

Global Environmental Research Fund (GERF/S-3)
Japan-UK Joint Research Project “Developing visions for a Low-Carbon Society (LCS)
through sustainable development”

Japan Scenarios towards Low-Carbon Society (LCS)

**-Feasibility study for 70% CO₂ emission
reduction by 2050 below 1990 level-**

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“2050 Japan Low-Carbon Society” scenario team

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Key Conclusions

Japan has the technological potential to reduce its CO₂ emissions by 70% compared to the 1990 level, while satisfying the expected demand for energy services in 2050.

Overview of the project:

1. This research assesses the possibility of achieving the Low-Carbon Society (LCS) in Japan by targeting at 70% CO₂ emission reduction by 2050 compared to the 1990 level.
2. The project has been sponsored by the Global Environmental Research Fund, which is funded by the Ministry of the Environment of Japan. Approximately 60 experts from research institutes, universities, and private companies, with diversified specialties such as environmental and energy engineering, economics, industry, transportation, urban engineering international law and politics have contributed to this research.

Socio-economic prerequisites:

3. To achieve the LCS, the following socio-economic prerequisites are considered:
 - ◇ Vibrant society maintaining a certain level of economic growth.
 - ◇ Satisfying of the energy services demand as envisioned in the expected socio-economic scenarios.
 - ◇ Consideration of innovative technologies, for example, electric vehicles and hydrogen vehicles; yet, this research does not take into account uncertain technologies such as nuclear fusion.
 - ◇ Consistency with the existing long-term governmental plan, such as a plan of nuclear energy.
 - ◇ Since the objective is to identify the carbon abatement potential of Japan, the policy options that aim at making the technological changes possible are out of the scope of this research project.

Potential of 70% carbon abatement, cost and sectors

4. Satisfying the prerequisites mentioned above, a 70% CO₂ emission reduction below the 1990 level can be achieved by reducing 40-45% the energy demand and by introducing low-carbon energy supply.
5. The annual direct cost related to a CO₂ emission reduction of 70% by 2050 would range between JPY 6.7 and 9.8 trillion, which would account for around 1% of the estimated GDP in 2050.
6. The energy demand-side emission reductions could be accomplished by combining a shrinking population scenario with promoting rational energy use, energy conservation and improvements in energy efficiency, while allowing the per capita GDP growth at 1-2% towards 2050.
7. Estimated reduction rates of sectoral energy demand (relative to the 2000 value) are as follows, where the range of reductions varies due to different scenarios in 2050:
 - Industrial sector: reduction of 20-40% due to structural changes and introduction of energy-saving technologies.
 - Passenger transportation sector: reduction of 80% due to proper land use, and improvement in energy efficiency and carbon intensity.
 - Freight transportation sector: reduction of 60-70% due to better logistics management and improvements in the energy efficiency of vehicles.
 - Household sector: reduction of 50% due to rebuilding and diffusion of high-insulated houses and introduction of energy-saving house appliances.

- Commercial sector: reduction of 40% due to renovation and rebuilding with high-insulated building and introduction of energy-saving office devices.
8. The energy supply side will also be low-carbon intensive by a combination of appropriate selection of improvement of energy efficiency and low-carbon content energy (partially including carbon capture and storage (CCS)).

To achieve LCS:

9. In order to achieve the LCS goals while satisfying the required amount of energy services at the same time, prompt actions should be taken at the earliest stage of the roadmap. Such actions involve structural changes in the industrial sector and investment in infrastructure. Moreover, it is necessary to accelerate development, investment, and use of energy-saving technologies and low-carbon energy technologies. The government should play a leading role in promoting a common vision towards LCS at the earliest stage, enforcing comprehensive measures for social and technological innovation, implementing strong measures for translating such reduction potentials into a reality, promoting measures for public investment based on long-term perspectives and leading incentives for private investment.

1. Methodology of the Low-Carbon Society (LCS) scenario approach:

Applying a back-casting approach

This study analyses the possibility of achieving a LCS in Japan, where CO₂ emissions, one of the major greenhouse drivers, would undergo a 70% reduction by 2050 below the 1990 level. Transformation in social, economic and technological activities is expected during the first half of the century. The range of such transformation varies widely. It is necessary to make preparations for the desired socioeconomic changes to achieve LCS.

Assuming that such a degree of socioeconomic change is possible, the back-casting method was adopted in this study to examine the strategies for achieving the LCS. Some of the key aspects of this method are shown in Fig. 1. Among the most important steps of this process we could highlight the following:

- 1) to envision the direction of future Japanese socioeconomic structure towards 2050 within a certain range (for instance, Scenario A: active, quick-changing, and technology oriented, and Scenario B: calmer, slower, and nature oriented) and to describe the characteristics of those two types of societies qualitatively through brainstorming by experts (narrative version),
- 2) to quantify behavior of people and households (how people spend time, what services will be needed), design of city and transportation (what kinds of city and houses people live in, how people travel), and industrial structure (estimation of the structural changes by a multi-sector computable general equilibrium model) for each scenario, and to estimate energy-service demand for each scenario (for instance, the volume of cooling [calories], hot water supply [liter], crude steel production [ton], and transportation demand [ton-km, passenger-km]),
- 3) to calculate energy services demand, while satisfying the CO₂ emission reduction target that supports the estimated socioeconomic activity in each scenario; to explore the appropriate combination of energy services demand, end-use energy technology (air conditioner, thermal insulation, boiler, steel plant, hybrid car, etc.), types of energy supply and energy supply technologies, based on the consideration of the available volume of energy supply (shown as (5) in Fig. 1), its cost-efficiency and its political feasibility; to identify the types of energy demand and supply technologies as well as their shares, and finally,
- 4) to quantify the primary and secondary energy demands and the amount of resulting CO₂ emissions.

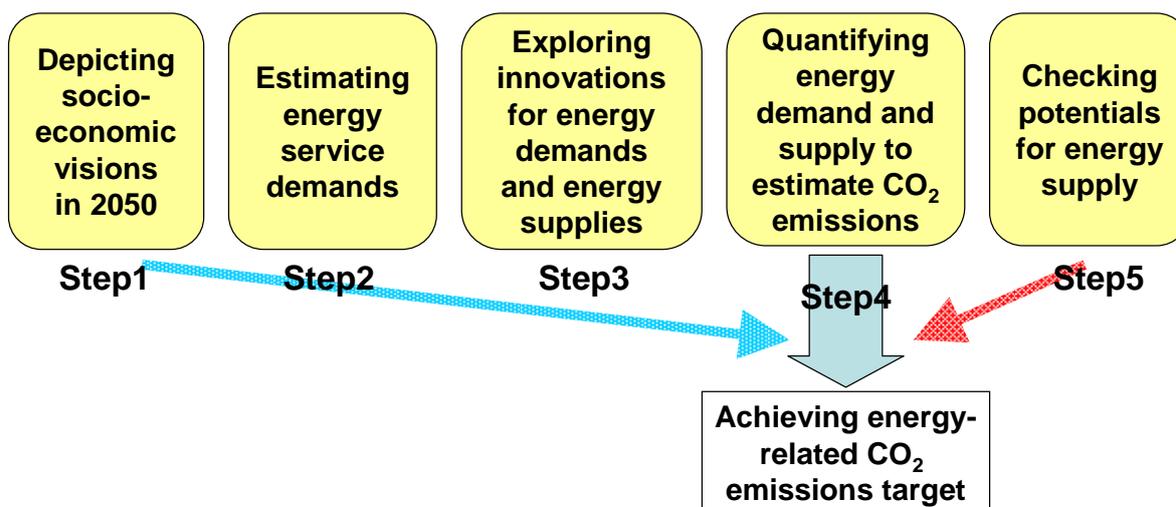


Fig. 1 LCS scenario approach

2. Visions for 2050's Japan:

Assumptions of possible future socio-economic scenarios and changes in industrial structures

Different pictures of future Japan:

Possible pictures of future Japan and their pathways towards the LCS have been discussed by experts from various fields. Two scenarios, A and B, have been developed as a result (Table 1, 2) [See also (1) in Fig. 1]. The features of Scenario A can be described as active, quick-changing, and technology oriented society. On the other hand, Scenario B is a calmer, slower, and nature oriented society. Changes in social indicators and various assumptions made in both scenarios are within the ranges of existing major studies of Japanese future society projections (Japan's visions for 21st century (2005, the Cabinet Office)). In reality, however, the future Japanese society may be a mixture of elements from both the scenarios.

In scenarios A and B, annual growth rate of per capita GDP has been assumed to be 2% and 1% respectively. The changes in services demand that are directly related to energy consumption (ex. heating, transportation, and built environment management, etc.) have been set by assuming the changes in lifestyle of the representative people in each scenario. The improvement in the service levels has been assumed to be gradual and moderate. Excessive service demands such as heavy loads in household and offices (such as air-conditioned throughout the day), or disorganized urban structure with inappropriate urban planning which leads to considerable increase in traffic demand, is not assumed in the scenarios.

