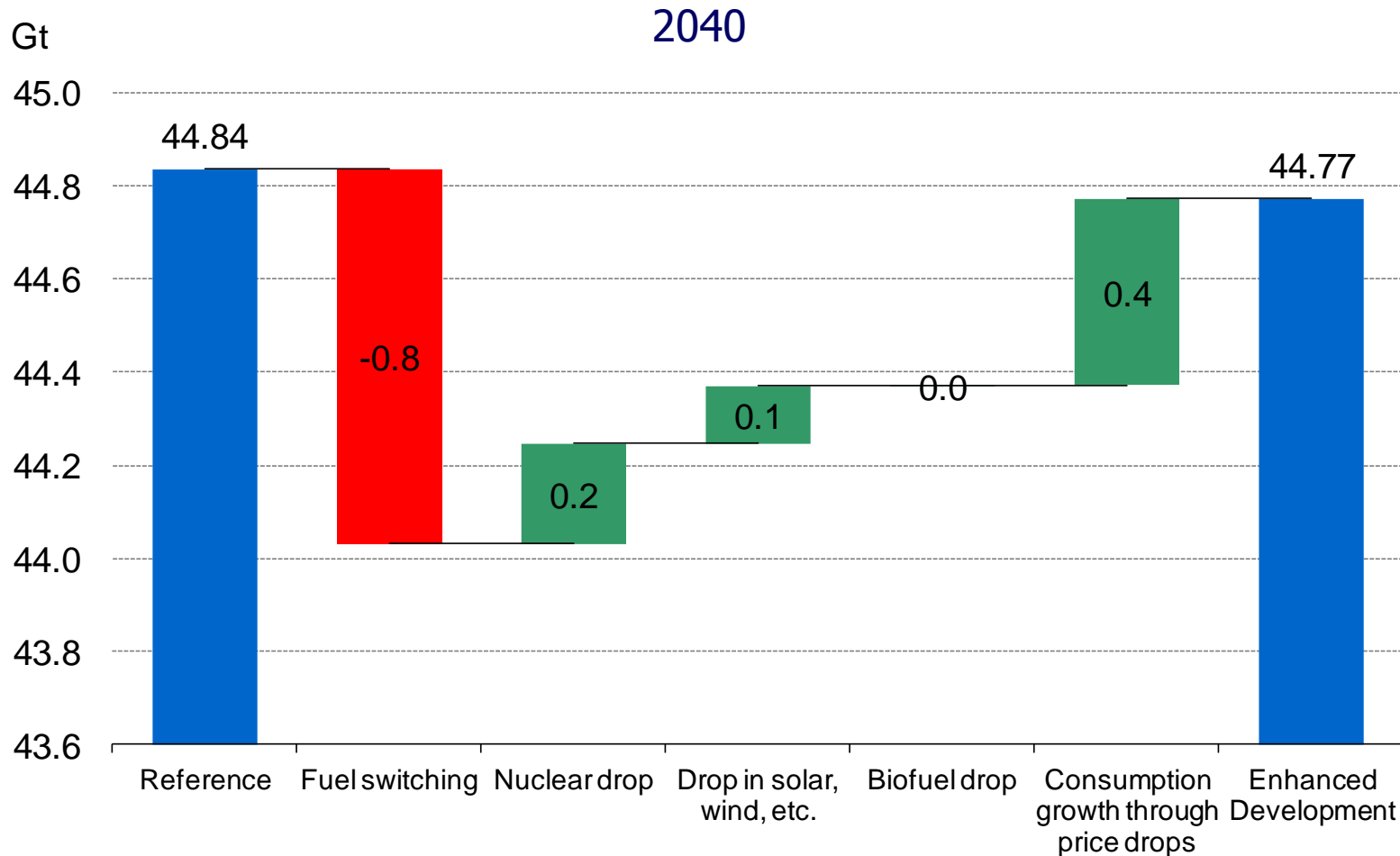


Natural gas Bcm



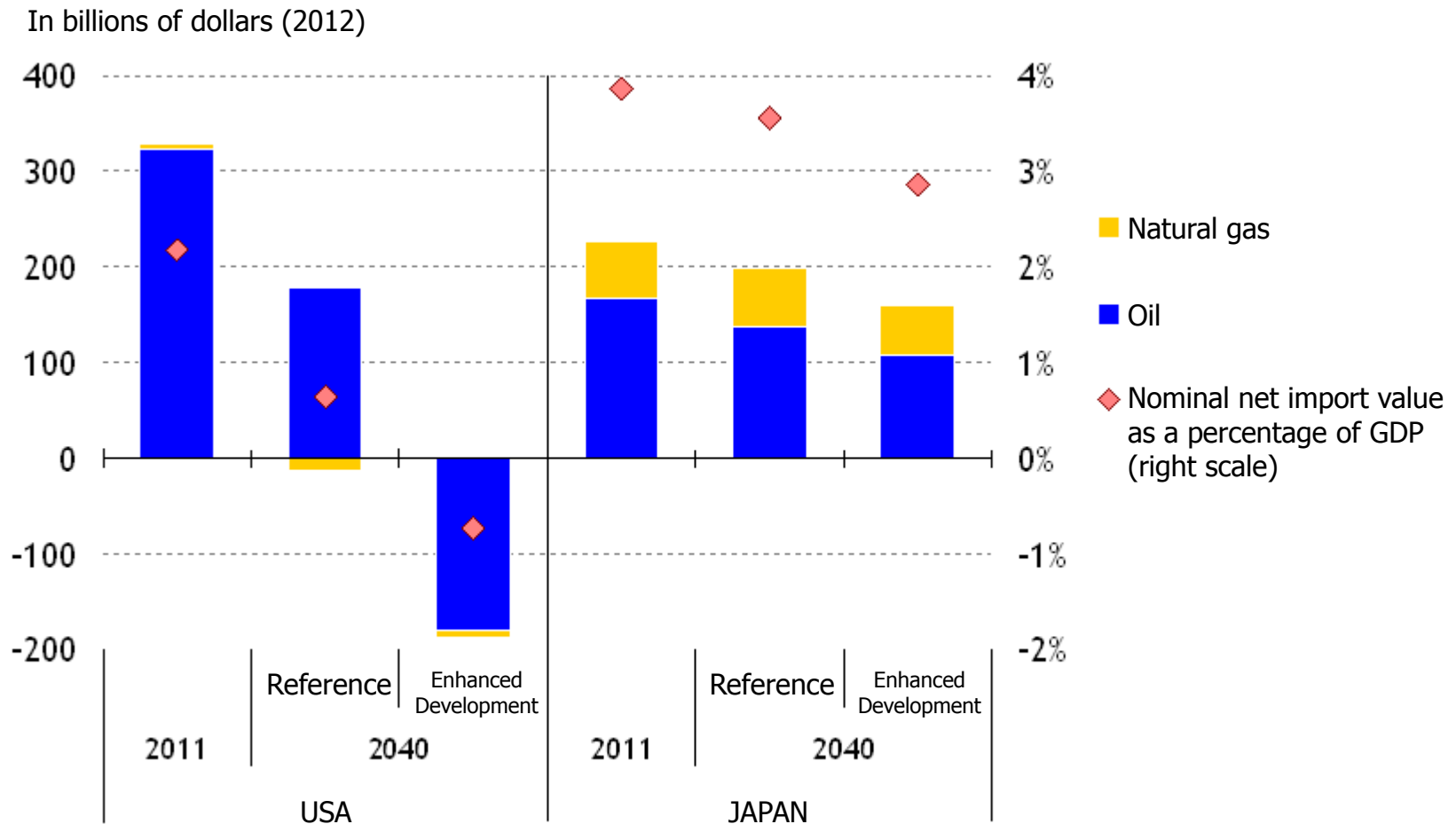
- In the Enhanced Development Scenario, net oil exports from the Americas will rise to 9 Mb/d, exceeding those from Africa. In China, net imports will fall by 2 Mb/d from the Reference Scenario. Meanwhile, net exports from the Middle East will fall by 8 Mb/d and those from Africa by 2 Mb/d.
- Net natural gas exports from Oceania and North America will increase substantially from the Reference Scenario. Net exports from the Middle East and the Former Soviet Union will decrease. Asia and Europe will be more clearly positioned as net natural gas importers.

