Sustainability Approach for Energy Production using Biomass at Household and Community Levels: A case study in Thailand

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Abstract- The aims of this study are to analyze economic, social and environmental impacts resulting from energy production using biomass at the household and community levels with a view to formulating sustainability approaches for energy production using biomass at the household and community levels. Gap analysis of the implementation of biomass energy production at the household and community levels based on the data collected through in-depth interviews with four representatives from the parties involved was carried out. In addition, contextual and weaknesses analysis of biomass energy production at the household and community levels based on the data collected through field-observation and in-depth interviews with the community leaders at six areas where biomass is used for heat and electricity production was conducted.

The results of this study show that in economic aspect, the Social Return on Investment (SROI) for electricity production is less than 1 whereas that for biomass-derived heat production exceeds 1. In social dimension, there are involvement of the relevant units and participation of the people in the community. Regarding environmental impacts, less pollution is caused in the use of biomass for heat production as compared to the use for electricity production. Sustainability approaches for biomass energy production include improvement on the efficiency of the biomass energy production process and its related services, inculcation of awareness of social co-benefits resulted from biomass energy production and resource management for biomass energy production in a systematic way.

Keywords- Biomass; Economic; Social Environment Impact; Household; Community.

1. Introduction

Nowadays many countries depend mainly on fossil fuels for transportation and electricity production. However, fossil fuel is exhaustible and fossil fuel reserves are found to be decreasing. At the present rate of production and consumption worldwide, it is estimated that oil, natural gas, and coal are going to run out in 42, 60, and 122 years respectively[1], resulting in worldwide concern over the problem of energy. [2] To replace fossil-derived energy, it is vital to seek alternative energies, especially those that are renewable, such as hydro, wind, solar, and biomass energies, as they can be used indefinitely, and cause less environmental impacts.

With its potential as a fuel which is able to produce substantial and continuous heat, biomass is a suitable fuel that can be used to displace fossil fuels. Biomass is comprised of carbon, hydrogen, oxygen, sulphur, and nitrogen, which can be converted into energy. Through photosynthesis, plants capture the energy from the sun by converting carbon dioxide and water into carbohydrates, which are stored in various parts of plants. Similar to fossil fuels, when biomass is burned, the energy is released in the form of heat energy, which can be used effectively to produce steam or electricity. [3] In addition, biomass is a green alternative to the utilization of fossil fuels. Despite the emission of carbon dioxide when biomass is burned, the amount of the carbon dioxide released into the environment is equal to that absorbed and exploited in the process of photosynthesis by biomass plants burned and such a cycle is thus termed 'Zero Carbon Emission. [4] This is in line with the study by Egbendewe-Mondazozo, Swinton, Izaurralde, Manowitz and Zhang [5] on the utilization of crops as biomass energy resources in the south of Michigan, USA, which found that the production of biomass energy from the residue from cellulosic crops causes far fewer environmental impacts than slash and burn farming. It can also help reduce the prospect of soil surface erosion and nutrient depletion. Furthermore, it helps generate income incurred from selling biomass for energy production in rural areas and in the agriculture sector. [6]

Nevertheless, there are some potential negative economic, social, and environmental impacts involved in the production of biomass energy. For example, burning biomass at the temperature lower than 800 degrees Celcius emits sulfur dioxide. Using biomass to generate electricity during the summer can emit 50% more nitrogen dioxide and 10% more particulate matters (PM_{10}) when compared to using coal. [7] At the household level, biomass-derived heat used for cooking can adversely affect health, especially through polycyclic aromatic hydrocarbons (PAHs), a cancer-causing substance resulting from incomplete combustion and the combustion of organic acids in biomass [8] Another side effect can be caused in case of too much cultivation of energy crops, which may lessen the land used to grow food crops and as a result lead to a shortage of food crops in the future [9]. Additionally, the supply of biomass is indeterminate, depending on the harvest season, during which the supply is high, whereas out of the harvest season the supply is likely to be low. Another important factor here is fluctuation in the prices of agricultural products. For instance, if in a certain year the price of cassava drops, agriculturists are likely opt for the cultivation of other crops such as corn in the following year. In consequence, the supply of cassava rootstocks will dwindle, while that of corncobs will rise, [10] In addition, lack of involvement on the part of the local people and the technology employed in biomass energy production which does not fit the context of the local communities may result in unsuccessful implementation of the projects to promote the use of biomass at the household and community levels. [11] All of these factors significantly impact the continuity and sustainability of the production of biomass energies to displace fossil energies.

