Research Journal of Business Management

ISSN 1819-1932

Academic Journals Inc.

www.academicjournals.com

Research Journal of Business Management 8 (4): 523-537, 2014
ISSN 1819-1932 / DOI: 10.3923/rjbm.2014.523.537

ASEAN Biomass Energy a Thai Environmental Impact Analysis by use of a Structural Equation Model (SEM)

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ABSTRACT

Thailand's economic growth is in many respects determined by power generation with the demand for electricity moving hand-in-hand with rapidly expanding economic growth. With the doubling of Thailand's population since the 1960s, the necessity for rural electricity coverage has also increased dramatically. This however is at times difficult and expensive to achieve in these remote rural locations with their sparsely populated areas. However, power must be available nationwide and when areas are not appropriate for a large-scale power plant investment, smaller and less expensive local power plants need to be chosen. In these rural cases, biomass power plants can be considered as one alternative. Since, Thailand outside the main metropolitan areas is still mostly rural and agricultural, there is a ready source of raw material for biomass power plant conversion. The purpose of this research therefore was to determine the environmental impact of certain variables on the environmental impact on the local community. This study concerns the modeling and analysis of Thailand's biomass power industry using both quantitative and qualitative research methods. Quantitative data was obtained using stratified sampling from 323 biomass power community members and qualitative data from in-depth research of 10 community leaders using simple random sampling while using Partial Least Square (PLS-Graph) software to apply Structural Equations Modeling (SEM) analysis. Results showed from the hypotheses that government policy and community participation had a significant and direct contribution on the overall environmental impact of the local community.

Key words: Environment, biomass, power plant, Thailand

INTRODUCTION

In the initial launch in Bangkok, Thailand of the 'Special Report on Energy Trends in Southeast Asia' in October, 2013, the importance of energy for both Thailand and the ASEAN community were expressed in some startlingly strong statistics. For the larger 600 million large ASEAN Economic Community (AEC) as a whole, fundamentals suggested Southeast Asia's energy needs will continue to grow with Southeast Asia's energy demand increasing by over four-fifths in the period to 2035 (Fig. 1), or by more than the current consumption of Japan (IEA, 2013a). Additionally, the 10 nation AEC's economy will triple by 2035 along with a population expansion of almost one-quarter by 2035-850 million people.

Furthermore, electricity generation is expected to increase by more than the current power output of India with coal emerging as the fuel of choice, accounting for 58% of the power generation growth (Fig. 3).

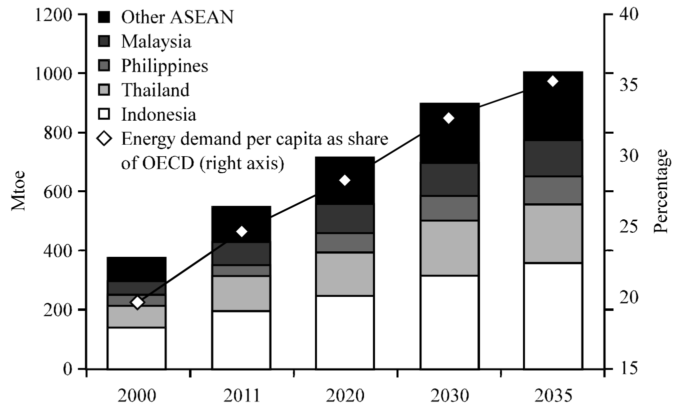

Fig. 1: Growth in ASEAN primary energy demand

In a high-level workshop organized by the IEA (International Energy Agency) and the Thailand Ministry of Energy in May 2013 in Bangkok, input was given as to new insights, feedback and data (IEA, 2013a) presented in this research. Some of this data suggests the following:

- Fossil-fuel subsidies amounted to $51 billion in Southeast Asia in 2012. Despite recent reform efforts, notably in Indonesia, Malaysia and Thailand, subsidies remain a significant factor distorting energy markets. They encourage wasteful energy use, burden government budgets and deter investment in energy infrastructure and efficient technologies
- More than 130 million people in Southeast Asia or over one-fifth of the population, still lack access to electricity. And almost half of the region's population still relies on traditional use of biomass for cooking which poses a serious risk of premature deaths from indoor air pollution. Although, Thailand only has 1 million people or 1% of the population with no electricity, it still has 26% of its population (18 million) still relying on traditional use of biomass for cooking
- Southeast Asia faces sharply increasing reliance on oil imports which will impose high costs and leave it more vulnerable to potential disruptions. Southeast Asia becomes the world's fourth-largest oil importer, behind China, India and the European Union. Thailand and Indonesia's spending on net oil imports triples to nearly $70 billion each in 2035. Indonesia, the largest energy user in the region with 36% of overall demand, consumes 66% more energy than Thailand (the second-largest user)