Table 1 Narrative Scenarios for land use and urban structure

Key words	Scenario A	Scenario B
Migration: Decrease in population across all region	Population and capital would be concentrated more in urban areas because of the increase in urban preference of the people and pursuit of convenience/efficient lifestyles	Decentralization of population and capital would occur because of the increasing need for slower lifestyles of the people.
Metropolitan area:		
Urban	Intensive land use (vertical use of land area including underground space) in urban areas would allow people to live near their work places, and the ratio of people who live in convenient urban areas increases.	It becomes more common to move out from urban centers and people want to migrate where living environment matches with their own lifestyles. The capital city and other core cities remain moderate in size and population.
Suburb	Emigration of population would be observed in suburb area, however, most of the it would be redeveloped as amusement facilities or natural symbiosis areas through well-planned and effective urban designing	Outflow of population and capital would continue. Therefore, the regeneration plan is targeted to develop these areas as independent urban cities rather than suburbs of mega-city.
Local area:		
Urban	A number of local cities discontinue functioning as core city, however, some cities get re-developed as bases for land intensive businesses such as mass plantation or power generation.	Decrease in population would be restricted since sufficient health services or education can be enjoyed in those areas. There would be many attractive local cities with original cultures and unique features. Citizens and NGOs play important roles in decision making processes.
Agricultural, Mountainous area	Many agricultural areas or mountainous areas would suffer from depopulation. The regeneration efforts are targeted to effective use of land and resources. Agriculture, forestry and fisheries industries are operated by big private companies, Efficient use of resources such as manpower, materials, and capital become possible. Some areas are designated as national parks.	More people migrate from urban to rural areas due to increasing attractiveness of agriculture, forestry and fisheries industries. In addition to permanent farmers, increasing numbers of families enjoy secure food supply and healthy life-styles in rural areas while pursuing businesses in the pattern of Small Office Home Office (SOHO).

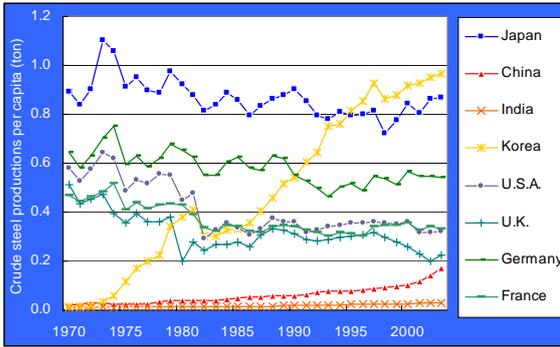
Projections of population and number of households:

Based on the methodology and assumptions made in the research publication, “Population Projections for Japan: 2001-2050, January 2002, National Institute of Population and Society Security Research”, changes in parameters including birth rate, mortality rate, and percentages of householders in the population were set (see Table 2), and the populations and number of households for each scenario were estimated. The results of the simulations show that the population in scenarios A and B would drastically decrease to 95 million and 100 million respectively, from 127 million in 2000, because of continuing trends of aging population and lowering fertility rates. The number of households in both scenarios has also diminished; however, the household reduction rate is much slower than that of population since the number of family members would also decrease because of increasing proportion of single households and elderly households. As a result, the number of households in scenarios A and B fades away from 47 million in 2000 to 43 million and 42 million in 2050, respectively.

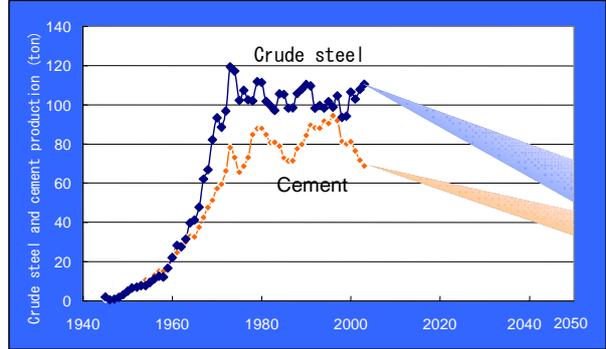
Table 2 Narrative scenarios for the economy and the industry

Keywords	Scenario A	Scenario B
Economy:		
Annual growth rate	• Approximately 2% of GDP per capita growth rate	• Approximately 1% of GDP per capita growth rate
Technology development rate	• High	• Moderately high
Industry:		
Market	• Reducing regulation	• Penetration of market rules with moderate regulation
Primary industry	• Decrease in share • Increase in import dependency	• Relatively less decrease • Reduced import dependency
Secondary industry	• Tendency to heighten the added value • Globalization of production bases	• Decrease in share • Limited production of diversified products with local brand
Service industry	• Increase in share • Increase in productivity	• Increase in share • Increase in social activity

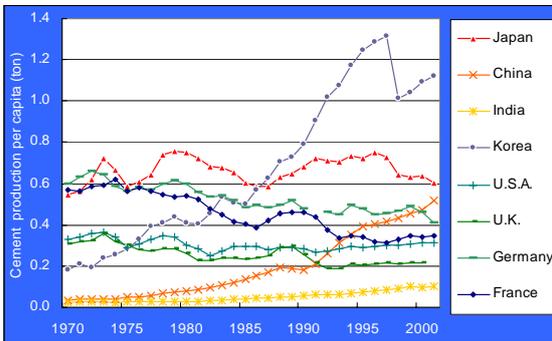
Crude steel production per capita by country



Assumed future trends for crude steel and cement production in Japan



Cement production per capita by country



Source:
 (Crude steel production, Cement production)
 Industrial Commodity Production Statistics (United Nations), World
 Development Indicators (World Bank)
 (Crude steel production, Cement production in Japan)
 Reports by Advisory Committee on Energy and Natural Resources
 (1998, 2004, 2005) and predictions by the Institute of Energy
 Economics, Japan.

Fig. 2 Estimations for productions of raw materials

Estimation of the Industrial Structure:

The industrial structure of 2050 is estimated according to that of 2025 presented in “Innovative Strategies for New Industries (2004, Ministry of Economy, Trade and Industry)”. At present, in Japan the national production per capita of steel and cement, both of which are the outputs of the energy-intensive industries, are about twice as much as in the Western industrialized nations (see Figure 2). The public infrastructure projects create a huge demand of construction materials such as steel and cement. However, their demands will certainly decline by 2050, once the public sector in infrastructure reaches maturity. As for the demand in Asia, it is assumed that the local production by the Japanese companies would increase. Consequently, the production of crude iron and cement in 2050 will be 60-70 million tons and 50 million tons, respectively. Their national productions per capita are expected to fall to the same level as that of the western industrialized nations.

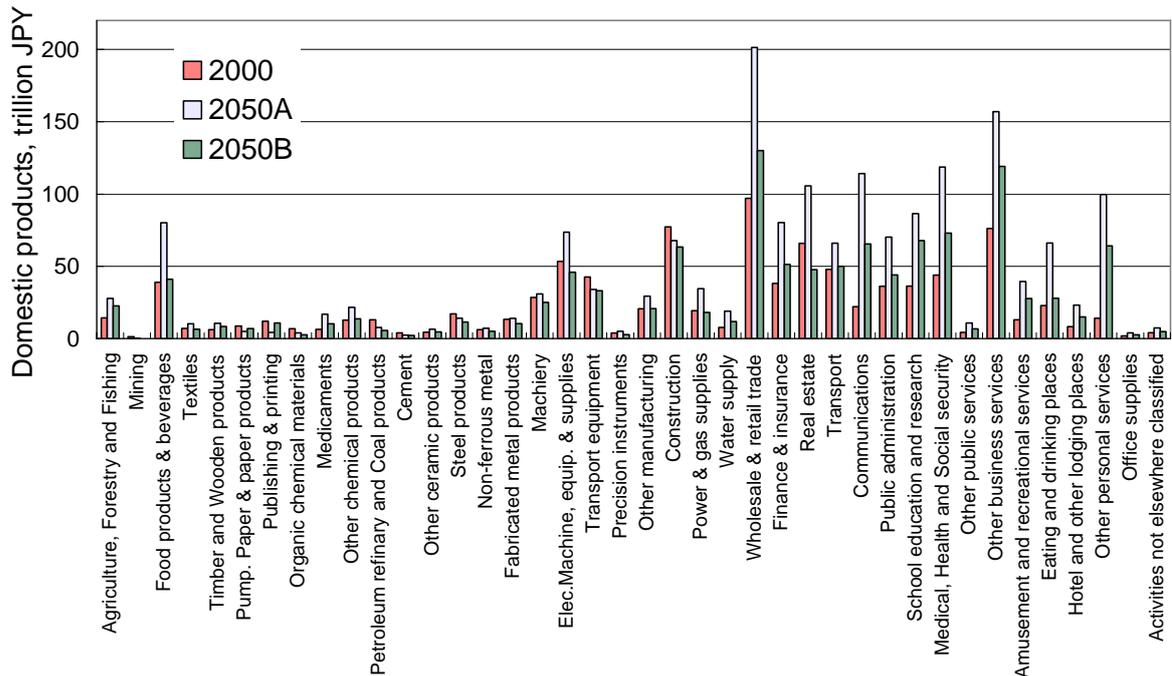


Fig. 3 Domestic outputs by industrial sectors in 2050

The industrial structure of 2050 aiming at the low-carbon target is estimated using a Computational General Equilibrium model (CGE) in 57 sectors. The macroeconomic indicators and productions by categories are estimated according to the consideration of the raw material production in Table 2 and Fig. 2. This estimation is based on a work force consistent with the demographic composition and a size of capital stock relevant to its productivity in 2050. The energy demand is estimated from the major parameters describing the society of 2050: the efficiency change (the improvement of energy efficiency by introducing the technologies essential to fulfill the low-carbon target, and the progress of dematerialization) and the pattern of energy supply; the change in demand function according to the change in demographic composition and social structure; the expansion of raw material recycling from the stock renewal; the change of the raw material production mentioned (as in Fig. 2); the shift in the public investment towards focusing on the maintenance of infrastructure; the change of trade structure based on relocation of production bases. Only a depiction of society in 2050 is considered, regardless of the change in production facilities over time, since most of them will be replaced by 2050 (see Step 2 in Fig. 1). Fig. 3 shows the results summed up into 40 sectors. Both scenarios A and B show the progress of the service sector, the increase of electric machines, equipment & supplies, the transport equipment industries, and the reduction of the energy-intensive industries. These results are not different from the previous estimations (Japan's visions for 21st century (2005, the Cabinet Office)). The active society (Scenario A) demonstrates a remarkable progress in sectors such as commercial services, and electromechanical machinery and transport machinery industries. Based on this estimation, in the following sectors, only the direct effect of measures for fulfilling the LCS is evaluated. The indirect

effects such as trigger effects by the measures will not be analyzed.

