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Asia/World Energy Outlook *2013*

Summary

The Institute of Energy Economics, Japan

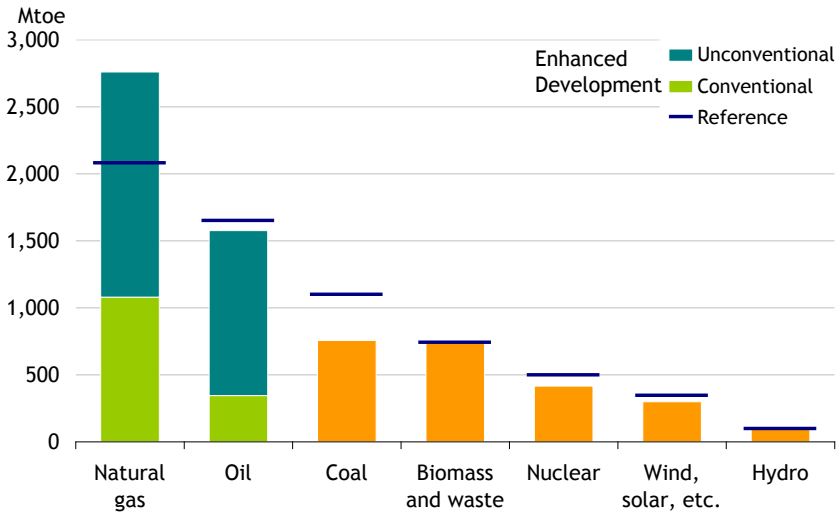
1. Changes induced by the Shale Revolution

<Enhanced Development Scenario>

Subject to certain conditions, over 70% of the growth in natural gas and oil production will come from unconventional resources

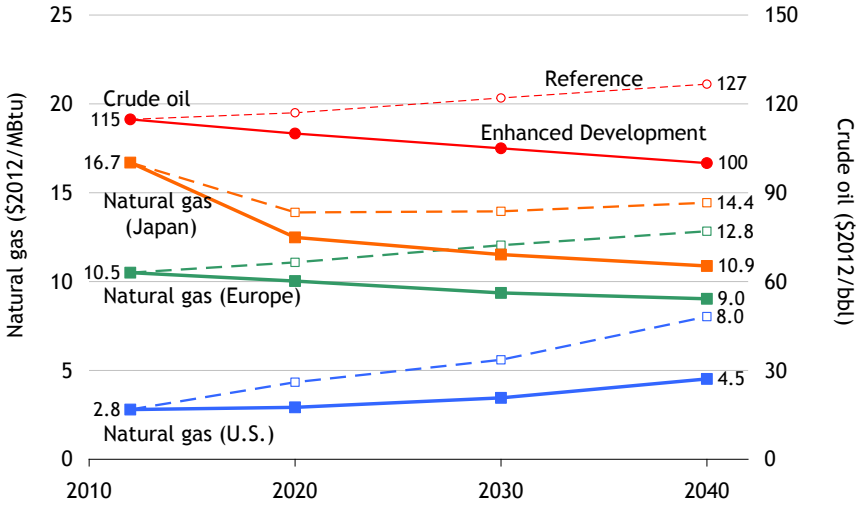
- This study analyzed not only a Reference Scenario, in which present trends of the international situation will remain unchanged but, as a result of the U.S. shale revolution, it also prepared an enhanced unconventional resources development scenario, later referred to as the Enhanced Development Scenario. In the Enhanced Development Scenario, unconventional resources worldwide are further developed under the assumptions that technologies and infrastructure as well as required institutional reforms for their development are available or in place (from production to consumption).
- In this scenario, global natural gas output will expand by 83% from current levels to 6.18 trillion cubic meters by 2040 (instead of 5.41 Tcm in the Reference Scenario). Unconventional resources will account for 1.84 Tcm or two–thirds of the natural gas output growth over the next 30 years. It is anticipated that China, Latin America and Australia will promote the development of their shale gas, coal bed methane and other unconventional gas resources. China will become the world's third largest natural gas producer, after the United States and Russia. In the Reference Scenario, North America's unconventional gas output was expected to reach 0.78 Tcm by 2040 (three times the conventional gas output). Production will increase to 0.94 Tcm in the Unconventional Resources Development Scenario.
- In this scenario, unconventional oil output will increase from 0.8 million barrels per day in 2011 to 26 Mb/d in 2040 (against 7.4 Mb/d in the Reference Scenario). Unconventional oil output growth will be mainly concentrated in the United States, Latin America and Canada.