The Paris-based International Energy Agency (IEA) projects that ASEAN's energy needs will increase by 83 percent between now and 2035 (IEA, 2013a). Demand will be met predominantly by fossil fuels, namely, coal, oil and natural gas. Electricity demand in Southeast Asia increased by about a factor of five between 1990 and 2011-712 terawatt-hours (TWh). Nonetheless, on a per-capita basis ASEAN electricity demand remains low compared with developed countries (Fig. 2). This is best illustrated by Indonesia: Until 2005, its electricity demand was less than Norway's, yet its population was approximately 50 times greater.

Although, Thailand is significantly below the OECD nations (8,500 kWh per capita) and other AEC neighbors such as Singapore (9,000 kWh per capita), it still has a significant per-capita electricity demand higher than the ASEAN average (Fig. 2) (IEA, 2013a).

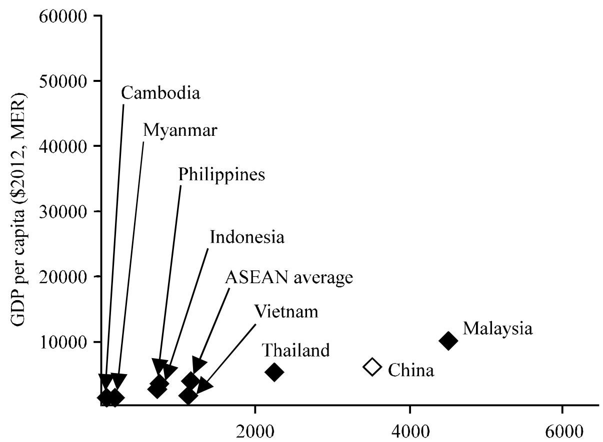

Fig. 2: Per-capita electricity demand and income in ASEAN, 2011 (IEA, 2013b). kWh per capita-MER: Market exchange rate

Given this environment, Thailand has stated that it is wants to increase its power generation capacity to 71 GW by 2030, with a gradual reduction in the share of natural gas along with the introduction of nuclear power from 2026. Thailand also wishes to increase the share of renewable energy in final consumption to 25% by 2021, with consumption targets for ethanol of 9 million litres/day and biodiesel of 5.97 million L day^{-1}, both in 2021. Thailand also wants to reduce the energy intensity by 25% by 2030, compared with 2005 levels and increase oil stock to 45 days of net import with the desire to expand his to 90 days in the longer term (IEA, 2013a).

Energy sources used most frequently in Thailand for commercial power generation include coal, oil products and natural gas. In 2007, 49% of the electricity was consumed by the industrial sector, followed by the commercial sector with 25% and residential users with 21% of the total. In 2010, the fuels used for electricity generation ranged from the 71.8% for natural gas, followed by 17.6% for coal and 6.3% for renewables (hydropower 4.8% and others, 1.5% the ministry of energy categorized hydropower as renewable) (Meetam and Kiatiprajuk, 2013). Industrial and transportation sectors use of natural gas would increase from 4,167 million cubic feet per day in 2011 to 5,331 million cubic feet per day in 2016 which is an average increase of 5.1% annually. In the long term, demand could increase to 6,999 million cubic feet per day in 2030 (Meetam and Kiatiprajuk, 2013).

This means the country is heavily dependent on imported foreign energy which is a primary reason for Thailand's policy to develop renewable energy and reduce its dependencies on imported oil and other types of fuel and energy used in electrical production. In 2011, Thailand was a net importer of 9 TW/h of electricity (IEA, 2013b).

Thailand has drawn complaints from investors about rising electricity costs and poor reliability after too much reliance on natural gas for power generation began causing more frequent blackouts and brownouts in recent years (FTI, 2014), with the Federation of Thai Industries claiming that a lack of energy security has reduced Thailand's competitiveness. Thailand depends on gas for as much as 70% of power generation, up from 60% a decade ago. Gas from the Gulf of Thailand however, is expected to be depleted within eight years and therefore Thailand will then have to depend on more costly liquefied natural gas (Bangkok Post, 2014).

