Study on Operation Problems in Biomass Power Plants: Northern Thailand

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A B S T R A C T

The purpose of this research is to study on the operation problems in the electricity production of biomass power plants in Northern Thailand. The surveying on the problems was conducted in 3 areas: 1) fuel supply issue, 2) technical and engineering issue, and 3) government support issue. From the analysis of the survey data, it was found that type of consumed fuel and the installation capacity of the power plant are the key parameters. By fuel consumption, the power plants in the northern region can be divided into two groups: bagasse based power plants, and agro residues based power plant. From the survey results of problems in bagasse based power plants, it was found that the most common problems was technical and engineering issue. This was due to high moisture and high ash contents of fuel supplies led to the poor burning process and problematic in the combustion system. Meanwhile, the agro residues based power plants had the most severe problems in fuel price because the biomass fuel was mainly purchased from many sources in order to generate sufficient electricity throughout the year. Other major problems were the fuel impurities, electricity purchasing price and electricity generation license. This study can be used to formulate a policy for sustainable biomass power generation and price determination, and to use it as a guideline to support the production of electricity from biomass power plants suitably in the future.

1. INTRODUCTION

Global warming has become the most important worldwide issue in recent years. The current engagement of the Intended National Determined Contributions (INDCs) incorporated in the Paris Agreement is still impossible to hold the rise of the average global temperature to below 2 °C by the end of the century [1, 2]. One of the possible ways to reduce energy-related global carbon emissions is the use of renewable energy resources instead of fossil fuel. In the past few years, total final energy consumption for modern renewables grew strongly about 21.5% (in the sum of 7.3 EJ) during 2013–2018 [3]. The share of renewable energy increased significantly and became 18% (the traditional biomass accounted for about 7%) of global total energy consumption in 2018. Biomass is recognized as a main alternative fuel to sustain renewable energy. Moreover, installed renewable power capacity grew more than 200 GW in 2019 and provided around 27% of global electricity generation by the end of 2019. Additionally, biomass is a versatile renewable energy resource and produces remarkably less GHG emissions than conventional fossil fuel [4, 5].

Biomass power plants increased significantly over the past few years due to the energy policy supported by the governments of different countries to achieve climate change target and the abundance of biomass resources. The EU energy policy, such as, public funding, government incentives, and financial support for research and development in biomass energy, raised the installed biomass power plant capacity from 10,566 MW in 2000 to 19,158 MW in 2015 [6]. The Chinese government provided many development plans in biomass electricity generation (such as the Medium and Long-term Development Plan of Renewable Energy (MLDP), the Twelfth Five-Year Plan of Biomass Energy Development, the Renewable Energy Law, and the Energy Saving Law) and some financial supports (such as, providing high feed-in tariff about 0.75 CNY/kWh for biomass power plant [7]) brought about the significant increase in China's biomass power generation. The installed biomass power capacity increased from 1.0 GW to 7.7 GW during 2000–2012 (increased around 18.54% annually) [8]. However, there were still many problems existing in biomass power plant development aspect. Despite the fact that biomass were abundant resources, their locations were quite scattered. This caused higher in biomass transportation

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costs, especially when the transportation distance was more than 50 km [9]. Balancing demand and supply of biomass resources was also an important problem. Increasing in demand could cause the biomass price higher. Moreover, as almost biomass obtained from crops, the amount of supply cannot be assured to obtain consistently. In the event of a disaster, outbreak, or a fluctuation of the global weather, it could cause shortage in biomass resources that will eventually raise their prices. Limited financing channels were also another problem to be concerned. Since the current biomass fuel and labor costs have increased consecutively in recent years, the financial support policies that were calculated for ten years ago may not be sufficient to the current situation. For instance, the feed in-tariff for agricultural biomass power generation in China is 0.75 CNY/kWh has determined from the costs in 2010 which was not sufficient for current biomass power plants in many areas [10]. Moreover, in some financial policies, only few projects can be applied because of many constraint conditions, and sometimes, few projects could get benefit from those policies. Technology and equipment shortage was also a problem in biomass power plant aspect. In some countries, the technology in biomass power generation equipment was still in the primary stage. The low efficiency in conversion biomass to electricity raised more cost. Some spare parts and fittings cannot be produced in their countries, so that the operation and maintenance of the machine had to depend on import only [11]. These are still general obstacles in the promotion and development of biomass power plants recently.