3. Options for LCS:

70% reduction of CO₂ emissions can be achieved by means of both a 40-45% reduction of final energy consumption through rationalization and appropriate choice of energy supply options with satisfying, and/or improving current service demand levels.

Technology choices for energy demand-side under the LCS:

Scenario A and B select packages of technological countermeasures for the LCS from the Environmental Option Database (EDB) [Step 2 in Fig. 1], on the basis of the estimated industrial structure in 2050, as shown in Fig. 3. The EDB includes more than 600 technology options (Table 3 lists key elements in the database). Prospects for future technological innovations have been set based on various reports, research articles, and white papers, such as “Strategic Technology Roadmap in Energy Field-Energy Technology Vision 2100” by Ministry of Economy, Trade and Industry, Japan (METI). After configurations of technological countermeasures, required secondary energy demands, such as grid electricity, fossil fuels, hydrogen, and others, were determined [Step 3 in Fig. 1]. These two steps (Step 2 and 3 in Fig. 1) have benefited from expert judgments.

Table 3 Key technological countermeasures in the Environmental Option Database

The table lists technologies which are currently expected to have potentials for deployment and diffusion in the future. In addition, innovations in other technologies are also expected to occur which may play an important role in achieving the LCS. Such innovations would be driven to accomplish other purposes, such as improving quality of life, as well as to implement the LCS.

Sector	Technology
Residential & Commercial	Efficient air conditioner, Efficient electric water heater, Efficient gas/oil water heater, Solar water heater, Efficient gas cooking appliances, Efficient electric cooling appliances, Efficient lights, Efficient visual display, Efficient refrigerator, Efficient cool/hot carrier system, Fuel cell cogeneration, Photovoltaic, Building energy management system (BEMS), Efficient insulation, Eco-life navigation, Electric newspaper/magazine etc.
Transportation	Efficient reciprocating engine vehicle, Hybrid engine vehicle, Bio-alcohol vehicle, Electric vehicle, Plug-in hybrid vehicle, Natural gas vehicle, Fuel cell vehicle, Weight reduction of vehicle, Friction and drag reduction in vehicle, Efficient railway, Efficient ship, Efficient airplane, Intelligent traffic system (ITS), Real-time and security traffic system, Supply-chain management, Virtual communication system etc.
Industrial	Efficient technologies for boiler, industrial furnace, Independent Power Plant (IPP), coke oven, and other innovations like Eco-cement, Fluidized catalytic cracking of naphtha, Methane coupling, and Gasification of black liquid.
Energy Transformation	Efficient coal-fired generation (IGCC, A-PFBC, Co-combustion with biomass etc), Efficient gas-fired generation, Efficient biomass-fired generation, Wind generation (On-shore, Off-shore), Nuclear power generation, Hydro power generation, By-product hydrogen, Natural gas reforming hydrogen production, Biomass reforming hydrogen production, Electrolysis hydrogen production, Hydrogen station, Hydrogen pipeline, Hydrogen tanker, CCS (Carbon Capture and Storage), etc.

Low-carbon alternatives for energy supply:

We have examined feasible combinations of energy sources in supply-side, shown in Fig. 4, which satisfy both secondary energy demands and quantity constraints for various energy resources [Step 4 and Step 5 in Fig. 1]. Various criteria for energy supply-side include economic efficiency, uncertainty of technological innovation, public acceptance, and expert judgments in the context of the narrative scenarios as mentioned in chapter 2. As per our estimate, required energy demands in 2050 would decrease to about 55-60% of 2000 level due to various kinds of innovations even with reasonable economic growth. In addition, decarbonization of energy supply will be necessary in order to achieve the LCS. Decarbonized energy supply systems exhibit a lot of variation (we shall discuss diversity of energy supply systems again in chapter 7). In this research, it is assumed that large-scale centralized energy systems, such as nuclear power, carbon capture and storage (CCS), and hydrogen production are suitable options for the scenario A, and small-sized distributed energy systems, such as solar, wind and biomass are suitable for scenario B.

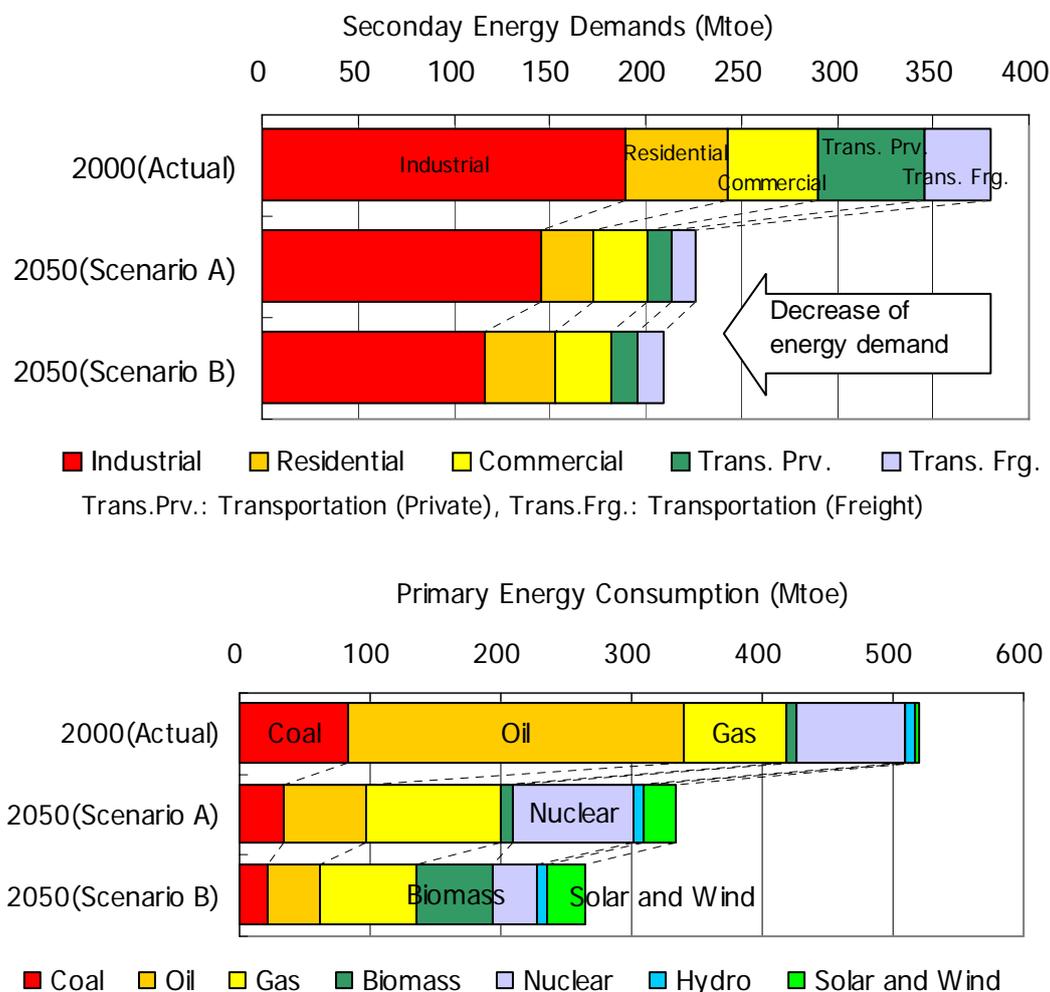
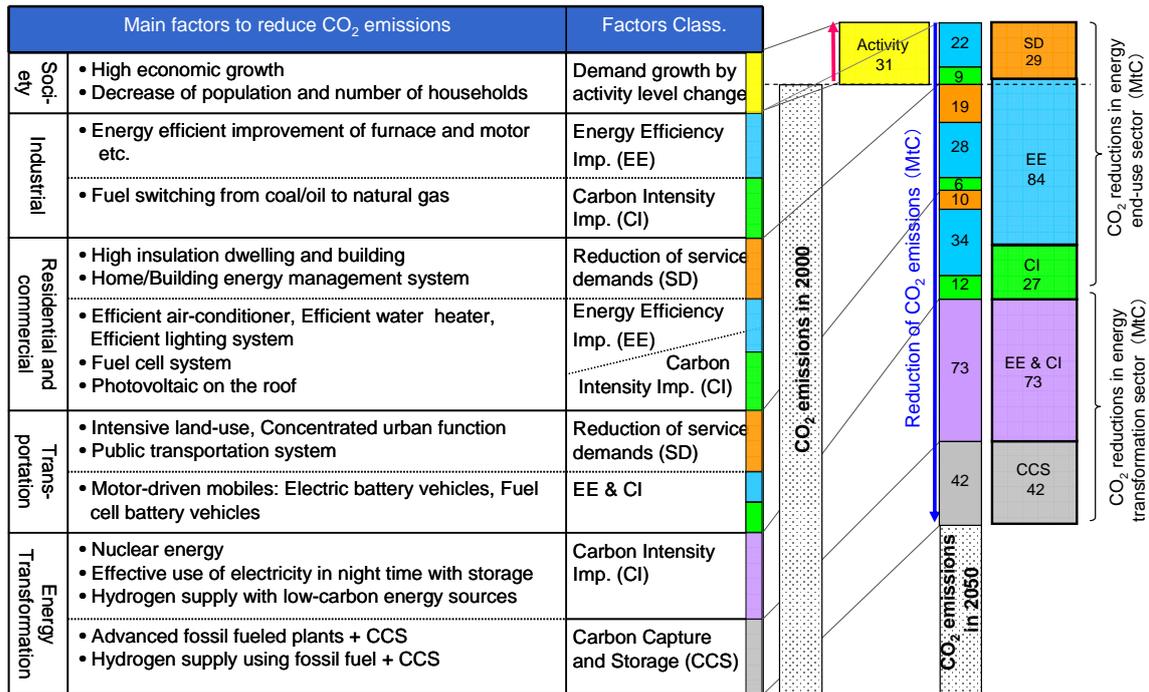