Figure 1 – Increase in primary energy supply by source (2011-2040)



- Natural gas and oil prices in the Enhanced Development Scenario will be lower than in the Reference Scenario due to the increase in supply.

Figure 2 – Crude oil and natural gas prices up to 2040



Enhanced unconventional resources development will greatly change the global energy supply/demand structure

- In the Enhanced Development Scenario, the anticipated growth in coal consumption, competing with natural gas in the electricity generation sector, will substantially decelerate due to lower natural gas prices. Primary coal consumption in 2040 will be 7% less than in the Reference Scenario and this trend will be particularly evident in China. Growth in nuclear, solar and wind power generation will also decelerate

somewhat. As oil demand is relatively inelastic to price, any consumption change under lower oil prices will be limited.

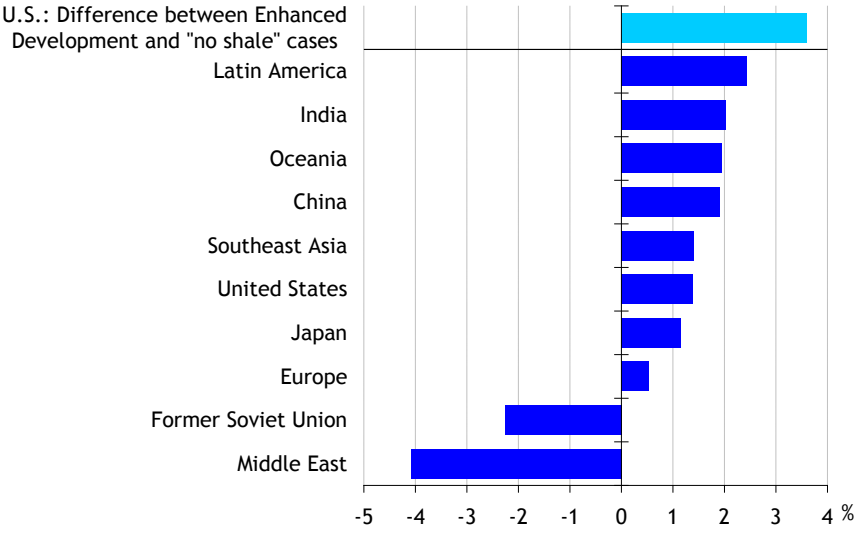
- Global energy–related carbon dioxide emissions will remain almost unchanged in both Scenarios due to a delay in the spread of low–carbon electricity sources including nuclear and renewable energy. In China where coal will be replaced with natural gas more rapidly, carbon dioxide emissions will decline by 3% in the Enhanced Development Scenario.
- Unconventional energy resources development will change the international oil and natural gas trade structure. The Middle East, Former Soviet Union and other exporters of conventional energy resources will be greatly affected by the enhanced resources development. Although the Middle East's net oil exports were expected to increase from 21 Mb/d in 2011 to 28 Mb/d in 2040 in the Reference Scenario, they will be limited to 20 Mb/d in 2040 in the Enhanced Development Scenario, due to increased exports from North America and Latin America. The Former Soviet Union's net natural gas exports that were anticipated to expand from 0.16 Tcm in 2011 to 0.47 Tcm in 2040 in the Reference Scenario will be slightly reduced to 0.42 Tcm in 2040 due to increased exports from North America and Australia in the Enhanced Development Scenario.

