IGES Policy Report-2011-02

Waste-based ethanol production and a sound material-cycle society

Case studies on construction and food wastes in Japan

Governance and Capacity Group, Institute for Global Environmental Strategies (IGES)

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Waste-based ethanol production and a sound material-cycle society
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Abbreviations and Acronyms

BJK	Bioethanol Japan Kansai Co., Ltd.
E3	gasoline blended with 3 percent of ethanol
ETBE	ethyl tertiary-butyl ether
EU	European Union
FY	fiscal year
GHG	greenhouse gas
LCA	life cycle assessments
MAFF	Ministry of Agriculture, Forestry and Fisheries
METI	Ministry of Economy, Trade and Industry
MIC	Ministry of Internal Affairs and Communications
MOE	Ministry of the Environment
NEDO	New Energy and Industrial Technology Development Organization
NGO	non-governmental organisation
NPO	non-profit organisation
NSE	Nippon Steel Engineering Co., Ltd.
PAJ	Petroleum Association of Japan
R&D	research and development
UNEP	United Nations Environment Programme
US	United States

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Abstract

This paper examines whether waste-based ethanol production can contribute to the realisation of a sound material-cycle society and what facilitates and hinders the implementation, based on two case studies conducted in Japan. Each of the selected projects is recognised as being the first projects of its kind in the world: ethanol production from construction waste timber in Osaka Prefecture and from food waste in Kitakyushu City.

The study estimates the waste reduction and ethanol production potential of construction and food wastes for two different scenarios based on the data obtained through case studies. The most optimistic scenario assumes that all waste could be used, and the more realistic scenario assumes some improvement of the waste utilisation rate. For both scenarios, the respective waste is found to have potential to achieve the national target of domestic production set for 2011. On the other hand, the contributions of those wastes to the national introduction targets, which are set in relation to the Kyoto Protocol Target Achievement Plan and the Law for the Sophisticated Structure of Energy Supply, are found to be moderate. It concludes that ethanol production from construction and food wastes could be a reasonable option to promote a material-cycle society, while it should be noted that ethanol production is not the only option to recycle the unutilised portion of such wastes and the utilisation of those wastes needs to consider the principles of a "Sound Material-Cycle Society."

The common facilitating factors identified in the case studies are financial support by the government, a set of laws on recycling, and local plans to establish an environmentally sound resource-cycle system (Eco Town Plans). Major challenges are identified including collection from small-scale sources, intensifying competition over construction waste timber, and divided specifications of ethanol blended gasoline in Japan.

Based on the analyses, the paper presents some policy implications including: need to improve life cycle assessments of greenhouse gas emissions reduction to secure the sustainable use of waste-based ethanol; need for coordination among the related ministries and data collection on the available amount of waste feedstocks in order to avoid excessive government support on waste biomass leading to over-competition; potential of utilisation of logging residue to further utilise wood biomass resources; importance of developing effective systems for separation and collection from small scale waste generators; and applicability of waste-based ethanol to other Asian countries.

Waste-based ethanol production and a sound material-cycle society

Chapter 1

Introduction

Biofuel promotion policies spread worldwide during the 2000s, Japan being no exception. The Japanese government introduced various promotion policies from target setting to implementing pilot projects. However, bioethanol production in Japan faces constraints such as the lack of a “major feedstock.” In contrast to large agriculture countries such as Brazil or the United States (US), the ethanol production projects in Japan vary in terms of feedstocks and production capacity. Under such circumstances, authors have discussed that the contribution of biofuels in Japan should be more significant in the area of a sound material-recycle society or regional development, rather than greenhouse gas (GHG) emissions reduction (Matsumoto, Sano, and Elder 2009). In fact, waste-based ethanol (ethanol produced from waste materials), which would bridge bioethanol and a sound material-recycle society, is already being produced and introduced in some areas of Japan. This paper focuses on such waste-based ethanol production and discusses its potential contribution towards a sound material-cycle society in Japan. [1]

This chapter sets the scope of the study with the overview of biofuel policies and production in Japan as a background. Chapter 2 outlines methodologies used for the analysis and Chapter 3 presents review results of the selected biofuel projects. Chapter 4 discusses contribution to waste reduction, GHG reduction, common facilitating factors, major barriers, and policy implications.

1. Overview of biofuel policies in Japan

Biofuels raised enormous public and private interest in the face of climate change, an increasing demand for energy, volatile oil prices, and energy poverty. For example, in the State of the Union address in January 2007, President Bush set a very ambitious goal to reduce the gasoline usage by 20 percent in 10 years and biofuels were eyed as a promising option. However, the momentum for biofuels gradually eroded as concerns about the negative implications of biofuels were widely recognised (International Panel for Sustainable Resource Management 2009).

Nevertheless, expansion of biofuel use for the transport sector continued worldwide. According to the United Nations Environment Programme (UNEP), the share of biofuels, including both ethanol and diesel, in global transport fuel was 1.8 percent by energy value in 2007 (36 million tonnes of oil equivalent out of a total of 2007 million tonnes of oil equivalent). The production of ethanol and biodiesel reached more than 52 billion litres and almost 11 billion litres,

[1] This paper was written based on the data available until the end of February 2011 and does not cover the changes in policy landscape related to biomass and energy after the Great East Japan Earthquake on 11 March 2011.

increasing by three and eleven times, respectively compared to 2000 (International Panel for Sustainable Resource Management 2009).

The three largest producing countries/regions of transport biofuels are the US, Brazil, and the European Union (EU). The US mostly produces ethanol from corn, Brazil ethanol from sugar cane, and the EU mostly biodiesel from rapeseed.

The rapid growth of biofuels sectors in the US and EU stimulated growth in Asia, and many Asian countries have now set targets and blending mandates to continue to increase their biofuels production. Total biofuels production in Asia has grown more than five-fold since 2004, from just over 2 billion litres to almost 12 billion litres in 2008 (USAID 2009).

Japan has also promoted biofuels since the "Biomass Nippon Strategy"[2] was approved by the Cabinet in 2002. The strategy lists multiple rationales for promotion of biomass utilisation: mitigation of global warming, development of a sound material-cycle society, incubation of new industry, and revitalisation of rural economies.

Policy targets related to both introduction and production have been developed. The first short-term target regarding introduction of liquid biofuels in the transport sector was set at 500 thousand kilolitres in oil equivalent (860 thousand kilolitres in ethanol volume) by 2010, incorporated in both the "Kyoto Protocol Target Achievement Plan"[3] (2005) and the revised version of the Biomass Nippon Strategy (2006). This target was not met by the end of the fiscal year (FY) 2010.[4] According to the policy evaluation report on the Biomass Nippon Strategy by the Ministry of Internal Affairs and Communications (MIC), the expected amount of the actual introduction remains 220 thousand kilolitres (MIC 2011).

A roadmap of the targets related to bioethanol introduction beyond FY 2010 was published in the fall of 2010 as requirements to the oil refiners to promote non-fossil energy (Table 1). Those targets were issued based on the "Law to Promote Utilisation of Non-fossil Energy Source and Efficient Use of Fossil Energy Raw Material by Energy Suppliers" (referred to as: "Law for the Sophisticated Structure of Energy Supply"),[5] which passed the Diet in 2009. The roadmap requests oil refiners to introduce 500 thousand kilolitres of ethanol (in crude oil equivalent) by FY 2017. It should be noted that, although this target volume in FY 2017 is the same as the one set for the FY 2010 in the Kyoto Protocol Target Achievement Plan, the roadmap for the oil refineries up to FY 2017 focuses only on bioethanol. In comparison, the target for FY 2010 by the Kyoto Protocol Target Achievement Plan and the revised version of the Biomass Nippon Strategy had a wider scope by aiming for the introduction of "biofuels in the transport fuels", which encompasses both bioethanol and biodiesel.

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2 "Baiomasu Nippon Sogo Senryaku"

3 "Kyoto Giteisho Mokuhyo Tassei Keikaku"

4 Japanese fiscal year starts on 1 April and ends on 31 March.

5 "Enerugi Kyokyu Jigyosha ni yoru Hi-kaseki Enerugi-gen no Riyo oyobi Kaseki Enerugi-genryo no Yuko na Riyo no Sokushin ni kansuru Horitsu" ("Enerugi Kyokyu Kozo Kodo-ka Ho")

Table 1. Targets of bioethanol to be introduced by the oil refiners set based on the regulation of the Law for the Sophisticated Structure of Energy Supply

FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
210,000 kl	210,000 kl	260,000 kl	320,000 kl	380,000 kl	440,000 kl	500,000 kl

(in crude oil equivalent)

Source: Government gazette extra edition no. 243, 11 November 2010

For the mid- and longer-term, the introduction targets were announced in the Basic Energy Plan in June 2010. The mid-term target intends to increase the share of biofuel in gasoline to more than 3 percent by 2020 nationwide, with the conditions that GHG emissions be reduced sufficiently and economic viability be ensured. The Plan further aims to increase biofuel introduction to the maximum possible by 2030 by establishing the next generation biofuel technologies such as biofuels from cellulosic materials and algae. However, this biofuel introduction target in Japan still remains modest compared to those of the US or EU. In the US, the Energy Independence and Security Act of 2007 set a mandatory Renewable Fuel Standard (RFS), which requires fuel producers to use at least 36 billion gallons (approximately 140 million kilolitres) of biofuel in 2022 (The White House 2007). The EU adopted an EU-wide binding target that a 10 percent share of energy consumption in the transport sector shall be from renewable sources by 2020, which is consistent with a 20 percent share of energy from renewable sources by the same year (European Union 2009). [6]

The targets related to the Japanese domestic production of biofuels were set in the roadmap entitled the "Large Scale Expansion of Domestic Biofuel Production" [7] developed by the Biomass Nippon Strategy Promotion Council[8] in February 2007. In the short-term, it was aimed to produce 50 thousand kilolitres (30 thousand kilolitres of oil equivalent from both bioethanol and biodiesel) in FY 2011, assuming production from currently available saccharides/starch materials and waste materials. In the middle and long-term, the production potential was estimated to reach 6 million kilolitres (3.6 million kilolitres of oil equivalent) if technical and institutional challenges were successfully resolved to produce biofuels from other sources such as cellulosic materials. The nationwide annual production of bioethanol was approximately 15 thousand kilolitres while the production capacity was estimated to be approximately 31 thousand kilolitres as of the end of the FY 2009, and the total amount of biodiesel production was estimated at 10 thousand kilolitres as of March 2008 (MAFF 2009). [9] [10]

Various policies have been implemented to promote biofuel introduction and production. They include import tax exemption on ethyl tertiary-butyl ether (ETBE), a fuel tax exemption for

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6 The mandatory 10 percent target for transport is defined as the share of final energy consumed in transport which is to be achieved from renewable sources as a whole, and not from biofuels alone.