Fig. 4 Energy demands and supply for achieving 70% reduction of CO₂ emissions (Mtoe: Million ton of equivalent)



EE: Energy Efficiency Improvement, CI: Carbon Intensity Improvement, SD: Reduction of Service Demand

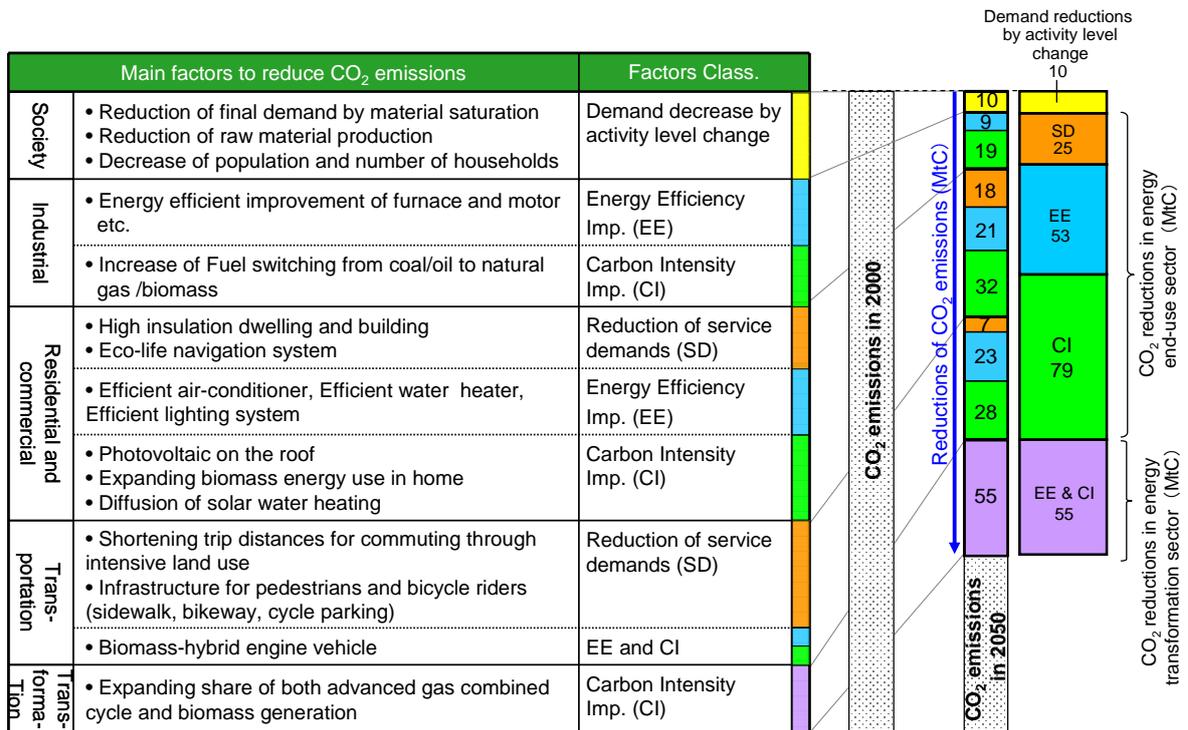


Fig. 5 List of countermeasures for 70% reduction of CO₂ emissions, scenario A and B

In the scenario A, countermeasures for housing complex and measures toward compact city have an effect on CO₂ reduction due to centralization of urban activities. Effective options in the scenario B include actions for detached house and automobiles as well as demand reduction strategies. There are common countermeasures to scenario A and B.

LCS can be achieved:

Through this research, we conclude that CO₂ emissions in 2050 can be reduced by 70% from the 2000 level, both in scenario A and scenario B, under acceleration of research, development and deployment of new technologies. 2050's GDPs in scenarios A and B are set to about double and 1.5 times the 2000 level, respectively. Expected future innovations will lead to the reductions in energy demand by 40-45% from the 2000 level while maintaining GDP growth and improving service demands. In addition, decarbonization of energy supply boosts CO₂ reductions to 70% below 2000 level. In each scenario, strategies for realizing LCS include three key elements: demand reduction through rationalization of energy use; development and deployment of energy efficient technologies and; decarbonization of energy in supply-side.

Effective countermeasures in the scenario A are energy efficiency options in demand-side, such as implementation of energy efficient appliances in the industrial, residential, commercial and transportation sectors, and fuel-switching options from conventional energy sources to low-carbon energy sources, such as nuclear power and hydrogen. In scenario B, the use of low-carbon energy, such as biomass and solar energy, in demand-side would result in drastic reductions of CO₂ emissions.

Although CO₂ reductions by sector vary according to the scenario, both scenarios share many technology options. These options involve no-regret investments, which reduce the energy costs and are profitable. Research and development activities for such technologies yield desirable outcomes for society. The technology options that take long periods of time for implementing such as hydrogen, nuclear power, and renewable-based energy systems, require early, well-planned strategies with consideration to uncertainties.

4. Technology cost to achieve LCS:

Annual implementation cost required for low-carbon technology is estimated at least 6.7 to 9.8 trillion JPY

Future cost of countermeasures will vary depending on the direction of socioeconomic development in the envisioned society. In order to achieve the envisioned society in 2050, it is necessary to appropriately lead industrial transformation and investment in transportation infrastructure as soon as possible. Those investments are not necessarily carried out as a climate change policy since they will be deployed anyway for enhancing Japan's international competitiveness, designing safe communities with comfortable levels of mobility and energy security. In this study, it is assumed that those investments, which also contribute for developing LCS, as a result, will occur with appropriate timing. Hence those investments are not included in the cost analysis for achieving LCS in this study. However, even if those investments are carried out, it will become necessary to accelerate the diffusion of innovative technologies to achieve LCS.

This study estimates the annual implementation cost of introducing low-carbon technologies in order to achieve LCS targeting at 70% emission reductions in 2050. Annual implementation cost of low-carbon technology needed in 2050 is estimated to be JPY 8.9 trillion to 9.8 trillion for scenario

A and 6.7 trillion to JPY 7.4 trillion for scenario B as shown in Table 4. The additional costs were estimated by subtraction of the cost of existing technology and the cost of selected low-carbon technology in each sector (Fig. 6). Annual additional cost in 2050 was estimated to be JPY 1.0 to 1.8 trillion for scenario A and JPY 0.7 to 1.6 trillion in scenario B. The corresponding average reduction costs are estimated in the range of 20,700 JPY/tC to 34,700 JPY/tC.

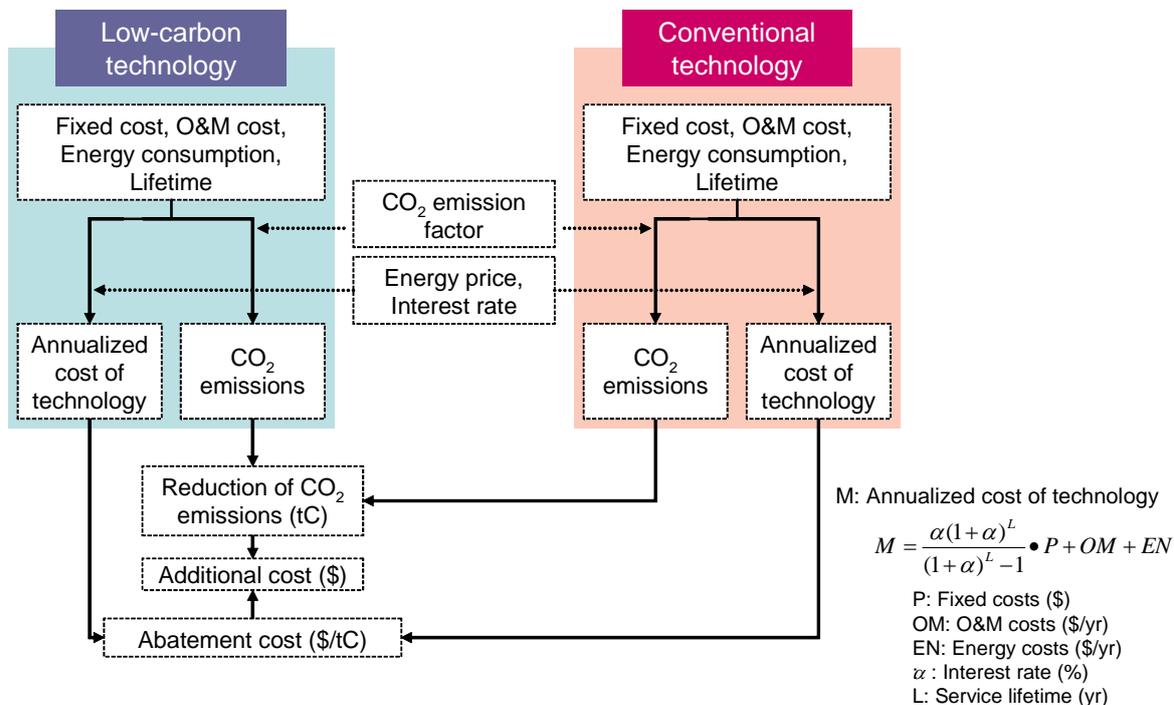


Fig. 6 Calculation of additional cost to induce low-carbon technology for 70% reduction

The difference between the cost of conventional technology (existing technology which is induced when no action for LCS is taken) and Low-carbon technology (necessary technology to actualize 70% reduction) is considered as the additional cost.

