B-53.1.2 Evaluation of small-scale on-site energy supply technologies in urban area (Filal Report)

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Abstract

CO_2 emissions during the life cycle of a 200 kW type fuel cell power generation system were investigated. It was estimated that the total CO_2 emissions during the life cycle of fuel cell system were 2.56x107kg-CO_2. CO_2 emissions caused by the construction of facility were 4.86x104kg-CO_2, 20% of which was attributable to electrodes and 10% of which was attributable to converter including catalysts. CO_2 emissions during the operation of fuel cell system dominated the total CO_2 emissions, which was up to 99.6% of the total CO_2 emissions. It was calculated that the CO_2 emission per kWh was 0.554 kg-CO_2/kWh, where the lifetime of the system was assumed to be 30 years. A preliminary investigation has been also carried out to develop life cycle inventories for solar heat systems to supply hot water in urban area. It was estimated that the energy pay back time (EPT) of solar heat systems was less than 4 years.

The reduction possibility of energy consumption, CO_2 emission and the costs in the area within a 2-km radius from the Shinagawa station was estimated. In this case study, it was assumed that new energy system like solar PV and solar hot-water supply system for a residence and district energy supply using co-generation system and unused energy source utilisation system (waste heat by waste-power generation and sewage) was equipped on the area. The calculation result shows that there is a possibility to reduce 10% of CO_2 emission in this area accompanying cost reduction.

Key Words Urban, Solar Energy, Fuel Cell, LCA, Cost

1. Introduction

Reduction of carbon dioxide emission is urgent and indispensable requirement for all the people in the world. In Japan, recent increase of carbon dioxide is mainly caused by the increase of energy usage among residential and commercial sectors. Drastic innovation is expected to achieve the reduction.

Most of carbon dioxide release is caused by combustion of fossil fuels. For the remarkable reduction of carbon dioxide, reduction of fossil fuel usage is essential. Electricity generated at concentrated plants has been considered as the most cost effective and the highest efficiency. However, because of recent technological advance, taking account of the load variation in the residential and commercial sectors, small-scale on-site energy supply technologies must be scientifically evaluated from the point of environmental protection.

In is research project, the evaluation of on-site energy supply system is conducted using LCA method and recent data.

2. Research Objective

Considering the background mentioned above, the objectives of this project could be written as follows.

(1) Quantitative evaluation of small-scale on-site energy supply system using life cycle assessment method.

(2) Estimation of carbon dioxide release reduction by usage of unused energy source in urban area.

(3) Cost estimates for instalment of on-site energy supply system to urban area.

3. Research Method

Taking fuel cell energy supply system, as an example, the quantitative environmental evaluation is conducted using life cycle assessment (LCA) method. NIRE's original LCA programme "NIRE-LCA v2" is applied for the calculation. For the database of the assessment, original investigation by governmental statistics and compilation of process data are used.

For the analysis of small-scale on-site energy supply system, Shinagawa area was chosen for the case study. GIS is effectively used to estimate energy demand and the floor spaces of the area. Unused energy sources such as wasted heat from incineration plants, swage and/or river heat, is evaluated with some assumptions. The costs of on-site energy sources are estimated from conventional construction experiences. Using optimisation method; GAMS, cost and carbon dioxide reduction is examined.

4. Results and Discussions

4.1 LCA for fuel cell

Assuming phosphoric acid fuel cell of 200kW output, life cycle inventories was investigated. According to the calculation by NIRE-LCA, 4.86×104kg of CO_2 is released for the construction of the plant. If the plant is able to generate over 30 years, CO_2 release for the power generation is 0.554kg-CO_2/kWh. Details of the emission are listed in table 1. The emission rate is generally lower than conventional power plants as shown in table 2..

Table 1 Carbon dioxide release by the lifetime of PAFC (200kW class)

	CO_2 release	Generated electricity	Change interval
construction	4.86×10^4 kg-CO_2		
electrode	4.32×10^4 kg-CO_2		5 times for 30 years
catalyst	4.3×10^3 kg-CO_2		5 times for 30 years
Converters	3.82×10^3 kg-CO_2		Once for 30 years
fuel	2.55×10^7 kg-CO_2		
total	2.56×10^7 kg-CO_2		
electricity generated		4.614x107 kWh	
CO_2 release unit	0.554 kg-CO_2/kWh		

Table 2 Carbon dioxide release for power generation

Type	CO_2 emission rate (kg-CO_2/kWh)
PAFC	0.554
Coal power plant	0.967
Oil power plant	0.797
LNG power plant	0.583

4.2 Utilisation of solar heat

The energy payback time of hot water system heated by solar power is estimated less than 4

1. years. CO_2 release unit is 13.8g-C/Mcal for home use and 13.8g-C/Mcal for office use. The results are less than the release by conventional water heaters powered by town gas, LPG or kerosene.

