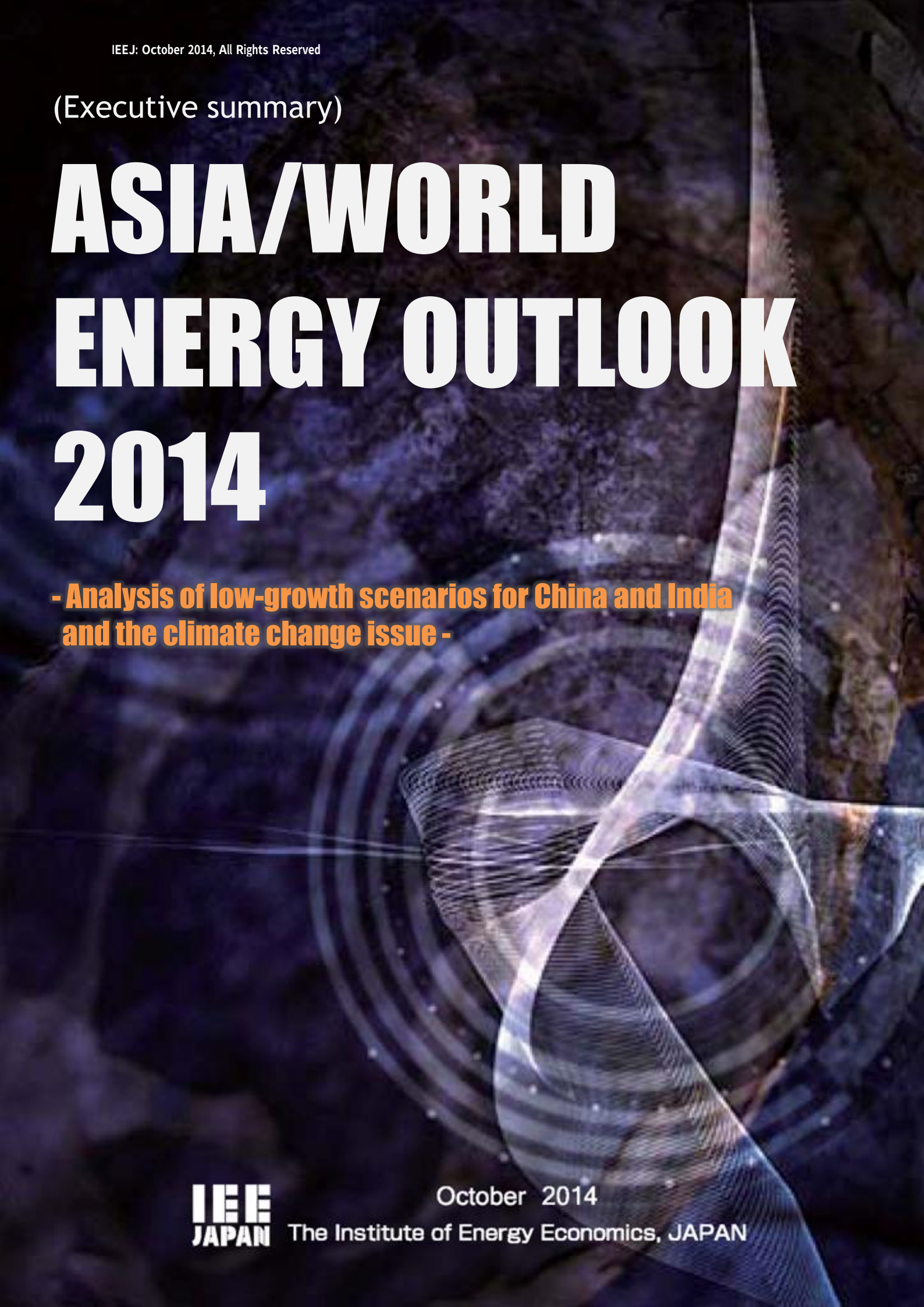
(Executive summary)

ASIA/WORLD ENERGY OUTLOOK 2014

- Analysis of low-growth scenarios for China and India and the climate change issue -



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The Institute of Energy Economics, JAPAN

Executive summary

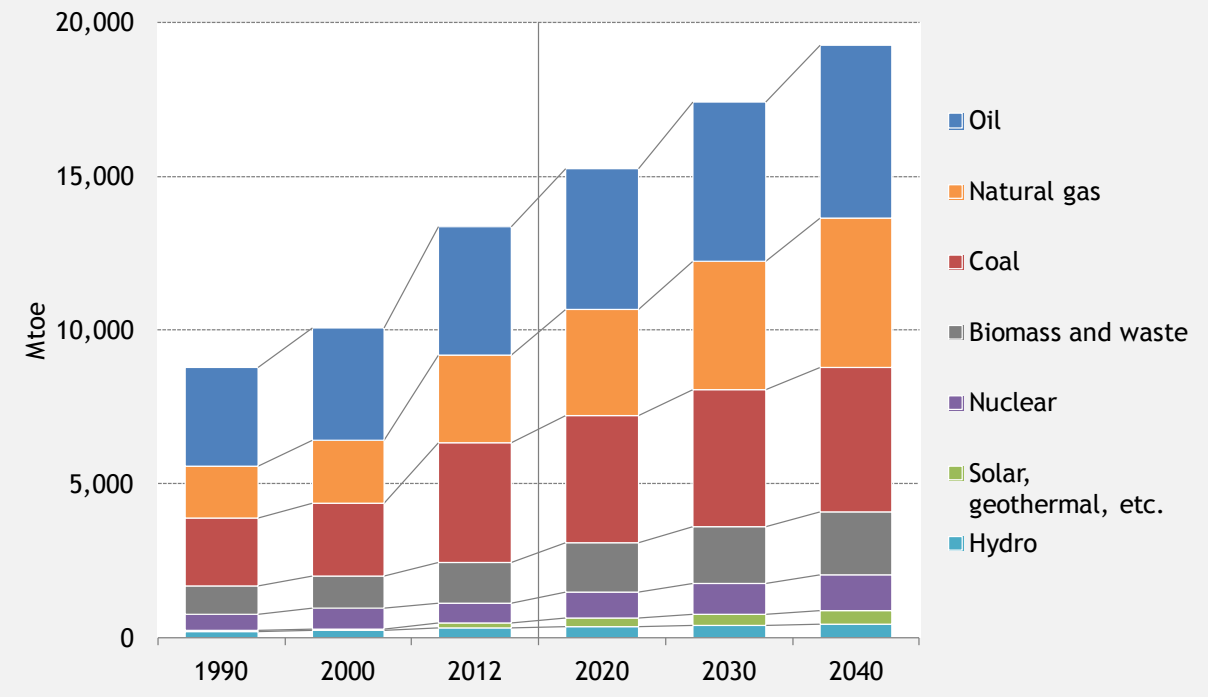
Asia/world energy supply and demand outlook – Reference Scenario