7 "Kokusan Baionenryo no Ohaba na Seisan Kakudai"

8 "Baiomasu Nippon Sogo Senryaku Suishin Kaigi"

9 The exact amount of production by each company is not published.

10 Koji Okura, Deputy Director of the Biomass Policy Division, MAFF, reply to the question by the author at the Biomass Expo 2010, 18 November 2010.

bioethanol, and various financial and tax support measures for the producers of feedstocks and biofuels. Financial support for pilot projects and research and development (R&D) of advanced biofuels also has been provided by relevant ministries including the Ministry of the Environment (MOE), the Ministry of Agriculture, Forestry and Fisheries (MAFF), and the Ministry of Economy, Trade and Industry (METI). Major fuel ethanol pilot projects in Japan as of FY 2008 are listed in Table 2. The table shows that feedstocks used for ethanol production vary from edible crops (high-yielding rice, sub-standard flour, sugar beets, etc.) to waste materials (construction waste timber, saw mill waste, food waste, etc.). As shown in the table, most projects conduct demonstrations of gasoline blended with 3 percent ethanol (E3), corresponding to the ethanol blending maximum ceiling at 3 percent. This level of blending ceiling is very low compared to international levels.[11]

In addition, the "Fundamental Law for the Promotion of Biomass Utilisation"[12] was enacted in 2009. The law clarifies the basic principles of biomass utilisation and specifies the responsibilities of stakeholders. It specifically stipulates the development of a Basic Plan for the Promotion of Biomass Utilisation and the Promotion Council for Biomass Utilisation Promotion and the Expert Committee on Biomass Utilisation Promotion.

Overall, the policy development trend in Japan shows the government's intention to expand biofuel introduction through various measures including provision of economic incentives, financial support for pilot-projects, and R&D, as well as the introduction of non-fossil energy use targets for energy suppliers underlined by laws and plans. The national targets and policies show more emphasis on bioethanol than biodiesels: the introduction target for FY 2017 and the exemptions on both import tax and a fuel tax are applied only to bioethanol, not biodiesel.

[11] On-road driving tests of vehicles fuelled by gasoline blended with 10% ethanol were conducted from 2008 in Hokkaido and Osaka. For further discussions on the issue of the maximum blending ceiling, please refer to Matsumoto, Sano, and Elder (2009).

[12] "Baiomasu Katsuyo Suishin Kihon Ho"

Table 2. Major pilot projects for fuel ethanol in Japan

Area	Implementer	Related ministry	Project outline
Shimizu Town, Hokkaido	Hokkaido Bioethanol Co., Ltd.	MAFF	Production from sugar beets, flour, etc.
Tokachi Area, Hokkaido	Tokachi Area Promotion Organisation	MOE, MAFF, METI	Production from substandard flour, corn, etc. and demonstration of gasoline blended with 3% ethanol (E3).
Tomakomai, Hokkaido	Oenon Holdings, Inc.	MAFF	Production from rice etc.
Shinjo City, Yamagata Prefecture	Shinjo City	MAFF	Production from sorghum and E3 demonstration.
Niigata City, Niigata Prefecture	National Federation of Agricultural Cooperative Associations	MAFF	Production from rice and E3 demonstration.
Sakai City, Osaka Prefecture	Bioethanol Japan Kansai Co., Ltd, Osaka Prefecture	MOE	Production from construction waste timber and E3 demonstration.
Maniwa City, Okayama Prefecture	Mitsui Engineering & Shipbuilding Co., Ltd, Okayama Prefecture, Maniwa City	METI	Production from lumber waste etc. and E3 demonstration.
Kitakyushu City, Fukuoka Prefecture	Nippon Steel Engineering Co., Ltd.	METI, MOE	Production from food waste and E3 demonstration.
Ie Island, Okinawa Prefecture	Asahi Breweries, Ltd., National Agricultural Research Center for Kyushu Okinawa Region (KONARC)	MOE, MAFF, METI, Cabinet Office	Production from high biomass amount molasses and E3 demonstration.
Miyakojima Island, Okinawa Prefecture	Ryuseki Corporation	METI, MOE, MAFF, Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Fire and Disaster Management Agency, Cabinet Office	Production from molasses and E3 demonstration.

(as of the end of November 2008)

Source: Committee for Eco-fuel Utilisation Promotion 2009

2. Scope of this study

The authors previously reviewed Japan's national strategies, plans and policies to reach their objectives in four areas corresponding to the rationales of biofuels listed in the Biomass Nippon Strategy, namely, reduction of GHG emissions, energy security, rural development, and the realisation of a sound material-cycle society.[13] The review concluded that development of a sound material-cycle society as well as revitalisation of rural economies seem to be the main areas in which biofuels could play a significant role in the long-term, while noting a contribution to mitigating GHG emissions to a certain extent in the short term (Matsumoto, Sano, and Elder 2009). This paper follows up the discussion related to biofuels and a sound material-cycle society. Among biofuels, this paper focuses on bioethanol as it has drawn more attention in national policy compared to diesel as discussed in the previous section.

A "Sound Material-Cycle Society" is defined in Article 2 of the Fundamental Law for Establishing a Sound Material-Cycle Society[14] as a "society in which the consumption of natural resources will be conserved and the environmental load will be reduced to the greatest extent possible", by preventing or reducing the generation of wastes, by promoting proper cyclical use of products, and by ensuring proper disposal of circulative resources.

The concept of a "sound material-cycle society" is important in the context of sustainability and it has close linkages with other visions of societies such as a "low-carbon society" and a "nature-harmonious society". The Strategy for an Environmental Nation in the 21st Century[15] calls for an integrated promotion of these three societies in order to achieve a "sustainable society." This paper intends to discuss waste-based ethanol production from the viewpoint of a sound material-cycle society and a low-carbon society.

This paper focuses on "waste biomass." Waste biomass, according to the definition by the Japanese government, includes matter composed of livestock excrement, organic sludge derived from water processing in sewage works or manufacturing, wood waste derived from construction sites and the manufacturing process of wood products, and household kitchen waste. Due to the high content of water and organic substances, waste biomass is primarily treated to reduce volume by incineration and dehydration (so called "volume reduction") and the amount treated through this process consists of 55 percent of total waste biomass. As a result, the recycling rate remains as low as 17 percent. Improving the recycling rate of waste biomass would hold the key for realising a sound material-cycle society, as waste biomass accounts for more than half (54 percent) of the total waste generated in Japan during FY 2007 (MOE 2010).[16]

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13 The original word in Japanese is "Junkan-gata shakai", which has been translated in various ways since it does not have an exact corresponding term in English. While the Japanese government initially translated it into "recycling-based society," it is now translated as "sound material-cycle society." This paper employs the newer term, although the authors' paper in 2009 used a translation similar to the older version ("recycle-based society").

14 "Junkan-gata Shakai Keisei Suishin Kihon Ho"

15 "21 Seiki Kankyo Rikkoku Senryaku" (adopted at a Cabinet meeting in June 2007).

16 Other kinds of wastes include: non-metallic minerals (36 percent), metals (7 percent) and fossil (3 percent).

To set the geographic scope of discussion, this paper focuses on the utilisation of waste biomass in urban areas, as the composition of waste biomass differs considerably between urban areas and local areas. In urban areas, household kitchen waste, construction waste, and sewage sludge play more important roles than livestock excrement or sawmill waste. Besides, urban areas are facing pressing problems related to treatment of various wastes generated through urban economic activities and GHG emission from heavy vehicle use. In Japan, approximately 65 percent of the total population live in urban areas, a ratio which is significantly higher than the world urban population ratio (50 percent in 2008) (MOE 2010).

In summary, the scope of this paper has three pillars: to analyse the potential contributions of bioethanol production from urban waste biomass in terms of waste reduction and ethanol production potential based on case studies; to discuss facilitating factors and challenges related to those cases; and to draw policy implications towards a sound material-cycle society.

Chapter 2

Research framework

The major research question of this paper is "*how could ethanol production from urban wastes contribute to the development of a sound material-cycle society?*" Specifically, this research addresses the following questions:

- *If state-of-the art technologies are applied on a large-scale, could ethanol production from selected urban wastes make a substantial contribution to waste reduction?*
- *Would such waste-based ethanol production also result in GHG emissions reduction?*
- *Are there any common facilitating factors to promote biofuel production from urban wastes?*
- *What are the major barriers for the implementation of urban waste-based ethanol production?*
- *What are the policy implications for facilitating contributions of waste-based ethanol production towards a sound material-cycle society?*

In order to address the research questions, two projects of ethanol production from urban wastes were selected as case studies: construction waste timber in Osaka Prefecture and food waste in Kitakyushu City. Each case is recognised as the first project in the world to produce bioethanol from respective waste feedstock. As discussed in the above section, both construction waste and household kitchen waste are important components of waste biomass in urban areas in Japan. Thus, examination of those pioneering cases would provide valuable implications towards the policy discussions related to waste-based ethanol production and a sound material-cycle society in Japan. Although there were some other ethanol production projects from waste when the case selection was done in the summer of 2008, they were screened out for reasons of different geographical scope and small production scale. One of these other projects was an ethanol production project from lumber waste in Maniwa City which was designed for a mountainous region. Another example was a project in Shizuoka City using waste from bean curd and potatoes with a very small production scale (the annual production capacity was only 4.8 kilolitres) (Committee for Eco-fuel Utilisation Promotion 2008a).

