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 Final Report）

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1. Introduction

Carbon dioxide emissions in transportation, office and commercial and household sector have increased significantly. Evaluation of potential reduction of carbon dioxide should be done taking into consideration urban activity and structure. Simple summation of reduction potential of each technology would 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

The aim of the first analysis was to understand the spatial distribution of CO_2 emission from buildings and houses in 3 target cities, namely Sapporo, Utsunomiya and Naha. By using the best available database of urban building survey, telephone books and city maps, the analysis developed a methodological framework on how the spatial distribution of the energy use and accompanied CO_2 emission could be estimated. A mixed floor use of each building and demand of electricity and gas were estimated by the database. In addition, regional differences were taken into consideration by calculating an adoption ratio of installed air conditioning unit in buildings and the composition of technologies for power generation at each

locality (e.g. nuclear, hydro, coal, natural gas etc.). Approximately 8.57 Mt-CO_2/year, 1.43 Mt-CO2/year, 2.53 Mt-CO2/year were emitted from Sapporo, Utsunomiya and Naha City, respectively. The methodological framework developed could be a base for setting a future scenario of cities and thus important in terms of assessing various CO_2 reduction technology options in cities.

2) Innovation in energy supply to urban area

The influence of the extensive introduction of the residential co-generation systems (CGS) and heat pump (HP) for water heaters were evaluated through the use of 4,700 of household energy system models and an optimal national power generation model for Japan. The optimal operations of CGS and HP for each household, which has severely fluctuating power and heat load curves, are modeled through stochastic dynamic programming. Optimal power generation model involves CO_2 capture and storage technology as one of the abatement measures of CO_2 emissions. The results show that 80% reduction of CO_2 emissions from the power generation sector against 1990 level is possible with the significant utilization of CO_2 capture and storage, and that the average CO_2 emission per unit kWh over the time horizon due to the introduction of CGS and HP is estimated about 0.7 and 0.4 kg-C/kWh, respectively.

3) Energy saving in building sector.

The aim of this research is a future estimation on energy consumption and CO_2 emission associated with construction, operation and renovation of houses and buildings.
As the second year, the amount of household in four cities, such as Sapporo, Utsunomiya, Hiroshima and Naha were estimated up to 2050as shown in figure 3.1. And the possible

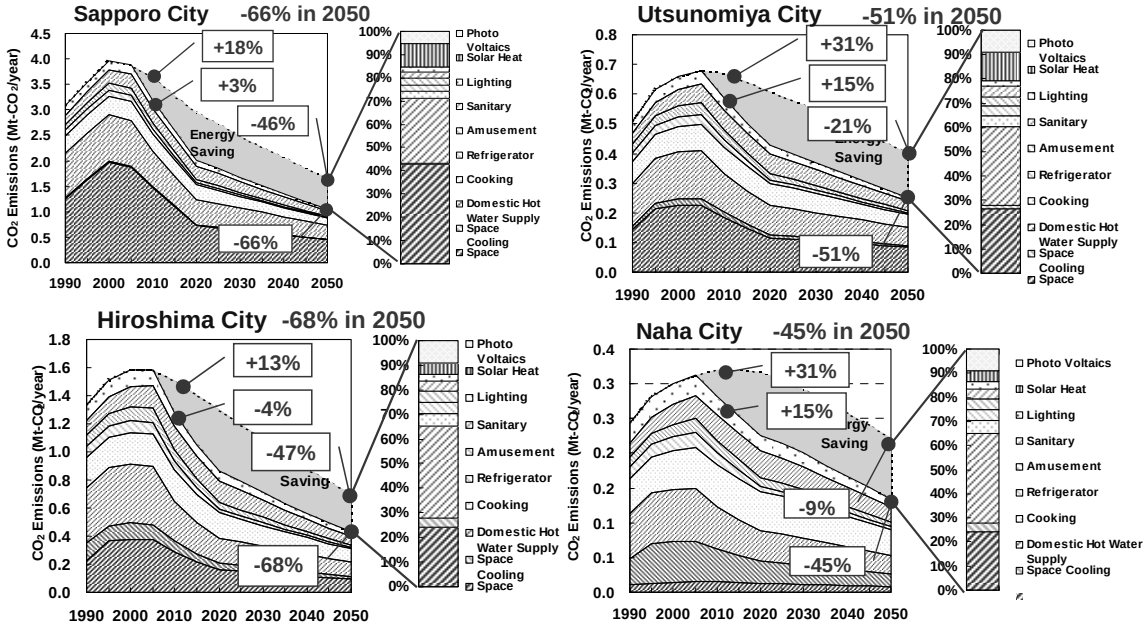

Fig.1. Estimation of CO_2 emission from houses in Sapporo, Utsunomiya, Hiroshima and Naha up to 2050

reduction of CO_2 emission from houses by increase in insulation performance, implementation of electric heating, cooling, and hot water supply system, innovative electric appliance, and life style change as shown in figure1.

4) Introduction of photovoltaic systems into cities

Electricity supply potentials by introducing grid-connected roof-top photovoltaic (PV) systems in cities were evaluated based on building areas of Utsunomiya City and Sapporo City. It was found that the PV systems could potentially supply about half of annual electricity consumption of Utsunomiya City and this potential supply by PV systems could reduce total annual CO2 emissions of the city by 17%. On the other hand, the potential supply by the PV systems in Sapporo City was estimated to be about quarter of annual electricity consumption and it could reduce total annual CO2 emissions of the city by 11%.

5) Urban mobility

Both passenger traffic and freight traffic were analyzed to see the potential reduction of carbon dioxide by decreasing the demand. Job-housing location model considering modal split and congestion in network was developed in last academic year. The model applied to three different regions and high potentials of carbon dioxide reduction were shown. A trip-chain-based network model was developed and applied to evaluate area-based congestion pricing. Also, a new estimation method of freight traffic OD was developed and applied to the evaluation of road pricing measures in the Tokyo region.