Energy consumption will expand 1.4-fold in 28 years. Natural gas will replace coal as the second largest energy source.

Humans will continue increasing energy consumption.

Primary energy consumption in the world will increase from 13,371 million tonnes of oil equivalent (Mtoe) in 2012 to 19,276 Mtoe in 2040 in the Reference Scenario. This means that global energy demand will annually expand by more than an equivalent of consumption in the United Kingdom and Ireland. Progress in energy conservation will make energy consumption growth slower than economic growth. Nevertheless, energy consumption will expand 44% over the next 28 years.

Figure 1 Global energy consumption [Reference Scenario]



At present, fossil fuels (oil, coal and natural gas) account for 82% of primary energy consumption. They will still capture more than 70% of future consumption growth. The world will thus remain heavily dependent on fossil fuels.

Oil consumption stood at 88.6 million barrels per day in 2012, will top 100 Mb/d in the next 10 years and will reach 116.5 Mb/d in 2040. The increase of 27.9 Mb/d amounts to more than 90%

of present crude oil production by the Organization of Petroleum Exporting Countries (OPEC). Up to two-thirds or 18.9 Mb/d of the increase will be attributable to the transport sector including automobiles. In 2040, 57% of oil supply will be consumed in the transport sector, with 15% being used as petrochemical feedstocks. Demand will shift to gasoline, diesel oil and naphtha from other petroleum products.

Natural gas will post a faster consumption increase than any other energy source, becoming the second largest energy source after oil by 2040. Natural gas consumption will expand 1.7-fold from 3.44 trillion cubic metres (Tcm) in 2012 to 5.88 Tcm in 2040. Of the total natural gas consumption, liquefied natural gas will increase from 237 million tonnes to 548 Mt. The largest driver of natural gas consumption growth will be the power generation sector. The industry and building sectors will also expand natural gas consumption remarkably. Natural gas consumption will also expand geographically. Although OECD and non-OECD Europe accounted for more than two-thirds of global natural gas consumption in 2012, the other countries will capture more than half of global consumption in 2040. In the United States, natural gas will surpass oil in consumption by 2030, becoming the largest energy source.

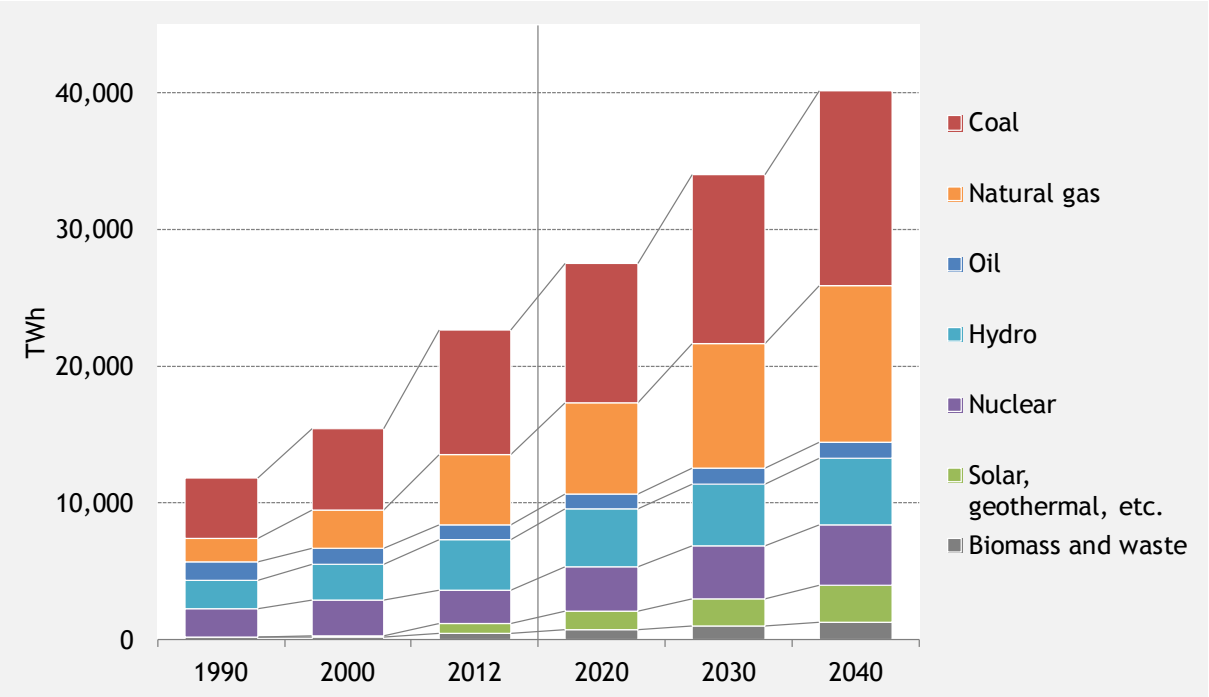
Among fossil fuels, coal will follow a different path. Coal consumption will slow down from the fast increase in the early 21st century due to changes in China's industrial production trends, the rising efficiency of coal use, energy switching and other factors. Coal consumption in 2040 will total 6,722 million tonnes of coal equivalent (1 Mtce = 0.7 Mtoe), up 1,181 Mtce from 2012. The increase over 28 years will be far below the 2,054 Mtce over the past decade. Steam coal for power generation will account for most of the coal consumption growth. Coking coal consumption for coke production will slightly decrease.

