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Bioenergy development in Thailand: challenges and strategies

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Abstract

In recognition of concerns about the security of energy supply and climate change, the Thai government has developed Alternative Energy Development Plan for the period 2012–2021. Under this plan, the production of bio-ethanol and biodiesel in 2021 is expected to grow significantly. This growth will add more pressures on water and land requirements for growing energy crops. This is likely to contribute to worsening the security of water and food supply. This paper, therefore, provides an overview of the bioenergy development and current policies in Thailand with a view to identify the challenges faced by the development of bioenergy. A review of the bioenergy policies reveals that the existing policies have been exclusively focus on energy perspective and largely ignore the significance of the implications arising from the interdependencies between energy, water and food. There is a lack of understanding of the interrelationships between bioenergy, water and food policy interactions. The lack of such understanding is likely to pose several challenges including food or fuel dilemma, security of water supply and issues surrounding land use for biofuel production. This paper further emphasizes the need to develop an integrated framework for developing an understanding of the relationships between energy, water and land.

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Keywords: Bioenergy policy, Challenges and strategies, Energy, water and food linkages, Thailand.

1. Introduction

Given growing demand for clean energy to mitigate greenhouse gas emissions and to enhance the security of energy supply, the Thai government seeks to identify possible options for bioenergy

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development. Since Thailand is an agricultural-based country, it has high potential for the development of bioenergy. In 2012, the Thai government has committed to the development of '*Low-Carbon Society*'. With the aim of achieving the '*Low-Carbon Society*' goal, the government has developed Alternative Energy Development Plan (AEDP: 2012-2021). The main objective of this plan is to increase the proportion of alternative energy, from 7,413 KTOE in 2012 to 25,000 KTOE in 2021 or 25% increase of total energy consumption [1]. Much of the focus of this plan was to increase the production capacity of bioenergy. Under the AEDP plan, biomass, biogas and MSW are expected to rise, as compared to the existing capacity, by about 2 times (3,630 MW), 4 times (600 MW) and 12 times (160 MW) respectively. In addition, biofuels will substitute about 44% of oil consumption in 2021. In order to meet the biofuels substitution target, bio-ethanol production is expected to rise considerably, from 1.3 million litres per day in 2012, to 9 million litres per day in 2021. The production of biodiesel will increase to 5.9 million litres per day in 2021 – more than three-fold increase as compared to 2012.

According to the AEDP, the production of bio-ethanol and biodiesel is expected to grow significantly. Such an increase in the biofuels production would require a substantial amount of energy crops including cassava, sugar cane and oil palm. This is likely to face challenges in terms of the impacts of increased demand for such friendly-environmental energy on water consumption and land use for growing energy crops. Since energy, water and land are intimately interconnected, an increasing amount of energy crops would require more water and land use. In addition, the growing scarcity of the energy, water and land resources is rapidly altering the value of ecosystem services. Lately concerns have risen about the security of energy, water, and food supply everywhere in the World, including Thailand. As these commodities are essential for survival and economic growth – more so for a developing economy like Thailand. Consequently, this paper provides an overview of the bioenergy development and current policies in Thailand with a view to identify the driving forces that have shaped the bioenergy policies and, specifically, the challenges faced by the development of bioenergy.

2. Bioenergy policies in Thailand

Due to limited indigenous energy supply, Thailand is heavily dependent on imported energy to meet the increasing energy demand of the nation. Between the years 2000 and 2011, commercial primary energy demand increased annually by about 5%, from 63.7 MTOE in 2000, to 101.2 MTOE in 2011 [2]. In order to supply the increased energy demand, imported energy increased substantially, from 39.7 MTOE in 2000, to 64.4 MTOE in 2011. Over this period, imported energy accounted for more than 60% of the total commercial primary energy in the country [2]. Of the total commercial energy, fossil fuels accounted for 96%, of which oil contributed 65%, followed by coal (16%) and natural gas (15%). Being heavily reliance on imported oil and agricultural-based economy, the Thai government has a policy to encourage the use of renewable energy over the last two decades. It was until 2003 that such a policy had materialized due mainly to a sharp increase in oil price [3].