Information and data related to the case studies were collected through field visits/interviews and published documents. Semi-structured interviews were conducted in July 2010 with the implementers [17] of the projects. Questionnaires covered the following topics: potential contributions to reduction of waste, fossil fuel use and GHG emissions, feedstock (waste) collection efficiency, energy efficiency, economic viability, marketing of the products, support by stakeholders, comparison with other uses, and potential implications for other Asian countries. In order to validate and update the information drawn from preliminary literature

[17] Interviewees were the Plant Manager and General Manager of the plant in the construction waste timber case and General Manager of the technology centre in the food waste case.

review research, specific questions were developed citing facts or data related to each project taken from the sources such as press releases by the project implementers or related government agencies, academic journal papers related to the projects, and newspaper articles.[18] As for statistical data related to waste generation in Japan, government publications such as the Annual Report on the Environment in Japan published by the MOE were referred to.

[18] An example of such questionnaire was: *"the press release of your company on 19 April 2010 reported that there is a potential to produce from 700 thousand to a million kilolitres of ethanol, if your company's technology is applied to all food waste. Would you explain the assumptions for those figures?"*

Chapter 3

Ethanol production from construction waste timber in Sakai City, Osaka Prefecture

1. Overview of construction waste

Construction waste accounts for about 20 percent of the industrial waste and for about 80 percent of illegal dumping, according to the Annual Report on the Environment in Japan (MOE 2010). The major components of construction waste are concrete lumps, asphalt concrete lumps, and construction waste timber, accounting for about 90 percent of the total construction waste. Recycling of these materials is mandated by of the "Law concerning Recycling of Materials from Construction Work (Construction Materials Recycling Act),"[19] which was promulgated in 2000 and came into force in 2002. The Law is applied to construction projects exceeding a certain scale: for example, a demolition work with a total floor area larger than or equal to 80 square meters or a new construction/extension work larger or equal to 500 square meters.

The recycling rate of concrete mass and asphalt concrete lumps was greatly improved by the introduction of the "Rules on the Present Operations Concerning the Use of Recycling Resources Involved in Public Works" (March 1991 revised as the "Rules on the Obligation of Recycling" in June 2006) implemented by each Regional Development Bureau.[20] The target of recycling rate of these materials (95 percent, set for FY 2010 in the Basic Principles of the Construction Materials Recycling Act) was already achieved in FY 2008.

The same recycling target applies to construction waste timber. However, the recycling rate of construction waste timber in FY 2008 still fell short at 89.4 percent. Strictly speaking, this number is still an overestimate since it includes "reduction," which means incineration that is allowed in cases where no recycling facility exists within 50 kilometres from the project site. If the amount reduced by such incineration is excluded, the net recycling rate is reduced to 80.3 percent (MOE 2010).[21] In other words, about 20 percent of construction waste is still either incinerated or left unutilised. This high ratio of incineration and low net recycling rate has been recognised as one of major issues related to the recycling of construction waste timber (Subcommittee on Construction Recycling Promotion of the Panel on Infrastructure Development and Expert Committee on Construction Recycling of the Central Environment Council 2008).

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[19] "Kensetu Koji ni kakaru Shizai no Saishigen-ka ni kansuru Horitsu (Kensetsu Risaikuru Ho)"

[20] "Kokyo Kensetsu Koji ni okeru Saisei Shigen Katsuyo no Tomen no Unyo ni tsuite" (revised in 2006 as "Risaikuru Gensoku-ka Ruru")

[21] The FY 2010 target includes the amount to be reduced by incineration.

The total amount of construction waste timber in FY 2008 was 4.1 million tonnes, and its ratio to the total construction waste was six percent. Although this ratio has remained the same since 1995, the amount of construction waste timber has been reduced by 2.2 million tonnes over 13 years reflecting a decrease in construction demand and an increase in the efficiency of material use. In the future, however, construction waste is expected to increase, as buildings built in the construction boom after 1965 will need refurbishment (MOE 2010). This implies that the amount of construction waste timber will increase accordingly.

2. Project outline and performance

Bioethanol Japan Kansai Co., Ltd. (BJK) was established in March 2004, co-funded by five companies: Taisei Corporation (construction company), Daiei Kankyo (industrial waste disposal firm), Marubeni Corporation (trading company), Sapporo Breweries (beverage producer), and Tokyo Board Industries (recycling company).[22] BJK produces recycled materials from waste wood, mainly construction waste timber and some branches pruned in parks. The products include not only fuel ethanol but also lignin pellets and electricity. Bean curd waste is also used in the production process as a yeast nutrient. The facility has an annual capacity to produce 1,400 kilolitres of ethanol from 16,500 tonnes of waste material and the capacity is planned to be increased to 4,000 kilolitres of ethanol from the 24,500 tonnes of waste material.

Photograph by author

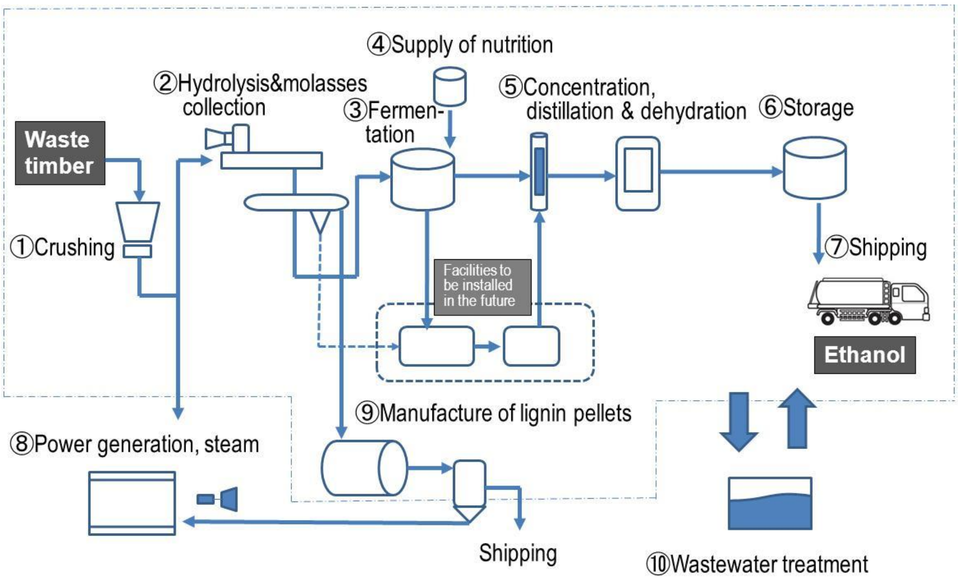
Photo 1. Ethanol Production facility from construction waste timber

[22] There were changes in the shareholders and corporate name in 2011. Daiei Kankyo purchased the shares held by other companies in April 2011 and became the owner of a one hundred percent stake in the company. The corporate name was changed to DINS Sakai Co., Ltd., following the merger with RAC Kansai Co., Ltd. in September 2011. As this article is written based on the interview held in July 2010, the former name of the company (BJK) is used throughout this report.

The BJK's business plan was a part of Osaka Eco Town Plan, which was approved by the MOE and METI on 28 July 2005. The ethanol production facility of BJK was constructed in a vacant lot after the demolition of a final disposal site in a water front area of Sakai City.[23] The total construction cost was approximately JPY 4 billion, with half of the cost being covered by a subsidy from the MOE. The operation of the plant was launched in January 2007.

The production flow of ethanol adopted by BJK is as shown in Figure 1. It includes:

- pre-treatment：crushing waste timber into pieces of a certain size
- hydrolytic degradation/recovery of carbohydrate solution: recovering five-carbon (C5) sugar by using dilute sulphuric acid
- ethanol fermentation : using Escherichia coli KO11 strain with bean curd waste (nutrition)
- condensation/distillation/dehydration: collecting ethanol .



Source: BJK pamphlet, replicated by author

Figure 1. Production flow of bioethanol from construction waste timber

Waste timber which is too stained to be used for ethanol production is separated at the pre-treatment stage and used to generate electricity for the plant. Lignin, solid residue after recovery of carbohydrate solution, is used as boiler fuel of the plant and/or sold to other plants as solid fuel. Waste water is treated and utilised in a circulative manner.[24]

23 Osaka-fu Ekotaun Puran Suishin Kyogikai [Osaka Prefecture Eco Town Promotion Council], Osaka-fu Ekotaun Puran [Osaka Prefecture Eco Town Plan] (official pamphlet). 2007.

24 Bio Ethanol Japan Kansai, Baio ethanol seizo shisetsu [Bio ethanol manufacturing facility] (official pamphlet).

The thrust of this process is that it can convert C5 sugars into alcohol, which has been regarded as difficult in fermentation by ordinary microorganisms and thus had a very low yield. Softwood is the major substance of construction waste timber and it contains cellulose (polymer substance of glucose-C6 sugar) (40 percent), hemicellulose (mainly composed of xylose-C5 sugar) (27 percent) and lignin (33 percent).[25] Therefore, utilising C5 sugar is critical to achieve higher yields. In comparison, corn that is used as the major feedstock of ethanol production in the US consists of 70 percent of C6 sugars (starch).

This relatively high content of C5 in wood biomass has been an inhibiting factor for the commercialisation of ethanol production in spite of the abundant availability of wood biomass, as C5 sugars cannot be converted into ethanol by yeast, which is widely used in alcohol fermentation (Tsukishima Kikai 2010). The technology used in BJK, which was developed by Tsukishima Kikai, utilises a genetically modified Escherichia coli KO11 strain, which enables the conversion of C5 sugars into ethanol.[26] As of July 2010, the BJK plant an annual production capacity of 1,400 kilolitres, converting only from C5 sugars. It is planned to start production prom C6 sugars as well to increase the capacity to 4,000 kilolitres.