In Thailand, the amount of electricity production from biomass has been increased significantly as a result of many policies from the Ministry of Energy, such as, the Renewable and Alternative Energy Development Plan 2018–2037 (AEDP2018), the 15-year Renewable Energy Development Plan (2008–2022) and many promoting measures from the Department of Alternative Energy Development and Efficiency (DEDE) over the past decades. According to the energy development plans, the renewable energy such as biomass, hydropower, solar, wind and factory wastewater were substantially used to produce heat and electricity for all sectors, and also to produce fuel in the transportation sector [12, 13]. Compared to the production of electricity from wind or solar, biomass is a more stable energy resource. Because of many modern biomass conversion technologies and large availability of biomass resources, there are a lot of emerging biomass power plants scattered throughout the country. In Thailand, by types of fuel supplies, the biomass power plant can be classified into 2 groups; a) power plant buying biomass fuels from external sources, and b) power plant taking biomass fuels as residues and/or by-product (such as rice husk and bagasse) from factories established in the same area of the power plant. Due to the lack of long-term planning, the government's promoting measures led to problems in a later period, especially for the power plants buying the biomass fuel. The power plants encountered many major problems including biomass fuel shortage, lack of purchase regulations, and no suitable prioritization in managing biomass resources. Additionally, there was also a problem of fluctuation in biomass price that led to higher costs in electricity production [14].

In 2017, the government proposed a solution to these problems by encouraging farmers to cultivate more quick-growing crops in order to feed much more into the power generation system, to increase new forest plantation area, and to strengthen the energy security [15]. Moreover, the government made the maps of the location of the biomass power plants and published the data on the amount of biomass fuel potential on the website which would help the biomass power plant owner to manage the fuel in line with the area of the energy resources [16, 17]. Besides the problems in the fuel quantity and management, the technical problems and environmental impact issues were other major problems which affected to the biomass power plants [18, 19]. Especially for a very small power plant or very small power producer (VSPP), the technical problems which were often found in power plant operations were lack of knowledge and understanding clearly in how to use and maintain the system of the operators, and also absence of the technicians due to the power plants always located in rural area. Furthermore, very small power plants in Thailand can be operated without having to complete the environmental and health impact assessment reports. Therefore, it often encountered problems that would affect the well-being of the people in the community. In many cases, the power plants had to shut down and was prosecuted in the administrative court for the cause of environmental problems to the nearby villagers [18, 20].

Up to the present time, Thailand's government has supported the biomass power plants by increase the purchasing price of electricity produced from renewable energy resources in 2 patterns: 1) adder and 2) feed in tariff (FiT). During 2009–2015, the adder system was launched to support the biomass power plants for a period of 7 years, and the extra purchasing cost was ranged from 0.3 to 0.5 baht/kWh depending on the installation capacity [21]. The adder has been used for quite short period of time (6 years) due to the quite short period of supporting time (7 years), higher fuel cost, and inappropriate purchasing price, after all, it has been canceled and transited to the FiT system [22]. The FiT system has been introduced to the new biomass power producer which has commercial operation date (COD) after 2015, and it was an optional for the old power plants that has been supported by adder system. By this system, the supporting period has been extended to 20 years and the purchasing price can be varied upon the core inflation [23]. The extra purchasing cost was the summation of FiT_{Fix} (2.39–3.13 baht/kWh), $FiT_{variable}$ (1.85–2.21 baht/kWh) and $FiT_{premium}$ (the supporting money for electricity producers established in Yala, Pattani, Narathiwat and 4 districts in Songkhla province). For instance, the 9.9 MW biomass power plant in Buriram obtained the electricity purchasing price about 4.54 baht/kWh [24].

Although, Thailand has 220 biomass power plants in 2020 [25], the supporting electricity production from biomass by the government is still doubtful. The same electricity purchase price seems to be improper in many areas because Thailand's power plants use a variety of production technologies and variety of biomass fuel resources. The research in the study of problems in electricity production was still lacking since there was no survey study about the biomass power plant problems in the north of Thailand in any literature review. Therefore, the researchers aim to study the problems that arise in the electricity generation, primarily to study only biomass power plants located in the North, by using questionnaires and interviews with the electricity supplier in three major problems; a) fuel supply, b) technical and engineering aspect and c) government support.