Renewables and nuclear will increase steadily

Overall renewable energy covering from hydro to biomass will post a consumption increase of 1,120 Mtoe through 2040, the third largest growth after natural gas and oil. Rapidly expanding solar, wind, etc. will jump 3.4-fold from 2012 to 2040. Renewables will cover 22% of global power generation totalling 40,000 terawatt-hours (TWh). However, low-cost biomass and waste including fuel wood and feces in developing countries will account for more than a quarter of the renewables growth.

Nuclear will also increase in many regions. Nuclear power generation capacity will rise from 389 gigawatts (GW) in 31 economies in 2013 to 618 GW in 39 economies in 2040. Russia, Korea and the Middle East will proactively expand nuclear power generation. But particularly remarkable growth of nuclear will come in China, India and other emerging countries where electricity demand will expand substantially.

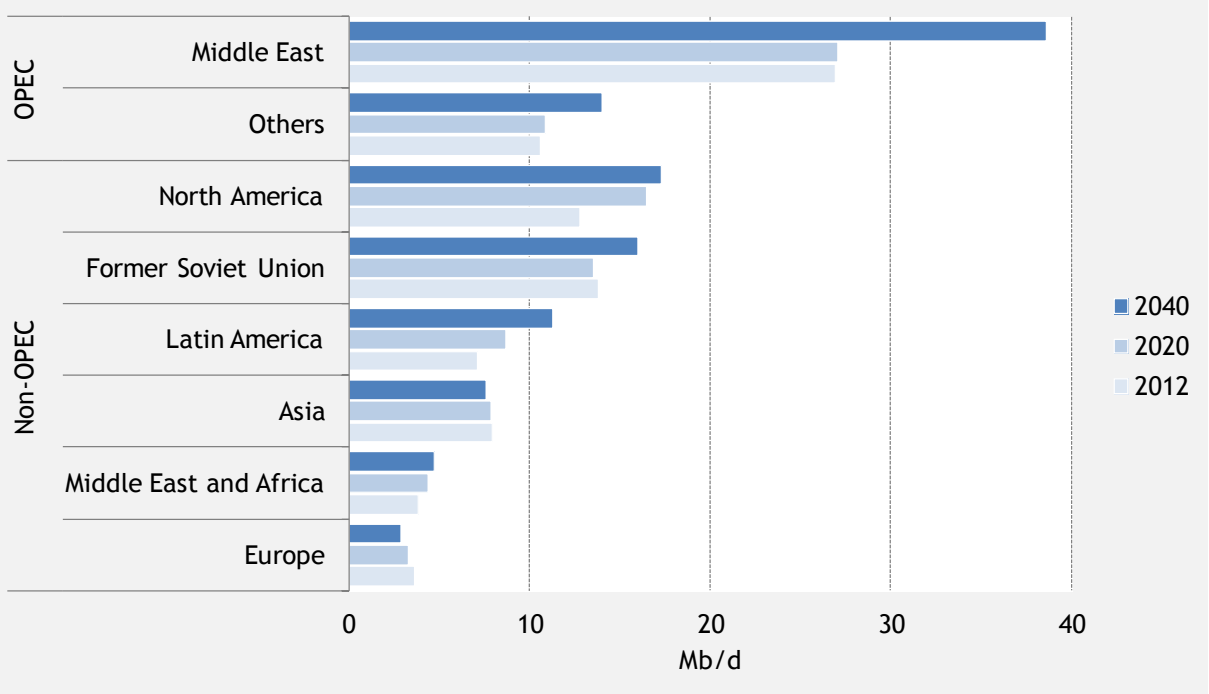
Figure 2 World power generation mix [Reference Scenario]



The emergence of new oil and natural gas suppliers will not affect the importance of traditional suppliers

Against the backdrop of unconventional resources development symbolised by the shale revolution, as well as resource development in deep-water and other extreme environments, multiple regions are about to emerge or resurge as key oil and natural gas suppliers. A crude oil production increase through 2020 in North and South Americas excluding OPEC members Venezuela and Ecuador will total 5.3 Mb/d accounting for an outstanding 93% of the global net expansion. However, their rise as major oil and natural gas suppliers will not necessarily expel traditional suppliers such as Middle Eastern and North African OPEC members and the former Soviet Union from the international energy market. Traditional suppliers will play an even greater role in satisfying growing demand while making up for a decline in existing oilfields. This phenomenon will be remarkable particularly in the second half of the outlook period. OPEC and the former Soviet Union will account for 84% of a net crude oil output increase of 20.4 Mb/d between 2020 and 2040.