The ethanol produced is being sold to two refineries to produce E3. This E3 is used in bioethanol pilot projects in Osaka Prefecture and in the Tokyo area.

[25] Suzuki Minoru, Plant Manager and General Manager, Product management department, Bioethanol Japan Kansai, interview by author, Sakai, Japan, 20 July, 2010.

[26] The strain was originally developed in the 1980s by Dr. Lonnie O. Ingram at the University of Florida and Prof. Kazuyoshi Ota of Miyazaki University, who was a visiting researcher at the University of Florida.

Chapter 4

Ethanol production from food waste in Kitakuyshu City, Fukuoka Prefecture

1. Overview of food waste

Food waste is generated from each stage of manufacturing, distribution and consumption of food, including unsalable food products from food manufacturing and/or distribution as well as left-over and/or waste from food industries or households. Under the Waste Disposal and Public Cleansing Law,[27] the food waste is classified into *industrial waste* and *municipal waste*: waste from food manufacturers are classified as the former and waste from food distributers and restaurants are classified in the latter category along with household waste. According to the MOE (2010), the total amount of food waste was 19.48 million tonnes in FY 2007, consisting of 3.07 million tonnes of industrial waste and 16.42 million tonnes of municipal waste. Households generated approximately 70 percent of municipal food waste during the year, which means that 57 percent of the total amount of food waste was made up of household kitchen waste.

Food waste from food manufacturers (industrial waste) is relatively easy to collect, as it is large in volume and similar in composition. Therefore, its recycling rate is relatively high (86 percent). The majority of industrial food waste is recycled into compost (35 percent) and animal feed (43 percent), and less than 10 percent is used for oil and fat extraction. Food waste from food distributors and restaurants (business type municipal waste) has moderate recycling rates: 41 and 31 percent respectively (Statistics Department of the Minister's Secretariat of MAFF 2009).

In comparison, the recycling rate of the food waste from households (household municipal waste) is considerably lower: only 640 thousand tonnes (6 percent) are now recycled. Separating and collecting food waste from households is difficult since they are generated by individual households in numerous locations in small amounts. Besides, treatment of household food waste is much more complicated than business related waste as the composition of household waste is complex and varies across households. Due to those difficulties, many cities still collect and incinerate such waste with other municipal waste. For example, the questionnaire survey conducted by a non-profit organisation (NPO) in the fall of 2008 found that 84.1 percent of the responding 788 municipalities incinerated household municipal waste. The percentage of the municipalities which "fully recycle" was only 8 percent and "partly recycle" was 6.9 percent (NPO Hojin Namagomi Recycle Zenkoku Nettowa-ku 2009). As a result, in total, still 14.14 million tonnes (73 percent) of food waste are incinerated, pushing the total recycling rate of

27 "Haikibutsu no Shori oyobi Seiso ni Kansuru Horitsu"

food waste as low as 27 percent. Yet, this fact indicates there are abundant potential resources if they are properly recycled.

2. Project outline and performance

Nippon Steel Engineering Co., Ltd. (NSE) was commissioned by the New Energy and Industrial Technology Development Organization (NEDO) to carry out a project to experiment “recycling system test business to process food waste into ethanol” from FY 2005 to 2009 as one of the seven projects in the “Biomass Energy Regional System Development Project.” [28] The idea for this system was developed by focusing on the large quantity of carbohydrate content found in food waste. The facilities to produce ethanol and blend it into gasoline were constructed in Kitakyushu Eco Town in Fukuoka Prefecture in 2007, fully funded by the NEDO. Kitakyushu Eco Town was the first Eco Town in Japan which was approved as pilot project in July 1997. The ethanol production facility has a daily capacity to process 12 tonnes of food waste (the net weight of 10 tonnes after removing trashes such as plastic bags) and produce 500 litres of dehydrated ethanol. In addition to ethanol, it recovers approximately 700 kilograms of oil (Bunker A equivalent) from plant and animal oil content of food waste (Nippon Steel Engineering 2010).

Photograph courtesy of NSE

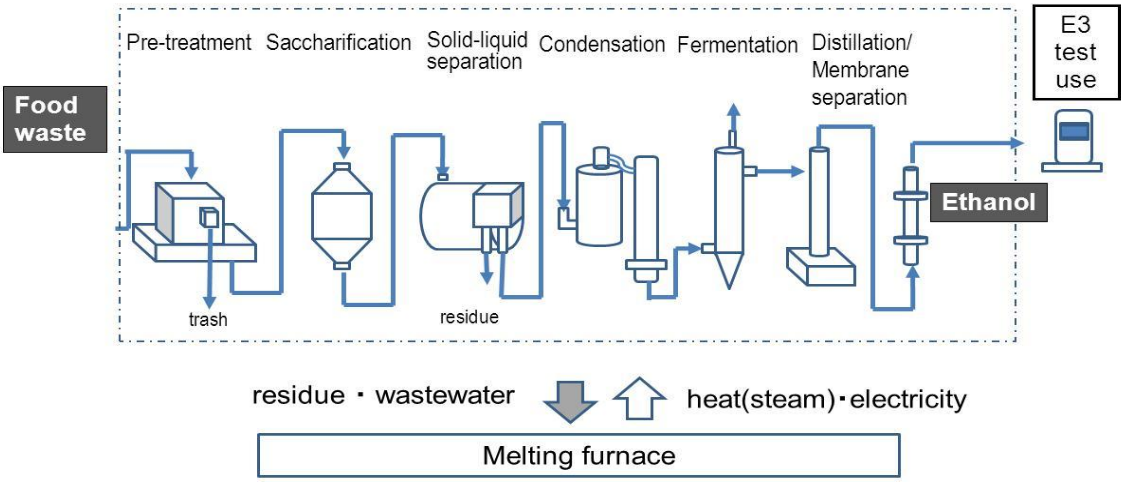
Photo 2. Ethanol pilot production facility from food waste

[28] “Baiomasu Shisutemu Enerugi Chiiki Shisutemu-ka Jikken Jigyo”

To implement the project, NSE tasked the Kitakyushu City government with collecting and sorting the food waste from small scale sources and Nishihara Co., a waste management company, with developing new technologies to implement the sorted collecting system from large scale businesses.[29]

The overall flow of the system includes:[30]

- pre-treatment: separating trash such as plastic bags and boxes from collected waste
- saccharification: converting to glucose by using amylase
- solid-liquid separation: separating substance for fermentation from the solid remainder
- condensation: preparing substance for fermentation
- ethanol fermentation: fermentation with flocculant yeast (efficiency is high, no nutrient is necessary since the food waste itself contains enough nutrition)
- distillation/ membrane separation: collection of ethanol (See Figure 2).



Source: NSE pamphlet, replicated by author

Figure 2. Production flow of bioethanol from food waste (pilot project)

The ethanol production facility was built next to a melting furnace for power generation from waste which was already in operation. These two facilities were connected through pipelines which enabled treatment of residue and wastewater from the ethanol production plant as well as supply of electricity and heat. For example, the ethanol facility could dispose of the solid remainder after solid-liquid separation to the melting furnace for incineration and receive the

29 Nippon Steel Engineering, Jikken jigyo no gaiyo [Outline of the experimental project] (power point presentation for visitors). 2010.

30 Nippon Steel Engineering, Shin Nittetsu Enjiniaringu Kitakyushu Knakyo Gijutsu Senta [Kitakyushu Environmental Technology Center] (official pamphlet), 2007

necessary steam for the condensation process from the furnace.[31] This could lead to cost reduction as the facility would have been charged treatment fees if it had disposed of the solid remainder as industrial waste.

In order to improve the transportation efficiency of collected waste, garbage collection trucks with two separate cells were invented: one cell for packing food waste and the other for other municipal waste. This invention made it possible to collect two types of waste in one trip, avoiding extra trips and reducing associated costs. To facilitate cooperation from the citizens to properly separate food waste, a point system was introduced as a part of the programme called "Kitakyushu Citizen Environmental Passport," which was introduced by the city government to raise citizens' awareness on the environment. Citizens could earn points each time they carry in a bag of food waste to the designated collection spots and could redeem the points for eco goods if a certain number of points are accumulated.

In February 2009, an experimental test use of E3 gasoline was started at the Kitakyushu Environmental Technology Center, which is located approximately five kilometres away from the production facility. In this experiment, blended E3 gasoline was supplied for test driving using official vehicles of the Kitakyushu City government and the company vehicles of NSE. The filling station of E3 gasoline was set up by receiving subsidies from the MOE.

The pilot project was completed in March 2010 as planned in the contract with NEDO. Based on the result, NSE started a commercial sale of food waste ethanol production plants involving local governments and large scale waste generators (Nippon Steel Engineering 2010).

31 Hideharu Shibaike, General Manager, Dr. Eng.,Technology Headquarters Engineering R & D Institute, Kitakyushu Environmental Technology Center, Nippon Steel Engineering Co. Ltd, interview by author, Kitakyushu, Japan 5 July, 2010.

Chapter 5

Multifaceted analyses

Based on the review of the case studies, this chapter addresses each of the research questions of this study listed in Chapter 2. The questions encompass contribution to waste reduction, GHG emission reduction, common facilitating factors, major barriers for the implementation, and policy implications.

1. Contribution to a sound material-cycle society

-If the state-of-the art technologies are applied in a large-scale, could ethanol production from selected urban wastes make a substantial contribution to waste reduction?-

Production potential of waste-based ethanol

Data presented in Chapter 3 and 4 show that a substantial amount of both construction waste timber and food waste is still unutilised, indicating that ethanol production can further promote recycling of waste which are currently incinerated. Table 3 lists the total amount, unutilised amount, and recycling rates of those wastes.

