Okhotsk Sea and Polar Oceans Research 3 (2019) 7-12

https://doi.org/10.57287/ospor.3.7

Article

Utilization of discarded and unused woody materials for biomass heating and power plant

Tsuyoshi YODA[1,2]

[1] *City Mombetsu, Mombetsu, Japan*
[2] *Hirosaki Industrial Research Institute, Aomori Prefectural Industrial Technology Research Center, Hirosaki, Japan*

(Received June 5, 2018; Revised manuscript accepted December 25, 2018)

Abstract

The global warming due to increases of warming gases in the atmosphere has well been recognized in the world. Reducing the emission of CO_2 is crucial now for every nation together with its regional governments. As biomass energy resources, discarded and unused woody materials from local forests will be one of the solutions, as the trees have consumed a great amount of CO_2 through the lifetime and they will emit nearly equal amount of CO_2 when burning, and the CO_2 liberated from their burning might be able to be isolated from the atmosphere into storage. The economic aspects are always key issue in biomass energy. Putting stress on the economic aspects of biomass energy, the author studied the biomass fuels for heating units and power plants on its present state and future prospective, in a local city in Hokkaido, northern island of Japan, where cold and frequent heavy snowing are typical in winter.

Key words: biomass energy, discarded wood, unused wood, heating, power plant

1. Background

Energy shortage such as oil and gas has featured Japan, where the society and industry have long covered it by import from rich countries in natural energy. Coal, abundantly reserved in Japan, is only an exception. However, unfortunately, most of coal found in deep under-ground layers has been defeated in its market by oversea cheap ones produced from opencast mines, and even coal has been imported.

Mountainous nature with few long and magnificent rivers and narrow continental shelves, has impeded development of water, tidal and wind forces as typical renewable energy. Contrary to the U.S. and other large countries, mountainous country does not directly mean rich in usable biomass reserves, particularly in wood, since the steep mountains often bring about relatively high market prices of those woody products, in particular, of discarded wood in forests.

The global warming due to increases of warming gases in the atmosphere has well been recognized in the world. Reducing the emission of CO_2 is crucial now for every nation together with its regional governments, through overcoming any hindrance and negative background. As biomass energy resources, discarded and unused woody materials from local forests will be one of the solutions, as the trees have consumed a large amount of CO_2 through the lifetime and they will emit nearly equal amount of CO_2 when burning, and the CO_2 liberated from their burning might be able to be isolated from the atmosphere into storage. As an alternative fuel from local forests will be one of the solutions, as the forest has consumed a great amount of CO_2 through its lifetime and it will emit the equal amount of CO_2 when burning and the CO_2 liberated from its burning might be able to be isolated from the atmosphere in storage. It will have an opportunity to bring great benefits to the environment with some measures to reduce the amount of the emission greatly. The energy stored in wood is able to be converted into useful energy by transferring heat from combustion to hot water, where boilers play key role. Biomass boilers have been developed in the world as alternative heating source generators to coal boilers (Saidur and others, 2011, for an instance).

Biomass boilers are used for heating buildings; industrial premises, central and municipal heating plants, farm building, hotels, operating facilities, etc. In Hokkaido, biomass boilers have widely been in use (Kuboyama, and others, 2004; Official Website of Hokkaido Prefecture 2018a, 2018b; Niseko's Towns efforts as an Eco Model city).

Eventually, the forest should be properly managed to keep it well in order to sustainable use of biomass woody materials, and to prevent illegal deforestations and any harmful activity, certificate systems should be requested for forest enterprises and performing parties and persons, together with related regulations (Yamamoto and others, 2014). The Sustainable Green Ecosystem Council (SGEC) established in 2003 provides a unique certificate system for forest sustainability, which is oriented toward the peculiar situation in Japan, where afforestation prevails and a number of small size forest owners holds a majority in its society. SGEC has controlled the amount of logging activity per year and area, ordered forestations after logging, and set up forestation plans and their road maps to future.

In the wider definitions, biomass includes agricultural and food processing wastes as well as sewage sludge and animal manure. The paper does not take considerations about them. Two clear reasons exist. One of them is that the amount of those fuel sources could not be available in cities of relatively small size in populations. The other is that the total amount of discarded wood over Hokkaido is about 110mil.m^3, of which 40 mil. m^3 is utilized as biomass energy source at the present. There remains considerable amount of discarded woods to be able to alter to active energy.

