S-3 Low-Carbon Society Scenario toward 2050: Scenario Development and its Implication for Policy Measures

3. Effects of introducing countermeasures for carbon dioxide emission reduction in urban area（Abstract of the Interim Report）

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1. Introduction

Carbon dioxide emissions in transportation, office and commercial and household sector have been increased significantly. Evaluation of potential reduction of carbon dioxide should be done with taking into consideration of urban activity and structure. Simple summation of reduction potential of each technology will overestimate the actual reduction in urban area, because its implementation is limited and there are interactive effects among technologies.

2. Research Objective

The research objectives are to develop the method of evaluation of potential carbon dioxide emission reduction in urban area, and to apply the developed method to cities with various sizes and in various climate conditions in Japan in 2020 and 2050. The unique method of this research is to evaluate the effect of implementing integrated technological options into actual cities for carbon dioxide emission reduction. Prediction of cities in the future target years is also included.

3. Research results

1) Urban scenario and integrated evaluation

An influence of 'urban form' to an installation of climate change mitigation technologies and their impacts were analyzed. Three urban forms were considered, namely 'centralized and concentrated distribution form', 'de-centralized and scattered distribution form' and 'mixed centralized and de-centralized form'. Considering the given social scenario in 2050 and those suggested urban forms, a photovoltaic cell technology and a local heat distribution technology, e.g. a district heating system, were analyzed, and their installation rate and CO_2 reduction potential were calculated in each case. The results showed that the centralized and concentrated distribution scenario enjoyed the benefit of both technologies, and in total of 24% of CO_2 emission from buildings' energy demand could be avoided. Whereas in the de-centralized and scattered distribution scenario, no area was found to be suitable for an installation of the local heat distribution technology and the total CO_2 reduction potential remained about 20%. The reduction potential of mixed centralized and de-centralized scenario was the lowest. This indicated clearly that a strategic urban planning for the future would be necessary to maximize the climate change mitigation impact for cities. Further study should improve the following two points, namely the analysis in terms of a threshold of installation for those technologies and other technologies largely depending on the urban form, e.g. waste collection & incineration, drinking and wastewater treatment & distribution, local public transportation etc.

2) Innovation in energy supply to urban area

The following two research topics which have a strong connection to an electric power generation sector were investigated.

(1) The Influence of the Electric Vehicles on the Power Generation Mixes and CO_2 Reductions

In the transportation sector, fuel-cell vehicles, hybrid vehicles, electric vehicles and other low-emission vehicles have been investigated and developed. In this study, we focused our attention on the electric vehicle, and studied the influence of the electric vehicles on the Japan's power generation mixes by using linear programming model that minimizes the total costs of the electric power sector. First, considering the automobile usage and use time, we made running time profiles of automobiles as a whole in Japan. From these running profiles, we made a few patterns of battery charging operation. We added this pattern to the daily electric load curves and made this additional power demand estimate built into the optimum power generation mix model. The result of our model analysis indicates that when the electric vehicles installing a battery of 6kWh are introduced extensively, we can expect 60% emissions reduction of CO_2 in both transportation sector and electric power sector, if CO_2 capture and storage is deployed in thermal power plants.

(2) Potential Evaluation of Rooftop Photovoltaic Systems on the Basis of Nationwide Meteorological Data

This study estimated the potential power output of photovoltaic systems installed on the rooftops of the whole residences in Japan. The estimation was made on the basis of the acquired time series data of AMeDAS (Automated Meteorological Data Acquisition System) such as daylight hours and precipitation at 686 observation points in the year 2000. The contribution of the photovoltaic systems as a home electric power supply source was evaluated. The estimation results indicate that even if the photovoltaic systems are located in many diverse areas all over the country, a daily variation of their total power generation output may range between 20% and 80% of the generation capacity. This indicates the necessity to build additional back-up generation facilities to compensate the unstable output of photovoltaic systems. The results also indicate that at many households which introduced the photovoltaic systems on their rooftops, excess amounts of electric power generated by photovoltaic systems are expected. Therefore, along with the introduction of electric power storage equipment, the reverse power flow from houses to power grids must play a very important role.

3) Energy saving in building sector

CO_2 emission associated with operation, construction and renovation of commercial buildings in Japan was predicted by administrative divisions until 2050. Scenario A (urban concentration type society: an active, quick-changing, and technology oriented society), scenario B (local decentralized society: a calmer, slower, and nature oriented society), and scenario M (average of scenario A and B) would be assumed as a society as shown in Table 1 and Future 1. Scenario 1 into which the CO_2 intensity of electric power supply does not change after 2005 and scenario 2 based on the “Energy technology vision 2100” of Economy, Trade and Industry was assumed. The forecast result of the M1 scenario (Figure 1 and Table 1) show that CO_2 emission in 2050 will be increased by 9% in the BAU case and reduced by 36% in the energy saving case. Moreover, the M2 scenario will be reduced by 47% in the BAU case and reduced by 71% in the energy saving case.