6) Utilization of biomass resource and its impacts on energy saving in cities

This analysis addressed the utilization of organic food waste as a potential biomass resource. By developing the analytical methodology to estimate the spatial distribution of resource and energy demand at an individual building level, a potential impact of installing a biogas plant in Sludge recycling center in Yokohama city was analyzed. The analysis on 8 collection scenarios and 7 different collection radius (i.e. 3km, 5km, 8km, 10km, 12km, 15km, 20km) yielded the maximum CO2 reduction by 5411.8 t-CO2/year in Scenario8 and 15km radius. The result indicated clearly that CO2 reduction is possible by utilizing the organic food waste in Yokohama but a caution was necessary in designing the collection boundaries. The current methodology with detailed spatial resolution also enabled a tailor-made discussion including, an energy demand-supply relationship, and an improvement of lower heating value in the incinerators, which were considered to be valuable inputs to the urban environmental management practice.

7) Induced carbon dioxide emission by urban activity

A method of the input-output analysis for physical distribution is proposed in this study. Using “Physical Distribution Census” published by National Land and Transportation Ministry, we 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. As an application of this method, we estimated CO2 emissions increase at 0.98 million ton by the physical distribution increase when Japan accomplishes the target of food self-sufficiency ratio. Also we evaluated CO2 reduction potential by the modal shift from automobile to railroad or ship. More than a million ton of CO2 are reduced by the modal shift in light industry product and metal-machine product.

8) Relationship among stakeholder for technology implementation

Cogeneration systems (CGS) and District Heating Systems (DHC) are often expected to contribute to the energy conservation and CO2 emission reduction in the commercial and residential buildings. However, since the contribution strongly depends on the regional conditions as well as the energy demand patterns, the existing assessments have mainly dealt with the certain building or a district. In this paper, to evaluate the potential reduction of CGS and DHC more generally, we develop a GIS based energy system assessment model. Our model generates optimal capacity of equipments and operation patterns reflecting partial operation properties of CGS and HP applying mixed-integer nonlinear optimization model.

We pick up seven regions of Utsunomiya-city which is located near Tokyo and has 450 thousand inhabitants, as a typical mid-size city of Japan. Applying GIS, we evaluate detailed energy demand statistics, which are then transferred to the energy flow model taking into account the properties of the energy equipments. The outputs of the model are then applied to estimate the potential contribution of the distributed energy systems to the whole Utsunomiya city. As results, Figure 1(a) shows the fraction of commercial building area of whole Utsunomiya city and Figure 1 (b) shows the roughly estimated CO2 emission reduction potential in case of CGS with surplus power under CO2 emission minimization case.

The results will be applied to assess the potential CO2 emission reduction contribution of CGS and other equipments in other regions based on GIS data.

9) Development of integrated tool for knowledge sharing

As a continuation of the work in 2004 on development of the “web-based collaboration platform” for supporting the achievement of the overall project goals, in 2005 we have focused on adding interfaces to the THP web site for operating the computational models that have been developed by us and other members of the project. We use the DOME (distribute object-based modeling environment) model integration software infrastructure to make models, which have been constructed using software applications such as MS Excel and Mathworks Matlab, accessible through the THP web site. In addition, we have continued to collaborate with the CAD laboratory at the Massachusetts Institute of Technology towards the development of the DOME software. This year we have focused on the construction of integrated model projects that interconnect the different models developed within the project. In particular, we have concentrated on integrating models of power generation technologies and of building energy-conservation measures to reduce power demand with the power planning and dispatch model that we have developed in previous research.

The main research results for 2005 related to development of the web-based collaboration platform for evaluation of technologies and policies for mid- to long-term reduction of CO2 emissions in cities are as follows:

1. Development of the THP website to support model operation
2. Development of DOME tools for doing iterative model calculations in order to evaluate scenarios through time
3. Evaluation of the DOME iteration tool using the power planning and dispatch model for Tokyo
4. Integration of the power planning and dispatch model with a residential sector model using DOME

References

Takashi Ikegami, Toshiya Aramaki and Keisuke Hanaki (2005) Effects of environmental load reduction by strategic implementation of district heating and cooling systems using wastewater heat, Selected Papers of Environmental Systems Research, Japan Society of Civil Engineers, Vol. 33, 343-354.

Ikaga, T., Miura, S., Tonooka, Y., Shimoda, Y. et.al. (2005) Development of Macro Simulation Method on Household Energy Consumption and CO_2 Emission by Each Administrative Division, AIJ Technical Journal, No.22, pp.263-268

Yuichi Furukawa, Takuya Maruyama and Noboru Harata (2006) Change of Freight Transport by Road Pricing in Tokyo Metropolitan Area, Journal of Japan Society of Civil Engineers, No.807/IV-70, pp.11-20.

Maruyama, T. and Harata, N. (2005) Optimal job-housing location pattern in several Japanese cities: Considering modal split and congestion in network, Proceedings of International Symposium on City Planning, pp. 159-171.

Takeshi Ishida, Kiyoshi Dowaki and Shunsuke Mori (2005) “The Development of the Optimum CGS Capacity Decision System Used for the Commercial Building”, Trans. of JIEE, Vol. 125-B, Vol.125, No.4, PP.373/380

Takeshi Ishida, Kiyoshi Dowaki and Shunsuke Mori (2005) “Research of the Decision Model on Capacity and Operation Condition of Airconditioning System of the Commercial Building Considering Weather Condition of the City “, Trans. of JIEE, Vol. 125-C, Vol.125, No.10, PP.373-380.