4.3 CO_2 release estimates for the instalment of new energy system in urban area

To estimate energy consumption in urban are, office district near Shinagawa station is sampled for the analysis. As new energy system, solar heaters、 solar batteries and fuel cells are considered to install to residential buildings. Co-generation systems by fuel cells, gas turbines, gas engines and diesel generators, and utilisation of unused heat such as wasted heat from incinerators and/or swage heat are assumed to be utilised for the area conditioning system in the district. Because of such system, CO_2 release can be reduced 20% in the urban area.

4.4 Cost analysis of instalment of new energy system to urban area

For the reduction of energy consumption in urban area, similar to the former section, area near Shinagawa station is chosen as an example. As for energy supply system, solar heaters, solar batteries and fuel cells for residential buildings and area conditioning by co-generation system of wasted heat from incinerators and swage heat are considered to be used for area conditioning addition to unit systems by conventional air conditioners or conventional area conditioners. Optimising models to minimise supply cost under the certain CO_2 release restriction condition is developed. Optimised system, the cost and CO_2 release are obtained from the model. The results show that 20% of the conventional cost would be reduced if CO_2 release is kept to the same level. (Figure 1)

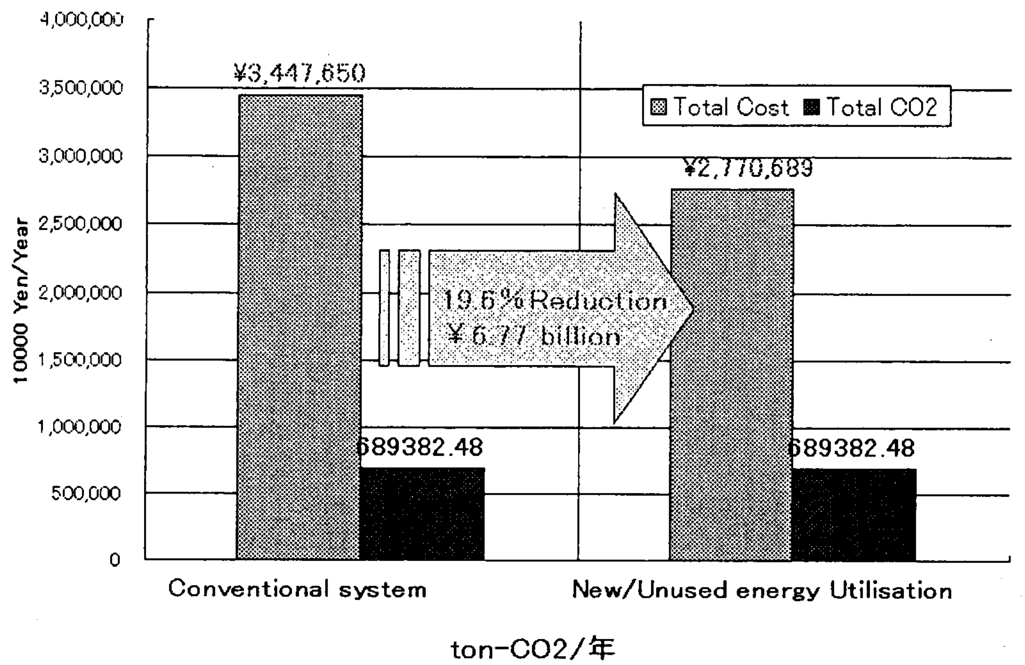

Fig.1 Cost estimates

5. Conclusion

If we compare the obtained results with conventional type, superiority of new energy system from the point of carbon dioxide release reduction is estimated through the research. However, financing for its instalment, law requirements, long term analysis and/or detailed system specifications should be evaluated for final decision of its instalment. The research bodies would continue such analysis to establish environmentally acceptable urban energy systems.