There are a few kinds of biomass fuels that come from local forests. They are wood pellets, precision dry wood chips, green wood chips, and general discarded wood chips. The main differences between them will be moisture content, calorific value, bark percentage, the amount of processing each one goes through, and the price as a consequence. The wood pellets, most energy dense one, usually contain a moisture between 5% and 8%, and they are the driest and easiest to manage. However, the pellets need large forest resources and slightly big consumer markets. Discarded wood chips will include the byproduct pieces and chips of lumbering, which are slightly different from the discarded ones in forests.

In the local city the present paper discusses, for the moment at least, the consumer market is not large enough for the pellets to be appropriate for purposes of heating and/or power generation. In the discarded wood, the bigger ones are the more useful as fuels. When the marketable timbers are taken away from the forest, the bigger ones are usually left in the forest, due to the cost to remove them, and as a consequence, they remain as obstacles for afforestation in the forest.

The biomass fuel resources are found abundant in regional forests in Hokkaido. For instance, the Official Website of Hokkaido Prefecture(2018b) noted the amount 1,110,000 m^3/year of them was left in the Hokkaido prefecture. Such large amount of discarded wood left in the forests aroused the interest of the regional researchers, to generate energy for heat through boilers for the regional societies. They soon found the transport cost of the discarded wood from the forests to boilers caused a main hindrance in this renewable energy usage, which included secure of transport measures, including preparing devices to transport them. The transport measures are often expensive. Both national and regional governments support the project by purchasing main particular devices and/or granting subsidies to the enterprises. Up to the present, the society of Japan has relied on imported fossil fuels to large extent. Although fossil fuels have higher calorific value per kg. and easy to manage, their prices have been unstable and fossil fuel resources are of limited amount of resources.

A previous study investigated the economic aspects of biomass related ecosystems (Bateman and others, 2011). However, the society and the market discussed in it are different from those of the present study. The economic aspects are always key issue in biomass energy. On the economic point of view of energy, the author studied the biomass fuels for heating units and power plants on its present state and future prospective, in a local city in Hokkaido, northern island of Japan, where cold and frequent heavy snowing are typical in winter.

2. Government policies for biomass utilization in Japan

To promote the renewable energy production and biomass utilization for heat and power generation, Japan has established a number of policies and incentives. Basic Act for the promotion of biomass utilization in 2009, its Amendment(2016) and Basic Plan for the promotion of biomass utilization in 2010 were aimed to set basic policies on the development of technologies for biomass utilization. The most critical policy was “Feed-in Tariff Scheme for Renewable Energy (Ministry of Economy, Trade and Industry:METI) which has been implemented since July 2012, soon after the tragic Tohoku Earthquake and Fukushima nuclear power plant accident. Since then, wood pellet consumption in Japan has grown up.

According to FAOSAT in 2016, the domestic production of wood pellets in the last five years was only 90t, most of which were exported to the market of China, and relatively high quality pellets, which covered a larger consumption of pellets in Japan, have been imported from Canada, China, Vietnam and the others.

To prevent illegal logging for wood pellets on the sustainable forest principle, the Basic Act for the Promotion of Biomass Utilization has a number of requirements for wood pellets and the other biomass use. Some of them are noted as follows:

·Mitigation of global warming,

·Revitalization of rural areas,

·Full utilization of different types of biomass,

·Considerations of environment preservation.

Under the Ministry of Agriculture, Forestry and Fisheries’ (MAFF) slogan, “illegal harvested timber should not be used”, the Clean Wood Act went into force in 2017, since illegal imports of wood products through complex trade routes had not been blocked.

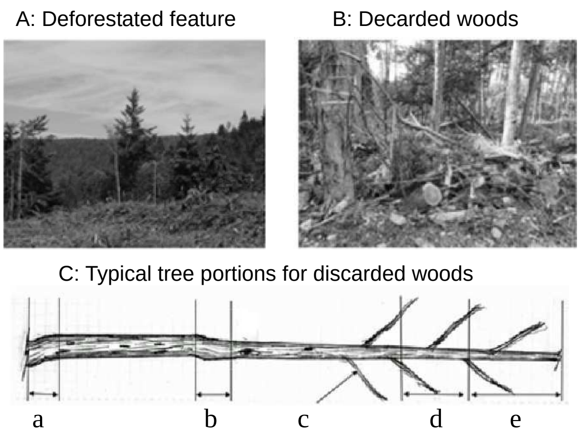
As to wood chips, the standardizations are still at the development stage, probably due to no notable trading market in Japan for the moment.