According to United Nations Sustainable Development Solutions Network, [12] economic development and poverty alleviation executed along with promotion of social rapport and environmental sustainability are the key mechanism for a nation's sustainable development. If applied to the management of renewable energy production, especially biomass energy production, such a tenet should lead to development at the household and community levels. With biomass as a device, income can be generated for the household and community, reduction in the use of exhaustible energies can be promoted both at the policy and local levels, and environmental protection can be fostered. [13] Agricultural products constituted 19% of Thailand's gross domestic product (GDP), and the total value of the country's agricultural product export came second to non-agricultural product exports during 2008-2012, [14] and as a result, agricultural residues are plentiful. Support is also available from relevant sectors in the production of alternative energies

from agricultural residue such as in biomass electricity plants use of charcoal and biomass stoves. According to the Alternative Energy Development Plan (AEDP) of Thailand which aims for 25% domestic use of renewable and alternative energies, 3,630 megawatts of biomass energy production are targeted for the next ten years. [15] This reflects the country's growing interest in biomass energy production. It is thus practical to develop guidelines for sustainability in biomass energy production both at the household and community levels. The main objectives of this study were to investigate and formulate guidelines for biomass energy production in the economic, social, and environmental dimensions, with the hope that the guidelines formulated can be further developed and applied to other types of renewable energies in the future.

2. Conceptual Framework

Along with the promotion of the use of energy that helps lessen environmental impacts, promoting sustainable use of energy is an important way to achieve sustainable development. [16] In consideration of sustainability—be it in the economic, social or environmental dimension—this line of energy development can help to enhance economic growth without resistance from people in the society and without environmental impacts. [17]

In terms of the economic dimension, the analysis is on the expenditure involved in biomass energy production at the household and community levels, whether it be in construction, maintenance, or raw material management, as well as on the economic gains, including reduced expenses for exhaustible energies and the cost effectiveness and profit incurred in biomass energy production.

Regarding the social dimension, the analysis is on how much biomass energy production at the household and community levels is embraced by people in the society, whether there are support and involvement from all the relevant parties, and how much income it generates.

For the environmental dimension, the analysis is on the pollutants caused by biomass energy production at the household and community levels and their impacts on the environment, biodiversity, and utilization of land.

The subjects analysed in the context of the sustainability of biomass energy production at the household and community levels are summarized in Table 1.

Table 1. The subjects analyzed in the context of the sustainability of biomass energy production at the household and community levels

Sustainable development dimension	Subjects analyzed	References
1. Economic Dimension	1.1 Expenditure involved in biomass energy production (transportation, construction, maintenance, raw material management)	-Mourmouris & Potolias (2013) -Daima, Li, Kimb & Simmsb (2012) -Sadeghi, Larimian & Molabashi (2012) -Angelis-Dimakis et al. (2011) -Amer & Daim (2011) -Amer & Daim (2011)
	1.2 Economic gains (reduced expenses on exhaustible energies, and cost effectiveness and profit incur)	- Mourmouris & Potolias (2013) Sadeghi, Larimian & Molabashi (2012) - Amer & Daim (2011)
2. Social Dimension	2.1 Acceptance by people in the society	-Mourmouris & Potolias (2013) -Daima, Li, Kimb & Simmsb (2012) -Sadeghi, Larimian & Molabashi (2012) -Escalante, Belmonte & Gea (2013) -Amer & Daim (2011)