Figure 3 Crude oil production in major regions [Reference Scenario]



Energy trade will grow even more important in the future

Regions that will sharply expand energy consumption in the future will not necessarily be identical to those endowed with abundant fossil fuel resources. Therefore, international energy trade will grow more prosperous. As crude oil trade is growingly regionalised, however, the share for crude oil for trade between major regions will remain almost unchanged at 40%. As for natural gas for which international trade is not as prosperous as for oil at present, the share for trade between major regions will rise from 14% to 22%. Energy is the largest tradable commodity at present and will maintain its great political and economic significance for most countries including both consumers and producers. An exception will be the United States that will take advantage of fuel efficiency improvements and the shale oil output expansion to head energy self sufficiency and terminate crude oil imports from the Middle East by 2040.

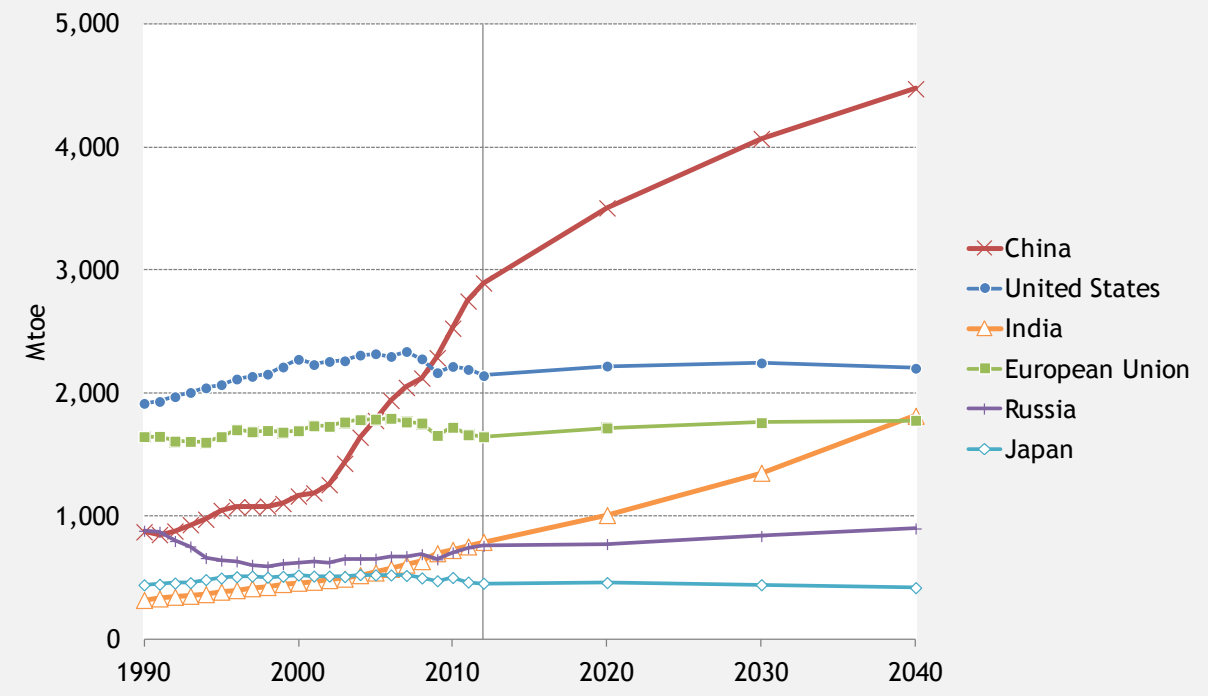
Chinese and Indian energy supply and demand and their impact on world

China and India will drive global energy demand growth

China now consumes more energy than any other country and will continue expanding energy consumption. It will take an unrivalled position by expanding energy consumption in 2040 to 4,474 Mtoe, more than double the consumption level in the United States, the second largest energy consumer in the world. Per-capita energy consumption in China has already exceeded the global average and will increase close to the European Union level in 2040. Another major Asian power, India, will also expand energy consumption remarkably. India's

energy consumption now falls short of half of the European Union consumption but will exceed the European Union level in the late 2030s. In the 2040s, India will replace the United States as the world's second largest energy consumer. China and India will depend more heavily on imports to satisfy rapidly expanding energy demand. The two countries will consume 45% of crude oil traded between major regions in the world and 40% of natural gas traded.

Figure 4 Energy consumption in major economies [Reference Scenario]



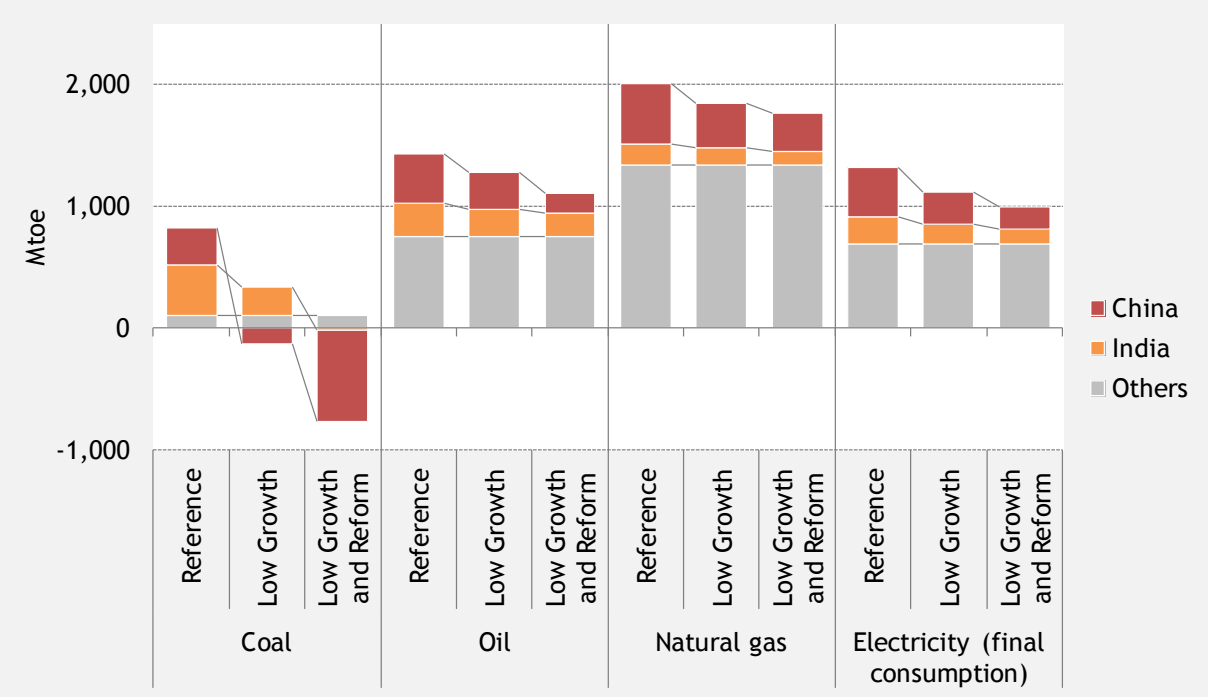
Low economic growth in China and India is shaking energy markets in the world