Table 3. Utilisation/recycling status of construction waste timber and food waste

	Construction Waste Timber (FY 2008)	Food Waste (FY 2007)
Total amount	4,100,000 t	19,480,000 t
Unutilised amount	807,700 t	14,140,000 t
Recycling rate	80.3 % (excluding “reduction”)	27.4 %

Source: MOE 2010

Based on the total and unutilised amount of the wastes, the production potentials of ethanol from construction waste timber and food waste are estimated for two scenarios. The first scenario assumes that all unutilised waste shall be converted to ethanol (***Full utilisation scenario***). If all the construction waste timber incinerated during the year was converted to ethanol using the same technology as the BJK’s, approximately 67 thousand kilolitres of ethanol could be produced.[32] Likewise, in the case of food waste, applying the final production rate

[32] The assumptions of this estimate are as follows: the daily fermentation capacity is 56 tonnes a day; the facility operates 300 days/year; and production capacity of the facility is 1,400 kilolitres. Those assumptions are based on the official data of the factory and advice obtained during the interview.

obtained in the project by NSE (0.05 kilolitres per tonne), 707 thousand kilolitres of ethanol could be produced by using the amount of food waste which was incinerated during the year with the NSE's technology (Table 4).

However, it is not realistic to assume that all unutilised waste shall be recovered. Therefore, the second scenario (***Utilisation improvement scenario***) takes into consideration of the differences in the rates of recovery depending on the characteristics of biomass (such as storage stability and ease of transportation). This scenario refers to the numerical targets to improve utilisation rates set in the Basic Plan for the Promotion of Biomass Utilisation,[33] which was published in December 2010. The Basic Plan sets different utilisation targets for each category of biomass for the year 2020, based on the calculation by the MAFF considering the purpose of biomass use and characteristics of each biomass.[34] The targets are 95 percent for construction waste timber and 40 percent for food, among others. Taking those target values for 2020 as references of potential utilisation rates, assuming that the increase in recovery is allocated to ethanol production, and applying the same production rates with the case studies, it is estimated that construction waste timber can produce 50.2 thousand kilolitres of bioethanol and food waste can produce 122.6 thousand (see Table 4).

Table 4. Production potential of ethanol from construction and food wastes

	Construction Waste Timber		Food Waste	
	Amount of waste feedstock (based on the data of FY 2008)	Estimated potential (rounded off to the nearest hundred)	Amount of waste feedstock (based on the data of FY 2007)	Estimated potential (rounded off to the nearest hundred)
Full utilisation scenario Assumption: all unutilised waste shall be converted to ethanol	807,700 t	67,300 kl	14,140,000 t	707,000 kl
Utilisation improvement scenario Assumption : waste utilisation rate be equivalent to the 2020 targets set in the Basic Plan for the Promotion of Biomass Utilisation and all the increase in recovery be allocated to ethanol production	602,700 t (2020 target: 95%)	50,200 kl	2,452,500 t (2020 target: 40%)	122,600 kl

Source: estimate by authors based on MOE 2010, plant data, and Basic Plan for the Promotion of Biomass Utilisation

33 "Baiomasu Katsuyo Suishin Kihon Keikaku"

34 Record of the Third Expert Committee on biomass Utilisation Promotion. 27 August 2010.

Table 5 shows the ratio of the estimated potentials for both scenarios to some indicators related to production (actual domestic production, production capacity, and domestic production target) and the introduction targets (targets related to the Law for the Sophisticated Structure of Energy Supply and achievement of the Kyoto Protocol, and gasoline consumption). Figures under the *full utilisation scenario* show that ethanol production from food waste could make a larger potential contribution to the increase in domestic production than that from construction waste timber. However, the difference between those different waste feedstocks becomes smaller when the difficulty of collection and storage of food waste is considered under the *utilisation improvement scenario*. For example, if all the unutilised food waste can be collected and processed into ethanol, it could theoretically exceed the introduction target with a significant margin (196 percent) that oil refineries need to meet (210,000 kilolitres in crude oil equivalent). However, assuming that the utilisation rate would increase only to 40 percent, which the Basic Plan for the Promotion of Biomass Utilisation aims for the year 2020, the potential contribution becomes modest (34.1 percent). Thus, the figures of the *full-utilisation scenario* should be considered as an extreme upper bound estimate. Even the *utilisation improvement scenario* should be treated as an optimistic scenario, as it assumes all the improvement in waste recovery shall be used for ethanol production. In reality, both wastes have other recycling options as will be discussed in the next sub-section.

Table 5. Potential of waste-based ethanol to meet Japan's ethanol targets

	Construction Waste Timber Potential		Food Waste Potential	
	*Full utilisation scenario**	*Utilisation improvement scenario***	*Full utilisation scenario**	*Utilisation improvement scenario***
Comparison with actual domestic production (FY 2009) [15,000 kl in ethanol]	449 %	335 %	4713 %	817 %
Comparison with domestic production capacity (estimate for FY 2009) [31,000 kl in ethanol]	217 %	162 %	2280 %	395 %
Domestic production target (FY 2011) [50,000 kl in ethanol]	134 %	100 %	1414 %	245 %
Introduction target required for the oil refiners (the Law for the Sophisticated Structure of Energy Supply) (FY 2011) [210,000 kl in crude oil]	18.7 %	14.0 %	196 %	34.1 %
Kyoto Target Achievement Plan (FY 2010) [500,000 kl in crude oil]	7.8 %	5.8 %	82 %	14.3 %
Gasoline supply (FY 2008) [57,473,000 kl in gasoline]	0.08 %	0.05 %	0.79 %	0.13 %

**Full utilisation scenario* assumes that all unutilised waste shall be converted to ethanol.
***Utilisation improvement scenario* assumes that waste utilisation rate be equivalent to the 2020 targets set in the Basic Plan for the Promotion of Biomass Utilisation (95 percent for construction waste timber and 40 percent for food waste) and all the increase in recovery be allocated to ethanol production.

Keeping in mind the above limitations of the estimates, it can be concluded that the figures show that both construction and food waste have the potential to increase the current production capacity significantly. Under the *utilisation improvement scenario*, the increase in ethanol production capacity through construction waste timber would be 1.6 times and through food waste would be almost 4 times. More importantly, each type of waste has the theoretical potential to meet the domestic production target set for 2011 respectively. The estimate for the construction waste under the *utilisation improvement scenario* is almost equivalent to the target and the potential of food waste is 2.5 times higher than the target. However, if compared with the introduction targets, production potentials of waste-based ethanol seem modest. Even food waste can supply only 34.1 percent of the introduction target required for the oil refiners under the Law for the Sophisticated Structure of Energy Supply and 14.3 percent of the Kyoto Target Achievement Plan. Besides, the shares to the current gasoline supply (57 million kilolitres in FY 2008[35]) are still extremely low (0.05 percent for construction waste timber and 0.13 percent for food waste under the *utilisation improvement scenario*).

Thus, waste-based ethanol from both construction waste timber and food waste seems to have a substantial potential for a sound material-cycle society by converting unutilised biomass waste which is otherwise incinerated. In addition, the potential amount of such waste-based ethanol production seems significant in comparison with current production status and domestic production target, while the share seems modest compared with the introduction targets.

Consideration of other recycling options

The estimates in the above subsection assumed that currently unutilised but potentially available construction and food wastes would be used for ethanol production. However, in practice, ethanol production is not the only option to recycle such wastes and the allocation of these wastes needs to consider the principle of a "Sound Material-Cycle Society." The related laws and principles clearly state some priorities of waste utilisation. First and foremost, the fundamental law clearly prioritises reducing waste generation over recycling. Therefore, the fact that the waste can be recycled into products such as ethanol should not be used as an excuse for continuing to waste foods.

Noting the importance of waste reduction does not deny the importance of recycling, as generation of waste to some extent is inevitable. Among the recycling uses of waste, priorities are also laid out in the basic principles of the specific recycling laws. The Basic Principles of the Construction Materials Recycling Act states that recycling of construction waste timber shall be first used in the form of wood chips for producing wood board and compost, and use as fuels shall be considered only if such uses are not appropriate from technological and environmental point of views. Similarly, the "Law for the Promotion of the Utilization of Recyclable Food Resources (Food Recycling Law),"[36] puts the higher priority on recycling into animal feed over

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35 Gasoline consumption data were drawn from the Energy Whitepaper 2010 published by METI. The conversion from the potential values in ethanol to gasoline was done according to the following calculation

gasoline = ethanol × 21.2 GJ/kl (ethanol lower heating value) ÷ 32.9 GJ/kl (gasoline lower heating value)

36 "Shokuhin Junkan Shigen no Saisei Riyo tou no Sokushin ni kansuru Horitsu (Syokuhin Risaikuru Ho)"

other recycling measures (compost, oil and oil products, methane, carbonised products and ethanol), for the sake of increasing the sufficiency rate of feed by making the most of the contents and calories of food based circulative resources.[37] In short, although use of fuels and ethanol production are considered as one of appropriate recycling measures in those laws, there are other measures with higher priorities such as wood board, compost, and animal feed. Accordingly, waste-based ethanol production should be considered from the perspective of a cascade use of biomass waste. To have a sound judgement on the cascade use, thorough analysis of the potential of waste reduction and material recycling will be necessary when deciding how much of the unutilised construction waste timber and food waste should be converted to energy.

Once it is decided to use the waste for energy, as energy conversion of waste includes not only ethanol production but also various measures, assessment is needed to make decisions on which measures should be taken or how they should be integrated. In order to maximise the contribution to a sound material-cycle society, such decisions should reflect the energy needs of the community as well as energy efficiency and marketability.

Among such measures, the advantages of ethanol production from waste wood are contingent on the development of the second-generation biofuel production technology from lignocellulosic feedstocks. In comparison, heat and electricity generation from woody biomass in the form of solid fuel has a longer history of application and some studies suggest that those uses usually require less fossil energy input than production of liquid biofuels (Cherubini *et al*. 2009). Yet, it could be argued that ethanol production from waste timber has some opportunities. For example, it can be stored and transported easily and has high energy density (Kumazaki 2000). Also, the interviewee of BJK claimed from a business point of view that ethanol has a large marketability as it can be mixed with gasoline, and, if introduction policies are appropriately implemented, the ethanol produced can be fully utilised.