	2.2 Involvement of all relevant parties	-Savocool (2013) -Sadeghi, Larimian & Molabashi (2012) -Escalante, Belmonte & Gea (2013)

Table 1. (Continued)

Sustainable development dimension	Subjects analyzed	References
	2.3 Income generation	-Mourmouris & Potolias (2013) -Savocool (2013) -Daima, Li, Kimb & Simmsb (2012) -Sadeghi, Larimian & Molabashi (2012) -Amer & Daim (2011)
3.Environmental Dimension	3.1 Environmental impacts	-Mourmouris & Potolias (2013) -Daima, Li, Kimb & Simmsb (2012) -Sadeghi, Larimian & Molabashi (2012) -Angelis-Dimakis et al. (2011)
	3.2 Impacts on utilization of land	Mourmouris & Potolias (2013) Sadeghi, Larimian & Molabashi (2012)

3. Research Methodology

In order to be able to formulate guidelines to promote sustainability in the use of biomass energy in Thailand, the author employed gap analysis of the implementation of biomass energy production at the household and community levels [18], based on the data collected through in-depth interviews with four representatives involved in the promotion of the use of biomass energy as follows.

1. Representatives from governmental organizations, which included representatives from the Energy Policy and Planning Office belonging to the Office of the Permanent Secretary of the Ministry of Energy, the Energy Policy and Planning Department, and the Bureau of Energy Research belonging to the Department of Alternative Energy Development and Efficiency

2. Representatives from non-governmental organizations, which included representatives from the Energy for Environment Foundation (E for E), the Thailand Environment Institute, and the National Innovation Agency (Public Organization)

3. Representatives from the private sector, which own of a biomass electricity production company in the community

4. Scholars from a project on the formulation of guidelines for the verified co-benefits derived from projects to reduce greenhouse gas emissions by the energy sector and waste management, which was organized by Thammasat University and the Thailand Greenhouse Gas Management Organization (TGO); and scholars from the Faculty of Engineering, Rajamangala University of Technology Thanyaburi, Pathum Thani Province.

In addition, the researcher conducted contextual analysis and analysis of the weaknesses involved in biomass energy production at the household and community levels. Through involved observation, in-depth investigation was executed in six areas regarding the production and promotion of biomass energy, which was put into use by being converted into heat and electricity. [19] Among these, two were areas where biomass energy was utilized in the form of heat at the household level, two were areas where biomass energy was utilized in the form of heat at the community level, and two were areas where biomass energy was used to produce electricity for the community, as shown in Table 2.

Table 2. Areas where production of biomass-derived heat and electricity was investigated

Form of Biomass Exploitation	Investigation Area	Note
1. Electricity production	Community biomass electricity plant of Company A (hypothetically named)	Promotion of cultivation of biomass crops in the community to "feed" the electricity plant
	Comprehensive Renewable Energy Demonstration and Development Center, a project of Chaipattana Foundation at Lad Bualuang, Ayudhaya Province	Use of rice husks from milling in the project under His Majesty's Royal Patronage and by the local people to produce electricity
2. Heat production	House of Mr. X (hypothetically named) Nong Prao Ngai, Sai Noi District, Nonthaburi Province	Production of charcoal from household biomass
	Municipality of Krasaebon Subdistrict, Klaeng Dictrict, Rayong Province	Household use of gasifiers and high-proficiency cooking stoves
	Pa Deng Community, Kaeng Krachan District, Phetchaburi Province	Household production of charcoal and community use of gasifiers
	High-proficiency cooking stove enterprise, Sanap Thuep, Wang Noi Didtrict, Ayudhaya Province	Production of high-proficiency cooking stoves as an enterprise, which helps generate additional income for the community

4. Results and Discussion

From the in-depth interview with the four representatives involved, including representatives from governmental and non-governmental organizations, the private sector, and scholars, and in-depth investigation through the observation of six areas in involved with the production and promotion of biomass-derived heat and electricity, the findings were as follows.