China is now plagued with various challenges. If they become major problems, China's annual economic growth rate through 2020 may plunge from the 7.2% assumed in the Reference Scenario to 6.0%. Throughout the outlook period, the Chinese growth rate may be limited to 3.9%, down 1.6 percentage points from the level assumed in the Reference Scenario. While China is assumed to replace the United States as the world's largest economy in terms of real gross domestic product in the late 2030s in the Reference Scenario, the Chinese economic size in the Low Growth Scenario is estimated at less than 70% of the United States size even in 2040. The economic growth slowdown will reduce an energy consumption increase, working to ease the international energy supply-demand balance. However, the economic growth deceleration accompanying social reform stagnation and the investment- or export-oriented economy may lead to wider income gaps, employment opportunity shortages and a delay in solutions to energy and environmental problems. If structural reforms are promoted to expand services industries absorbing more labour and consuming less energy, to support China's shift to a consumption-driven economy and to thoroughly introduce energy conservation and low-carbon technologies for energy systems, social welfare may be upgraded even under the lower economic growth.

Indian economic growth is likely to hit the bottom and get on a recovery path after deceleration in recent years. In the Reference Scenario, India is assumed to grow at an annual rate of 6.2% through the outlook period, the fastest growth among major countries. However, foreign investment's outflow, a prolonged European economic slump, a protracted Chinese economic deceleration, economic and administrative reform stagnation and other risks factors could work to lower the annual growth by some 1 percentage point from the assumed level to 5.3%. While the Indian economy is assumed to exceed Japan's economic size in the mid-2030s in the Reference Scenario, it is expected to be slightly smaller than the Japanese size even in 2040 in the Low Growth Scenario.

An increase in energy consumption by China and India through 2040 will total as much as 2,606 Mtoe in the Reference Scenario, surpassing the present annual consumption by the United States and Japan. In the Low Growth and Reform Scenario in which China and India will energetically reform their social and energy consumption systems under slower economic growth, their energy consumption growth will be reduced by 71% to 768 Mtoe. Although coal, a mainstay energy source in the two countries, will post the largest consumption change among energy sources, drops in oil and natural gas consumption will also be of great significance to the international energy market due to the two countries' growing dependence on oil and natural gas imports.

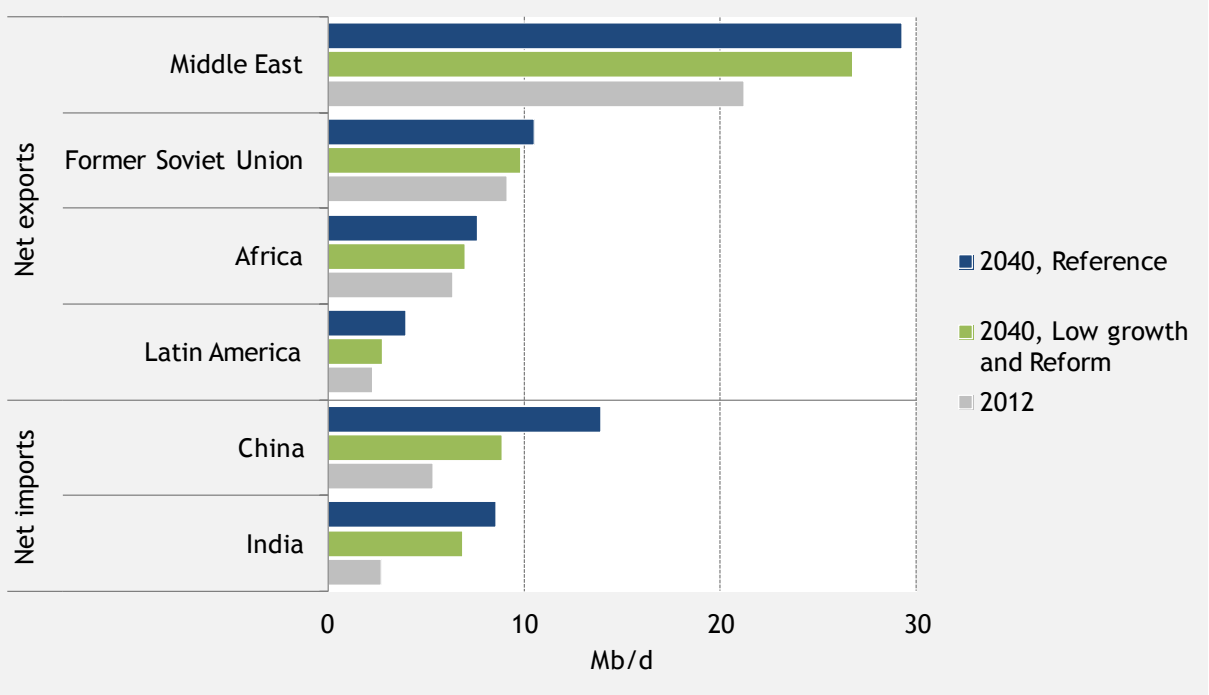
Figure 5 Chinese and Indian energy consumption growth [2012-2040]