2. METHODS

2.1 Population and sample

According to the data from Energy Regulatory Commission, Electricity Generating Authority of Thailand (EGAT), Metropolitan Electricity Authority (MEA) and Provincial Electricity Authority (PEA) in 2018, there are 13 biomass power plants in the northern region of Thailand, locating in 6 provinces; Chiang Rai, Nakhon Sawan, Phetchabun, Uttaradit, Lampang and Lamphun. The conventional postal modes and telephone interviews have been made to evaluate the problems relating to the operation of the 13 biomass power plants. However, only 7 power plants responded and agreed to give the information for this survey activities. Figure 1 shows the map of the northern region of Thailand and location of biomass power plants for this survey study.

Prior to the analysis, the F-test (One Way ANOVA) and multiple comparisons using LSD statistics have been performed to verify the important parameters that effects on the level of problem. From three selected variables: a) rated capacity of power plant, b) combustion technology, and c) fuel types used in the biomass power plant, it was found that only the rated capacity of power plant and the fuel types have the significant effects on the problems that arise in power generation.

2.2 Questionnaire structure

The survey questions were created based on the problems relating on the operation of biomass power plants by searching the data from newspaper, interviewing, and literature review of academic publications. After that, item-objective congruence (IOC) was used to evaluate the items in the draft of the survey questions for avoiding the ambiguity [26], and the IOC committees were a language expert, an engineer in charge of the power plant, and one of the interviewees. Finally, the questionnaire was revised and used.

Fig. 1. Map of the northern region of Thailand and location of biomass power plants in this study.

Table 1. Five-point Likert scale for accessing the problem levels

Scale	Indication	Score
5	Severe	4.21 – 5.00
4	Major	3.41 – 4.20
3	Moderate	2.61 – 3.40
2	Minor	1.81 – 2.60
1	Insignificant	1.00 – 1.80

The questionnaire consisted of 3 parts: 1) general information of the biomass power plant (open-ended and close-ended questions), 2) problems encountered in the operation, and 3) semi-structured interview. In part 2 of the questionnaire, the table type questions used a Likert scale method for assessing the level of the problem, and a five-level evaluation with the criteria are shown in Table 1. The problems in the operation of the surveyed biomass power generation have 42 questions, and it can be divided into 3 main areas: 1) problems in fuel supply, 2) technical and engineering problems, and 3) government support issues. The conventional postal modes and telephone interviews have been made for this survey exercise to evaluate the operating problems of biomass power plants. The returned questionnaires were then analyzed with a statistical tool.

3. RESULTS AND DISCUSSIONS

3.1 General information of the biomass power plant

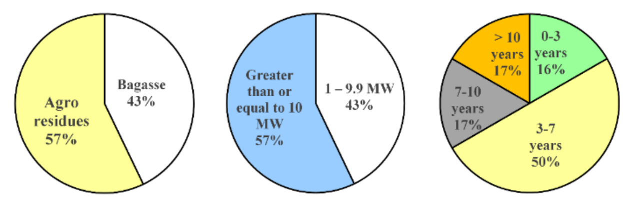
Since Thailand has a long-term renewable energy plan, the Alternative Energy Development Plan (AEDP), and has been continuously updated, the renewable energy use in Thailand has increased continuously. In 2018, total renewable energy consumption in Thailand was 12,996 ktoe, increasing 10.8% from the previous year, which accounted for 15.48% of the final energy consumption. Meanwhile, the AEDP2018 plan aims the renewable energy use to account for 30% of the final energy consumption in 2037. In terms of power generation capacity, in 2018, the installed capacity of biomass power plants in Thailand was 3,372.93 MW accounting for 30 percent of the renewable energy use in total electricity generation. This increased from the previous year for 6.83 percent. While, according to the AEDP2018 plan, the goal was set to increase the installed capacity of biomass power plants to 5,790 MW in 2037. In addition, there was still a lot of biomass potential left in Thailand as the residual biomass potential for energy use in 2017 was at 42,610 ktoe/year [12].