4.1 Economic Dimension

4.1.1 Expenditure involved and economic gains in biomass energy production

With respect to the biomass energy used for heating at the household and community levels, which includes the production of charcoal and gasifiers, and the production and promotion of the use of high-proficiency cooking stoves (as shown in Figure 1, the findings from the in-depth investigation of the areas under study revealed that, in order to make the equipment used in biomass energy production, the expenditure ranged from 300 to 17,212 baht. Among the economic gains, it saves on the exhaustible energy used for cooking. The by-

products from the biomass energy production used for heating, such as wood vinegar derived from charcoal production, can be used as a pesticide. The net present value in the production of biomass-derived heat at the household and community levels exceeded 1, indicating the cost effectiveness of its production, [2] whereas for the biomass energy used for electricity production, as shown in Table 3, the net present value was lower than 1, indicating that the economic gains incurred were lower than the production costs. This is because the technology employed in biomass electricity production is sophisticated and expensive. There are also other relevant expenses, for example on transportation and those concerning environmental standard control. The benefit is, however, a 200 watt-per-hour reduction in electricity production from exhaustible energy such as coal, fuel oil, and natural gas.

Table 3. Net present value of biomass energy production at the household and community levels

Equipment employed in biomass energy production	Cost per one piece of equipment (baht)	Economic gains per one piece of equipment (baht)	Net present value
1. High-proficiency cooking stove	300	1.1) Saving of 755 baht on charcoal per year** 1.2) Saving of 250 baht on cooking gas per year	3.33
2. 200liter charcoal kiln (with 6 combustion compartments)	17,212	2.1) Annual yield of 2016 kg. of charcoal, which can be sold at 20 baht per kg., totaling 40,320 baht per year 2.2) Monthly yield of 50 liters of wood vinegar for agricultural purposes, which can be sold at 100 baht per liter, totaling 60,000 baht per year	5.83
3. Gasifier	600	Spending on cooking gas, which is approximately 183.33 baht per month, is reduced by 50%, totaling a saving of 1,099.98 baht per year	1.83
4. High-proficiency grill stove	2,330	Saving of 7,740 baht spent on charcoal for grilling per year per one high-proficiency grill stove	3.32
5. Biomass electricity plant	36,115,020	5.1) Biomass-derived electricity sold at 4.50 baht per kilowatt-hour, with the production capacity of 200 kilowatts per hour, with a total revenue of 2,419,020 baht 5.2) Biomass ashes sold at 50 baht per kg. for the production of silica, with 432000 kg. of ashes in total, making 21,600,000 baht	0.67

Note: * Including wages, costs of transportation of raw materials, pollution treatment, and biomass fuels as well as other expenses involved

** [20]

200-liter charcoal kiln Gasifier

Figure 2. Biomass electricity generator

High-proficiency cooking stove High-proficiency grill stove

Figure 1. Equipment used in the production of biomass - derived heat at the household and community levels

4.2 Social Dimension

4.2.1 Acceptance from people in the community

Investigation of the area under study, where biomass energy is used for heating, revealed that biomass energy was embraced, in particular as cooking fuel. A household or community which opts for biomass energy can reduce its expenses on non-renewable energies, especially on cooking gas, by up to 50%. Some can cut the consumption of conventional biomass, for example, from previous use of 1,560 kg. of charcoal in grilling to 1,290 kg. per year. Interestingly, use of biomass energy is generally found only in the rural area. According to the interviews with the representatives involved, promotion of the use of biomass energy in urban communities is likely to be difficult for it takes time for material desiccation as well as for combustion, which is not as convenient as the use of non-renewable fuels. Likewise, Mr. X (hypothetically named) would like to promote biomass energy production through charcoal production but is unable to in his urban community owing to a lack of involvement and interest in the development or further application of biomass energy on the part of the local people.