Table 1. Scenarios of case studies and reduction rate of CO_2 emission associated with operation, construction and renovation of commercial buildings in Japan.

Scenarios of case studies							Reduction rate of CO_2 emission (1990=100％)			
No.	Future society	Scenarios of power supply sector and CO_2 intensity of electricity (kg-CO_2/kWh)					Business as usual case in building sector		Energy saving case in building sector	
				1990	2020	2050	2020	2050	2020	2050
A1	A scenario	1	No change after 2005	0.421	0.390	0.390	+18%	+11%	-7%	-33%
A2		2	Energy Technology Vision 2100 by METI	0.421	0.315	0.120	-7%	-45%	-21%	-70%
B1	B scenario	1	No change after 2005	0.421	0.390	0.390	+13%	+7%	-3%	-40%
B2		2	Energy Technology Vision 2100 by METI	0.421	0.315	0.120	-8%	-49%	-22%	-73%
M1	M scenario	1	No change after 2005	0.421	0.390	0.390	+15%	+9%	-5%	-36%
M2		2	Energy Technology Vision 2100 by METI	0.421	0.315	0.120	-7%	-47%	-21%	-71%

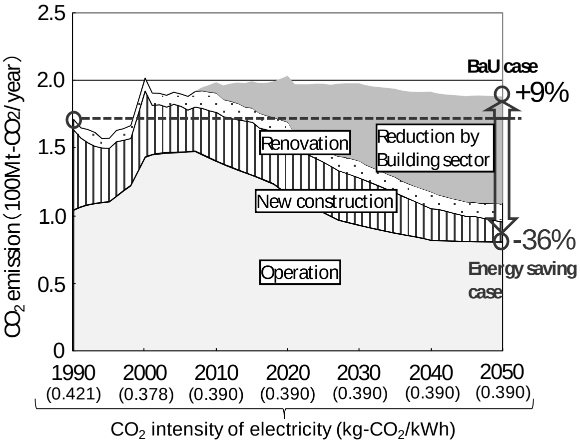

Fig.1 Estimation of CO_2 emission from commercial buildings in Japan up to 2050 (Scenario M1)

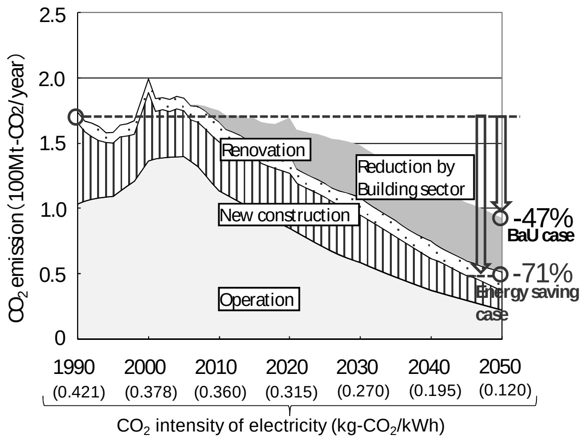

Fig.2 Estimation of CO_2 emission from commercial buildings in Japan up to 2050 (Scenario M2)

4) Introduction of photovoltaic systems into cities

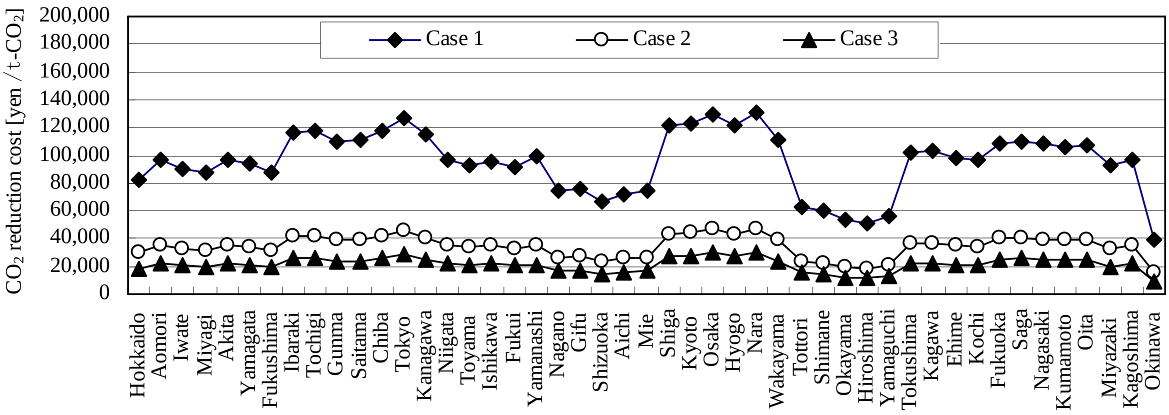

Fig. 3 CO_2 reduction cost of a 3.5 kW roof-top photovoltaic system estimated by considering generation cost and CO_2 emission per unit of electricity by electric companies (Case 1-present status, Case 2 and Case 3-future status of technological level and production scale)