3. Methodology

3.1 Calorific values of wood chips

Among a variety of kinds of tree, Japanese larch, abundant in Hokkaido, was focused. Japanese larch timber is mainly processed for general timber market and for paper industry as pulp. Pictures of a forest and discarded wood conditions of Japanese larch are shown in Fig. 1. They were taken in Engaru, local town in Hokkaido, at the time when the National and Private Forests Meeting was held in this area.

The Stylus TG-630 camera (Olympus Tokyo, Japan) was used. Analyses were carried out, using the Image J and IrfanView.



a) warped wood shaft nearby ground, b) twisted part in the middle of shaft, c) bough, d) slender shaft unusable for pulp, e) thin shaft up to crown and twig

Fig. 1 Japanese larch in Hokkaido (modified illustrations via Official Website of Hokkaido Prefecture, 2018c)

Calorific assessment is crucial for each available wood chip for boilers. There remain a variety of arguments on standardization of calorific assessment of wood chips for even wood-burning stoves. Actual calories of burning wood fuels are dependent on the moisture content of them, and on various factors, such as wood materials themselves, boilers and structures of power plants, including the storage conditions.

In this paper, the author decided to choose the calculation method available at the web site of Japan Woodchip Manufacture's Association 2018. The calculation scheme, originally for cone calorimeter, is on the base of perfectly dry wood conditions, although the moisture contains in actual wood fuels even at the furnace to some extent.

The fraction of the evaporable moisture /water content of the wood fuels designated by U_w, is simply given by

$$U_w = (W - W_0) / W \times 100 \quad \text{in \%} \qquad (1)$$

where W_0 is the mass of the wood fuel in perfectly dried conditions and W is the mass of the one in actual conditions. Heat potential estimations were carried out for actually available wood chips, applying the simple formula (1).

3.2 Market prices of timber and fuel oil

Monthly average timber prices are available on the Min-yurin Shimbun, timber market newspaper in Japan. As to the both of fuel prices, the actually paid prices by the City of Mombetsu were adopted in this study.

These prices are key factors on this theme. There had been a few discussion papers published on the prices before (Yoda and others, 2010, 2011, 2012a and 2012b; Vesergaard, and others, 2011a and 2011b; Chahal and others, 2011; Phan and others, 2013; Yoda and others, 2017). The experience led to adopt the abovementioned price system.

4.Results and Discussion

The trees in Hokkaido have reportedly around 4,000 - 5,000 kcal/kg. The heat potentials of several kinds of wood are available in various reports. Fig. 2 shows one of them (Official Website of Japan Woodchip Manufacturers' Association, 2018). Those data were obtained by use of a cone calorie meter in completely dry conditions.

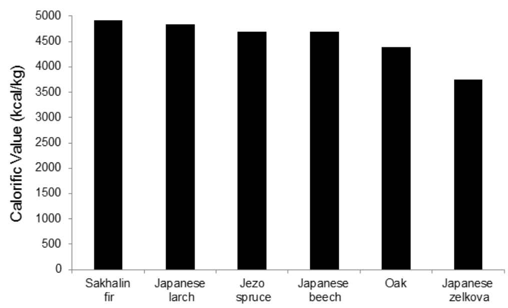


Fig. 2 Calorific values of several kinds of tree

The calorific values of trees in the ideal moisture conditions were found of a little difference among the kinds of tree.

It has been empirically well known that the heat potentials of wood or wood chips are dependent on the moisture or water content in them. The traditional data tell the woods of 20% water content has as much as double calorific value to those of 100% content ones, and the woods within 10-20% water content are ideal for burning for heat generation, while in reality, most of woods for heating have around 30% water content, except for extreme cases.

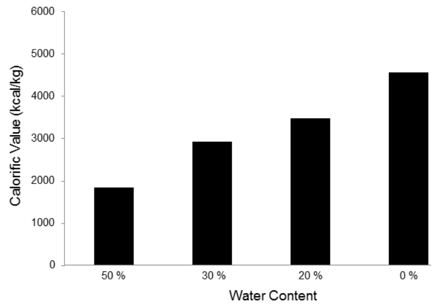


Fig. 3 Calorific values of a wood in different water content conditions

Calorific values in the different moisture conditions were obtained by collecting and analyzing those open web data, as shown in Fig.3.

There has been no reliable data about the water/moisture contents of each portion of discarded wood which is kept in the same natural conditions. Boughs and twigs would have rapid responses to the change of ambient moisture content, that is to say, in rainy days or in dry and windy days. Together with this, heat mass volume of boughs and twigs is minor in biomass heating and wood chips are usually stored in open enclosures.