4.2.2 Involvement of all the relevant parties

According to the interviews with the representatives involved in promoting biomass production, on the part of the government sector, a self-support energy scheme has been devised and implemented in over 700 communities all over the country, in almost all of which the use of biomass energy is promoted. Another supportive measure is in the form of "adder cost" whereby 0.50 baht per unit is additionally paid in case of biomass electricity production of less than 1 megawatt, and 0.30 baht per unit in case of biomass electricity production of more than 1 megawatt. In the three southernmost provinces and four districts in Songkhla Province, 1 baht per unit is additionally paid. In addition, for more effective promotion of the production of renewable energy, the "feed-in-tariff" system has been introduced. The private sector has also been encouraged to get involved in pilot projects in biomass energy production at the community level. In accordance with the community energy planning project, promotion of the cultivation of certain energy crops has been carried out as a source of biomass energy as well as the production of biomass energy in the community. Additionally, in establishing a biomass electricity plant, it is compulsory that some local people be designated members of its tri-lateral committee in order to monitor and inspect the administration. Overall, all of

the relevant parties should be significantly involved in the production of biomass energy at the household and community levels in a comprehensive manner.

4.2.3 Income generation

Biomass energy production at the household and community levels can significantly generate income for the local people. The case in point according to the study was charcoal production and its by-product—wood vinegar. In Pa Deng, Kaeng Krachan District, Phetchaburi Province, in return for a charcoal kiln provided to the community members, a sack of charcoal produced by the community must be given to the community center to be sold at 100 baht. All of the money from the sale goes to the community development fund. Another example can be seen in the Ban Klong Sib Tan Community, Sanap Thuep, Wang Noi District in Ayudhaya Province, as shown in Figure 3, where the local people have come together to establish their own high-proficiency cooking stove enterprise. The profit gained is allocated to all of the members, enabling each to supplement his or her income witharound 470 baht a month [20]

Figure 3. Community high-proficiency cooking stove enterprise in Ban Klong Sib Tan Community, Sanap Thuep, Wang Noi District, Ayudhaya Province

4.3 Environmental Dimension

4.3.1 Environmental impacts caused by biomass production

With reference to the interviews with the four representatives involved, the production of biomass-derived energy, be it in the form of heat or electricity, causes more positive than negative impacts. In the case where waste is recycled, this mode of biomass energy production is essentially a means to protect the environment and to preserve the natural resources. Compared to the conventional mode, biomass energy production from organic waste can help lessen deforestation, as fewer trees in the wild are felled, and can also reduce the burning of biomass in the open air, an unsuitable way to get rid of biomass waste and which discharges pollutants such as toxic smoke and dust particles. However, some level of certain adverse environmental impacts is inevitable, as biomass energy production results in carbon monoxide, nitrogen dioxide, sulfur dioxide, particulate matter, and phosphate. This is in line with a study by Perilhona et al. (2012: 165-176),[22] in which the life cycle of a biomass electricity plant was investigated. According to the study, when 681 grams of hardwood biomass is used for generating 2 megawatts of electricity, 674 grams of carbon dioxide are produced in the combustion, 2,951 grams in the transportation, and 2,295 grams in the electricity production process. Additionally, smoke resulting from the incomplete combustion of biomass and combustion of organic acid substances in the biomass can produce cancer-causing substances in living beings. [23]

In charcoal production, in the thermal conversion process called “pyrolysis,” where little or no oxygen is present, biomass is broken down into carbon monoxide, carbon dioxide, and methane and hydrogen. In gasification, another mode of technology for converting biomass into energy, the products include hydrogen (30-40%), carbon monoxide (20-30%), methane (10-15%), carbon dioxide (15-20%), ethylene (1%), nitrogen (1%), and water (6%). [4] On the other hand, exploitation of biomass materials which are organic waste or residue helps reduce adverse environmental impacts such as refuse going to landfill sites, air pollutants such as smoke and