Economic benefits and costs associated with the enhanced unconventional energy resources development will differ from region to region

- Energy–importing countries' costs under the Enhanced Development Scenario will be less than in the Reference Scenario because of lower natural gas and oil prices. The United States, which spent $330 billion (in 2012 prices) on net oil and natural gas imports in 2011, will generate net revenues of more than $180 billion in 2040. As a result of the shale revolution, the United States will become a net oil and natural gas exporter under this scenario. Japan's net oil and natural gas import costs for 2040 in the Enhanced Development Scenario will fall from $200 billion in the Reference Scenario to $160 billion. Such imports in China will decline from $780 billion to $540 billion.
- The Enhanced Development Scenario will provide for three kinds of benefits — lower net energy imports, the expansion of oil, natural gas and relevant industries, and lower domestic energy prices. This scenario, relative to the Reference Scenario, will increase the United States and China's 2040 GDP by 1.4% and 1.9% respectively, if all other conditions remain unchanged. As a result of the shale revolution, the United States will have turned a net oil and natural gas exporter in 2040, even in the Reference Scenario. Compared to a scenario that does not include any of the impact of the shale revolution, the U.S. GDP will increase by nearly 4%. The combination of lower energy import prices and the indirect benefits of U.S. and other countries economic growths will boost Japan's GDP by 1.1%, a slower rise than in the United States or China. In contrast, lower levels of exports for the Middle East and the Former Soviet Union under this

Scenario will reduce the anticipated 2040 GDP from the Reference Scenario for those regions by 4.1% and 2.3%, respectively.

Figure 3 – Impact of enhanced unconventional resources development on real GDP in 2040 (Difference between the Reference and the Enhanced Development Scenarios)



2. World/Asia Energy Consumption through 2040

<Reference Scenario>

Energy consumption will grow by 1.5-fold in 30 years with growth led by Asia

- In the Reference Scenario, the world's primary energy consumption will expand by 50% from 13,113 million tons of oil equivalent in 2011 to 19,642 Mtoe in 2040.
- Asian countries outside the Organization for Economic Cooperation and Development will account for 59% of the global energy consumption growth. As Asia will become more dependent on energy imports, the region will absorb 77% of the crude oil trade between major regions and 71% of the natural gas trade. Asia will further strengthen its oil trade relations with the Middle East while promoting natural gas procurements from various regions.
- China, the largest energy consumer in the world, will continue to expand its energy needs consuming 1.9 times more energy than the United States, the second largest consumer, in 2040. Late in the 2030s, India will become the third largest energy consumer in the world, requiring more energy than the entire European Union. Asia will further increase its presence on the demand side in the energy market.

Table 1 – Primary energy by region (Reference Scenario)