In order to promote the use of alternative energy and the development of bioenergy, the Thai government has developed the first National Alternative Energy Development Plan (2004–2011) with a particular focus on production mandate for biofuels (especially biodiesel), tax and non-tax incentives, research and development supports, and public awareness promotion [4]. In 2004, oil companies began to sale E10 premium gasoline (gasohol blended from 10% ethanol and 90% gasoline with octane number of 95 RON). According to Amaranand [3], E10 sale initially increased rapidly to reach 17.4% of premium gasoline sale in December 2005, however started to stagnate since 2006. This, argued some, was due to consumer perception that E10 caused underperformance in vehicles, unclear information about types of vehicles capable of using E10, the price differential being too small as the net benefit was only 3% and the relatively high price of ethanol charged by ethanol manufacturers. As a result of this, the government has made some policy changes which resulted in lower ex-factory price and the lower level of oil fund contribution for E10. Such changes in policy effectively increased the differential between the normal gasoline and E10 prices from 1.50 baht per litre to 4.00 baht per litre in November 2007 [3]. As a consequence of the policy changes, the sale of E10 rose from 3.5 million litres per day in 2006 to reach 12.0 million litres per day in 2009 (see Table 1). The sale of premium gasoline dropped from 8.1 million litres per day in 2004 to 0.11 million litres per day in 2011. The government further initiated a promotion campaign for gasohol E20 and E85 in 2007 and 2008 respectively. It should be noted that E20 gasohol is a blend of 20% ethanol and 80% gasoline whereas E85 gasohol is a mixture of 85% ethanol and 15% gasoline. The sale of E20 and E85 gasohol then began in 2008. According to Table 1, the sale of E20 gasohol, in 2011, rose to 0.6 million litres per day in 2011 – about five–fold increase as compared to the beginning year. This was mainly because of the government subsidy for E20 gasohol from State Oil Fund. For E85 gasohol, its sale rose insignificantly, from 0.01 million litres per day in 2010 to 0.02 million litres per day in 2011. Such a slight increase, argued by some, is partly due to technical incompatibility of old cars in using E85 and limited number of new E85 vehicles.

Table 1. Sales of Gasohol and Premium Gasoline 95

Year	Million litres/day			
	Premium Gasoline	Gasohol		
		E10	E20	E85
2004	8.1	0.2	-	-
2005	6.1	1.8	-	-
2006	4.0	3.5	-	-
2007	3.0	4.8	-	-
2008	0.9	9.2	0.1	*
2009	0.5	12.0	0.2	*
2010	0.2	11.6	0.4	0.01
2011	0.1	10.9	0.6	0.02

Note: * refers to insignificant number

Source: [5]

In terms of biodiesel, the government began a campaign to promote the production and consumption of biodiesel in 2005 [4]. B5 (a blend of 5% methyl ester (B100) and 95% normal diesel) has been on sale since 2005. Initial production of biodiesel was, however, insignificant. In 2006, the sale of B5 amounted to 0.12 million litres per day compared with total diesel sale of 50 million litres per day [5]. This was because of unclear pricing policy, unclear standards and enforcement of B100 standards, and refusal by automobile companies to provide warranty for vehicles using B5. It was until February 1, 2008, the government implemented a policy requiring compulsory production of B2 biodiesel (high-speed diesel with the two percent of B100 content by weight) in order to allow a period of about one year for all related parties to make adjustments [4]. From Fig. 1, the sale of B5 biodiesel increased significantly, from 0.12 million litres per day in 2006 to 19.3 million litres per day in 2010. In 2010, production of B2 has been compulsorily replaced by B3 because of the fact that raw material of crude palm oil (CPO) is available in sufficient quantity for the anticipated production. In order to promote consumption of B5, the government provided price subsidies from the State Oil Fund that allowed price of B5 to be lower than those of B2 and B3 blends. Additionally, the Ministry of Agriculture and Cooperatives and the Ministry of Energy initiated, in 2008, Committee on Biofuel Development and Promotion (CBDP) with the aim to expand the palm growing area and to increase domestic production of palm oil [6].