CO_2 reduction cost is an important index for evaluation of economical feasibility and priority as a countermeasure against global warming. In this study, CO_2 reduction cost of a 3.5 kW roof-top grid-connected photovoltaic (PV) system was estimated for different prefectures in Japan by taking into consideration meteorological conditions of prefectures and generation cost and CO_2 emission per unit of electricity by electric companies.

The CO_2 reduction cost at the present status of technological level and production scale (Case 1) considerably varied with prefectures ranging from 40,000 yen/t-CO_2 at Okinawa to 130,000 yen/t-CO_2 at Nara, while an average CO_2 reduction cost was estimated at 95,000 yen/t-CO_2. When it was assumed that the PV system was substituted for an oil-fired plant and a coal-fired plant, the average CO_2 reduction cost in Case 1 was estimated at 43,000 yen/t-CO_2 and 37,000 yen/t-CO_2, respectively. Under these assumptions, a difference in the CO_2 reduction cost among prefectures became more significant as the status of the technology and production scale changed into the future ones (Case 2 and Case 3) and the cost of the PV system was reduced. In order to enhance introduction of PV systems in an more economical way, it would be better that the introduction of the PV systems is started from regions where the CO_2 reduction cost is lower and is extended to other regions where the CO_2 reduction cost is relatively higher after the cost of a PV system is reduced due to development of technology and growth of the production scale.

5) Utilization of biomass resource and unused energy in urban areas for energy saving in cities
CO2 reduction potential was estimated when household, commercial, office, and other users around incineration plant would use waste heat from the plant for cooling, heating, and hot water supply through district heating and cooling systems (DHC). The amount of available heat from plants and surrounding heat demand were estimated from GIS information. Then, CO2 reduction potential was calculated by monthly heat supply and demand with considering the induced CO2 emission from construction of pipe network for district heating and cooling system. In the analysis for 5 plants in Yokohama City, the estimated CO2 reduction potential was 64-150 thousand tons per year. In the analysis for 500 continuously operated plants in Japan, the estimated CO2 reduction potential was 0.5-2.8 million tons per year, which corresponds to 0.04-0.22% of all CO2 emissions in Japan.
Using the results on the analysis of bio-ethanol production potential from construction wooden waste and cultivated biomass last year, an evaluation framework for policy scenarios related to wood resource flow under long-term social change in Japan was also developed.

6) CO_2 emission change in interregional physical distribution
We utilized the database of “Physical Distribution Census” published by National Land and Transportation Ministry and developed the method to calculate the physical distribution induced by a unit of final demand and the physical distribution derived by a unit of production. We proposed induced and derived physical distribution. Induced and/or derived CO_2 emissions are directly calculated from induced and/or derived physical distribution. The consistency between the estimated and actual physical distributions is verified for the method of the input-output analysis for physical distribution proposed in FY2006. It is very significant to verify the consistency between the actual data and the estimation so that we can maintain the reliability of this study. The model was revised in detail for the purpose.

After verifying the model, we calculated the derived physical distribution by a unit of final distribution in each region. Larger CO_2 emissions are derived from the regions whose consumption structure induces the transport from the other regions than the regions of local production and local consumption. Okinawa, for example, has large CO_2 emissions due to its location and Tokyo also emits large CO_2 due to its dependence to the other regions for the production of agricultural products consumed in the region.

Using the population scenario in 2050, we then calculated the CO_2 emission change from the physical distribution in 2000. Then, we evaluated CO_2 reduction potential of modal shift to ship or train from automobile. If the rate of modal shift is assumed as 40%, CO_2 emission reduction from 2000 reaches approximately 30% and 26% in the population scenario A and B, respectively.

This result is promising for the contribution of the environment policy making because the CO_2 reduction potential in the automobile sector is explicitly evaluated.