	(Mtoe)						Share (%)			AAGR(%)				
	1990	2000	2011	2020	2030	2040	1990	2011	2040	1990/ 2011	2011/ 2020	2020/ 2030	2030/ 2040	2011/ 2040
World	8,782	10,082	13,113	15,216	17,517	19,642	100	100	100	1.9	1.7	1.4	1.2	1.4
[by region]														
Asia	2,120	2,934	5,058	6,339	7,663	8,931	24	39	45	4.2	2.5	1.9	1.5	2.0
China	871	1,161	2,728	3,433	4,009	4,423	9.9	21	23	5.6	2.6	1.6	1.0	1.7
India	317	457	749	1,011	1,403	1,896	3.6	5.7	9.7	4.2	3.4	3.3	3.1	3.3
Japan	439	519	461	466	449	425	5.0	3.5	2.2	0.2	0.1	-0.4	-0.6	-0.3
S.Korea	93	188	260	290	309	310	1.1	2.0	1.6	5.0	1.2	0.6	0.0	0.6
Taiwan	48	85	109	121	128	130	0.5	0.8	0.7	3.9	1.2	0.6	0.1	0.6
ASEAN	233	377	557	767	1,038	1,349	2.6	4.2	6.9	4.2	3.6	3.1	2.7	3.1
North America	2,124	2,525	2,443	2,494	2,580	2,625	24	19	13	0.7	0.2	0.3	0.2	0.2
U.S.	1,915	2,273	2,191	2,234	2,299	2,327	22	17	12	0.6	0.2	0.3	0.1	0.2
Latin America	467	599	809	1,024	1,284	1,508	5.3	6.2	7.7	2.7	2.7	2.3	1.6	2.2
OECD Europe	1,619	1,747	1,756	1,806	1,847	1,860	18	13	9.5	0.4	0.3	0.2	0.1	0.2
EU	1,636	1,685	1,654	1,699	1,737	1,753	19	13	8.9	0.1	0.3	0.2	0.1	0.2
Non-OECD Europe	1,537	1,003	1,176	1,273	1,380	1,464	18	9.0	7.5	-1.3	0.9	0.8	0.6	0.8
Africa	392	502	700	850	1,037	1,252	4.5	5.3	6.4	2.8	2.2	2.0	1.9	2.0
Middle East	223	376	670	828	1,027	1,223	2.5	5.1	6.2	5.4	2.4	2.2	1.8	2.1
Oceania	99	125	141	152	160	165	1.1	1.1	0.8	1.7	0.9	0.5	0.3	0.5
OECD	4,511	5,274	5,282	5,484	5,685	5,795	51	40	30	0.8	0.4	0.4	0.2	0.3
Non-OECD	4,070	4,537	7,471	9,283	11,294	13,234	46	57	67	2.9	2.4	2.0	1.6	2.0
[by source]														
Coal	2,230	2,358	3,776	4,074	4,480	4,877	25	29	25	2.5	0.8	1.0	0.9	0.9
Oil	3,230	3,657	4,136	4,694	5,288	5,788	37	32	29	1.2	1.4	1.2	0.9	1.2
Natural gas	1,668	2,072	2,787	3,428	4,173	4,870	19	21	25	2.5	2.3	2.0	1.6	1.9
Nuclear	526	676	674	891	1,050	1,175	6.0	5.1	6.0	1.2	3.1	1.7	1.1	1.9
Hydro	184	225	300	344	374	400	2.1	2.3	2.0	2.3	1.5	0.8	0.7	1.0
Geothermal	34	52	66	113	174	235	0.4	0.5	1.2	3.2	6.1	4.5	3.1	4.5
Wind, solar, etc.	2.4	7.9	61	118	174	239	0.0	0.5	1.2	16.8	7.5	4.0	3.3	4.8
Biomass and waste	907	1,033	1,312	1,554	1,802	2,055	10	10	10	1.8	1.9	1.5	1.3	1.6

Note: "World" includes international bunkers

Nuclear and renewables will increase steadily

- Nuclear power generation will increase in all regions, except for the European OECD members and for Japan. In addition to China, India and other emerging countries, where electricity demand will grow substantially, Russia, the Middle East and the United States will positively expand nuclear power generation. Global nuclear power generation capacity will increase from 388 gigawatts (GW) in 2012 to 631 GW in 2040.
- Photovoltaic, wind and other renewable energy power generation, which have already been expanding globally, will increase by 3.9–fold from 2011 to 2040. Renewable energy power generation, excluding hydroelectric generation, will account for 10% of total electricity generation in the world in 2040. Meanwhile, low–cost biomass, including firewood used in developing countries, will represent 62% of the growth in renewable energy generation.

The world will remain dependent on fossil fuels

- All renewable energy sources, from hydro to biomass, will account for the third largest share of the total primary energy consumption increase through 2040, following natural

gas and oil. The share, however, will be limited to 15%, rising slightly from the present level of 13%. Fossil fuels (oil, coal and natural gas) now represent 82% of primary energy consumption and will account for three–quarters of the energy consumption growth through 2040. As such, the world will remain heavily dependent on fossil fuels through 2040.

- Oil consumption currently at 85 Mb/d (in 2011) will exceed 100 Mb/d by the mid–2020s and reach 118 Mb/d by 2040. The transportation sector including automobiles will be responsible for two–thirds of the increase of more than 33 Mb/d. The transportation sector will account for 57% of the total oil consumption in 2040, while oil will capture 88% of energy consumption in that sector.
- Natural gas consumption will increase substantially for power generation and final consumption in the consumer, industrial and other sectors. Natural gas will post the largest consumption growth among energy sources over the next 30 years. Natural gas consumption will total 5.41 Tcm in 2040, rivaling coal. Natural gas will become the second largest energy source, after oil, for the first time in history soon after 2040.
- Coal consumption growth will decelerate from its present rapid pace due to greater coal consumption efficiency, fuel–switching and changes in industrial production trends in China. The coal consumption increase for the next 30 years will total 1,573 million tons of coal equivalent, slipping below the rise of 2,000 Mtce of the past 10 years. Most of the increase will be for power generation in India, China and ASEAN (Association of Southeast Asian Nations) countries.