According to the research results and the AEDP2018 plan, the aims to increase the number of biomass power plants and the electricity production from 3,372.93 MW to 5,790 MW in 19 years (from 2018 to 2037) can be achieved with the supporting by the government and the biomass-fuel suppliers. The problems relating to fuel supply seem to be the most important issue. The long term supporting such as the promotion of economic forest planting by the fast-growing plants with the good management can prevent the problems relating to the fuel storage space, the fluctuation of fuel price as well as the fuel quality, and makes the power plant operators confident in their investments.

In Northern Thailand, there are many types of biomass conversion technologies to produce electricity including step-grate stoker, circulating fluidized bed, and traveling-grate stoker; however, most of the power plants are the steam turbine plants. The electrostatic precipitators (ESP) are commonly used as particulate matter collector, and only one power plant use the combination system of ESP and multi cyclone system.

In this study, sub-problem analysis was carried out according to the types of biomass fuels used in the power plant which were divided into 2 groups: 1) bagasse based power plants, and 2) woody and agricultural based power plants (referred as agro residues based power plant). In this survey study, it was found that there were three power plants using only bagasse, and the other four power plants using various types of biomass fuel including bagasse, tops and leaves of sugarcane, rice husk, bamboo, corncobs, woodchips, and corn leaves.

All of the three bagasse based power plants were small power plant (SPP) categorized by the production capacity ≥ 10 MW, and it had the operating periods of 9–11 months a year. For the other four agro residues based power plants, three power plants were very small power plants (VSPPs) with a capacity of 1–9.9 MW, and another one was SPP with a capacity of 16.5 MW which operated throughout the year. For the VSPPs, the operation period was quite different depending on the availability of fuels, and it ranged from 1–4 months a year, 5–8 months a year, and throughout the year. Figure 2 shows the general information of the biomass power plants in this survey study.



(a) (b) (c)

Fig. 2. General information of respondents for a) type of fuel supply, b) installation capacity and c) periods of time after commercial operation date (COD).

3.2 Survey results on problems of biomass power plants

3.2.1 Fuel Supply

3.2.1.1 Amount of fuel

Table 2 shows the analysis results of the problem on fuel amount from the respondents. As can be seen, both types of power plants had the highest scores in fuel procurement problem during the rainy season due to fuel shortage. Moreover, the transportation during the rainy season led some difficulties in controlling the quality of fuel.

Table 2. Mean levels of the problem relating to amount of fuel supply

Problem	Bagasse	Agro residues
Fuel procurement in summer	2.33±1.15	2.75±0.96
Fuel procurement in rainy season	4.67±0.58	4.25±0.50
Fuel procurement in winter	3.00±1.00	2.75±0.50
Flood	3.33±1.53	4.50±0.58
Drought	3.33±0.58	3.75±0.50
Plant disease	3.00±1.00	2.75±0.50
Pest	3.00±1.00	2.75±0.96
Not enough biomass due to competition in the neighboring areas	3.00±1.00	2.75±1.26
Scattered biomass fuel resource	2.33±0.58	2.25±0.96
No reserve biomass fuel resource	2.33±0.58	2.00±0.82
Mean	3.03±0.67	3.05±0.79

While the flood problem affected the agro residues based power plants in severe level, the effect on the bagasse based power plant was found at a moderate level. In agro residues based power plant, the fuel was travelled in lengthy distance, and therefore flood caused difficulty in the transportation and leading to insufficient raw materials to feed into the power plants.

3.2.1.2 Fuel price

Table 3 shows the analysis results of the problem on fuel price from the respondents. According to the survey data, it was found that the power plants using the agro residues had severe problem on finding the reasonable price fuel. Moreover, the problems on fuel prices fluctuation and competition in buying fuel were found in higher level than bagasse based power plant.