Table 4 Additional Cost for LCS

	Scenario A	Scenario B
Annual implementation	8.9-9.8 trillion yen	6.7-7.4 trillion yen
Cost (% of GDP in 2050)	(0.83%-0.90%)	(0.96%-1.06%)
Annual Additional Cost	1.0-1.8 trillion yen	0.7-1.6 trillion yen
Average Reduction Cost	24,600-33,400yen/tC	20,700-34,700yen/tC

Average Reduction Cost=Additional Cost/Emission quantity reduced by the additional measure

5. Technology roadmap for 2050:

A long-term saving effect through early investments in energy saving technologies

For a preliminary analysis, the emission reduction target for 2050 was set and the optimal path (i.e., the path of minimum economic loss), of mitigation measures from 2000 to 2050 were simulated by a dynamic optimization model. The important point to note is that this analysis was based on a comprehensive database of feasible technology options shown in Table 3 and Figure 5 and it excluded unrealistic technologies that exhibit high uncertainty. As a result, it was found that, considering lifetime of capital, promoting an early investment on energy savings as well as those in the target year becomes the optimal path of mitigation action. When energy saving investments are delayed and yet the reduction target is to be achieved by the target year, introduction of technologies at a higher marginal cost becomes essential and it is estimated that economic loss will be greater than the loss in the case of early investment. The effect of price reduction due to diffusion of energy saving technologies is not considered in this simulation model, but if such an effect is taken into account, much earlier mitigation action is chosen and it will further reduce the economic loss. On the other hand, as for investment amount, incremental costs are caused by introducing energy saving investments. Considering an efficient use of existing capital invested, it is vital to promote energy saving investments without missing an opportunity of new investment, because recruitment and replacement of existing technologies by new technologies take time.

With regard to full-scale action aiming at LCS, there is an argument that it is better to delay current mitigation action at a high cost and wait for development of cheaper measures in the future because mitigation costs are expected to become cheaper in the future as a result of technical innovation. However, judging from this analysis, such an argument would be unsound.

6. Feasibility from the viewpoint of rate of change of technology and society:

Further acceleration from the past improvement rate is necessary.

The improvement rates of Energy intensity (Energy consumption/GDP) and Carbon intensity (Carbon emission/Energy consumption) achieved by the technology innovations and social structure changes that were adopted by this analysis for 70% reduction are faster than that of the historical improvement rate (Fig. 7). Especially, as for Energy intensity, the improvement rate is necessary to be accelerated up to about 2%/year. In the past this has been less than 1.5%/year. With regard to Carbon intensity, if CCS is not introduced the required improvement rate exceeds the historical improvement rate. In scenarios of European countries aiming at reductions of 60-80% in 2050, technology improvement rates need to be at the same level as that estimated for Japan. It cannot be overlooked that the decoupling of GDP growth and the amount of the energy service demand is essential due to the requirement of dematerialization under resource constraints; in scenario B, energy service demand does not increase whereas GDP increases by about 1.5 times, as shown in Fig. 5. As a result, 0.5-1% of energy intensity improvement rate can be achieved. A drastic social innovation and an exceptional technological competition will start in the future (Fig. 7 and Table 5).

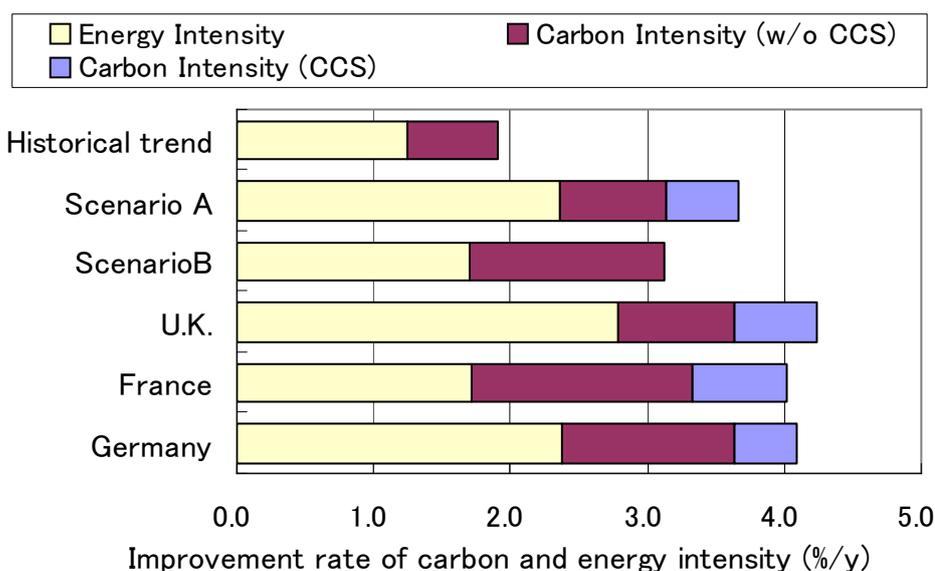


Fig. 7 Required improvement rate of carbon intensity and energy intensity

To realize a Low-Carbon Society which reduces CO₂ by 60-80% toward 2050, it is necessary to keep up the improvement rate of Energy intensity (earn GDP with a less energy) and Carbon intensity (fuel switch into low-carbon energy) which have been achieved before and even more.

Table 5 Speed of Improvement for Low-Carbon Society from 2000 to 2050

		Improvement rate of energy intensity (%/year)	Improvement rate of carbon intensity [rate of CCS] (%/year)	Assumed GDP growth rate [Per capita GDP growth rate] (%/year)	Reduction target in 2050 [Reduction rate from 2000] (%)
Range of historical change rate	World	1.0~1.5	0.3~0.4		
2050 Japan's LCS scenario (this study) (base year: 1990)	Scenario A	2.4	1.3 [0.5]	1.4 [2.0]	70 [73]
	Scenario B	1.7	1.4 [0]	0.5 [1.0]	70 [73]
European Countries	United Kingdom	2.6~2.9	1.2~1.8 [0.3~0.9]	2.2~3.0 [2.1~2.8]	60 [60]
	Germany	1.8~2.8	1.3~2.3 [0~1.4]	1.4 [1.7]	80 [75]
	France	1.3~2.3	1.7~2.6 [0~2.0]	1.7 [1.7]	75 [70]

Base year of reduction target in United Kingdom is current state (1997), those in Germany and France are 2000.

Reference:

(Historical change) Third Assessment Report of the IPCC

(United Kingdom) Dept. of Trade and Industry (DTI) in UK, 2003; Future Energy Solutions: Options for a low-carbon future, DTI. Economic Paper No. 4., DTI, London.

(Germany) Deutscher Bundestag in Germany, 2002; Enquete Commission on Sustainable Energy Supply Against the Background of Globalisation and Liberalisation: Summary of the Final Report.

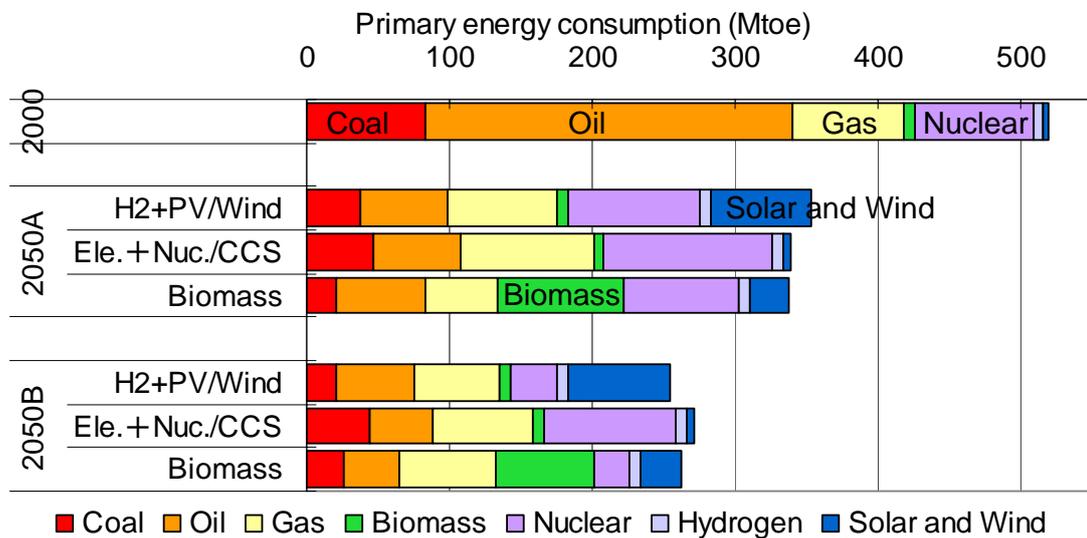
(France) Interministerial Task Force on Climate Change (MIES) in France, 2004; Reducing CO₂ emissions fourfold in France by 2050 -Introduction to the debate-.