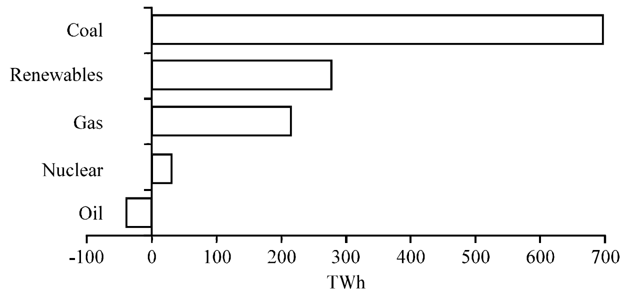

Fig. 3: ASEAN Incremental electricity generation by fuel type (2011-2035)

Biogas and renewable, waste energy technologies have widely been seen to reduce these costs and can be developed as a primary energy to produce electricity for Thailand in the future with ethanol and alternative energy representing 25% of the total within 10 years. In a study concerning greenwaste to biogas in Thailand, results illustrated that for the selected market, converting organic waste into biogas is advantageous both environmentally as well as financially; further, the benefit-cost ratio is three times higher after conversion, compared to before. Additionally, there is a huge margin of conversion and production of biogas (Ali *et al*., 2012). The production of electricity from biomass is one of the renewable energy alternatives with the fuel used in power plant coming from the waste in the agricultural community. It is also necessary to make the community members more familiar with biomass power plants and let them know it can also secure their power needs against commercial power outages allowing them to relax when such events do inevitably occur.

As can been seen from Fig. 3 data, renewables are second only to coal for current and projected ASEAN power generation until 2035.

Renewable energy however is a broad term and according to the US Department of Energy is energy that comes from resources which are naturally replenished on a human timescale such as sunlight (solar), wind, geothermal, bioenergy and water (DoE, 2014).

The Asia Pacific Renewable Energy (RE) markets especially wind, solar and biomass power projects are expected to continue its high growth trajectory and fare significantly well because of the continued support from the government in the form of incentives, achievable numerical RE targets and launch of industry specific programs (Frost and Sullivan, 2011).

Southeast Asia continues to be an attractive market for developing renewable energy sources, especially biomass, given that it accounts for nearly 230 million tonnes annually. Biomass from crop residues, municipal solid waste and forest residues, such as wood, is available in abundance and the need to harness it effectively has been widely discussed by industry stakeholders (Frost and Sullivan, 2011). Opportunities abound for generating electricity from significantly large biomass stocks in the region. The growing market for biomass can lead to healthy competition to source feedstock at competitive prices and with Thailand still having 26% of its population or 18 million still relying on traditional uses of biomass for cooking, any additional readily available, cheap and abundant source of fuel for consumers should be a welcomed addition to consumers.

Community benefits: Frost and Sullivan (2012). Researchers characterise the various types of biomass in different ways but one simple method is to define four main types, namely; woody plants, herbaceous plants/grasses, aquatic plants and manures (McKendry, 2002).

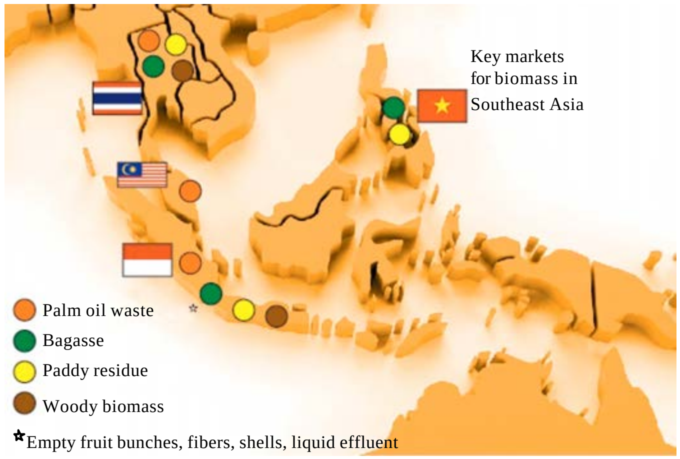

Fig. 4: Key biomass markets in Southeast Asia

Biomass power plants located in the community can involve community participation and the right to develop and control the power through its ownership of the power plants through cooperatives/organizations or local communities (right to property rights) or through investment in other areas that affect the project. This can also include the business of supplying biomass fuel, etc., or the various byproducts of these power plants as the people should benefit from the biomass project itself.