China and India have diversified oil procurement sources more than Japan, although the three countries are located in Asia. Nevertheless, the two countries' energy demand growth deceleration will bring about a remarkable change in the Middle East. If their oil consumption growth in 2040 is cut by 6.9 Mb/d from the Reference Scenario, 2.5 Mb/d will be covered by a production cut in the Middle East with 31% of the region's net export growth lost. The former

Soviet Union's net export growth will be halved. Similarly, net export growth for natural gas in the former Soviet Union and the Middle East will be cut by 30%. As a result, the Middle Eastern economy will contract by some 5% from the Reference Scenario. The former Soviet Union economy will shrink by some 4%. Energy suppliers that place great expectations on China and India as their promising customers will have to diversify further export destinations and their economies. They particularly include the second largest natural gas producer that now cannot expect to expand oil and natural gas exports to Europe that had been its major export market.

Figure 6 Net oil imports by China and India, and major regions' net exports



"Turning the circuitous into the direct, and turning adversity into advantage" (Sun Tzu)

Not only China and India but also many other emerging countries have pursued high economic growth to improve national livelihood, stabilise society and enhance public support for government. If high growth is given too much priority, however, respect for human rights, environmental conservation and legal compliance may be undervalued, leading to undesirable results. Infrastructure development may also fail to catch up with rapid economic growth, resulting in chronically insufficient social services including energy.

If China is to get on a stable growth path as planned by its government, it will have to overcome a large number of challenges. If China shifts its priority from quantitative aspects of society to qualitative aspects, however, it may be able to reduce energy consumption and halve sulphur oxide emissions causing particulate matter 2.5 pollution while securing job opportunities. Then, China may make the first step forward to building more sustainable systems for social development, resources and the environment.

Infrastructure underdevelopment has become a chronic issue in India. Electricity shortages amounting to 10% of demand triggered a large-scale blackout affecting 600 million people – half India's population – in 2012. Electricity demand has increased so rapidly that power generation capacity expansion fell short of solving the electricity shortages. Even if the current economic growth deceleration is prolonged over a medium term, infrastructure development and administrative efficiency enhancement for the future are indispensable for upgrading the stage of economic development over a long term.

Low economic growth represents the problem of if low growth could be turned into an advantage.

Low-carbonisation and climate change mitigation measures – Advanced Technologies Scenario

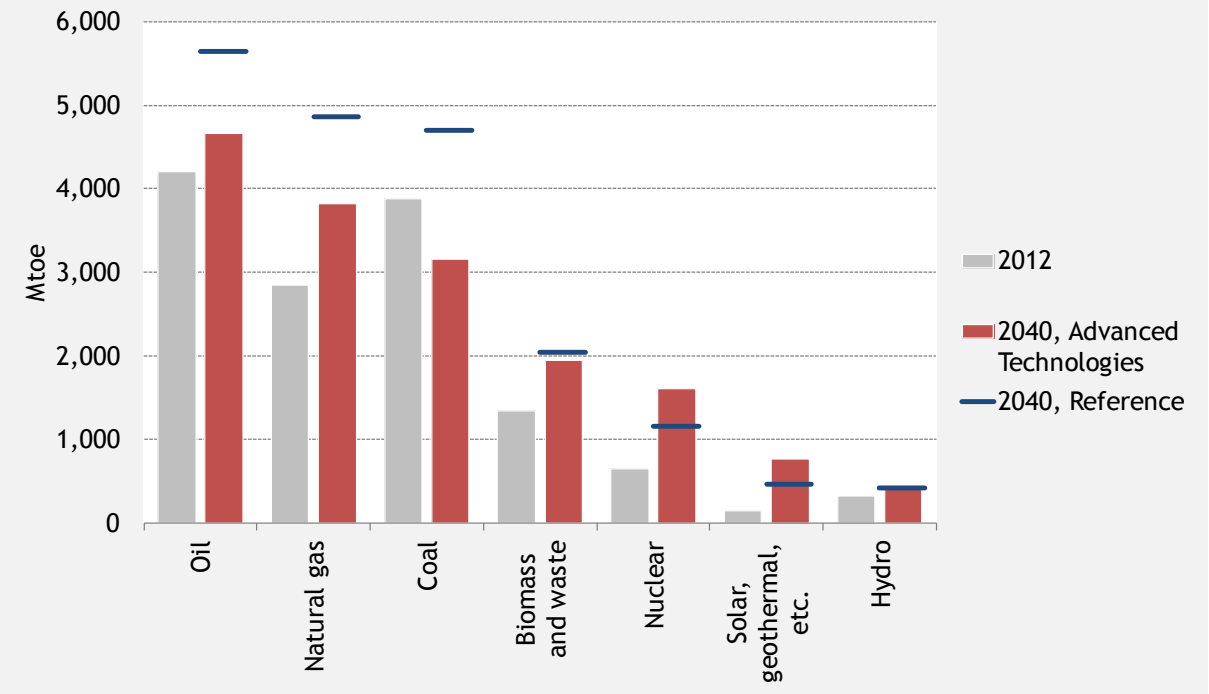
Global energy efficiency enhancement could bring about energy savings amounting to China's consumption

In the Advanced Technologies Scenario in which energy technologies on both the supply and demand sides will be substantially developed and diffused widely to enhance energy security and climate change measures, global primary energy consumption in 2040 will be limited to 16,374 Mtoe, 15% less than in the Reference Scenario. The cut of 2,902 Mtoe exceeds present annual consumption by China, the largest energy consumer in the world.