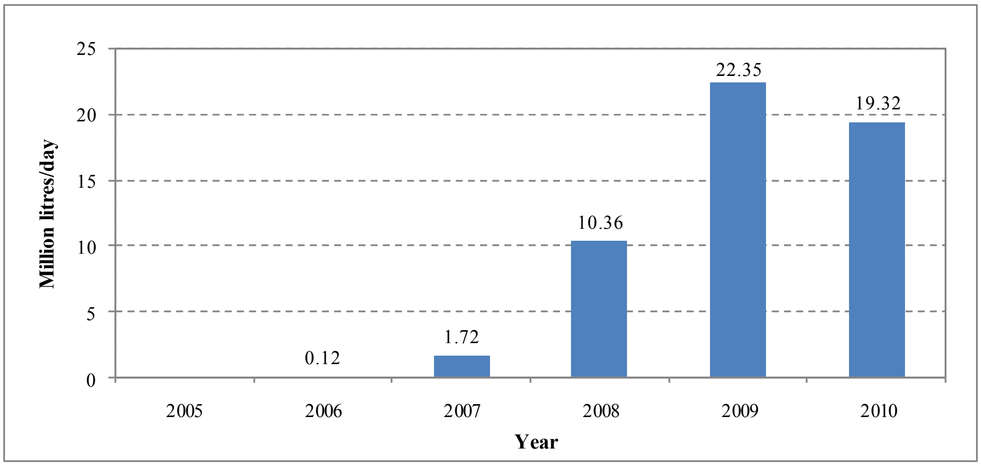

Fig. 1. Sales of B5 biodiesel in Thailand [5]

In 2008, the Second Alternative Energy Development Plan (2008–2022) was developed with the main target of increasing the proportion of alternative energy, to 20% of the national final energy consumption by 2022 [7]. The objectives of this plan are to: a) utilize alternative energy as a major energy substitute for imported oil; b) increase energy security of the country; c) promote an integrated green energy utilization in communities; d) enhance the development of alternative energy industry; and 5) research, and develop high efficient technology for alternative energy. The plan is divided into 3 stages:

- Short term (2008-2011): focus on promotion of commercial alternative energy technology from high potential energy sources including biofuels, biomass, and biogas.
- Medium term (2012-2016): focus on development of alternative energy technology industry, encourage new alternative energy R&D of economically viable technological methods and sources, and introduce a model for the concept of “Green City” to help communities move toward energy self-sufficiency through sustainable development.
- Long term (2017-2022): enhance utilization of new available alternative energy technology, i.e., hydrogen, bio hydrogenated (BHD), extend green city models throughout the country and ASEAN countries.

Under this plan, the government has set targets of ethanol production of 3.0 million liters per day during the period 2008–2011, 6.2 million liters per day in the medium-term (2012 – 2016) and 9.0 million liters per day in the long term (2017 – 2022). In order to carry out this plan, the government provided tax incentives and subsidies to ethanol producers, gasohol refineries, and automobile manufacturers (as discussed above). The plan, however, have fallen short of achieving its short-term target of 3 million liters per day because the consumption of ethanol was only 1.45 million liters per day in 2011 [8]. This was because the government does not have compulsory mandates on gasohol use and most consumers have substituted the consumption of gasoline and gasohol for the highly-subsidized LPG and NGV. For biodiesel, biodiesel blending has been mandatory since the implementation of this plan. The production of biodiesel (B100 biodiesel) was expected to increase to 1.35 million litres per day over the period 2008–2010, 3.02 million litres per day in 2011, 3.64 million litres per day in 2016, and 4.5 million litres per day in 2022 [7]. As previously discussed, the government has implemented a policy that required compulsory production of B2 blend in 2008. In addition, B5 blend was planned to be enforced by 2011. The feedstock production was, however, insufficient to meet the plan's target as a result of under-targeted planting of palm oil tree and unpredictable weather conditions.

Due to the fact that the 15-year AEDP plan (2008–2022) has failed to achieve its short-term targets, the government has developed a new 10-year Alternative Energy Development Plan (AEDP: 2012-2021) with a view to replace the 15-year plan. The new AEDP (2012–2021) was developed by DEDE [1] with the main target of increasing the proportion of alternative energy, to 25% of the national final energy consumption by 2021. Fig. 2 presents the AEDP target categorized by alternative energy type in 2021. The objectives of the new AEDP plan are to: a) develop renewable energy as the country's major energy sources in a sustainable manner; b) enhance the security of energy supply; c) promote integrated green energy utilization in communities; d) support alternative energy technology production; and e) research, develop and promote Thailand's alternative energy technology for international competitiveness.