7. Feasibility of energy supply:

Assessing energy supply constraints and early determination of future directions of energy system

There are many possible combinations of primary energy sources. Those considered in scenarios A and B, as shown in Fig. 8, achieve 70% CO₂ emission reductions of as shown in Fig. 4. Each primary energy source has two types of constraints: supply constraints and demand-side constraints. Supply constraints are limitations of available quantity of energy sources, and demand-side constraints include preference of energy sources by customers. For example, nuclear power would be restricted by locational conditions, level of public acceptance, lead time for newly constructed plant, and load factor at demand-side. Biomass energy has limitations of both domestic production and import volume due to competition for land-use. Renewables, such as wind and solar, have physical limits of supply potentials and instability of output in essence. Hydrogen-based energy system requires building entire systems from scratch including low-carbon energy resources to produce hydrogen.

In order to consolidate future energy systems for the LCS, it is important to determine as soon as possible the future directions of the energy system in consideration both of keeping energy security and of achieving the LCS, on the grounds of perspectives for primary energy supply, energy types at demand-side, and diversifications both of energy supply and of applications.



H2+PV/Wind: Hydrogen by renewables (Photovoltaics+Wind), Ele.+Nuc./CCS: Electricity by Nuclear and CCS

Fig. 8 Examples of energy compositions for achieving 70% of CO₂ reductions in 2050

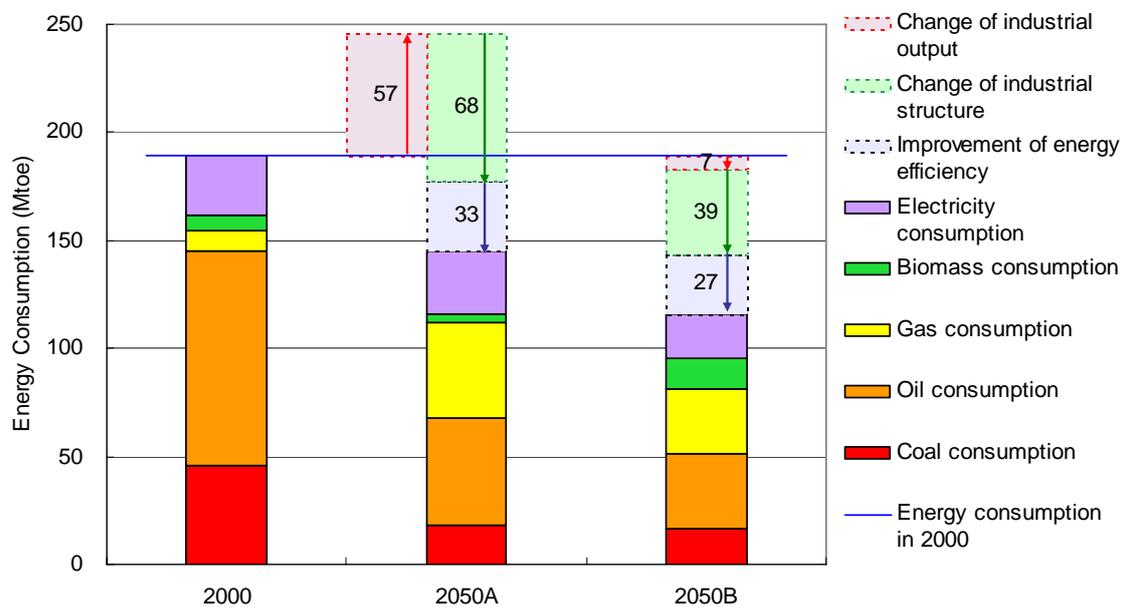
Above figure shows three extreme conditions of energy supply. H2+PV/Wind case represents installation of solar, wind, hydrogen system and fuel cell at a maximum with the assistance of micro-grid system. Electricity+Nuclear/CCS case accelerates electrification of demand-side, and expands the utilization both of nuclear power and of fossil-fueled plants with CCS. Biomass case boosts the use of biomass energy at demand-side as well as in the electricity sector. Energy compositions at scenario A and B lie between these three cases.

8. Feasibility for reducing energy demand

Huge potential for energy demand reduction in various sectors

Energy demands in industry, transportation, household, and commercial sector in 2050 can be reduced by approximately 40-45% below the 2000 level by accelerating social technological innovations and energy technology development, as well as by developing appropriate infrastructure and by transforming the industrial structure.

Industrial sector: 20%-40% reduction in energy demand through structural transformation and energy efficient technologies



Change of industrial output: changes in total production of primary and secondary industry
 Change of industrial structure: structural changes in primary and secondary sectors
 Improvement of energy efficiency: efficient energy devices such as furnaces and motors

Fig. 9 Energy demand reduction in industry sector

The industrial structure would shift towards service economy (see Figure 3). Productions of electric/transport machinery industries would also increase enhancing industrial competitiveness of manufacturing sectors. Social infrastructures would be further developed and the volumes of steel or cement stocked in such infrastructures would increase considerably. An innovative recycling technology would be developed and the stocked materials within the society could be re-used for high-quality purposes. Applications of such technologies would lead to improvements in resource usage rates of raw materials.

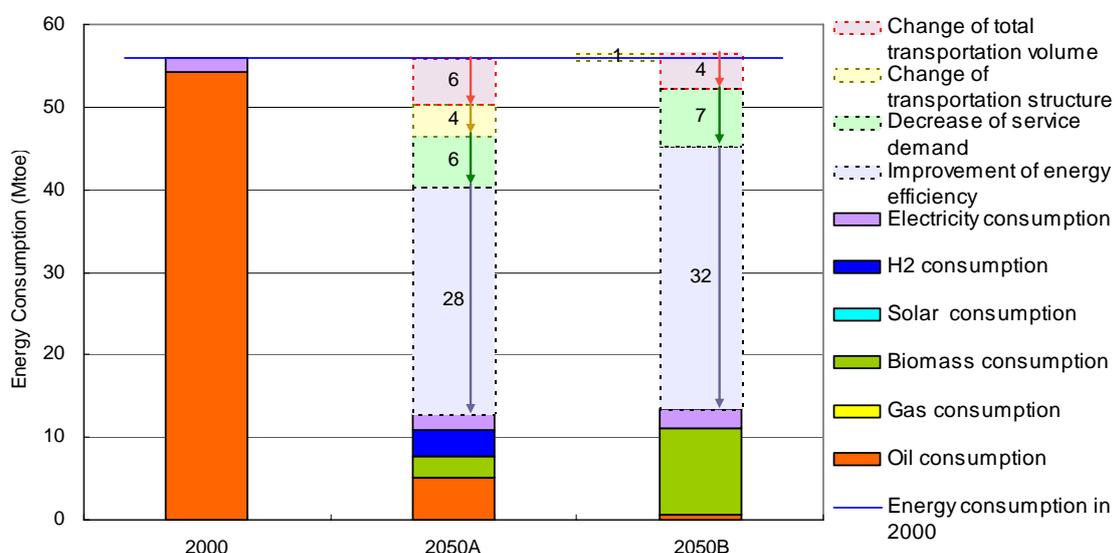
Energy demand in manufacturing processes can be classified as direct heating, steam, mechanical power, chemical reduction, refining, and others. Energy efficiencies of the technologies to fulfill those energy demands such as furnaces, boilers, and motors have great potential in terms of energy

efficiency improvements.

In scenario A, in which 2% of annual GDP per capita growth rate is assumed, the production of primary industries and secondary industries will increase. Nevertheless, it is estimated that 20% of energy savings can be achieved through reduced output of energy-intensive raw materials and energy efficiency improvements (the energy saving effects are 68 Mtoe and 33 Mtoe respectively).

In scenario B, it is estimated that further 40% of energy reduction is possible by industrial transformations and energy efficiency improvements (see Fig. 9).

Passenger transportation sector: 80% reduction in energy demand through appropriate land use and energy efficient technologies



Change of total transportation volume: decrease in total transportation demand associated with population decrease
 Change of transportation structure: modal shift towards public transportation due to change of population allocation (LRT, public buses, etc.)
 Decrease of service demand: shortened average trip distances associated with changes in urban structure such as compact city
 Improvement of energy efficiency: Improvement of energy efficiency of vehicles (hybrid vehicle, lightening of car body, etc)

Fig. 10 Energy demand reduction in passenger transportation sector

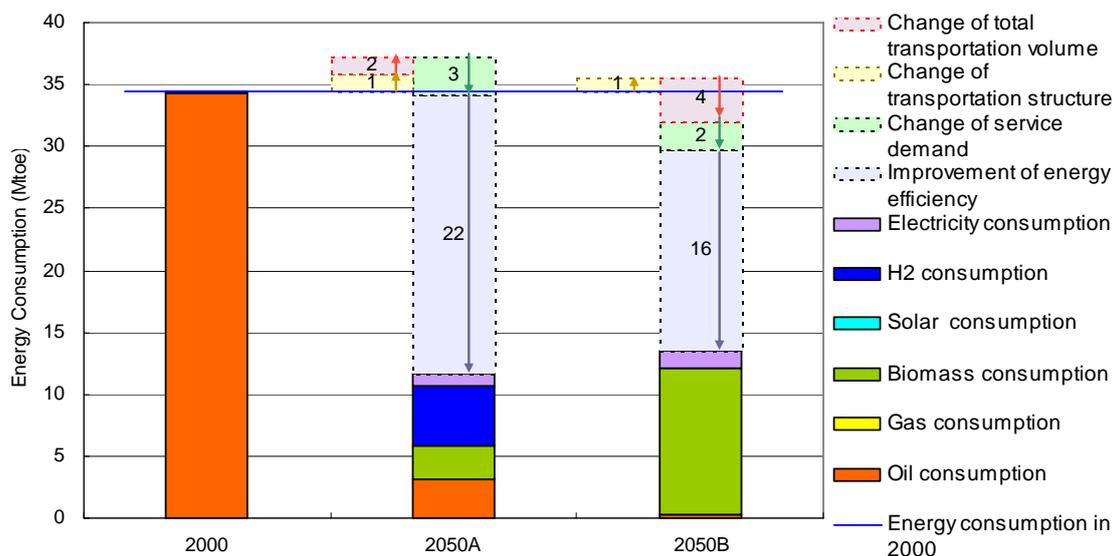
Passenger transportation demand reduces due to several factors which include decrease in population, reduction in average trip distance via development of “compact city” aimed at secure and safe society, promotion of public transformation in order to achieve urban development dedicated to vulnerable road users, and other measures.