Taking account of these, in practice, the heat potential of biomass wood chips would be assumed to be the value of the market timber approximately, probably without choice, particularly in the case of feasibility study of wood chips for biomass heating. Fig. 3 suggests that the wood chips could have the heat potential of 3,000 kcal/kg, while fuel oil has 9,600 kcal/kg in the EU industry.

The price trends of biomass wood and the price of fuel oil, as a strong competitor in energy market, form the staple of the total cost. Monthly timber price trends are available in the Min-yurin Shimbun in 2015.

The wood chip price market was found stable through the year. The wood chips of broad-leaf trees have the highest price, and a notable difference exists in the prices between the wood chips of broad-leaf and the others.

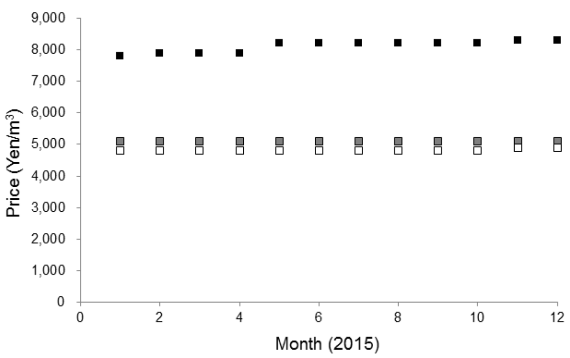


Fig. 4 Monthly price trends of discarded woods. Broad-leaf trees (back squares in the figure), Yezo spruce and Sakhalin fir (grey squares), and Japanese larch (white squares).

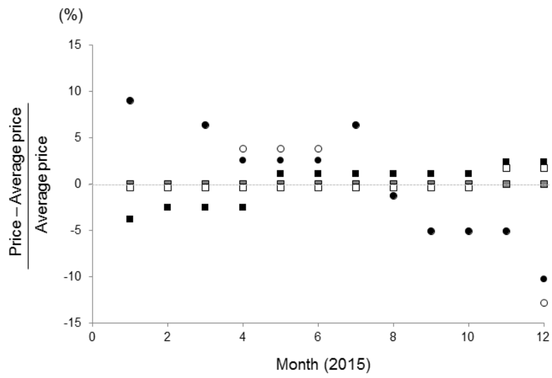


Fig. 5 Monthly oil and wood chips price deviations. Deviations in price of heating oil (black circles), those of fuel oil (white circles), and those of wood chips. Squares are as same as in Fig.4.

Monthly fuel oil price and wood chip price deviations are shown in Fig.5. The oil price varied throughout the year and its trend was of typical ones in the regions cold in winter and warm in summer. However, it should note that the recent oil price trends have been affected by the global markets and international political policies.

As far as the timber market concerns, the price of broad-leaf timber was the highest among these three kinds through the year. The Japanese larch was the cheapest. The prices of both Sakhalin fir and Japanese larch had similar trends.

Discarded wood for power plants has advantages in cost and emission, although another advantage, which will accrue to much better circumstances for reforestation, has been never recognized in those prices.

The disadvantages of the discarded wood chips lye with their thermal qualities, in particular, water contents; depending on the portions of trees while discarded, and natural conditions during the storage.

Especially in Hokkaido, winter season with snowing lasts six or seven months. The discarded wood chips are kept in wet conditions for a long time.

Drying discarded wood chips will be technically easy, but it requires the energy for drying and closed storage rooms, likely bunkers. Such additional, relatively high, expenditures of energy, equipment and facility do not meet the market principle.

The combustion of wood fuels in boilers requires the invariance of the thermal quality of them to generate the maximum efficiency in combustion by easy control. Conversely, boilers need a high capability where fuels of various thermal qualities are stoked up at random into the furnaces, and shall meet the safety regulations at the same time. Eventually, such boilers are slightly more expensive than pellet fueling boilers, where burning dry and nearly homogeneous wood fuels and being easily controlled, and much more expensive that oil fueling boilers.