Table 3. Mean levels of the problem on fuel price

Problem	Bagasse	Agro residues
Prices fluctuation	2.33±0.58	3.00±0.00
Competitive for buying	2.33±0.58	3.00±0.00
Finding the reasonable price	2.33±0.58	4.25±0.96
Mean	2.33±0.00	3.42±0.72

In agro residues based power plant, most of the fuel was purchased from the middleman, and therefore, the price of fuel was quite expensive comparing with buying from farmers or agriculturists. Moreover, some types of biomass were mainly available in cultivatable period such as rice husk and corncob [27] leading to the price fluctuation. Therefore, the fuel price had a direct impact on the cost of production and the profit. In contrast with the agro residues based power plants, the problems on fuel price were found in minor level because they had their own fuel resources. In contrast with the problem of biomass fuel prices in China, most of the agricultural residues were crop straws, which seems to have the less fuel prices fluctuation problem because the fuel price was mainly dominated by the labors to collect and transport, and the straw collection costs accounted for 64% of the total cost of electricity generated from straw biomass [28].

3.2.1.3 Fuel transportation

Table 4 shows the analysis results of the problem on fuel transportation from the respondents. As reveled from the data, it was found that bagasse based power plants had a low level of transport problems, while the agro residues based power plant had a moderate level of transportation problems. Because the transportation distance was quite long for the agro residues based power plant which utilized both direct and indirect fuel purchase methods. From the interviewing, it was found that the farthest fuel purchased was from the southern region and it was more than 200 kilometers far away from the power plant. The bagasse based power plants had transportation distances in the range of 0–49 kilometers because the fuel was transported from the nearby sugar refinery plant. By comparing this problem in Thailand with the revealed literature, the high transportation cost and long-distance transportation within a radius further than 200 km have also been stated in some provinces of China because of the high competition for seeking biomass fuel against the vicinity of nearby power plants [29]. Moreover, this is one of the reasons that the researchers in Ref. [29] recommended the Chinese government to implement the customized financial subsidy standards specific to different biomass power technologies.

Table 4. Mean levels of fuel transportation problems

Problem	Bagasse	Agro residues
Transport for relatively long distance	2.33±0.58	3.00±0.82
Weather conditions impacted on transportation delay	3.00±0.00	2.50±1.00
Insufficient drivers or trucks	2.00±0.00	2.50±1.00
Mean	2.44±0.51	2.67±0.29

The moderate level of weather conditions impacted on transportation delay was found in the bagasse based power plants, while it was in minor level for the agro residues based power plants. This can be explained by the shorter period of plant operation time in the agro residues based power plant which was not run throughout the year, and they may be common shut down in the rainy season. In Thailand, the bagasse based power plants were normally operated during sugar milling season from December to May (about 6 months). In this survey study, the bagasse power plant operated for 9–11 months, therefore they needed to collect the sufficient amount of bagasse in the safe storage for a whole period of operating time.

Table 5. Mean levels of fuel storage problems

Problem	Bagasse	Agro residues
Insufficient storage space	4.00±1.00	2.75±1.71
Spontaneous ignition	3.67±1.15	2.75±0.96
Lack of in-first-out, first-out (FIFO) system	3.33±0.58	2.5±1.26
Mean	3.50±0.43	2.81±0.31

3.2.1.4 Fuel storage

Table 5 shows the analysis results of the problem on fuel storage from the respondents. As mention above, the big amount of bagasse should be kept for the power plant to operate for 9–11 months, and this leaded to the major level for the storage problems encountering insufficient storage space, and spontaneous ignition. The sugar industry and bagasse based power plants were reported to have the problem of safe bagasse storage over extended periods due to the spontaneous ignition of bagasse stockpile [30], and the first-in, first-out (FIFO) system. For the agro residues based power plants, they often do not have to reserve large volumes of fuel because the fuel has arrived from many resources by the middleman at the specified time.

3.2.1.5 Fuel Quality

Table 6 shows the analysis results of the problem on fuel quality from the respondents. From the results, it was found that the fuel quality problems for both groups were at the moderate level; however, the problem on ash content of the two type of power plants was significantly different. The level of ash problem was major in the bagasse based power plants, while it was moderate in the agro residues based power plants. According to inquiries from the SPP firing with bagasse, to sustain the same electricity production for the moist and high ash bagasse, the fuel consumption noticeably increased due to the low calorific value of fuel and low combustion efficiency, and it was quite hard to generate electricity at maximum capacity. With the poor fuel quality, the incomplete combustion was significantly high and difficult to stabilize the combustion process in the boiler.