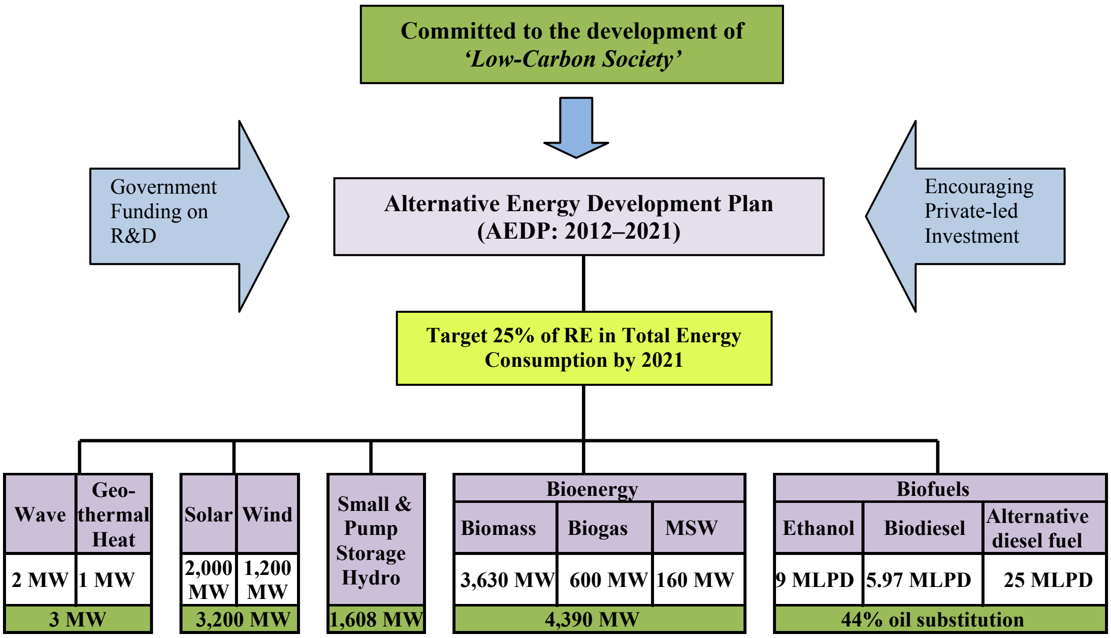

Fig. 2. Alternative Energy Development Plan (AEDP: 2012–2021) [1]

With an aim to achieve the alternative energy target of 25% in 2021, the country's planners have developed several alternative energy development strategies. For example, according to the AEDP, biomass is expected to grow from 1,751 MW in 2012, to 3,630 MW in 2021. The development of biomass would be particularly focused on the establishment of '*Distributed Green Generation (DGG)*' in order to promote the participation of local communities in alternative energy production. In addition, with view to provide sufficient agricultural residues to the *DGG*, the government supports planting the fast-growing crops on marginal land. For biogas, it would increase to 600 MW in 2021 – more than four-fold increase as compared to 2012. The strategies for biogas development would be promotion of the biogas production for household consumption and development of biogas pipeline in the communities for sharing the excess capacity.

In terms of biofuels, it is estimated to substitute about 44% of oil consumption in 2021. For Thailand, biofuels can be divided into ethanol, bio-diesel and new fuel for diesel substitution. According to the AEDP, ethanol production would increase from 1.3 million litres per day in 2012, to 9 million litres per day in 2021. In order to achieve ethanol target, the production of cassava and sugarcane – major crops for producing ethanol, are expected to rise to 35 tons/year and 105 tons/year in 2021 respectively. Such an increase in cassava and sugarcane production would subsequently result in the planting areas which are likely to increase to 2.8 million acres for both energy crops. It should be noted that the planted area is estimated under the assumption that cassava and sugar cane yields are not less than 5 and 15 tons/year respectively. For bio-diesel, the production of bio-diesel would increase from 1.62 million litres per day in 2012, to 5.97 million litres per day in 2021. For achieving such target, crude oil palm would be required for 3 million tons/year and the planted area would be 2.2 million acres. In terms of new fuel for diesel substitution, it is expected to produce 25 million litres per day in 2021. Due to limited resources for producing bio-diesel to supply sufficient demand, the development of new fuel is considered to be an alternative. The new fuel development strategies include new energy crop development (for example, jatropha and micro algae), the development of oil conversion technology (for example, BHD (Bio Hydrofined Diesel) and BTL (Biomass to Liquid), and ethanol blending for diesel oil (i.e., FAEE (Fatty Acid Ethyl Ester), ED95 (Ethanol blended with additives) and diesohol).