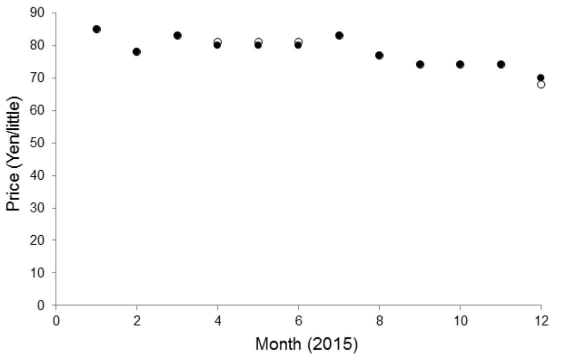


Fig. 6 Price trends of wood and oil fuel. These are actual prices for both heating oil (black dots) and fuel oil (white dots).

The prices in Fig.6 are those of actually paid by the city of Mombetsu. Fig. 6 suggests, to protect biomass industry, the city had controlled the price of biomass wood.

The price of 300kW biomass boiler is around 30 – 40 million yen in Hokkaido, while in Europe the similar boilers are available at the price of about 5 million yen.

The other disadvantage lies with the process of discarded wood chips from forest to power plant. The high processing cost of them consequent the wood chips had been discarded in forest until the time of reforestation.

The author obtained the data as high as 10,000 yen/m^3 for the processing cost estimations from several companies. The cost should be added to the total cost of biomass power plant. Biomass power plant using wood chips as basic fuels would hardly survive under such high cost structure.

To find and examine another relatively cheap wood material had naturally been carried out to solve this cost problem. They were by-products and residues from wood processing industry (BPS in brief). The author obtained the market price of those wood materials around 1,000 – 3,500 yen/m^3.

A previous study derived the conclusion by cost simulations: when the price of BPS in market hovers around or goes over 3,605 yen/m^3, the profit of biomass power plant would be likely to accrue (Nakama and others, 2011). The study also estimated the possible highest price about 6,800 yen/m^3.

The price of BPS materials were lower than those of discarded wood. In case of the unusable timber chips as the base fuel materials for boilers, the total cost for generation of heat or energy would be considerably reduced. However, a question arises; whether the timber industry could provide the amount of such materials enough to stable use for the boilers as its base fuel. In practice, the wood fuels for power plant would be blends and mixtures of discarded wood and BPS chips. Another problem still remains; the cost of boilers for them, in comparison to oil fueling boilers.

If wood fueling boilers are working well for a long time, without serious slagging and fouling problems, the difference at initial investment could be collected through the operations over 15 years due to low price of fueling wood.

As beforementioned, under the new government energy policy to reduce carbon emission, local governments have been demanded to use the discarded wood for heating units and power plants, where those biomass materials could be available. Local governments such as the city of Mombetsu had established the subsidy scheme for the discarded wood, mainly for its processing expenditures. The city of Mombetsu, for instance, has granted 300yen/m^3 subsidy to utilizations of unusable timber materials for the biomass power plant.

The Hokkaido Prefectures grant the subsidies for the acquisition of boilers burning unusable wood materials and other necessary facilities (Official Website of Hokkaido Prefecture, 2018d). The similar subsidies afforded the city of Mombetsu to support a hospital management where biomass boilers are working for heating system.

Enlargement efforts of the local consumer's market would contribute further reduction of the cost as well as total amount of carbon emission, where the role of proximity dimensions in facilitating biomass power plants should be demanded.

5.Conclusion

The economic aspects are always key issues in biomass energy. Putting stress on it, the author studied the biomass fuels for heating units and power plants, discussing their present state and future prospective, in a local city in Hokkaido. There are several problems left in the effective use of biomass materials. To solve them, the local governments together with the local communities will have to assume the executive responsibilities on the biomass issues.

Since we can no longer leave the nature to manage itself under our onslaught, changing the discarded or wasted materials to be useful energy resources could be one step forward to realize the healthy nature again as well as sustainable human society.

Acknowledgements

The author is grateful to Mr. Shuichi Tokusho, a manager in the biomass section of the city of Mombetsu for his warm support. The author would like to extend the author's deepest thanks to the reviewer for his painstaking reviewing work.

References

Bateman I.J., G.M. Mace and 3 and others (2011) Economic Analysis for Ecosystem Service Assessments. *Environ. Resource. Econ.* **48**:177-218.

Chahal B, M.C. Vestergaard and 3 others (2011) Structure-dependent membrane interaction and bioactivity of flavonoids with lipid bilayers., *Micro-Nanomechatronics and Human Science (MHS)*, *2011 International Symposium* 451-455.

FAOSAT (2016) Annual Report on Forest and Forestry in Japan; 34.

Government of Japan (2009) Fundamental Law of Promoting Usage of Biomass, Act No.52, enacted 2009 (in Japanese).