3. Energy Conservation and CO_2 Emission Reduction Potential

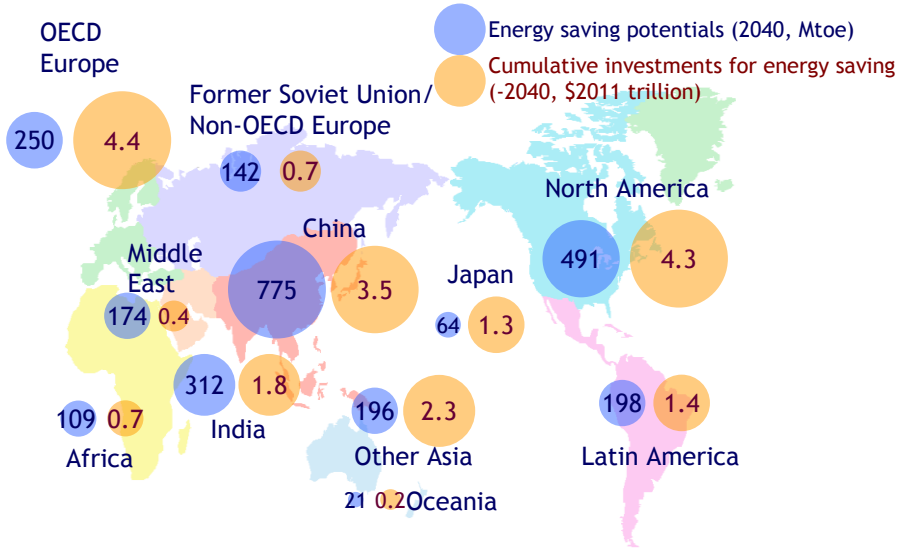
<Advanced Technology Scenario>

Maximum energy savings will be equivalent to China's current energy consumption

- This study also analyzed an Advanced Technology Scenario in which energy technologies on both the supply and demand sides are substantially developed to enhance energy security and support climate change measures. The world's primary energy consumption in 2040 in the Advanced Technology Scenario will reach 16,910 Mtoe, down 2,731 Mtoe or 14% from the Reference Scenario.
- In the Advanced Technology Scenario, the present level of coal consumption will soon peak and decline by 12% by 2040. In this scenario, coal consumption will drop while oil and natural gas consumption will continue to rise, though at a far slower pace than in the Reference Scenario. Oil savings will exceed present Saudi and Russian output and natural gas savings will rival present Russian and U.S. output.
- In non–OECD and Asian countries that have great potential to expand their economies and are well positioned to take conservation measures, energy consumption will change

substantially as they adopt advanced technologies. Non–OECD countries will account for two–thirds of global energy savings attributable to technological advancements in 2040, and Asia will capture half the savings. Non–OECD and Asian countries hold the key to reforming the global energy system.

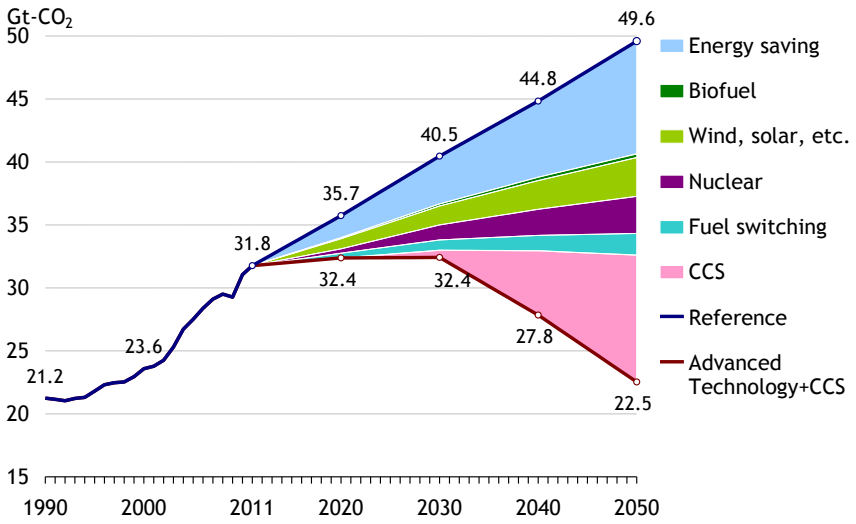
Figure 4 – Energy saving potentials and cumulative investments by region (difference between the Reference and Advanced Technology Scenarios)