3. Rationale behind bioenergy policies

The discussion in the previous section suggests that the development of bioenergy policies in Thailand has been driven by several factors including security of energy supply, environmental concerns, and opportunities for enhancing rural development.

3.1. Security of energy supply

Concerns about energy security have, in the recent times, moved to the forefront of global policy debate. In the case of Thailand – the country where domestic energy resources are limited, energy diversity and energy import dependency are matters of concern. For example, imported energy accounted for more than 60% of the total commercial primary energy in the country over the period 2000–2011 [2]. And, the Thai electricity industry is heavily dependent on natural gas, constituted nearly 71% of total primary energy consumption in 2011 [9]. In addition, due to the uncertainty of oil prices, oil import for electricity production would increase fuel price risk which the investor is unwilling to take. Also, importing more oil would result in a lessening of energy security. Hence, the substitution of other energy resources for natural gas and oil is a way to enhancing energy security. With a view to reduce dependency on energy import and to diversify the energy sources used for generating electricity, the government promotes the use of alternative energy as a matter of priority. Alternative energy, specifically bioenergy, appears to be an attractive option for the government. This is because this option allows the government to be able to meet its policy targets including diversification of energy supply, reduction of GHG emissions, utilization of agricultural residues and promotion of clean energy in accordance with the Alternative Energy Development Plan (AEDP 2012–2021).

3.2. Environmental concerns

Environmental concerns appear to be one of the key drivers behind bioenergy policies in Thailand. As previously discussed, Thailand is heavily dependent on fossil fuels, accounting for nearly 96% of total commercial primary energy consumption, of which oil and coal have a 81% share [2]. Such a significant reliance on fossil fuels has inevitably serious environmental consequences. Over the period 2001–2011, CO_2 emissions have increased at an average annual rate of 3.5%, from 154 million tons in 2001 to 206 million tons in 2011 [2]. In order to meet the growing demand for energy, CO_2 emissions in 2030 are expected to increase nearly three-times more than the CO_2 emissions level in 2010 [10]. In response to the environmental concerns, the promotion of bioenergy is therefore become key strategy for the government in order to achieve the target of CO_2 emissions mitigation.

3.3. Opportunities for enhancing rural development

Being an agricultural-based country, Thailand grows a wide range of agricultural crops (including palm oil, sugar cane, and cassava) and hence potential for bioenergy is quite high in the country. In addition, much of the agricultural activities are in the countryside. The Thai government, therefore, promotes bioenergy as the opportunities to stimulate rural development. For example, farmers can earn extra income from agricultural residues such as rice husk, rice straw, and bagasse. Also, biofuels can create new markets for agricultural products. Furthermore, due to the fact that agricultural production is generally labor-intensive, increased demand for agricultural products will create more jobs in the rural areas. Such an increase in demand for agricultural feedstock will also result in higher commodity prices and hence higher income for farmers. Generating more farmers' income will, in turn, boost the rural economy by rural population spending.

4. Challenges faced by bioenergy development

A review of the existing bioenergy policies in Thailand reveals that the existing policies have been exclusively focus on energy perspective and largely neglect the significance of implications arising from the interdependencies between energy, water and food. As previously discussed, concerns about energy security and environmental constraints are major factors influencing the development of bioenergy policies. Therefore, discussions on the impacts of these policies have often been conducted in terms of addressing energy and environmental issues, without considering the inter-linkages of energy, water and food systems. It appears that there is a lack of understanding of the interrelationships between bioenergy, water and food policy interactions. In addition, the lack of such understanding is likely to pose several challenges. These include food or fuel dilemma, security of water supply, and issues surrounding land use for biofuel production.