Table 6. Mean levels of fuel quality problems

Problem	Bagasse	Agro residues
Uncertain quality such as size, moisture.	3.00±0.00	3.00±0.82
Impurities (dirt, gravel, sand, oil stain, wood roots, scrap, cement, brick, screw)	3.33±1.15	3.5±1.73
Level of ash	3.67±1.15	2.75±1.71
Mean	3.33±0.33	3.08±0.31

For agro residues based power plants that buy biomass fuels from the middlemen, the variation on the impurity and ash problems were quite significant at ±1.73 and ±1.71, respectively. The impurity problem was at the severe level in some power plants. There were many kinds of impurities such as dirt, gravel, sand, oil stains, roots, scrap iron, cement, bricks, and nuts. Owing to the diversity of fuel sources and a wide variety of fuels (such as, rice husk, corn cob, bamboo chop, wood chip, as well as corn leave), the problems on quality fuel were quite different in each agro residues power plants. For the power plants using rice husk, there were a lot of problems with ashes, but the problems were less for the power plants that consumed woody biomass. Meanwhile, in the power plants using wood chip and agricultural residues, the problems in the impurity were significant.

3.2.2 Technical and engineering aspect

3.2.2.1 Boiler/combustion systems

The results from the examination showed that all of the responding power plants equipped with steam turbines; however, the combustion systems were diversified. In all of the bagasse power plants, the traveling grate stokers were used, while the agro residues power plants used three different combustion systems depending on the installation capacity as follows: 1) capacity of 1–4.9 MW using a circulating fluidized bed, 2) capacity of 5–9.9 MW using a step grate stoker, and 3) capacity of greater than or equal to 10 MW using a traveling grate combustion system.

Table 7. Mean levels of problems associated with boiler/combustion systems

Problem	Bagasse	Agro residues
Slagging/fouling	3.33±1.15	2.75±1.26
Corrosion of pipes, fittings and heat exchanger surface	3.67±0.58	2.50±1.26
Need to be supervised by a specialist	3.00±0.00	2.75±1.26
Machine parts shortage and high replacement cost	3.33±0.58	3.25±1.26
Equipment installation	4.00±0.00	2.75±0.96
Mean	3.47±0.38	2.70±0.37

Table 7 shows the analysis result of the problem associated with boiler/combustion systems from the respondents. From inquiries, it was found that the root cause of the technical and engineering problems of both types of power plants was fuel quality. The quality of the fuel (ash and moisture contents) directly affected the stability of combustion system, slagging and fouling of heat exchanger surface, as well as jamming fuel feed and clogging of bottom ash in removal systems. The problems arising in this topic for both power plant groups were clearly in different levels, especially in the topics of corrosion problems on pipes, fittings and heat exchanger surface, and the problems owing to device installation. It was found to be in major level for the bagasse based power plants, while it was in moderate level for the agro residues based power plants. For the bagasse-based power plants, the bagasse consisted of high content of alkali minerals in ashes, especially Sodium (Na^{+}), Calcium (Ca^{2+}), and Potassium (K^{+}) [31], which caused fouling and slagging problems in higher level than the agro residues-based power plants. These caused damage and system problems more frequently and resulted in the need to repair or replace the equipment more often in the bagasse based power plants. Additionally, the more time of plants operation and the higher plant capacity, the more problems related to the technical and engineering aspect were found in bagasse based power plants.

3.2.2.2 Maintenance

Table 8 shows the analysis result of the maintenance problem from the respondents. The maintenance problems of both types of power plants were at a moderate level. The oldest biomass power plant in this survey study was operated since 2010, and the newest power plants was COD in 2017. Since then, the power plants have been operated for 3–10 years, therefore the maintenance systems were well set up, and they have the employees for maintenance and service. Moreover, almost power plants using agro residues as a fuel were very small power plant producers (VSPP) which did not have spare parts stored in the power plants. When there were maintenance problems, they always had to wait for external qualified technicians and long waiting time for spare parts from dealers. Unlike the larger bagasse based power plants, there were skilled technicians and necessary spare parts for emergency repairs. Consequently, the speed of troubleshooting and lack of progress notification from parts dealers became the major problem for the agro residues based power plants in maintenance problems.