Coal consumption will peak out presently. In 2040, it will be 19% less than the present level, posting the largest consumption decline among energy sources. Oil consumption will total 96.2 Mb/d in 2040, far less than 116.5 Mb/d in the Reference Scenario. The savings totalling 20.3 Mb/d amount to present crude oil production by Saudi Arabia and Russia. Natural gas consumption in 2040 will aggregate 4.62 Tcm, with a future increase halved from the Reference Scenario. The savings of 1.26 Tcm from the Reference Scenario exceed the output of Russia and the Middle East.

While reducing fossil fuel consumption or slowing down consumption growth, the world will further expand non-fossil energy consumption including nuclear, solar and wind energy. In 2040, zero-emission electricity sources will account for a half of power generation in the world and two-thirds of generation in OECD. Biofuel consumption will increase mainly in the transport sector, reaching 243 Mtoe exceeding an equivalent of present crude oil production by the United Arab Emirates and Qatar. Traditional biomass use, seen frequently in the residential sector in developing countries, will decline by 13% from the Reference Scenario.

Figure 7 Global energy consumption [Advanced Technologies Scenario]

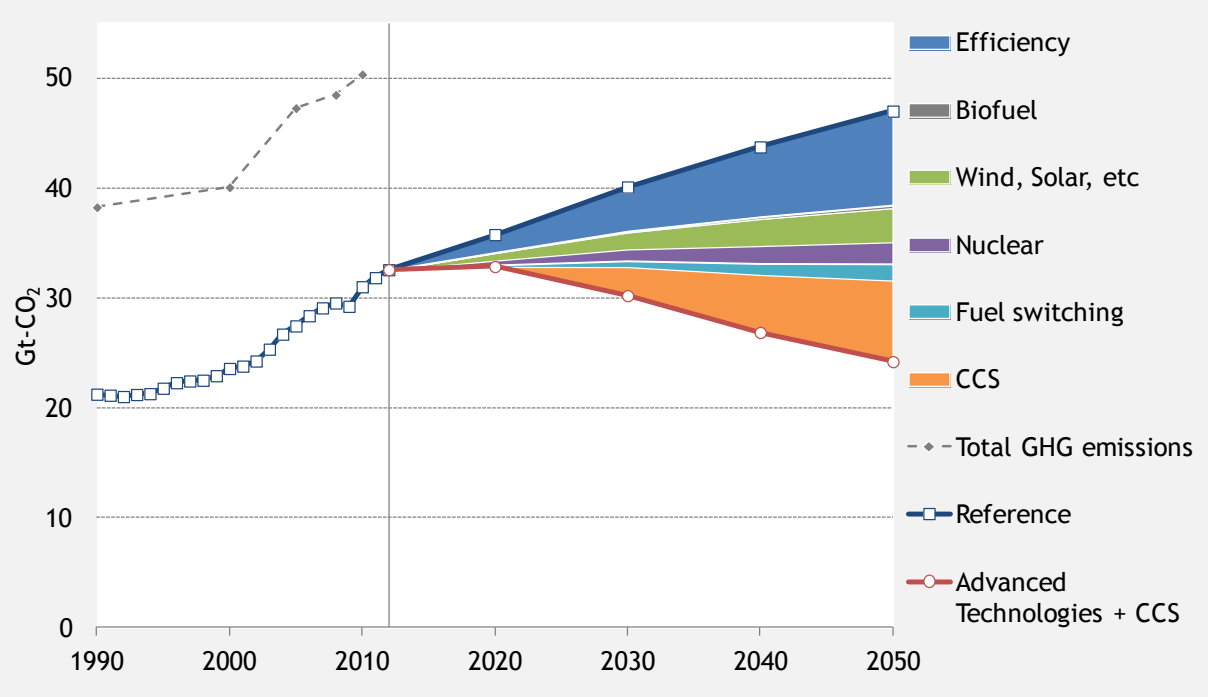


Not only advanced technology development but also cost reduction for higher economic efficiency and the global diffusion of advanced technologies through their adaptation to local needs will be required to realise such massive energy conservation and low-carbon potentials. Energy conservation potentials in non-OECD and Asia, where inefficient energy consumption now accompanies rapid economic expansion, account for two-thirds and a half of global energy conservation potentials, respectively. Non-OECD and Asia hold the key to reforming global energy systems.

If you can dream it, you can do it except for halving greenhouse gas emissions

Energy-related carbon dioxide emissions, accounting for 60% of global greenhouse gas emissions, will continuously increase in the Reference Scenario. In 2050, energy-related CO_2 emissions will jump by 44% from 2012 to 47.0 gigatonnes (Gt). In the Advanced Technologies Scenario, energy-related CO_2 emissions will level off or decrease slightly instead of increasing substantially. If carbon capture and storage (CCS) effects in fossil fuel power generation and industry sectors are taken into account, energy-related CO_2 emissions will clearly turn downward in or after 2020 and reach 24.2 Gt in 2050, up 14% from 1990 but down 26% from 2012. However, the reduction will fall far short of the target of halving GHG emissions in 2050 from the present level.