4.1. Food or fuel dilemma

In Thailand, biofuels has generally produced from food crops including sugar cane, cassava and palm oil. It is, therefore, clearly that the feedstock production of biofuels has a direct impact on food supply reduction and thus adding substantial pressures on food prices increase. These issues become critical and a serious consideration of these issues is urgently needed if one takes note of the fact that, during the period of 2010–2011, there was a shortage of palm oil supply to meet the consumer demand and the government's target under biodiesel development plan. Following the severe shortages, retail prices of cooking palm oil increased significantly by about 30%. In order to alleviate the palm cooking oil shortage problem, the government decided to divert 5,000 metric tons of crude palm oil stocks planned for biodiesel production to refinery [11]. As a consequence, the feedstock production of biodiesel was insufficient to meet the government's target. Under the biodiesel development plan, the government has, in fact, set the short term target of biodiesel production of 3.02 million litres per day in 2011. The production was, however, estimated at only 2.22 million litres per day [6].

With a view to achieve the biodiesel target, the government has a plan for expanding palm growing area. The effort to increase palm planting and productivity to meet the growing demand is, however, a challenging task. This is because the expanding area for growing palm is limited due to competitive rubber plantation, and unpredictable weather patterns have negatively impacted palm yields [6]. In addition, the government has a plan for developing the future new fuel for diesel substitution. According to AEDP, second generation biodiesel (that is, producing biodiesel from jatropha and micro algae) is one of the strategies for new fuel development. The development of new fuel for diesel substitution is still in its infancy and hence food security will continue to be a critical issue for Thailand in the coming decade.

4.2. Security of water supply

Growing agricultural crops for the whole country has been mainly relied on rain-fed agriculture, accounting for nearly 70% of total agricultural area [12]. As noted above, the government's strategic plan is to increase productivity yield in order to provide adequate feedstock supply for biofuel production. It is clear that improving productivity yield of energy crops through expanding irrigation system might have significant implications for local water availability. In addition to the yield improvement, biofuel production processes are also water intensive. For example, water requirement for growing sugar cane accounts for less than 10 per cent of total water requirement for sugar-based ethanol production [13]. Achieving government's target by producing significant amounts of biofuels is, therefore, likely to have greater impacts on water security in the near future.

In fact, concerns about water scarcity are not only the severe issue for Thailand. Flooding has also become a serious problem that could cause damages for agricultural crops. In 2011, Thailand encountered worst flood crisis in 70 years which caused enormous damage to people and severely affected all sectors of the Thai economy including agricultural sectors [14]. It was estimated that about 280,000 rai of cassava, sugarcane and maize have been under water.

4.3. Issues surrounding land use for biofuel production

Due to continued development and policy of increasing biofuel production for substituting oil consumption, a surging demand for biofuel feedstock is a major issue that will confront the government in the next decades. Such a surging demand, argued some, could be met by several strategies, including expanding the plantation area for energy crops, conversion of traditional crop land into land for growing specific energy crops, and improvement in the yields of existing energy crops. While it is true that these strategies would be able to help increase biofuel feedstock production, adverse consequences arising from the strategies should also be taken into consideration. For example, an expansion of energy crops plantation areas might be generally made possible by conversion of forest area to agricultural area. The deforestation of rainforest for the purpose of monoculture plantation could significantly contribute to loss of biodiversity, habitats and ecosystem services. In terms of conversion of traditional crop land into land for growing energy crops, this strategy is based on the fact that new land for agricultural purposes is extremely scarce and expanding area for energy crops by deforestation is limited. Converting traditional crop land into energy crops would result in monoculture biofuel crop farming which subsequently cause natural resource degradation. Also, the strategy to increase energy crop yield would increase the use of fertilizers, pesticides and water resource. The increasing use of chemical-based fertilizer and pesticide are, therefore, likely to intensify environmental impacts in terms of air, water and soil pollution.