Table 8. Mean levels of maintenance problems

Problem	Bagasse	Agro residues
No 24 hours service	3.00±0.00	3.00±1.41
Speed of troubleshooting and lack of progress notification from parts dealers	3.00±0.00	3.25±0.96
Availability of spare parts	3.00±0.00	2.75±1.50
Speed of replacement or maintenance	3.00±0.00	3.00±1.41
Mean	3.00±0.00	3.00±0.20

3.2.3 Government support

Table 9 shows the analysis result of the government support problem from the respondents. As mentioned before, in Thailand the role of government mainly subsidies for biomass power generation by FiT system. Nowadays, the producing electricity from biomass is a high risk of operating the business due to the fluctuation of the cost of the fuel supply. As can be seen in Table 9, the major concerning problem in the agro residues based power plants was about the purchasing electricity price due to the high fuel prices as mentioned in section 3.2.1.2 that the agro residues had severe problem on finding the reasonable price of fuel. Therefore, the power plants need the higher purchasing electricity price as can be seen in the quite high value of the analysing data at $\overline{x} = 4.0$. This problem was also encountered in China, which was a result of the competition for biomass fuel of power plants caused extremely high fuel prices. But the government policy to support in purchasing of electricity from biomass power plants was still the same rate as it was 10 years ago, which does not respond to higher fuel prices [10]. Additionally, one more major problem was the difficulty in applying for the electricity generation license, because the application for the permission to establish the biomass power plant was quite complex and time consuming. Furthermore, the problems related to lack of government support during construction, power transmission line and grid connections which involving with the provincial electricity authority were in the moderate level for both type of power plants.

Table 9. Mean levels of government support problems

Problem	Bagasse	Agro residues
Electricity purchasing price	3.00±1.00	4.00±1.41
Electricity generation license	3.33±0.58	3.50±1.29
Lack of government support during construction	3.33±0.58	3.00±0.82
Power transmission line and grid connection	2.67±0.58	3.00±0.82
Mean	3.08±0.32	3.38±0.48

3.3 Effects of type of fuel supply and installation capacity on operation problems of biomass power plants

From the statistical analysis (One way ANOVA) and the multiple comparison using LSD statistics, it was showed that both types of fuel supply and installation capacity had significant impact on the problems arising in the biomass power generation**.** Figure 3 shows the level of 8 problems: fuel supply, fuel price, fuel transportation, fuel storage, fuel quality, boiler/combustion systems, maintenance, and government support for different types of fuel used in the biomass power plants in the north of Thailand. The results of the survey data showed that power plants using the agro residues had the most price problems which leading to the high cost for electricity generation, and they needed more support from the government.

For the biomass power plants using bagasse, the major problem was the fuel storage due to the prolonged period in storing fuel and the high volume of bagasse. In Northern Thailand, sugarcane is commonly planted in the months of December to April, thus the good management of fuel procurement and storage are needed for avoiding the fuel shortage problems during the off-season of sugarcane planting. The following noticeably problems were the problems associated with boiler/combustion systems which related to the corrosion of heat transfer surface, pipes and fittings, and the fuel quality. The bagasse was the by-product or waste from sugar refinery factory, then, it was impossible to control the quality of biomass fuel for the bagasse-based power plants.

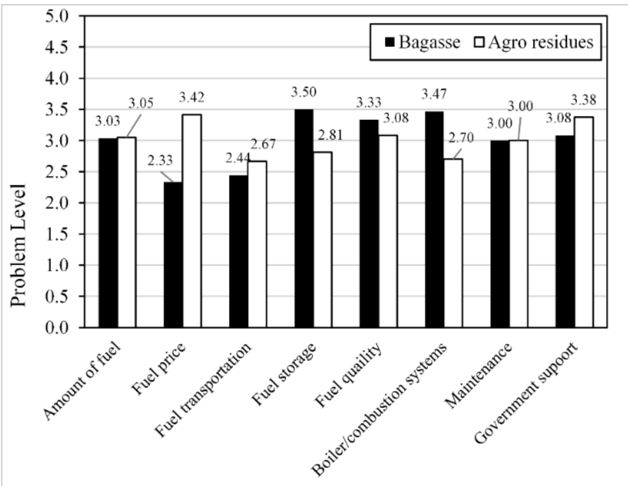


Fig. 3. Problem levels of biomass power plant operation classified by type of fuel supply.