Combining the demand reduction measures together with more efficient vehicles, such as hybrid vehicles or electric motor vehicles, and changes in fuel towards lower carbon intensity (electricity, hydrogen, and biomass) can lead to 80% reduction in energy demand from the passenger transportation sector.

In scenario A, households, offices, and shopping centers are located more intensively in the urban areas compared with scenario B. Therefore, the average trip distance is shorter and modal share of public transportation is higher. The energy saving effects of intensive land use and modal shift are 6 Mtoe and 4 Mtoe respectively. In addition, promotion of increasing density of urban structures could additionally reduce 6-7 Mtoe of energy consumption for both scenarios.

Note, however, that car transportation would still have the highest share in passenger transportation sector in 2050. Technology innovations of the vehicle including penetration of electric or hydrogen vehicle, lightness of car body, improvement of air resistance, installation of hybrid engine, and other similar measures can save 28 Mtoe of energy demand for scenario A and 32 Mtoe for scenario B.

Freight transportation sector: 60-70% reduction in energy demand through efficient transportation management system and energy efficient technologies



Change of total transportation volume: changes in freight transportation demand associated with industrial production
 Change of transportation structure: changes in mode of transportation through modal-shift
 Change of service demand: changes associated with application of rational logistic systems such as SCM (supply chain management)
 Improvement of energy efficiency: improvement of energy efficiency of vehicles

Fig. 11 Energy demand reduction in freight transportation sector

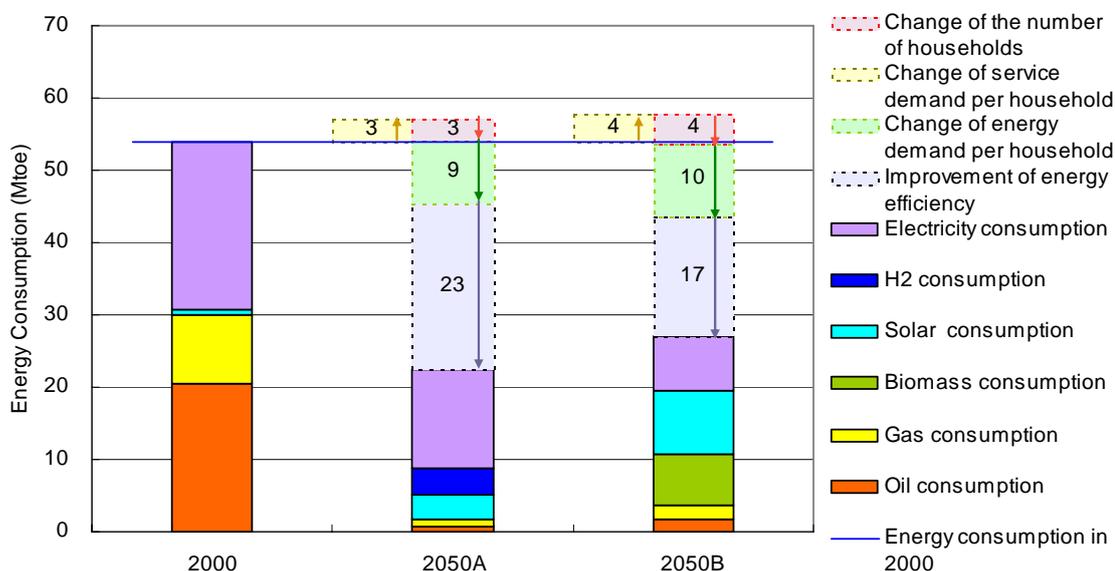
It is possible to save approximately 70% and 60% of energy demand in scenario A and B respectively by developing rational logistics systems with Information and Communications Technologies (ICT) and by promoting more efficient transportation vehicles (see Fig. 11).

SCM (Supply Chain Management), which includes appropriate management of product flows and efficient route search through ICT, would be expected to enhance the load efficiency and lessen the volumes of returned or disposed products. In addition, advanced management of logistics networks

would make connections between small lot cargoes by truck and large lot cargoes by ship/train smoother, thus facilitating modal-shift. Those effects are estimated to be 3 Mtoe for scenario A and 2 Mtoe for scenario B respectively.

Through drastic improvement of energy efficiency vehicles in the freight transportation sector, for scenario A, 22 Mtoe of energy would be saved with penetration of electric or hydrogen fueled vehicles. In scenario B, on the other hand, it is assumed that 50% more efficient vehicles fueled with biomass would reduce the energy demand by 16 Mtoe in this sector.

Residential sector: Leading future replacement building to high insulated dwellings, which strike a balance between comfortable living space and energy saving, reduces 50% of energy demand



Change of the number of households: the number of households decrease both in scenario A and B from present to 2050
 Change of service demand per household: convenient lifestyle increases service demand per household
 Change of energy demand per household: high insulated dwellings, thermo bathtub and Home Energy Management System (HEMS) decrease service demand per household
 Improvement of energy efficiency: energy efficiency improvement of air conditioner, water heater, cooking stove, lighting and standby power

Fig. 12 Energy demand reduction in residential sector

The average lifetime of dwellings in Japan is around 35 years and a lot of existing dwellings will be rebuilt by 2050. Therefore it is possible to create a dwelling stock that can strike a balance between comfortable living space and energy saving by leading future replacement buildings to energy-saving highly-insulated dwellings (Fig. 12).

The decrease in the number of households compensates for the increase of energy demand with the rise of service demand. The reason why the service demand of scenario A, in which people seek convenience, almost equals that of scenario B in which people prefer more sustainable ways of

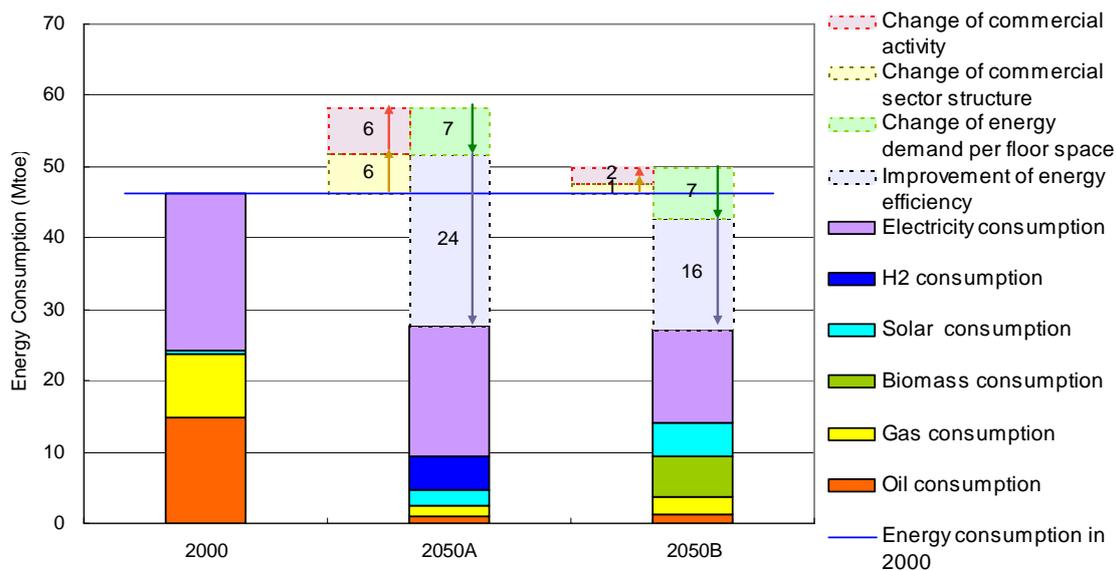
living, is that energy service demand of scenario A will decrease due to eating out, increase of collective houses, and other new practices.

Rebuilding into highly insulated dwellings could reduce about 10 Mtoe. In addition to this, technological innovations such as efficiency improvement of heat pumps (for air conditioners and electric water heaters), cooking stoves, lightings, and standby power could reduce 50% of total energy demand below the 2000 level.

Similar results are shown in The UK “40% House (2005, Boardman)” and Japan “Guideline for self-sustainable recycling-oriented dwellings (2005, Ministry of Land, Infrastructure and Transport Japan Project for technological improvement)”.