Likewise, food waste can be used for production of refuse-derived fuel (RDF) or methane fermentation. Advantages of RDF include long-term storage, easiness for transportation, and stability in combustion. Although development of RDF facilities have spread nationwide in Japan since 1984, its introduction declined after explosions at an RDF power plant in Mie Prefecture and some troubles in other places such as Fukuoka and Ishikawa Prefecture. Another measure is a methane fermentation (biomethanation) process to produces biogas, which can be used for generation of both electricity and heat. Biomethanation is already commercialised for not only food waste, but also for cattle waste, sewage sludge and waste water, with the number of biogas plants gradually and steadily increasing in Japan. The shortcomings of biomethanation include low digestion ratio, low removal ratios of ammonium and phosphate, long treatment time, and necessity of heat (The Japan Institute of Energy 2008). In addition, a full utilisation of biogas is constrained because its composition is different from liquefied natural gas (LNG) and requires adjustment of the content and calorie (Soma 2010). Compared to biomethanation, ethanol production is behind as its commercialisation just started in 2010, after the completion of the pilot project by NSE. Strengths of ethanol production from food waste include high rate of fermentation, compact size of production facilities, and ease in handling and storage. It also

[37] Ethanol production from food waste was added as an approved method of recycling in the partial amendment of the Food Recycling Law in 2007.

has a high potential in terms of energy efficiency as fat contents of food oil can also be collected during the process (Hidaka 2010).

Therefore, when considering the contribution of biofuels to a sound material-cycle society, it needs to be noted that biofuel production is not the only option for waste recycling. Decisions related to utilisation of waste should be made based on full consideration of the principle of a "Sound Material-Cycle Society." Specifically, in order to maximise the contribution of waste-based ethanol production to a sound material-cycle society, it is necessary to consider the balance at multiple levels, addressing the questions such as: "Can the waste further reduced?," "Can the waste be allocated for higher priority uses such as wood board, composting, or animal feed?," or "Which energy conversion measures would suit the community's need and how should such measures be integrated?"

Some of the above questions were addressed in one way or another when the projects examined in this paper were planned. In the case of BJK, when the project was launched, it was recognised that waste wood is usually thermally recycled in the form of wood chips through combustion or electric generation. However, the decision was made to produce ethanol from construction waste on the ground that ethanol production is a "material recycle" and it can process not only industrial waste but also general waste such as pallets (Kaneko 2007).

Likewise, in the ethanol production project from food waste, other options were reviewed. Conversions to animal feeding and fertiliser were found to have some limitations including: difficulty to sort out mixed trash such as lunch boxes. Methane fermentation was also assessed from two perspectives, namely, conversion and final use. In terms of conversion, methane was found not to be commercially viable due to a low energy profit ratio and cost of residual treatment. From the view of final use, in order to utilise the gas generated through methane fermentation, infrastructures are needed to convert the energy to electricity and transmit it (NEDO 2007).

2. Contribution to GHG emissions reduction

-Would such waste-based ethanol production also result in GHG emissions reduction?-

It is technically reasonable to expect GHG emissions reduction from the production and use of waste-based ethanol. First, it has potential to reduce GHG emissions by reducing the unutilised waste which would be otherwise incinerated. Second, by partially replacing fossil fuels with produced ethanol, GHG emissions can be also reduced. The introduction target of liquid biofuels for transport in the Kyoto Protocol Target Achievement Plan focuses on this category of GHG reduction. In the Kyoto Protocol, biofuels produced from plants are considered to be "carbon neutral," as the feedstock plants absorb carbon dioxide (CO_2) in the atmosphere while they grow. In addition, waste-based ethanol production does not require additional land to produce feedstocks and thus does not cause deforestation.

However, estimating GHG emissions reduction from waste-based ethanol is not straightforward. There have been some life cycle assessments (LCA) on GHG emissions reduction related to our case studies, although still limited in numbers. For example, the Committee on the Sustainability Criteria related to Biofuel Introduction[38] concluded that "the feedstocks with potential of GHG emissions reduction by more than 50 percent are sugarcane in Brazil (existing croplands), domestic sugar beet, and construction waste timber." The estimated lifecycle unit emission value (including feedstock transportation, fuel production, and fuel transportation) for construction waste timber varies from 8 gCO_2/MJ to 23 gCO_2/MJ. The lowest value shows that the ethanol produced through the plant process could reduce GHGs by 90 percent compared to gasoline.[39] However, the report itself noted caveats related to the reported values on domestically produced biofuels, including: small scale of the domestic biofuel production plants, insufficient amount of sample data for setting default values, and differences in operation conditions among the plants.

Specifically, the estimate related to construction waste timber should be regarded as an upper bound, because the calculation attributes GHG reductions not only to ethanol production itself but also to the production of a sub-product (lignin). However, this caution does not mean that GHG emission reduction potential of construction waste timber does not seem promising. Even if the GHG reduction from a sub-product is excluded, the estimated lifecycle emission per MJ is 34 g CO_2 and shows a larger reduction of more than 50 percent compared to the lifecycle unit emission of gasoline adopted in this estimate (81.7g CO_{2eq}/MJ).[40] Another point which should be considered when treating those values is that LCAs compared with only gasoline are important but not sufficient. In order to assess the GHG emission reduction rigorously, assessments should be carried out for other measures for energy conversion, such as use as solid fuels (Moriguchi 2009). Thus, the interpretation of those figures requires careful judgement, given that estimated unit emission still has a wide variation, the calculation includes GHG emissions of sub-products, and comparison is only done with gasoline.

In relation to a food waste ethanol production facility, an LCA study estimated the environmental impact of the case when a food waste ethanol production facility with the same system as the one in the Kitakyushu is introduced assuming a city with a 450 thousand population and residential area of 56 square kilometres. The study concluded that the CO_2 emissions reduction would be only 9.2 percent compared to the business-as-usual case (no separation of food waste from municipal waste) if only business type municipal waste is converted into ethanol, and 26.5 percent if household municipal waste is added to the previous case (Minagawa *et al.* 2010). Although this study provides valuable implication, it should be noted that the estimates would vary greatly among individual cases based on the assumptions.

Therefore, while the available LCA studies generally support the potential of GHG emissions reduction from ethanol production from construction waste timber and food waste, the exact

[38] "Baio Nenryo Donyu ni kakaru Jizoku Kanosei Kijun tou ni kansuru Kentokai"

[39] Other cases include: NEDO process in which both electricity and steam would be supplied by lignin (by-product) (86 percent reduction); NEDO process in which only steam would be supplied by lignin (77 percent reduction) and EU Directive case (72 percent reduction).

[40] Yuichi Moriguchi, National Institute for Environmental Studies, e-mail message to author, 18 March 2010.

degree of the reduction still remains inconclusive, calling for more studies for both methodologies and assumptions.

3. Facilitating factors

-Are there any common facilitating factors to promote biofuel production from urban wastes?-

This study identified three main common facilitating factors behind the initiation and implementation of waste-based ethanol production. First, both projects received financial support from the government. Second, both waste materials are regulated under the specific laws related to the Fundamental Law for Establishing a Sound Material-Cycle Society. Third, both production facilities were located in the Eco Towns. This section examines those factors, namely, the roles of subsidies, laws related to recycling and Eco Towns, to see how those factors facilitated the waste-based ethanol production cases.

Subsidies

Both reviewed projects received subsidies from the government, albeit from different major funding ministries. The ethanol production project from construction waste timber in Osaka received the fund for "Business Model Incubator Project Fund to Address Global Warming" [41] by the MOE . The total funded amount was approximately JPY 2 billion, which is the half of the construction costs. Regarding the operation of the plan, the company does not receive subsidies, except for a subsidy from the Osaka Prefecture for fuel quality management. On the other hand, the ethanol production pilot project from food waste in Kitakyushu was fully funded by the NEDO, a semi-governmental organisation under METI, as a commissioned project ("Biomass Energy Regional System Development Project"). It also received subsidies from the MOE for installing the filling station of E3 for the test driving. Thus, the justification of subsidisation in one case was to address global warming in one case and to promote biomass energy regional development in the other.

Laws related to recycling

In addition to the financial support by the government, the laws related to recycling which were introduced in Japan in the early 2000s seem to have provided the enabling policy environment for waste-based ethanol. The Fundamental Law for Establishing a Sound Material-Cycle Society was promulgated in July 2000 and enforced in January 2001, with the aim of securing a material cycle in society by revising the present state of our mass-production, mass-consumption, and mass-disposal society and lifestyle, to thereby establish "a sound material-cycle society" where consumption of natural resources is curbed and the environmental load is

[41] "Chikyu Ondanka Taisaku Business Model Inkyubeta Jigyo"

decreased. This law is considered as a "basic framework law," and five specific laws were promulgated to regulate different recyclable resources, namely, containers and packaging, home appliances, food resources, construction materials, and end-of-life vehicles (Table 6).