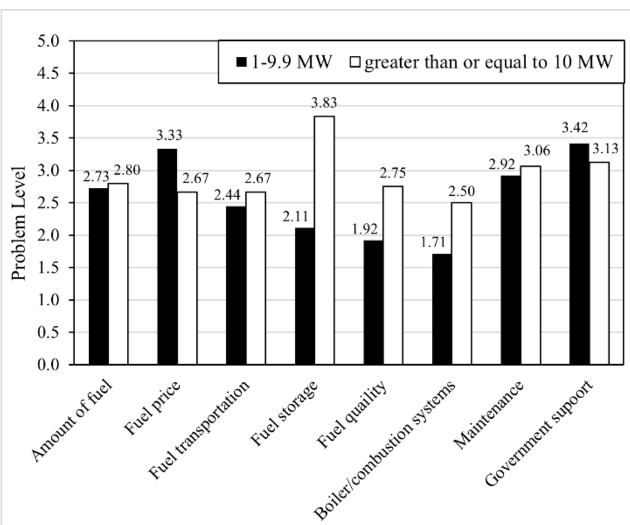


Fig. 4. Problem levels of biomass power plant operation classified by installation capacity.

Figure 4 shows the level of 8 problems for the different installation capacity of biomass power plants in the north of Thailand. Considering the impact of power plant capacity on the operation problems in the biomass power plants, it was found that SPPs with the installation capacity ≥ 10 MW encountered the major problem on fuel storage. As mentioned in section 3.1, almost SPPs were bagasse based power plants operated almost all the year while the fuel can be collected and stored for some months each year. The SPPs must plan to accumulate enough fuel to generate electricity throughout the year. The SPP power plants therefore often confronted this problem every year if they did not manage the fuel properly. In the meantime, it was likely to encounter the less problem in this issue for the VSPPs with the capacity of 1-9.9 MW. These may be because all of the VSPPs in this research were run by the agro residues which can be supplied throughout the year. Moreover, the problems related to fuel transportation, fuel quality, fuel storage and boiler/combustion systems for the VSPPs were in the minor level. However, the major problem for the VSPPs was the government support as they produced the electricity at the higher cost of fuel supply.

4. CONCLUSIONS

In the current survey study, the problem in the operation of the biomass power plants in Northern Thailand were collected by conventional postal modes and telephone interviews. The three major problems: fuel supply, technical and engineering aspect, and government support were clarified and analysed based on two major parameters: the type of fuel use and the installation capacity of the biomass power plants. The results can be summarized as follows:

- In both bagasse based and agro residues based power plants had severe problem on fuel shortage problem during the rainy season, and the difficulty in the controlling of the fuel quality was the following problem. The power plants using the agro residues had two more severe problems (at $\overline{x}$ = 4.21–5) on the fuel shortage during flood season, and difficulty in the finding of reasonable fuel price.
- Meanwhile, the bagasse based power plants had five major problems (at $\overline{x}$ = 3.41–4.20) on the shortage of fuel storage space, spontaneous ignition, fuel ash, corrosion of pipes, fittings and heat exchanger surface, and equipment installation. The major problems in the agro residues based power plants were the fuel impurities, electricity purchasing price and electricity generation license.
- The major problem for the SPPs were the insufficient of fuel storage space, while it was government support for VSPPs. For the VSPPs, they produced the electricity from agro residues at the higher cost of fuel supply, therefore they needed more FiT from the government. Finally, from the operating cost point of view, the same FiT for different fuel resources seems not to be appropriate.

However, this research was the preliminary study of the problems in the electricity production of biomass power plants especially only in Northern Thailand. Therefore, based on this study, we will study in detail of the problems of biomass power plants in the North of Thailand as well as expand the scope of the research to a broader extent for the whole country to obtain an overview of the problems of biomass power plants in Thailand. Moreover, the further study can be used to formulate a policy for sustainable biomass power generation and price determination, and to use it as a guideline to support the production of electricity from biomass power plants suitably in the future.

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