dust particles resulting from burning of agricultural waste, and water pollution caused by the use of fossil energies. Further, certain by-products of biomass can be exploited. For instance, wood vinegar derived from the charcoal production of Mr. X (hypothetically named), is a viable alternative to chemical pesticides. Another case in point is at the Comprehensive Renewable Energy Demonstration and Development Center, a project of the Chaipattana Foundation in Lad Bualuang, Ayudhaya Province. Waste water from electricity generation there, the pH level of which is greater than 7, can be effectively applied to tackle the problem of acidic soil. Investigation of the six areas under study revealed that the biomass-derived heat generation in charcoal production and the use of high-proficiency cooking stoves, gasifiers, and high-proficiency grill stoves caused minimum negative environmental impacts. There may be impacts from smoke released in the burning process; this problem depends on the wind direction. In the context of biomass electricity production, it is necessary for the management to have relevant equipment installed, for example, dust particle trapping equipment and a waste water treatment system, in order to prevent and minimize any potential adverse environmental impacts.

4.3.2 Impacts on utilization of land

In line with the Renewable and Alternative Energy Development Plan, which targets 25% production of renewable and alternative energies in 10 years (2011-2021), Distrubuted-Green-Generation (DGG) has been established to help elevate biomass energy production to 3,630 megawatts. This energy enterprise, owned and comprehensively-managed by the local communities, promotes the cultivation on uncultivated or unutilized land of fast growing trees, which are to be utilized as fuel by the local electricity plant. Though in such promotion of biomass energy production land is exploited to the utmost, food security must also be taken into consideration. A case in point can be seen in Brazil in its promotion of the cultivation of physic nut trees for biodiesel production, with a view to encouraging more use of renewable energies and lessening emission of green house gases. However, the policy has resulted in more deforestation, especially in the Amazon jungle. In addition, some food crops are likely to become scarce, as the land previously used for their cultivation have been used for planting physic nut trees instead, [24] Another factor leading to the possible shortage of food crops is the drop in agricultural product prices, which can in turn motivate some farmers to opt for cultivation of energy crops instead of food crops. If 10% of the land is used in growing energy crops, over 50% must be used in growing food crops to meet the global food demand. Hence, the cultivation of energy crops should be promoted on unutilized land and analysis of its social and environmental impacts should be conducted, for example concerning land utilization and the use of agricultural residue and waste as an energy source [25][26][27].

5. Guidelines for promoting biomass energy production at the household and community levels in a sustainable manner

An analysis of biomass energy production at the household and community levels in the form of heat and electricity with a view to promoting sustainable economic, social, and environmental development revealed that, in the economic dimension, spending on exhaustible energies can be significantly reduced. The costs of the production of biomass-derived heat energy at the household and community levels, with respect to the equipment involved, are not very high. On the other hand, in the production of biomass-derived electricity, the costs are relatively high, but return on investment is relatively low.

In the social dimension, biomass energy production in households and in the community can help generate additional income for the local people in a tangible manner. The production can also backed up by the parties involved, ranging from the government, the private sector, non-governmental organizations, and the local people. However, biomass exploitation is common only in rural areas, whereas in urban communities, it is not yet promoted and embraced owing to the inconvenience involved, particularly regarding the relatively long time it takes for ignition.

In the environmental dimension, if correctly managed, biomass energy production should cause minimum environmental impacts If not, and with incomplete combustion, it can emit a high number of atmospheric pollutants. In biomass electricity production, technology for pollution treatment, be it air or water pollution, must be employed to minimize adverse environmental impacts. With regard to the promotion of the cultivation of energy crops on unutilized land in support of biomass energy production, even if the land is exploited to the utmost, food security can be negatively affected if only energy crops are promoted and cultivated.

The strengths and weaknesses discussed above are summarized in Table 4.