Table 6. Specific Laws under the Fundamental Law for Establishing a Sound Material-Cycle Society

Name of the law	Dates of Enforcement/ Amendment	Outline of regulations	Specific items to be recycled
Law for the Promotion of Sorted Collection and Recycling of Containers and Packaging	Completely enforced in April 2000 Partially amended in June 2006	• Sorted collection of containers and packages by municipalities • Recycling by container manufacturers and business operators who use containers and packages	bottles, PET bottles, paper or plastic containers and packages
Law for the Recycling of Specified Kinds of Home Appliances	Completely enforced in April 2001	• Collection of waste electric appliances from consumers by retailers,etc. • Recycling by manufacturers, etc.	air conditioners, refrigerators & freezers, TVs, washing machines
Law for the Promotion of the Utilisation of Recyclable Food Resources	Completely enforced in May 2001 Partially amended in June 2007	• Recycling of commercial food waste by food manufacturers, processors, and retailers	food residues
Construction Materials Recycling Act	Completely enforced in May 2002	• Sorted demolition, etc. of buildings • Recycling of construction waste materials, etc. by contractors	timber, concrete, asphalt
Law for the Recycling of End-of-Life Vehicles	Partially enforced in January 2003 Completely enforced in January 2005	• Collection of used vehicles, collection of CFC gas, demolition, and crushing by concerned business operators • Recycling of airbag shredder dust, and destruction of CFCs by manufacturers	vehicles

Source: MOE 2009a

The Construction Materials Recycling Act, completely enforced in May 2002, covers demolition works or new construction which uses designated construction materials (concrete, asphalt concrete and timber) larger than a certain scale and obliges the contractors of such works to conduct sorted demolition and recycle waste materials. The Food Recycling Law, completely enforced in May 2001 and partially amended in June 2007, regulates handling of commercial food waste from food manufacturers, processors, and retailers.

Both laws set targets for recycling in the basic principles of each law. The Basic Principles of the Construction Materials Recycling Act set the common target recycling rate of 95 percent in FY 2010 for three kinds of waste materials (concrete lumps, asphalt concrete lumps and construction waste timber). As discussed above, construction waste timber has not achieved the target while the other two categories already have a higher recycling rate than the target.

The targets in the Basic Principles of the Food Recycling Law are set for each category of business for the FY 2012 as listed in Table 7 along with the actual recycling rates in 2007. The Table shows that both food manufacturers and wholesalers already achieved the target and food retailers and restaurants need to make further efforts.

Table 7. Target and recycling rate of different categories of food waste

Source of waste	Target for FY 2012 (percent)	Recycling rate achieved in FY 2007 (percent)
Food Manufacturers	85	86
Food Retailers	45	41
Food Wholesalers	70	70
Restaurants	40	31

Source: Statistics Department of the Minister's Secretariat of MAFF 2009

The positive effects of these laws on facilitating cooperation between waste generators and recyclers were noted in the interviews with both project implementers. Also mentioned was that these laws raised the awareness of waste separation and recycling by both construction companies and food related businesses. Besides, the laws introduced the rules of cost burden. As the ordering parties of construction need to pay the treatment costs under the Construction Materials Recycling Act, the ethanol production company could raise revenues to the project in the form of waste treatment fees.

Roles of Eco Towns

Eco Town Plans are implemented under the coalition of the MOE and METI, with the aim of establishing a socio-economic system with environmentally-sound resource cycles in the local areas. Projects under approved plans can receive comprehensive and multifaceted support from the ministries. As of March 2010, there are 26 Eco Towns in Japan. According to an evaluation of the Eco Town Projects published in 2009, approximately 2.2 million tonnes of circulative resources (waste and by-products) have been put into Eco Town facilities nationwide and the utilisation rate of such inputs is as much as 91 percent, in the form of either material or energy (including reduction). It also estimated the contribution of Eco Town facilities to the reduction of the final disposal waste to be 1 million tonnes, which is equivalent to approximately 3 percent of the final disposal waste in 2005 (MOE 2009b).

The ethanol production facility from construction waste timber in Sakai City was among the seven recycling facilities launched under the Osaka Eco Town Plan (24th Eco Town Plan). Those facilities set up a Promotion Council in collaboration with related local governments for information outreach and collaboration among the parties. The contribution of the Promotion Council to enhance collaboration among the recycling facilities to solve common problems related to recycling and waste treatment was stressed by the project implementer during the interview, stating that locating the plant in the Eco Town where many recycling facilities operate was very beneficial for the company and it would have been more difficult otherwise if the company had to carry out business alone. Meanwhile, in terms of physical cooperation, the ethanol production plant in Osaka Eco Town does not share any heat or electricity with neighbouring facilities.

On the other hand, the food waste ethanol pilot plant, which is located in the Next Generation Energy Park in Kitakyushu Eco Town, made the most of the exchange of martial and energy with the neighbouring gasification melting furnace: the ethanol production utilised waste heat from the furnace and provided residue as a solid fuel to the furnace. However, the interviewee commented that opportunities of food waste ethanol production plants should not be limited within Eco Towns but any place where production facilities are constructed in vicinity to energy plants such as gasification melting furnaces.

These findings indicate that Eco Towns had a role to play in one way or another. In one case, it was more on the “soft” side at the moment, meaning that the Eco Town enabled collaboration among the recycling facilities to solve the common problems. In the other case, physical linkage with other waste treatment facility improved the energy efficiency of the plant operation.

4. Major barriers

-What are the major barriers for the implementation of urban waste-based ethanol production?-

Waste-based ethanol production consists of three major steps: collection of feedstock waste, ethanol production, and sale or use of the ethanol. Although the technical aspect is very important, as a policy discussion paper, this section focuses on the challenges related to the collection of the feedstock waste and ethanol sale/use. In the area of feedstock collection, challenges were identified in two areas: difficulties in collecting waste from small scale generators and intensifying competition over waste wood supplies. Regarding the sale or use of the ethanol, the division on specifications of ethanol blended gasoline was found to be a challenge.

Separation and collection system from small scale waste generators

While NSE, the project implementer of ethanol production pilot project from food waste, concluded that their pilot project was completed successfully, one remaining challenge was noted in their press release: how to develop a separation and collection system of food waste which does not increase collection costs (NSE 2010).

The Kitakyushu Citizen Environmental Passport Programme[42] provided the incentives for citizen participation and was recognised by the interviewee of NSE as effective and valuable for the pilot study. However, it was pointed out that the system was based on the funding by the Kitakyushu City government and, in order to develop a less costly collection system, a new scheme should be developed to promote voluntary cooperation from the citizens.

In addition, the project data indicate the difficulty of collecting from smaller sources. According to the mid-term report of the project published by the Kitakyushu City government, the amount collected from small scale sources was much less than the amount collected from larger sources. That is, only a total of 0.3 tonne of food waste per day was collected for the ethanol production project from small scale waste generators, including not only households but also shopping streets, elementary schools, and a hospital. In comparison, 9.7 tonnes per day could be collected from larger sources including department stores, supermarkets, convenience stores, and hotels, as a part of the project (Kitakyushu City 2007).

As already discussed, domestic kitchen waste has a very low recycling rate (6 percent) even though it consists of 57 percent of the total food waste. Promotion of separation and collection of household food waste would be a key for enhancing the recycling rate of food waste. However, the Food Recycling Law obliges only for the large scale business (i.e. a business entity which generated more than 100 tonnes of waste during the previous year) to submit periodical reports but not for smaller sized enterprises. In many cities of Japan, treatment fees

[42] See Chapter 4 for more details of this programme.

for incineration set by the municipal governments are found to be lower than the recycling costs, and small-scale business entities find it difficult to commit to recycling (Environment Institute for Plan Inc. 2009). Thus, some argue that the current law system has provided very weak incentives for small scale waste generators to separate and collect waste.

The issue of small scale waste generators is also common to construction waste timber. Under the current law, demolition works and new construction under a certain scale are exempted from the regulation. A petition was submitted to include smaller scale demolition works to improve the recycling rate and making the regulation more effective by the National Wood Waste Recycling Association.[43]

Therefore, it would be worth revising the exemption conditions of small-scale waste generators in both the Food Recycling Law and the Construction Materials Recycling Act. However, it should be noted that smaller scale projects tend to be less effective in collecting and transporting waste resources. In order to identify appropriate level of exemption, it is necessary to conduct research on the relationship between the scale of business/project and recycling rate, and to examine the feasibility of the efficient systems to collect and transport the waste resources (Subcommittee on Construction Recycling Promotion of the Panel on Infrastructure Development and Expert Committee on Construction Recycling of the Central Environment Council 2008).

Competition over waste resources

In recent years, the wood chip market has been experiencing drastic fluctuation. One cause is an increase in demand for biomass energy. According to the MIC, the number of power generation facilities utilising wood biomass has increased to 144 in 2008 from 26 in 2002 and this increase seems to be facilitated by the supporting projects by the ministries such as the MAFF and METI based on the Biomass Nippon Strategy (MIC2011). Other factors for the increase in biomass energy are found to be strengthening the Renewable Portfolio Standard (RPS) Law and requests to the construction companies for Corporate Social Responsibility (CSR).[44] One further factor of the fluctuation in the wood chip market is a reduction in supply of construction waste timber due to stagnation in the construction market. As a result, the competition over wood chips among companies is reported to have intensified (Kankyo Shimbun 2010). This market climate has also affected the operation of the ethanol production plant from construction waste timber. The production plant has not been operating to full capacity in order to adjust to the shortage in supply of waste timber and thus has been making a lower than expected profit.

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43 Zenkoku Mokuzai Shigen Risaikuru Kyokai Rengokai. http://www.woodrecycle.gr.jp/2010/01/21_1.html (accessed 4 August)

44 Comment by Shunsuke Aoyama at the Third Meeting of the Expert Committee on Biomass Utilisation Promotion on 27 August 2010, Tokyo.

Divided specifications on ethanol-blended gasoline

The “exit routes” of the produced ethanol were different between the reviewed two cases. In the case of ethanol produced from construction waste in Sakai City, the product is sold to two refineries, which blend ethanol with gasoline to produce E3. In the case of ethanol from food waste, the ethanol was not for sale but used for an experimental test of E3 using official vehicles of Kitakyushu City government and its own company vehicles. However, in both interviews, a challenge due to a lack of cooperation from the refineries affiliated with the Petroleum Association of Japan (PAJ) was mentioned. This challenge is related to the fact that there are two different specifications in the bioethanol-blended gasoline market caused by a disagreement between the MOE and the PAJ. While the MOE favours bioethanol directly blended with gasoline, which is a common method in most countries, the PAJ prefers blending of bioethanol-based ETBE. The PAJ's rationales include that E3 increases the chances of photochemical oxidant formation due to increased vapour pressure, and has higher risks of changes in fuel properties when accidentally mixed with water. Those divided specifications especially affect BJK. BJK needs to transport the produced ethanol over 1,000 km to a refinery in Okayama Prefecture to directly blend with gasoline, as refineries affiliated with PAJ do not conduct direct blending. The blended gasoline, in return, is transported back to petrol stations in Osaka as a part of the project to promote E3 by the Osaka Prefecture government. This lack of the agreed national principle was noted in the screening process to reduce the national budget in 2010, and consequently the MOE’s budget related to E3 promotion was requested to be halved.