As a natural energy source which can include palm-oil waste, bagasse, paddy residue or woody biomass (Fig. 4), biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of biofuel. Conversion of biomass to biofuel can be achieved by different methods which are broadly classified into: Thermal, chemical and biochemical methods. The production of energy from biomass can be achieved by burning agricultural waste producing heat which generates electricity instead of more costly, imported fossil fuels. These fuel sources can include but are not limited to in Thailand to rice husks, bagasse, palm residue, wood chips, pulp, corn cobs, etc.

There can also be additional benefits from a community biogas plant or one located on just a single farm. These include:

- No more open burning of organic farm waste. Even animal carcasses can be deboned and placed into the bio-digester for conversion into biogas
- No more smelly sewage ditches. Closed systems can channel waste slurry directly to the bio-digester tanks
- Removes the need for unsightly cesspools and large waste water treatment ponds. Farm owners can then reclaim valuable real estate for commercial use
- With all animal waste piped into bio-digesters, there will be no unsightly spillovers in the rainy season. This means improved overall farm cleanliness and reduced risk of water-borne diseases
- The digestate (solid and liquid byproducts of anaerobic digestion) makes excellent free organic fertilizer for beautifying the surroundings (Green Prospect Asia, 2013)

Biomass electricity: Biotechnology-based production of fuels continues to attract much attention. Bioethanol (Wyman, 1996; Roehr, 2001), firewood, biogas, biodiesel (Graboski and McCormick,

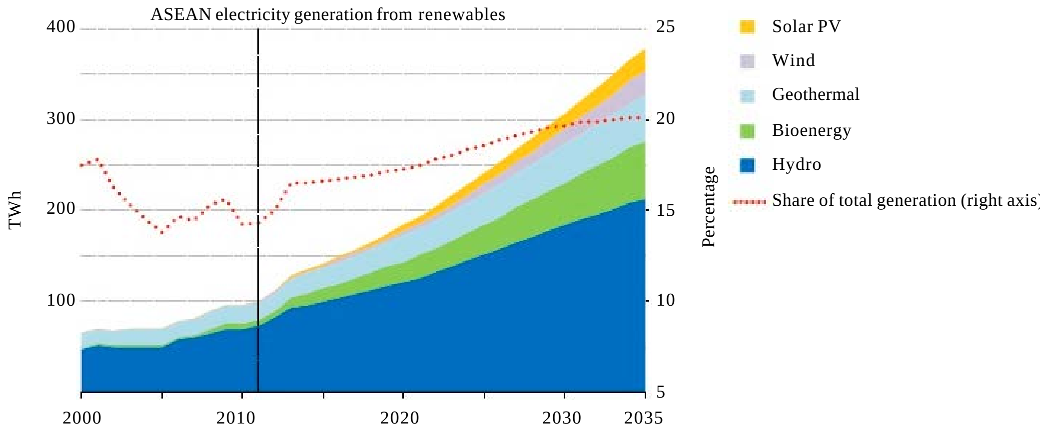

Fig. 5: ASEAN electricity generation from renewables (IEA, 2013b)

1998) and biohydrogen (Nandi and Sengupta, 1998) are examples of biofuels. Biomass can be converted into three main types of product (1) Electrical/heat energy, (2) Transport fuel and (3) Chemical feedstock. Of particular interest in this study is the generation of electricity (McKendry, 2002).

In 2011, renewables-based power increased by more than the current total power output of Indonesia and Thailand combined (Fig. 5), although barriers to deployment need to be tackled (IEA, 2013b).

Power generation can be done directly by burning biomass through a process called 'direct combustion' or through a chemical heat process heat referred to as 'thermochemical conversion'. Using these processes, biomass power plants have the potential to cause environmental impact which could affect the health of the surrounding communities. This could include such things as air pollution from the burning and combustion of selected organic matter such as wood chips.

Some bad things about biomass are; combustion of wood gives out carbon dioxide thus adding to global warming. Although, biomass fuels are renewable fuel sources, there is still no significant reduction in their emission levels. Biofuels produce the same amounts of harmful pollutants as fossil fuels. Noise and water pollution can also be factors as water is required for the cooling process to the machines.