Table 4. Strengths and weaknesses of biomass energy production at the household and community levels

Dimension in sustainable development	Subject analyzed	Strengths	Weaknesses
1. Economic dimension	1.1 Expenses incurred in biomass energy production	Not very high costs in biomass-derived heat generation at the household and community levels	Very high costs in biomass electricity production and thus high risks involved if raw materials are not properly managed
	1.2 Economic gains	Significantly reduced expenses on exhaustible energies	Relatively low return on investment
2. Social dimension	2.1 Acceptance by local people	Quite warmly embraced as a viable alternative to exhaustible energies	Certain kinds of biomass are unsuitable for urban communities becaue of the inconvenience involved, especially a relatively long time required for their ignition
	2.2 Involvement of relevant parties	Cooperation and involvement from the government, private sector, non-governmental organizations and the local people in biomass energy production to displace exhaustible energies	
	2.3 Income generation	Sound economic opportunities created as new jobs and additional income are generated in the community	
3. Environmental dimension	3.1 Environmental impacts	Minimum environmental impacts	High level of atmospheric pollutants in case of incomplete combustion
			Technology for pollution treatment required
	3.2 Land utilization	Exploitation of unutilized land by planting biomass crops on it	Possible risk of food security resulting from too much cultivation of energy crops

Promoting biomass energy production at the household and community levels, be it in the form of heat or electricity, is a means to support energy self-dependence and foster energy security. [28] Still, some weaknesses were detected with respect to the sustainability of production. In order to promote biomass energy production in Thailand in a sustainable manner, guidelines are thus formulated as follows.

5.1. Feasibility study of biomass energy production at the household and community levels

The investigation revealed a considerably high level of instability in terms of the supply of raw materials for biomass energy production, which depends on the harvest season. This issue is particularly relevant in the case of biomass electricity production, for a far greater amount of biomass is demanded when compared to biomass energy production at the household level. It is thus necessary to conduct a feasibility study before biomass energy production both at the household and community levels is implemented. This can be done in cooperation with agencies having relevant knowledge and understanding, ranging from those about the technicalities and the community itself, of certain relevant physical, such as the availability and types of biomass, storage and transportation of the biomass in question, and of certain social aspects such as the establishment of local networks, job generation in the community, and the establishment of local enterprises. Gleaning such knowledge and understanding is indispensable in assessing the feasibility of biomass energy production is also useful in choosing the mode of production suitable for the community—something not complicated to implement and easily maintained by the local people themselves with no necessity to ask for expert help.

5.2 Improvement of the efficiency of biomass energy production process

In biomass electricity production, transportation poses a significant problem. Due to the very light weight of biomass, the load is bulky and thus costs relatively a lot for transportation, [29] Other points of concern are the environmental impacts, particularly the dust particles released during the transportation [30] and skepticism on the part of the local people regarding the potential environmental impacts arising from biomass electricity production. Before the production is implemented, it is recommendable, hence, to promote better understanding as well as confidence in the community by regularly providing reliable data and possibly through field trips. Improvement of the efficiency of biomass energy production methods and processes should be planned for the future, for example regarding biomass transportation which releases no atmospheric pollutants, and the storage of biomass that is space saving and ensures quality preservation of the biomass. In addition, data should be collected on various economic aspects of biomass energy production, ranging from costs, income, expenditure, and assessment of the environmental impacts in terms of pollution level which can be compared to other standard values.

With respect to the promotion of the use of biomass energy at the household level, for a rural community, biomass is likely to be sourced easily and its preparation is unlikely to be complicated. In contrast, the sourcing and preparation process can be complicated and time-consuming for an urban community, especially one with no biomass source of its own. To promote greater access to biomass energy exploitation, an easy-to-operate means for generating biomass-derived heat should be developed for people in the city, for example oil extraction from biomass plants using the process called Vacuum Pyrolysis [31] and development of biomass with improved combustion efficiency but with minimum emission levels.

5.3 Improvement of the efficiency of the services related to biomass energy production

Implementation of biomass energy production at the household and community levels may not be successful if the equipment involved in the production is damaged or rendered irreparable. Therefore, in order to ensure continuity in production, a service unit or repair and maintenance system should be set up by the people in the community to take care of the equipment.