Realistic targets and measures should be adopted to tackle climate change

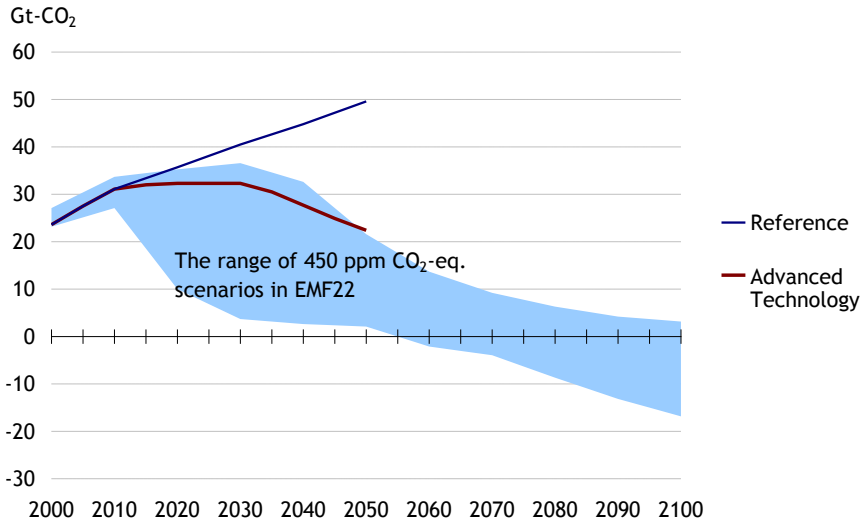
- In the Reference Scenario, energy–related CO_2 emissions in 2050 will increase by 56% from the present level to 49.6 billion tons. In the Advanced Technology Scenario, however, the emissions will peak in the mid–2030s and then start decreasing. If carbon capture and storage in the power generation and industrial sectors is taken into account, the emissions trend will turn downward around 2030 and fall to 22.5 billion tons of CO_2 (down 18% from 2005) in 2050. However, even with carbon capture and storage (CCS) the CO_2 emissions in 2050 will not be halved from current levels.

Figure 5 – Global energy-related CO_2 emissions
(Reference and Advanced Technology Scenarios)



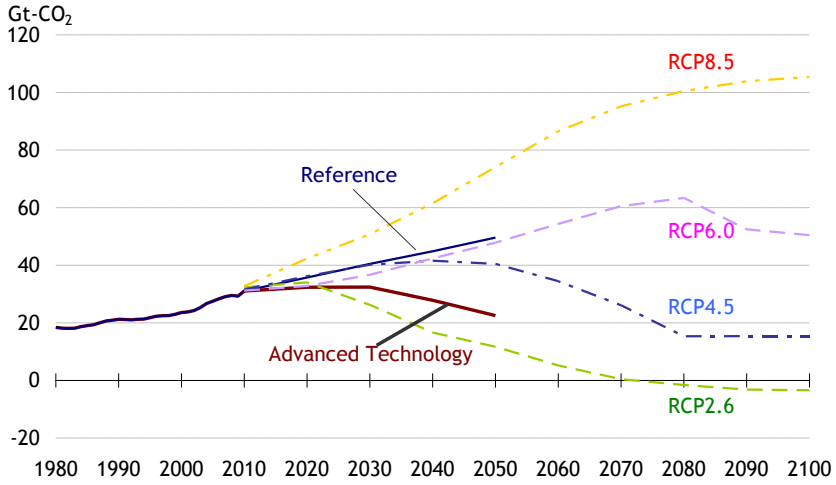
- Given that energy–related CO_2 emissions in 2050 in the Advanced Technology Scenario still slightly exceed various published maximum estimates (such as EMF), it would appear difficult to reduce the atmospheric concentration of greenhouse gases to 450 ppm (CO_2 equivalent) by the end of the 21st century. However, it will still be possible. Energy–related CO_2 emissions in 2040 in the Advanced Technology Scenario are close to the maximum estimate in the 2–degree Celsius scenario, indicating that the 2°C target could fail to be achieved unless CO_2 emissions are substantially reduced further in the second half of the 21st century. To achieve the target, drastic and innovative technologies including bioenergy with CCS (BECCS) to reduce the CO_2 concentration on a net basis and carbon capture and use (CCU) technologies like artificial photosynthesis will have to be substantially developed to reduce CO_2 emissions in the second half of the century. Given that the 2°C scenario covers a very long term, we may have to pay close attention to uncertain factors, including the future expansion and deepening of scientific knowledge, the timing for the diffusion of global emission reduction measures affecting accumulated emissions, and the reduction of GHG emissions other than energy–related CO_2.