Biomass power generation has been shown to be a valuable and beneficial component of the economy but can still create issues for communities around the power plant, so the researchers were interested in studying the subject in further detail with the objective to study the impact of environmental factors on biomass power plants and the influence of individual factors that have an impact on the environment by the use of a structural model of environmental factors that affect biomass power plants.

CONCEPTUAL DEVELOPMENT

Environmental impact: The use of renewable energy sources is becoming increasingly necessary, if we are to achieve the changes required to address the impacts of global warming. Biomass is the most common form of renewable energy, widely used in the third world but until recently, less so in the Western world (McKendry, 2002). Renewable energy resources from biomass can be a good solution for heating in rural zones with the growth of energy demand being increasingly satisfied by diversified energy resources, including sustainable and renewable sources (Gavrilescua and Chisti, 2005). Renewable energy however, does leave a footprint on the environment, with biomass being no different.

Biomass materials such as wood, agricultural crop wastes, fast-growing willow and switchgrass crops, animal wastes and even garbage cans are used as renewable sources of energy to generate heat and power. They also can be used as alternatives to petrochemicals in making plastics and other products. Today, biomass energy systems are very small-scale; some examples include ethanol in gasoline and use of municipal waste to produce methane gas. According to the American Petroleum Institute, the biggest user of biomass energy is the forest products industry which burns much of its waste to make heat and electricity. Biomass fuels contain a lot of carbon; using them requires high-tech burners that reduce smoke (API, 2014). Still, biomass energy can productively use wastes that would otherwise go to landfills or incinerators.

Much attention has been focused on identifying suitable biomass species which can provide high-energy outputs, to replace conventional fossil fuel energy sources. The type of biomass required is largely determined by the energy conversion process and the form in which the energy is required (McKendry, 2002).

The environment can be divided into two categories, the natural environment and the man-made environment. The natural environment includes such things as soil, air, plants, animals, humans, etc., which includes both the living and dead. The environment can also be classified as the man-made environment, such as politics, law, culture, roads, towns etc. As a result, environmental impact can be classified into 4 categories:

- Resource characteristics are a critical component to the sustainable management of the environment. They also play an important role in the control of environmental systems and the rehabilitation of degraded systems
- Technology characteristics is the scientific knowledge used by humanity with technology whose useage mistake could lead to a negative environment impact such as a nuclear power plant explosion
- Waste and environmental pollution which entails 4 types including solid waste pollution (toxic waste, garbage, dust), liquid pollution (water, oil, grease), gas pollution (air contaminated with toxins, soot, oxides of nitrogen, etc.) and the physical and thermal pollution (noise pollution, heat, light, radiation)
- Human/socioeconomic environment refers to the environmental, economic and social elements in the environment that is created by humans, such as demographic, cultural and environmental regulations relevant to humans

Government policy: Governments in Southeast Asia have introduced industry-friendly policies to stimulate biomass power growth, such as the feed-in tariff policy and adder policy. In addition to policy level guidelines, project developers are given investment incentives, guaranteed minimum prices, power purchase agreements with the utility grid, exemptions pertaining to the import of equipment and certain tax credits.

For instance, Thailand was an early mover in identifying the underlying opportunities and had formulated policies to encourage biomass projects through the Very Small Power Producers (VSPPs) scheme. The country has set an ambitious target to achieve 3.7 GW of biomass capacity by 2022 (Frost and Sullivan, 2012).

Currently, the country has an installed biomass capacity of 670 MW out of which nearly 240 MW is connected to the utility grid. With strong policy support and a conducive investment climate, several new industry participants have entered the country since 2010 to develop biomass power projects.

Thailand's Eleventh National Economic and Social Development Plan (2012-2016) states that "The issue of energy security is vital and requires that more clean energy be used and alternative energy sources be developed, leading to overall improvement in energy efficiency" (NESDB, 2011). Thailand and the King's plan is a philosophy of "Sufficiency Economy" which was stated in 1974 by the Thai king His Majesty King Bhumibol Adulyadej and is now firmly rooted in Thai government and society. The heart of this Philosophy is "human development" toward well-being based on sufficiency, moderation, reasonableness and resilience (NESDB, 2011).

State policy also has different policies and objectives in creating Thai energy security. These policies include the supply and use of energy resources as well as providing enough energy to meet demand at an affordable price. So, to lower the risk of an 'energy crisis', organizations must be prepared with backup power sources.