5. Policy Implications

-What are the policy implications for facilitating contributions of waste-based ethanol production towards a sound material-cycle society?-

In this section, policy implications towards a sound material-cycle society are drawn based on the above discussions. Firstly, it was found that, in order to fully assess the potential of waste-based ethanol in terms of GHG reduction, more efforts are needed to improve the assessment methodology. Secondly, as the use of construction waste timber has substantially increased owing to facilitating factors such as subsidies and the related recycling law, competition over the wood waste has started to emerge ironically. This implies a need for improved coordination among the related ministries. Thirdly, use of unutilised logging residue should be considered to fully utilise the technologies to produce ethanol from wood resources. Fourthly, policy responses are needed to improve the waste collection from small scale sources, which was identified as one of the challenges. Lastly, the implications to other Asian countries are discussed as other Asian countries are facing more rapid increase in waste as their economies develop.

Improvement in assessment methodology

The extent of contribution that waste-based ethanol could make not only for waste reduction but also for GHG reduction should be properly assessed, in order to secure its sustainable use. As the examination of the current LCA results indicated, there are still uncertainties related to the GHG emission reductions potential of waste-based ethanol in Japan. Meanwhile, the importance of LCAs will increase worldwide as sustainability criteria are being implemented at the country and regional levels. Those standards are already introduced in EU (Directive on Renewable Energy), United Kingdom (RTFO: Renewable Transport Fuel Obligation) and the US (Renewable Fuel Standard), and now being examined in Japan. Further efforts are needed to improve the LCAs on domestically produced biofuels and identify how much contribution waste-based ethanol can make for GHG emissions reductions.

Coordination among the related ministries

Government support promoting the use of biomass waste, in forms such as providing subsidies, is important for a sound material-cycle society. Such support seems to have contributed to an increase in recycling rates of waste resources. Now that the recycling rate of the construction waste timber has increased quite significantly, the decision should be more coordinated among the related ministries and they should consider the data on the available amount of the unutilised waste to avoid triggering over-competition beyond the available amount of resources. As discussed in the previous section, governments support seems to contribute to the increase in the number of biomass power generation facilities and affects competition over waste wood. The problem is not that the related ministries are supporting biomass utilisation but that such government support is not necessarily coordinated. The policy evaluation report by the MIC on the Biomass Nippon Strategy points out that biomass-related projects are supported by different ministries or different sections of the same ministry (MIC 2011).

Therefore, the decisions related to government subsidies on utilisation of wood biofuels, whether it is for power generation or ethanol production, need more coordination. For such coordinated decisions, data on the availability of the waste is important. As quantitative data and analyses are insufficient regarding the status of the quantity of construction waste which are actually incinerated as “reduction” and the demand for wood chips in Japan, development of a database on demand and supply of waste timber would be necessary (Subcommittee on Construction Recycling Promotion of the Panel on Infrastructure Development and Expert Committee on Construction Recycling of the Central Environment Council 2008). Such a database should contain information related to the quantity of generated construction waste, the actual available amount (the amount which is not incinerated), and the treatment capacities of the projects aiming to utilise wood waste.

Potential for utilising forest logging residues

It is important to expand the scope of the utilisation of wood biomass resource from construction waste timber to logging residues. In Japan, as the utilisation rates of not only construction waste timber but also saw mill residues are increasing due to the sharp rise in demands as discussed above, the role of logging residues in the forests is becoming important. According to the report by the Biofuel Technology Innovation Conference (2008), the utilisation of logging residues remains as low as 2 percent among the generated amount of 3.4 million tonnes per year, leaving 3.3 million tonnes of wood unutilised. This unutilised amount of forest logging residues is almost equivalent to the construction waste recycled in FY 2008. The reasons of this extremely low rate of forest biomass utilisation include difficulties and high costs of collection. The total costs related to procurement of forest logging residue are estimated to be from JPY 15,000 to 30,000 per tonne, including the logging costs of JPY 4,000 to 15,000 per tonne. Those costs are much higher than in other countries with advanced forest roads and forestry machines. For example, data shows that the cost could be between JPY 2,000 to 3,500 in Austria (Biofuel Technology Innovation Conference 2008). In addition, there is a lack of a proper market or "exit route" for the thinned wood, which is considered as one of the barriers for maintaining forests in a good condition. Integrating the forest logging residues into the currently intensified wood biomass market and thus providing exit routes for logging residues would further promote a sound material-cycle society (Katsuki 2010).

Small scale waste generators

Enhancing separation and collection from small scale waste generators is the key to achieving a sound material-cycle society. Specifically in Japan, both the Construction Materials Recycling Act and the Food Recycling Law would need to be revised in terms of the exemption conditions of small scale generators. The project on food waste showed that ingenious approaches such as introduction of garbage collection trucks with two separate cells or a point system to reward collaborating citizens could improve such collections by reducing costs and encouraging citizen participation. More holistic approaches should be further developed to make a major breakthrough. For this purpose, collaboration among stakeholders including citizens, non-governmental organisations (NGOs), private companies, and local government would be very important especially in the area of food recycling.

Potential in other Asian countries

It would be worth considering the applicability of waste-based ethanol to other Asian countries. Technical possibilities to apply the same technology to ethanol plants in Asian countries were affirmed during the interviews. In fact, a project based on the same technology adopted by the ethanol plant in Sakai City was already launched in Thailand by Marubeni Cooperation (trading company), using sugarcane waste and bagasse (Komabashi 2010). Potential bottlenecks would be availability and collection of feedstocks and cost, similar to the challenges found in Japan. If waste timber collection systems are successfully developed and measures are taken to avoid deforestation, ethanol production from waste wood might become an effective policy option in Asia. The Asian Region is rich in biomass resources and at the same time it is experiencing an increase in waste as its economies grow. As a result, international cooperation in the effective use of waste shall be crucial from the perspective of a sound material-cycle society.

Chapter 6

Conclusion

This paper reviewed two cases of waste-based ethanol production and discussed the potential for waste and GHG emissions reduction, facilitating factors and challenges, and policy implications.

Data show that waste-based ethanol production from construction waste timber and food waste can make a certain contribution to a sound material-cycle society by promoting the recycling of unutilised urban wastes. The production potential of ethanol from these wastes with the technology used in the case studies were estimated for two scenarios, namely, the scenario assuming utilisation of all unutilised waste and the scenario assuming more realistic utilisation improvement. The results for both scenarios indicated significant increases in domestic production capacity and contribution to the domestic production target set by the Biomass Nippon Strategy Promotion Council (50,000 kilolitres in ethanol in FY 2011). However, compared with the introduction targets, the contribution of waste-based ethanol was found to be modest. In the light of the regulations and laws under "Sound Material-Cycle Society," decisions on how to allocate unutilised waste, that is, how much can be used for ethanol production, should consider multiple factors. In terms of GHG emissions reduction, the exact degree of GHG emissions reduction from urban wastes remains inconclusive at this stage although existing LCA studies for both scenarios show a potential net GHG reduction.

In terms of facilitating factors of waste-ethanol production, this study identified the important roles of subsidies, recycling laws and Eco Towns. Both projects received subsidies even though the major funding ministries were different. Subsidies played a crucial role in the projects: one was fully funded and the other received support for half of the plant construction cost. The recycling laws, the Fundamental Law for Establishing a Sound Material-Cycle Society and its specific laws related to construction materials and food waste, had significant impacts on both waste-based ethanol production cases by motivating the waste generators to cooperate and by providing revenue source in the form of a waste treatment fee to the ethanol production facilities. Eco Towns and support by the national government for local efforts to promote environmentally sound resource cycles, were found to be effective in two ways: collaboration among the facilities within the Eco Town in one case, and exchange of material and energy in the other.

One of the major challenges commonly found in these two cases was waste collection from small scale waste generators. The second challenge, which was specific to the construction waste timber case, was intensified competition over waste wood. The third challenge was the existence of two different specifications of ethanol blended gasoline.

Based on the above discussions, the following policy implications towards a sound material-cycle society were drawn. First, improving the LCA of the contribution of waste-based ethanol for GHG reduction is important in order to secure the sustainable use of waste-based ethanol. Second, government support promoting the use of biomass waste should be more coordinated among the related ministries and should consider the data on the available amount of the unutilised waste to avoid triggering over-competition beyond the available amount of resources. Third, in order to utilise wood biomass resources, utilisation of logging residue should be also considered. Fourth, developing effective systems for separation and collection from small scale waste generators is crucial. Fifth, applicability of waste-based ethanol to other Asian countries should be examined from the perspective of a sound material-cycle society.

Further research would be needed on the points raised as policy implications, in order to develop more concrete policy suggestions. For example, on the issue of collection from small scale waste generators, more detailed analyses on stakeholders and important factors leading to successes or failures would provide useful insights for policy-makers to enhance a sound material-cycle society. In addition, additional case studies, related to not only Japanese experiences but also those of other countries, would be beneficial to enhance understanding of the relationship between waste-based ethanol production and a sound material-cycle society. Specifically, as this study uncovered the relationship between energy and waste policies in the discussion on facilitating factors, analysing case studies from the viewpoint of linkages between those policies would provide beneficial policy implications to further promote a sound material-cycle society not only in Japan but across the Asia Pacific region.

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