CO₂ emissions from the residential sector could be almost reduced to zero by increasing the use of hydrogen and electricity which does not emit CO₂ in scenario A, and increasing the use of distributed renewable energy such as solar heat, solar power and biomass in scenario B.

Service sector: Combination of comfortable servicing space/working environment and energy efficiency improvement reduces 40% of energy demand



Change of commercial activity: floor space increases with the rise of activity
 Change of commercial sector structure: share of energy intensive business fields such as hotels and restaurant increases
 Change of energy demand per floor space: high insulated buildings and Building Energy Management System (BEMS) reduce energy demand
 Improvement of energy efficiency: efficient air conditioner, water heater, lightings fulfills service demand with less energy

Fig. 13 Energy demand reduction in commercial sector

The demand for floor space in service industries would rise due to increase of their outputs as the economy becomes more service-oriented in both scenarios, A and B (Fig. 3). However, the labor population of service industry would not increase much because of population decrease. The

number of electric appliances in the offices would increase in order to improve the working environment, but insulation, BEMS and energy efficiency improvement of appliances could reduce 40% of energy demand in 2050 (Fig. 13).

The activity of hotels, restaurants and amusement places which consume a lot of energy would increase with the active consumption in scenario A. As a result, the energy consumption would increase by 12 Mtoe. However, rebuilding to high insulated buildings and distributing BEMS could reduce 7 Mtoe of energy demand. Besides, high efficient air conditioners, high efficient water heaters and high efficient lightings could reduce 24 Mtoe of energy demand.

9. Incentives for achieving LCS:

It is necessary to build a common vision towards LCS at an earlier stage, establish comprehensive measures, and implement actions in a long-term schedule.

This research shows that there are technological potentials to achieve LCS by implementing appropriate changes of industrial structure, maintaining land-use and infrastructure, and introducing innovative technologies while satisfying a certain level of social welfare. However, to realize LCS, the government should take a strong leadership in promoting a common awareness about risks of climate change, coordinating a national agreement on aiming at LCS, and implementing policy measures which internalizes the negative externalities of carbon dioxide emissions.

Especially, it is important to note that early actions are cost-effective. Adoption of industrial transformation and technological development and its use depends on each decision maker (i.e. each private sector, thus the government needs to clearly show a vision for LCS at an earlier stage, and provide a social system where there are incentives for private sectors to reduce carbon emissions. Moreover, the government should immediately determine a consistent policy to promote investment on transportation and urban infrastructure towards LCS so as to avoid a social structure of high carbon society in the future.

The challenge for achieving LCS is now in a global main stream and there is no turning back in this trend. It is necessary to face this problem sincerely and the Japanese government must take steps to enhance international competitiveness by promoting innovative technologies envisioned for achieving LCS

In order to achieve LCS by 2050 without missing opportunities for various investments on capital formation and technology development, it is necessary to set up the national goals (i.e., the vision of LCS, rather than target rates of reduction) at an early stage, establish the abatement schemes, and realize a society that internalizes the negative externalities of carbon dioxide emissions. In this process, it stimulates and accelerates social and technological innovations that help in getting an advantage in international competition in the future low-carbon world.

10. Step towards global participation on climate change mitigation strategies:

Japan would set an attractive example of a LCS to Asian countries as well as to the rest of the world.

This research focuses not only on domestic actions, but also on international collective actions for achieving the global LCSs under the UNFCCC, and on grass-roots activities. Our team has made collaborative researches with some Asian countries, namely, China, India and Thailand, through the development and application of integrated assessment models. Such joint research projects attempt to depict feasible LCS visions in developing Asian countries, and to explore ways for building frameworks of international cooperation for the realization of the LCSs. Such activities begin to affect national energy policies. Also, recent tight conditions of energy supply accelerate these trends.

The Ministry of the Environment of Japan and the Department for Environment, Food and Rural Affairs in the UK has been jointly promoting a scientific research project, “Developing visions for a LCS through sustainable development”, since February 16, 2006. Our team plays a central role in the project. The first workshop was held in June, 2006 in Tokyo, and had 54 experts from 19 countries including developing countries, such as China and India, and 6 international organizations. The second workshop will be held in June, 2007 in London, UK.

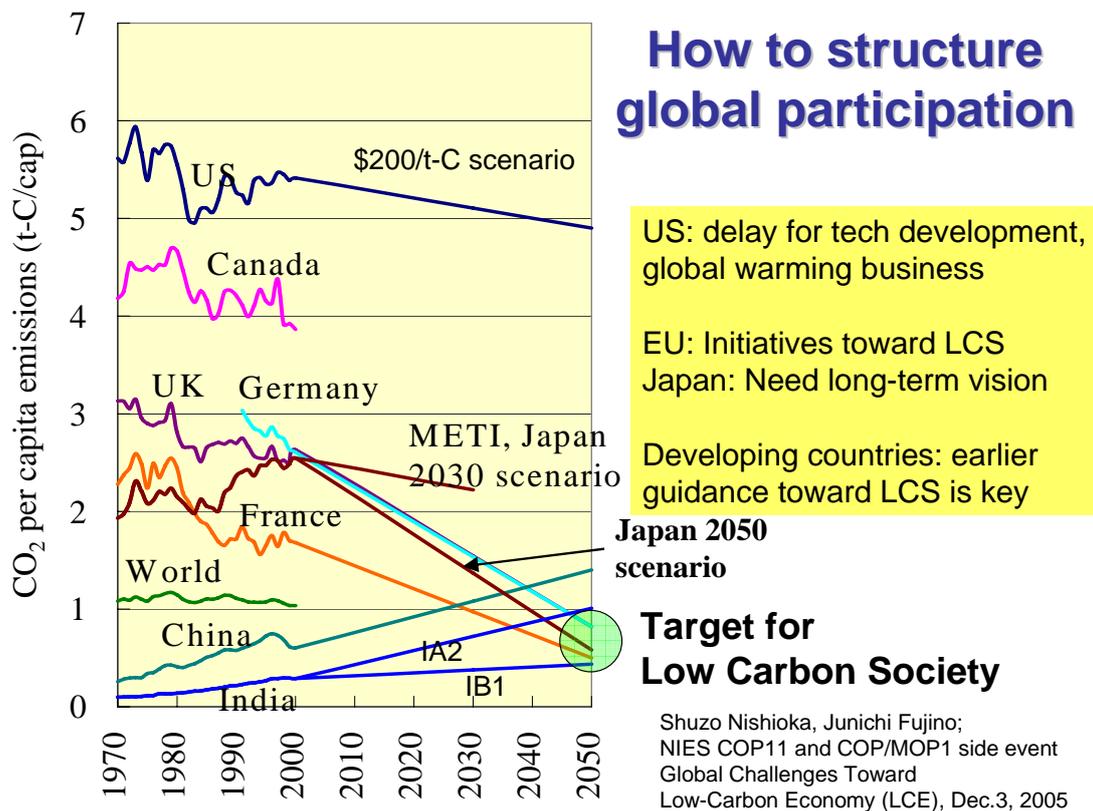


Fig. 14 Current per capita CO₂ emissions and international targets for LCS

European countries and Japan have gone into action for the LCS. U.S.A and Canada have CO₂ reduction plans, such as emission trading schemes. On the other hand, although CO₂ emissions per capita in developing countries, such as China and India, is below compared to developed countries at the present time, these countries have large potentials to drastic increases in CO₂ emissions. How LCS is attained in developing countries? How do they get freedom from lock-in on their energy system to high carbon infrastructures, such as private-vehicle dependent transportation systems? How can they enjoy high quality of life under the LCS by leap-frogging into developed countries through both technological and social innovations?

“Japan-UK Joint Research Project Developing Visions for a Low-Carbon Society (LCS) through Sustainable Development”

The Ministry of the Environment of Japan (MoEJ) and the Department for Environment, Food and Rural Affairs in the UK (Defra) are jointly promoting a scientific research project toward achieving a Low-Carbon Society by 2050.

The objectives of the joint research project are:

- Identifying and understanding the necessity for deep cuts in greenhouse gas (GHG) emissions toward 2050 based on scientific findings (e.g. 50% global GHG emissions reductions in 2050 to 2100 compared to 1990 levels).
- Reviewing country-level GHG emissions scenario studies in some developed and developing countries such as Japan, UK, Australia, Brazil, Canada, China, France, Germany, India, Mexico, Russia, South Africa, Thailand, and USA. Looking at possible options such as for supply-side, demand-side, policy, institution, financial, lifestyle based on national circumstance.
- Aligning sustainable development and climate objectives: win-win strategies. Investigating possible co-benefits of LCS such as tackling poverty; other environmental concerns (air pollution, water, land use, etc); and energy security.
- Studying methodologies to achieve LCS, such as depicting visions and pathways (i.e. back-casting); qualitative modeling of the future society; possible combination of options (technological, institutional, behavioral); financial mechanisms; LCS scenarios harmonization at national, regional and global levels.
- Identifying gaps between our goals to develop country-level LCS scenarios and the current reality.
- Sharing best practice and information; identifying opportunities for cooperation and how best to cooperate in estimating country, regional and global-level LCS scenarios.



“Japan Low-Carbon Society Scenarios toward 2050”

This research project, initiated in 2004, is sponsored by Global Environment Research Fund of MoEJ. The objective of the project is to propose concrete countermeasures to achieve LCSs in Japan by 2050, including institutional change, technology development and lifestyle change. More than 50 research experts have studied together to develop visions and roadmaps. This project supports the “Japan-UK Joint Research Project.”

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