7) Contribution of CGS, DHC and HP to the potential CO_2 emission reduction in the urban area

This study aims at the estimation of the contributions of distributed power systems to CO_2 emission reduction and cost saving. In 2006 we evaluated the potential CO_2 reduction by applying the method developed in 2005 to Sapporo and Okinawa which locate north and south part of Japan. The results showed us that a linear relationship between the ratios of commercial building floor area to total building floor area holds across the sub regions of Sapporo, Okinawa and Utsunomiya in spite of the difference of climate conditions. Extrapolating the relationship on the geographical distribution of residential building area of Utsunomiya, we evaluated the potential CO_2 reduction of the new energy equipments for 950 Japan cities where 18.6% CO_2 emission reduction potential in total is indicated. In 2007 we applied the above method to the two future population projection cases, i.e. scenario A and B. The results suggest that the potential CO_2 reduction rate in 2050 comes to 42% and 38.6% in scenario A and B respectively according to the population decline in Japan. We also evaluate the new solar heat utilization technologies focusing on the efficient air-conditioning. Expanding our model to include the desiccant systems, we evaluate the potential contribution of the solar heat system in house and commercial building. The results show the optimum allocation of PV and desiccant system can improve the energy efficiency and CO_2 reduction than the case of PV only.

We next construct a model to evaluate the distributed energy supply network system of urban district and assess a practical urban district of Japan middle city, Utsunomiya. Using this model, it is possible to deduce the energy saving plans under the conditions of energy transportation among buildings and houses within the district. We carry out case studies based on the actual urban district values and examine the possibility of energy saving and CO_2 reduction. Based on the GIS data, we can calculate the floor space and building space. Using the model to estimate the energy load of building, we calculate the whole energy load of the urban district under three cases, case 1; installing cogeneration system in each building, case 2; installing cogeneration system in each building and energy exchanges with houses, case3; installation of CGS and energy transportation network under the minimization of electricity import from the district. The results show that the case of energy exchange with houses demonstrates the minimized energy consumption which is around 2% lower than that of case 1.

8) Development of integration tools for sharing knowledge between various actors

We have been designing and constructing a Web-based collaboration and knowledge-sharing platform to support the achievement of the project goals. In 2004 we constructed a basic web portal with an innovative "CO_2 technology table" for knowledge sharing between researchers. In 2005, we implemented interfaces for manipulating the computational models constructed by researchers both inside and outside the group through the Web-based platform. In 2006, we constructed an environment enabling access of computational models through the Web-based platform using DOME (the Distributed Object-based Modeling Environment) that integrated models for evaluating energy saving countermeasures in residential and commercial buildings and the effect on reducing electric power demand. We then used the integrated system model to calculate the CO_2 emissions for each of the nine major power companies in Japan. In 2007 we adapted the EKOSS (Expert Knowledge Ontology-based Semantic Search) system developed in other research for application to the Web-based platform in order to realize more effective sharing of models and expert knowledge over the Internet. The main results from 2007 are as follows:

1. Selection of researchers at the University of Tokyo studying issues related to energy and sustainability technologies (technologies for climate change mitigation, etc.)
2. Construction of "Semantic Statements" describing the research topics of the researchers chosen in 1. using the existing SCINTENG ontology grounded in a description logic and the EKOSS system
3. Creation of an ontology as a knowledge representation language capable of expressing the multifaceted nature of mid-term policy options for realizing a Low-Carbon Society, with reference to the "semantic statements" created in 2

Major Publications

1) T. Aramaki, S. Ishii, T. Sonoda, C. Kayo and K. Hanaki, "Projection of utilization potential of urban wet biowastes and construction wood waste for greenhouse gas mitigation in Japan" (in Japanese), Global Environmental Research, 12(2), 201-207, 2007
2) T. Ikaga, "Prediction of Global Warming Mitigation Measures in Residential and Office Buildings toward 205" (in Japanese), Global Environmental Research, 12(2), 191-199, 2007
3) Y. Yoshida, M Kanayama, R. Matsuhashi, "Preference Analysis on the dissemination of Residential Photovoltaic Power Generation" (in Japanese), Joural of Japan Solar Energy Society, 34(1), 47-54, 2008
4) Y. Yoshida and R. Matsuhashi, "Analyzing the Environmental Effect of Greening the Automobile Tax System in Consideration of Consumers' Preferences", Journal of Environmental Information Science, 36(5), 81-86, 2008
5) S. Mori, S. Koike, and T. Ishida, " An Analysis of Regional Energy Demand and an Assessment of Potential CO2 Emission Reduction in Japan using GIS", Environmental Informatics and Systems Research, Shaker Verlag, Aachen, 1, 459-463, 2007.
6) T. Ishida and S. Mori, "Development of Evaluate Model of the Distributed Energy Supply Network System of Urban District" (in Japanese), Energy and Resources, 29(1), 53, 2008
7) T. Ishida, "Evaluation Model to Calculate Duplicated Effect of CO2 Reduction Countermeasures

of Commercial Buildings Sector" (in Japanese), Papers on Environmental Information Science, 21, 625-630, 2007

8) T. Ishida, "Construction of the Environmental Load Evaluation Model Considering Life Cycle Activities of Commercial Building" (in Japanese), Civil Engineering, 63(4), 366-375, 2007