Figure 8 Global energy-related CO_2 emissions and each measure's contribution to reducing emissions [Advanced Technologies Scenario + CCS]

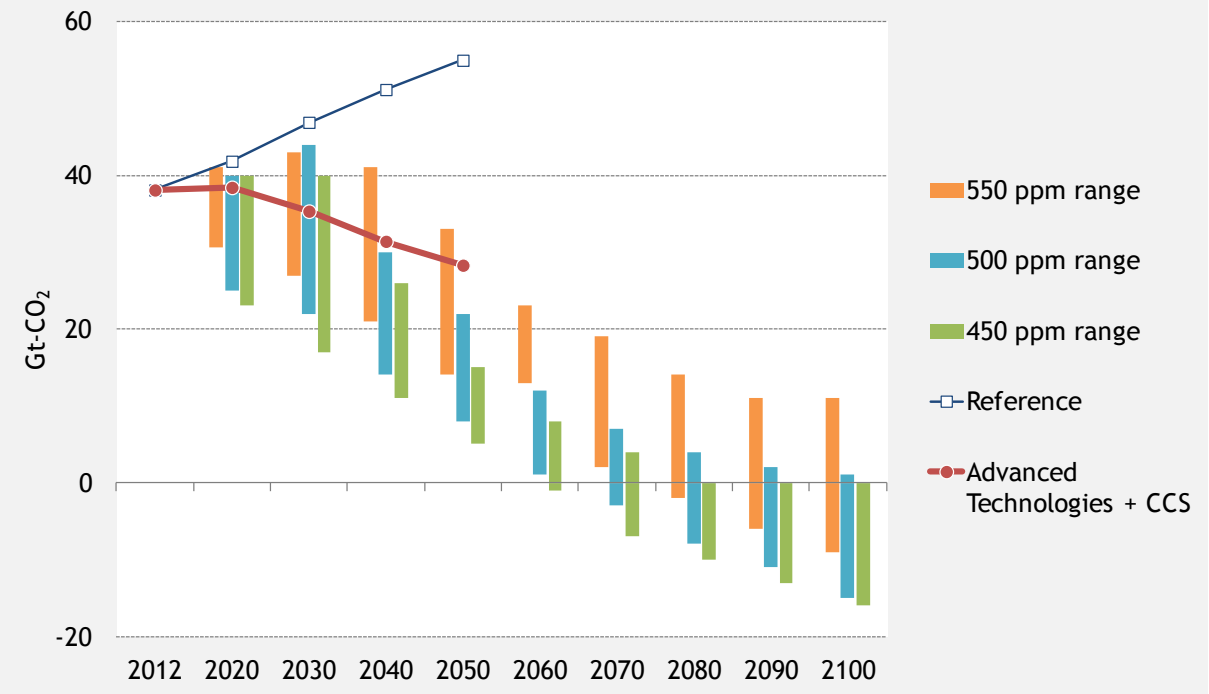


"Make efforts until your goal is attained. See your goal being attained as it is." (Gautama Siddhartha)

A scenario for reducing the atmospheric concentration of GHGs to about 450 ppm (parts-per-million CO_2-equivalent) in 2100 is well known as a climate change mitigation scenario in which the temperature rise from the pre-industrialisation level attributable to human-induced GHG emissions will be restricted to less than 2 degrees Celsius. The 450 ppm scenario depends on bioenergy with carbon capture and storage (BECCS) systems, afforestation and their wide diffusion in the second half of this century. However, the availability and scales of BECCS systems, afforestation and other CO_2 removal technologies or means are uncertain, indicating that there will be more or less challenges or risks.

A Working Group III report published in April 2014 for the Fifth Assessment Report by the Intergovernmental Panel on Climate Change does not limit scenarios for holding down the temperature rise to less than 2°C to the 450 ppm scenarios. Noteworthy is the report cites 500 ppm scenarios as having about a 50% probability of restricting the temperature increase to less than 2°C. According to the report, the probability of staying the temperature increase below 2°C will be 50-100% without a concentration overshoot and 33-66% with such overshoot in the 500 ppm scenarios. If the temperature increase is allowed to widen to 2.5°C with appropriate adaptation measures assumed, 550 ppm scenarios (with the probability of staying the temperature increase below 2.5°C through the 21st century at 65-80%) can become one of the options. The Advanced Technologies Scenario + CCS amounts to a 550 ppm scenario regarding emission paths and to a 500 ppm scenario regarding cumulative emissions.

Figure 9 Global CO_2 emissions and emission ranges for 450, 500 and 550 ppm scenarios



Note: Including CO_2 emissions other than energy-related emissions.
Sources: Prepared from the 5th IPCC Assessment Report (Working Group III), and UNEP, "The Emissions Gap Report 2013," etc.

If participants in international negotiations on a new emission control framework stick to the 450 ppm scenarios, the negotiations will be prolonged with major countries' coordination remaining difficult. As a result, it could become more difficult to hold down the temperature increase. In order to solve the dilemma, negotiators should adopt the 500 ppm or 550 ppm scenarios to conclude the negotiations as early as possible. A conceivable option would be to proceed with adaptation measures including the enhancement of disaster prevention facilities and a switch to heat resistant crops while developing BECCS, carbon capture and utilisation (CCU), space solar power system and other advanced technologies to restore the 2°C scenario later. In a realistic manner, we must consider climate change mitigation measures with various scenario options other than the 450 ppm scenarios being kept in mind.

Climate change mitigation, adaptation and damage are closely related to each other and should be considered simultaneously. An optimum balance between mitigation and adaptation costs should be achieved to minimise efficiently and effectively total climate change damage. However, correlations between mitigation costs, climate change impacts and adaptation costs have yet to be clarified, with optimum assessment failing to be conducted. Research into the three costs, particularly the adaptation cost, must be promoted quickly. Nevertheless, it may be needless to say that all countries should make maximum efforts to do what they can.

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