Figure 6 – Comparison with the range of 450 ppm scenarios in EMF22



EMF (Energy Modeling Forum): An international forum for sharing and facilitating discussions on energy policy and global climate issues among experts. The EMF22 engaged ten of the world leading integrated assessment models to focus on long-term climate-related target (GHG concentration) and the mitigation scenarios.

Figure 7 – Comparison with the Representative Concentration Pathways (RCPs) in the IPCC fifth assessment report



Rise in global average temperature from pre-industrialiation to the end of 21st century:
1.2-2.0°C for RCP2.6, 1.9-2.9°C for RCP4.5, 2.3-3.3°C for RCP6.0 and 3.6-5.0°C for RCP8.5.

4. Realizing a Better Energy System

"'Tis the part of a wise man to keep himself today for tomorrow, and not venture all his eggs in one basket." (Miguel de Cervantes Saavedra)

- A substantial increase in energy consumption focused mainly on fossil fuels can destabilize energy markets, increase the environmental load and boost energy costs. It

represents a risk and may side–track the world's sustainable development. On the other hand, securing safety for nuclear and other energy sources is a natural premise.

- In solving such problem, we must adopt medium– to long–term and comprehensive perspectives based on the so–called 3Es — Energy security, Environmental protection and Economic efficiency — and S — Safety. Regrettably, no versatile and easy solution exists. All possible measures, including further energy conservation on the demand side combined with cleaner fossil fuel use, cheaper renewable energy and safer nuclear energy technologies on the supply side, will have to be pursued simultaneously.

"It is not enough to have knowledge, one must also apply it. It is not enough to have wishes, one must also accomplish." (Johann Wolfgang von Goethe)

- Energy security is a particularly important challenge for Japan, a country poor in fossil fuel resources and dependent on imports for most of its requirements. In procuring fossil fuels, Japan must enhance the level of medium– to long–term international cooperation including collaboration with other Asian energy consuming countries. Japan must also enhance its relations with Middle Eastern and other energy producing countries through technical and educational support for reducing their dependence on commodities for economic development. At the same time, Japan must diversify its fossil fuel procurement sources by promoting liquefied natural gas imports from North America and Russia.
- With regard to climate change, Japan must adopt reasonable and realistic targets for reducing GHG emissions and implement a series of effective/efficient emission reductions at home and abroad. Japan must also explore effective emission reduction measures for Asia, a region that presents great potential to cut CO_2 and other GHG emissions efficiently and effectively.
- The world, including many Asian countries, will expand nuclear power generation in the future. Based on lessons learned from the Fukushima nuclear incident, Japan must contribute in the drafting of international standards for nuclear safety regulations, share its nuclear safety technologies with other countries and provide for relevant training in human resources.
- Japan can play great roles in leading the world and Asia to the achievement of sustainable development. Japan must develop and enhance energy conservation and environmental technologies to meet the needs and expand their deployment. This must be one of Japan's pillars for growth and for its international energy strategies.

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