Government of Japan (Cabinet) (2010) Basic Plan for the Promotion of Biomass Utilization, (in Japanese).

Government of Japan (Cabinet) (2016) Basic Plan for Promotion of Biomass Utilization, (in Japanese).

Government of Japan (2017) Act on Promotion of Use and Distribution of Legally-harvested Wood and Wood- Products (Clean Wood Act), 13.

Kuboyama H, T. Nishizono, T Iehara, H. Okuda (2004) Feasibility of Wood-biomass Utilization as an Energy Source: Case Study in Tohno City, Iwate Prefecture. *J. Jpn. For. Soc.* **86**: 112—420.

Ministry of Agriculture, Forestry and Fisheries (MAFA) (2012) Annual Report on Forest and Forestry in Japan (in Japanese)

Ministry of Economy, Trade and Industry of Japan (METI) (2012) Feed-in Tariff Scheme in Japan, 36.

Nakama K., T. Ota, N. Mizoue, S. Yoshida (2011) Effects of recovering logging residues on strategy and benefits of forest stand management. *J. Jpn. For. Soc.* 93: 226-234.

Niseko's Towns efforts as an Eco Model City (2018) [online] http://futuecity.jp/pdf/forum/2015_malaysia/Case/Study_of_Japan_01_06_01_Town_of_Niseko.pdf

Official Website of Japan Woodchip Manufactures̓ Association (2018) [online]http://zmchip.com/houkoku232.pdf (Accessed 5 Mar 2018).

Official Website of Hokkaido Prefecture (2018a) [online]http://www.okhotsk.pref.hokkaido.lg.jp/ss/rnn/biomas /kouminkan.pdf (Accessed 5 Mar 2018).

Official Website of Hokkaido Prefecture (2018b) [online] http: //www.okhotsk. pref.hokkaido.lg.jp/ss/ biomass/ kouminkan.pdf (Accessed 5 Mar 2018).

Official Website of Hokkaido Prefecture (2018c) [online] http://www.pref.hokkaido.lg.jp/sr/srk/grp/03/sigendoukoukekka siryou3.pdf (Accessed 5 Mar 2018).

Official Website of Hokkaido Prefecture (2018d) [online] http://www.pref.hokkaido.lg.jp/ks/jss/recycle_2/H23itirann. pdf (Accessed 5 Mar 2018).

Official Website of Hokkaido Prefecture (2018e) [online] http://www.pref.hokkaido.lg.jp/ks/tot/gnd/saienekeiakuH25H26.pdf (Accessed 5 Mar 2018).

Phan HTT, T. Hata and 5 others (2013) The effect of Oxysterols on the interaction of Alzheimer's amyloid beta with model membranes. *Biochim. Biophys. Acta. (BBA)-Biomembr.* **1828**: 2487-2495.

Saidur R, E.A. Abdelaziz and others. (2011). A review on biomass as a fuel for boilers. *Renew.Sustain.Energy.Rev.* **15** (5): 2262-2289.

Vestergaard M.C., T. Yoda and 4 and others (2011) The effect oxycholesterols on thermo-induced membrane dynamics. *Biochim. Biophys. Acta (BBA)- Biomembr.* **1808**: 2245-2251.

Vestergaard MC, T. Yoda and 4 and others (2011) Thermo responsiveness of autooxidized cholesterol-containing lipid membranes, observed in real-time. *Micro Nano Mechatronics and Human Science (MHS), 2011 International Symposium*, 451-455.

Yamamoto Y, K. Takeuchi, T. Shinkuma (2014) Is there a price premium for certified wood? Empirical evidence from log auction data in Japan. *For. Policy. Econ.* **38**: 168-172.

Yoda T (2017) The influx of temporary visitors and lodgers to Mombetsu City for construction projects: a quantitative study of the period between 2009 and 2014 *Int. J. Knowl. Manag. Tour. Hosp*, **1**: 477-488.

Yoda T, M.C. Mun' delanji and 3 others (2012a) Thermo-induced vesicular dynamics of membranes containing cholesterol derivatives. *Lipids*, **47**: 813-820.

Yoda T, H.T.T. Phan and 3 others (2012b) Thermo-induced dynamics of membranes and liquid crystals containing cholesterol derivatives. *Micro-Nano Mechatronics and Human Science (MHS), 2012 International Symposium*, 87-92.

Yoda T, M. C. Vestergaard and 4 others (2010) Dynamic response of a cholesterol-containing model membrane to oxidative stress. *Chem. Lett.* **39**: 1273-1274.