Energy-related CO₂ Emissions



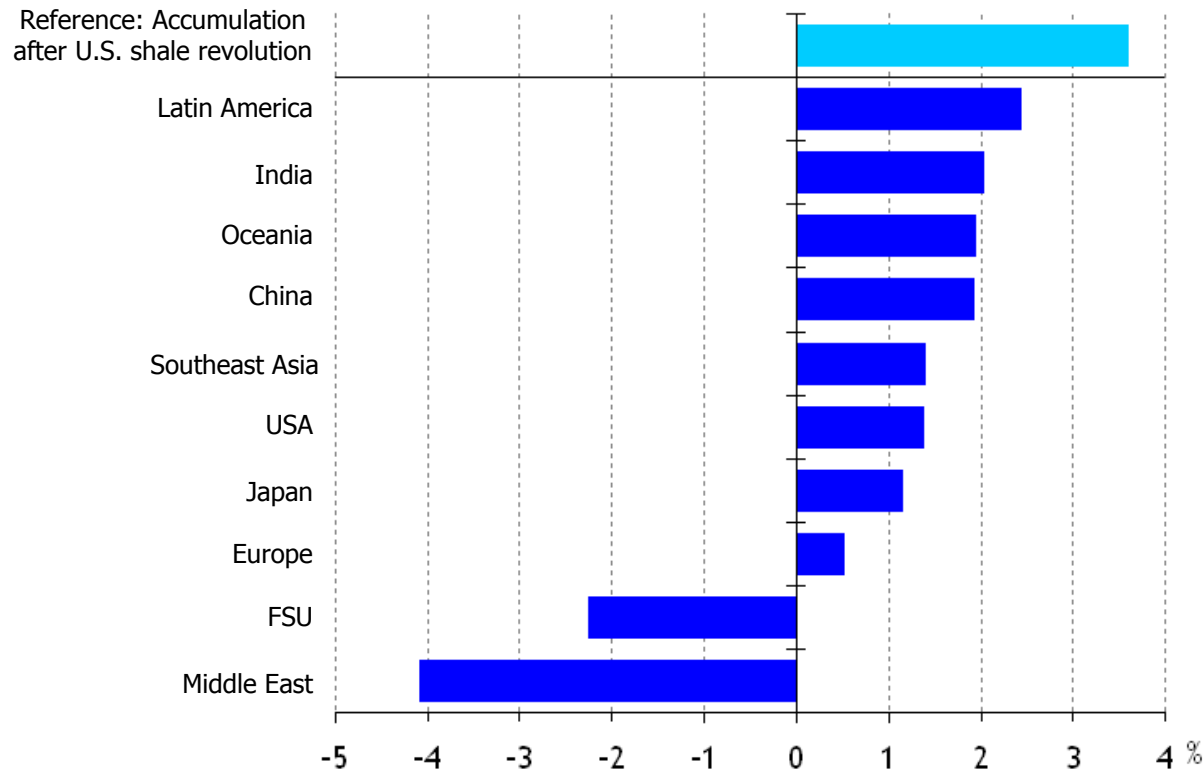
- Global CO₂ emissions in 2040 in the Enhanced Development Scenario will be down only 0.1% from the Reference Scenario. In Asia where switching from coal will have a greater effect, emissions will be down 1.1%.
- While switching to natural gas will contribute to reducing CO₂ emissions, a slowdown in energy conservation along with nuclear and renewable energy consumption will work to expand emissions.

Impact on Net Oil/Natural Gas Imports



- Although the shale revolution has begun with natural gas development in the United States, shale oil development will have a greater economic impact. In the Enhanced Development Scenario, the United States will receive more than \$180 billion in net revenues from oil exports in 2040.
- While little unconventional resources development is expected in Japan, international energy price drops in the Enhanced Development Scenario will allow Japan to reduce imports by \$40 billion despite growth in natural gas demand.

Changes in 2040 from the Reference Scenario



Note: Effects of a shift from the Reference Scenario to the Enhanced Development Scenario

- As oil & gas industries expands, net energy import value drops and energy price falls, most national economies benefit. The degree of benefits depends on output growth, industrial structure, oil and natural gas industries' portion of the economy, energy supply and demand structure, external demand changes in trading partners, etc.
- Traditional energy producing countries will face downward pressures on their GDP due to a combination of demand loss and price drops.

Conclusion

Enhanced unconventional energy resources development

- The expansion of unconventional natural gas production will lower prices and as such, promote fuel switching from all other energy sources to natural gas as well as growth in natural gas consumption. The deceleration of nuclear and renewable energy power plant development also limit the CO₂ emission cut to a very small level.
- Progress in the development of unconventional resources including shale gas and oil will benefit most of the world economies, facilitating the energy supply-demand balance and dropping prices.
- A net fossil fuel export increase will have a great impact on the Americas. Net importers including China will benefit from slower import value growth. Japan will expand natural gas imports in volume while reducing them in value thanks to price drops. Japan will also economically benefit from export growth in line with greater global economic growth.

Energy conservation and climate change measures (CO₂ emission reduction)

- The maximum promotion of energy conservation and non-fossil energy introduction is required to address climate change issues. Reducing fossil fuel consumption through conservation measures will lower CO₂ emissions and stabilize energy supply markets.
- The maximum promotion of existing energy conservation and climate change measures and the introduction of CCS technologies will allow energy-related CO₂ emissions in 2050 to be cut by 20% from 2011. But the target of halving emissions by 2050 will fail to be attained.
- It would be difficult to reduce the atmospheric concentration of greenhouse gases to 450 ppm (CO₂ equivalent) by the end of the 21st century. However, it will still be possible. To substantially reduce CO₂ emissions, innovative technologies including bioenergy with CCS (BECCS) and carbon capture and use (CCU) technologies like artificial photosynthesis will have to be developed and diffused.

Toward developing future energy systems

- Global energy consumption will increase 1.5-fold over the next 30 years. Particularly, Asia will remarkably expand energy demand and raise its import dependence rate, increasing its presence as an energy consumer in the international energy market.
- How to use energy is greatly changing due to progress in unconventional resources development and non-fossil energy promotion trends. Nevertheless, pursuing objectives such as the Three Es plus S (energy security, environmental protection and economic efficiency plus security) remain important.
- Japan can play great roles in leading the world and Asia to achieve sustainable development. Japan must further enhance energy conservation and low-carbon technologies (including renewable and nuclear energy technologies and their security) to meet the needs and expand their deployment.