For a community that is interested in biomass electricity production, but which has no necessary knowledge, a consultant committee should be designated from all the parties involved—the government, the private sector, and non-governmental organizations—to provide advice and support. In addition to knowledge about biomass electricity production, of particular importance is also the financial aid provided to interested entrepreneurs or communities, such as low-interest loans for electricity production from renewable energies.

5.4 Inculcation of awareness of social co-benefits rendered by biomass energy production

Promotion of biomass energy production at the household level can help families reduce their energy expenses and generate jobs such those involving charcoal production. For biomass energy production at the community level, the scope can be enlarged in the form of a community enterprise, from which income can be generated and which can become a knowledge center where biomass energy production at the household and community levels can be learned about. A mechanism to foster cooperation both at the household and community levels should be developed to promote the social co-benefits from biomass energy production. For instance, a family experienced in employing biomass energy equipment can be invited to be speakers at biomass energy production demonstrations, and a cooperative of users of biomass energy production equipment can be established. The financial gain from the operation of the cooperative can be used primarily for repair and maintenance of the equipment, and what is left can contribute to other community benefit programs.

5.5 Resource management of biomass energy production in a systematic manner

As aforementioned, resource shortages can become a major problem, as the supply of some raw materials for biomass energy production depends on the harvest season. Additionally, too much cultivation of energy crops means less cultivation of food crops, which may result in a shortage of some food crops in the future. In this regard, biomass crops should be grown on uncultivated or unutilized land, for example along the earth embankment in a rice paddy. Furthermore, a database should be formulated in order for the community to be informed about the sources of biomass and their harvesting seasons, which can be useful in choosing the materials and help reduce the problem of the shortage of biomass supply. For a community with forest resources, a community forest management system should be set up, with a committee designated to be in charge of the preservation of the

community's forest area, which can help prevent deforestation for the purpose of biomass energy production.

6. Conclusion

Agricultural products constitute 19% of Thailand's gross domestic product, and the total value of the country's agricultural product export came second to non-agricultural product exports during 2008-2012 [32] As a result, domestic agricultural residue is plentiful. Support is also available from relevant sectors in the production of alternative energies from agricultural residue, such as in the forms of biomass electricity plants and the use of charcoal and biomass stoves. In urban areas, nevertheless, promotion of the use of biomass energy is likely to be difficult owing to lack of involvement and interest in developeing and further applying the use of biomass energy, which is not as convenient as the use of non-renewable fuels, on the part of the local people, since it takes time for material desiccation as well as for combustion. In rural areas, interest in energy production using biomass is more tangible at both household and community levels thanks to the various benefits incurred, be they economic, social, or environmental. Regarding the economic gains, the use of biomass can help save exhaustible energy sources such coal, natural gas, and oil, and its by-products such as wood vinegar can be used as pesticide. In addition, use of charcoal produced from biomass can reduce household expenses, especially on cooking gas, by up to 50% and can also generate income for the local people. In the social dimension, all of the relevant sectors can be significantly involved in the production of biomass energy at the household and community levels in a comprehensive manner. With a view to promoting more community involvement, some local people can be designated members of an energy production committee to monitor and inspect the administration of the local biomass electricity plant. In the environmental aspect, biomass energy production from recycled waste is essentially a means for protecting the environment and preserving natural resources. Decreased deforestation and burning of biomass in the open air are also benefits from the use of biomass as energy. However, there are some adverse environmental impacts such as the emission of carbon monoxide, nitrogen dioxide, and particulate matter.

Sustainability guidelines for energy production using biomass at the household and community levels therefore can include improvement of the efficiency of the biomass energy production process and its related services, inculcation of awareness of the social co-benefits resulting from biomass energy production, and resource management for biomass energy production in a systematic manner. Also of importance are feasibility studies on biomass energy production at the household and community levels.

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