The foregoing discussion suggests that a satisfactory solution must be found to deal with these issues in order to maintain the security of energy, water, and food, and to achieve sustainable development goals. It is clear that such a solution cannot be found by looking at each system separately, because of the linkages that exist between these systems. An understanding of bioenergy, water and food policy interactions is essential in order to provide a satisfactory redress to the challenges noted above. There is, therefore, a need to develop an integrated framework that takes into account the interactions between energy, water and food systems. This framework could be employed to develop an understanding of the relationships between energy, water and land and, equally importantly, to assess the implications of possible future development of bioenergy, water and land resources. This understanding will be useful for the Thai planners and policy makers to design policies to overcome the energy, water and food security issues.

5. Conclusion

This paper provides an overview of the bioenergy development and current policies in Thailand with an emphasis on the driving forces that have shaped biofuel development and policies. It then identifies the challenges faced by the development of bioenergy. A review of the existing bioenergy policies reveals that the existing policies have been exclusively focus on energy perspective and largely neglect the significance of implications arising from the interdependencies between energy, water and food. There is a lack of understanding of the interrelationships between bioenergy, water and food policy interactions. The lack of such understanding is, therefore, likely to pose several challenges including food or fuel dilemma, security of water supply and issues surrounding land use for biofuel production. This paper further suggests that the development of an integrated framework for assessing the implications of possible future development of bioenergy, water and land resources is crucial in order to provide a basis for identifying the trade-offs and co-benefits that may exist. For this purpose, the development of such an integrated framework is being undertaken – as part of a research initiative at this university.

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References

[1] DEDE; *Alternative Energy Development Plan (2012–2021)*. Department of Alternative Energy Development and Efficiency, Ministry of Energy, Bangkok, 2012.

[2] DEDE; *Thailand Energy Situation: 2000–2011, Annual Reports*. Department of Alternative Energy Development and Efficiency, Ministry of Energy, Bangkok, 2011a.

[3] Amaranand P.; *Alternative Energy, Cogeneration and Distributed Generation: Crucial Strategy for Sustainability of Thailand's Energy Sector*. Paper submitted to the Energy Policy and Planning Office (EPPO), 2007. [Available online] http://www.eppo.go.th. Retrieved December, 2008.

[4] Precharjarn S., Prasertsri P.; *Thailand Biofuels Annual 2010.* USDA Foreign Agricultural Services, Gain Report Number TH0098, approved by Orestes Vasquez, 2010.

[5] DOEB; *Petroleum Sale Volume in Thailand*. Department of Energy Business, Ministry of Energy, Bangkok, 2012.

[6] Precharjarn S., Prasertsri P.; *Thailand Biofuels Annual 2011*. USDA Foreign Agricultural Services, Gain Report Number TH1088, approved by Orestes Vasquez, 2011.

[7] DEDE; *Renewable Energy Development Plan (2008–2022)*. Department of Alternative Energy Development and Efficiency, Ministry of Energy, Bangkok, 2008.

[8] Precharjarn S., Prasertsri P.; *Thailand Biofuels Annual 2012*. USDA Foreign Agricultural Services, Gain Report Number TH2064, approved by J. Wades, 2012.

[9] DEDE; *Thailand Electric Power 2011*. Department of Alternative Energy Development and Efficiency, Ministry of Energy, Bangkok, 2011b.

[10] SIIT; *Low Carbon Society Vision 2030: Thailand*. Sirindhorn International Institute of Technology, corroborating with Asian Institute of Technology, the National Institute for Environmental Studies Japan, Kyoto University and Mizuho Information and Research Institute Japan, 2010.

[11] Biofuels Digest; *Thailand Diverts Biodiesel Oil Stock for Cooking Oil*. 2011. [Available online] http://www.biofuelsdigest.com. Retrieved February 24, 2011.

[12] NSO; *Land Use in Thailand*. National Statistical Office, Bangkok, 2012. [Available online] http://www.nso.go.th. Retrieved March, 2012.

[13] FAO; *Bioenergy and Food Security: the BEFS Analysis for Thailand*. Environmental and Natural Resources Management Working Paper, Food and Agricultural Organization of the United Nations, Rome, 2010.

[14] BOT; *Thailand Floods 2011: Impact and Recovery from Business Survey*. Bank of Thailand, Bangkok, 2012. [Available online] http://www.bot.go.th. Retrieved December, 2012.