Agencies must also have policies for the intensive care, environmental quality and pollution control as well as policies which promote and create awareness of natural resources and the environment. There needs to be a wide range of other policies that the state determines necessary for strategic or policy goals, methods and movements.

Under the heading, 'Enhance food security and develop bio-energy at household and community levels', Thailand's Economic and Social Plan stated that communities and their citizens should plant trees in around their homes and in public areas. Farmers should utilize sustainable agriculture following the Philosophy of Sufficiency Economy. Information regarding agriculture and food production should be widely and continuously disseminated. Appropriate consumption behavior at individual and community levels and creation of production and consumption networks among nearby communities should be promoted. Application of the zero waste approach in agriculture should be encouraged by utilizing farm residues to produce renewable energy at the community level and infrastructure should be developed to systematically enhance food security for farmers and communities (NESDB, 2011).

Policies needed in order to achieve the policy objectives include factors such as being involved in research and development. This can be seen from the statistics which show that when investment R and D is implemented in developed countries such as North America that the margin on the cost of research and development is the highest in the world with 2.6% while Africa has the lowest proportion percentage with 0.4% (UNESCO, 2010).

Bhattacharyya (2007) stated that governments need to develop technology with the goal of reducing environmental problems, such as the development of the transport systems which reduces carbon emissions. Additionally, the government also needs supporting legislation which is driven by civil society groups in the community (Kolk and van den Buuse, 2012), or in other words, enable people to participate in the operation and legal oversight threats to the environment will have legal penalties and fines.

Others factors in investment, research and development and law is the monitoring and evaluation and to know the level of participation in the program evaluation as well as the results of operations achieved their objectives or not (Kangsanarak, 2001), because monitoring is important to take into consideration comments/views, preferences and expectations/hope. This can influence the behavior of individuals in the various groups (Cohen and Uphoff, 1980).

Community participation: The term “community renewable energy” generally means locally owned, locally sited renewable energy (electricity and/or heat). In general, definitions of community energy or community renewable energy tend to include engagement or participation by the community that reaches beyond a simple investment or shareholding relation (CEC, 2010).

In the same Commission for Environmental Cooperation study (CEC, 2010), some of the economic, environmental and social benefits from a community renewable energy project are as follows:

- Creates jobs and additional money in the local economy
- Adds new technical skills to the local community
- Reduces the dependence on expensive fossil fuel imports
- Help reduce greenhouse emissions and pollution related illnesses
- Increases community awareness of energy use and impacts
- Helps lead to greater conservation and sustainable energy behavior
- May reduce the need for large scale hydro-projects
- Does not require large amounts of water
- Can help provide an opportunity for building and participating in local communities
- May build greater acceptance of new renewable energy technologies
- Offers skills training with work based in rural communities
- Creates long-term, high quality jobs and skills

A number of other North American studies have provided statistics on community benefits of renewable energy development for specific areas. Many of these have focused on the economic benefits and include a range of project size and ownership models (Flowers and Kelly, 2005).

Another author in the book ‘Small is Profitable’ (Lovins *et al*., 2002), detailed 207 economic benefits to community-scale power while Welsh (2005) in the Iowa Policy Project demonstrated that smaller (20 MW or less) locally owned wind projects keep over five times as much money in the community as do larger wind projects owned by out-of-state companies.

The kinds of participation that warrant major concern are (1) Participation in decision making, (2) Participation in implementation, (3) Participation in benefits and (4) Participation in evaluation (Cohen and Uphoff, 1980). If they [the rural poor] are considered in such an aggregated mass, it is very difficult to assess their participation in any respect, since they are a large and heterogeneous group. Their being considered as a group is not, indeed, something they would themselves be likely to suggest. There are significant differences in occupation, location, land tenure status, sex, caste, religion or tribe which are related in different ways to their poverty (1980).

In a study conducted in Bangladesh, elected council members, both male and female, equally participate in planning development projects but participation of common people in the preparation stage of these same projects is negligible (Mohammad, 2010). Participation of community people in project planning is as low as 7% which rises to 24% during implementation stage. However, there is a pervasive feeling that development projects are generally non-participatory.

In addition, participation also has different levels which depends on the importance and purpose of their participation. Forms of participation are divided in many ways, such as a true involvement for citizens start to finish, including project activities allowing the use of available resources. Another but limited for of co-operation is the planned participation with no real intent to contribute to part of the project.

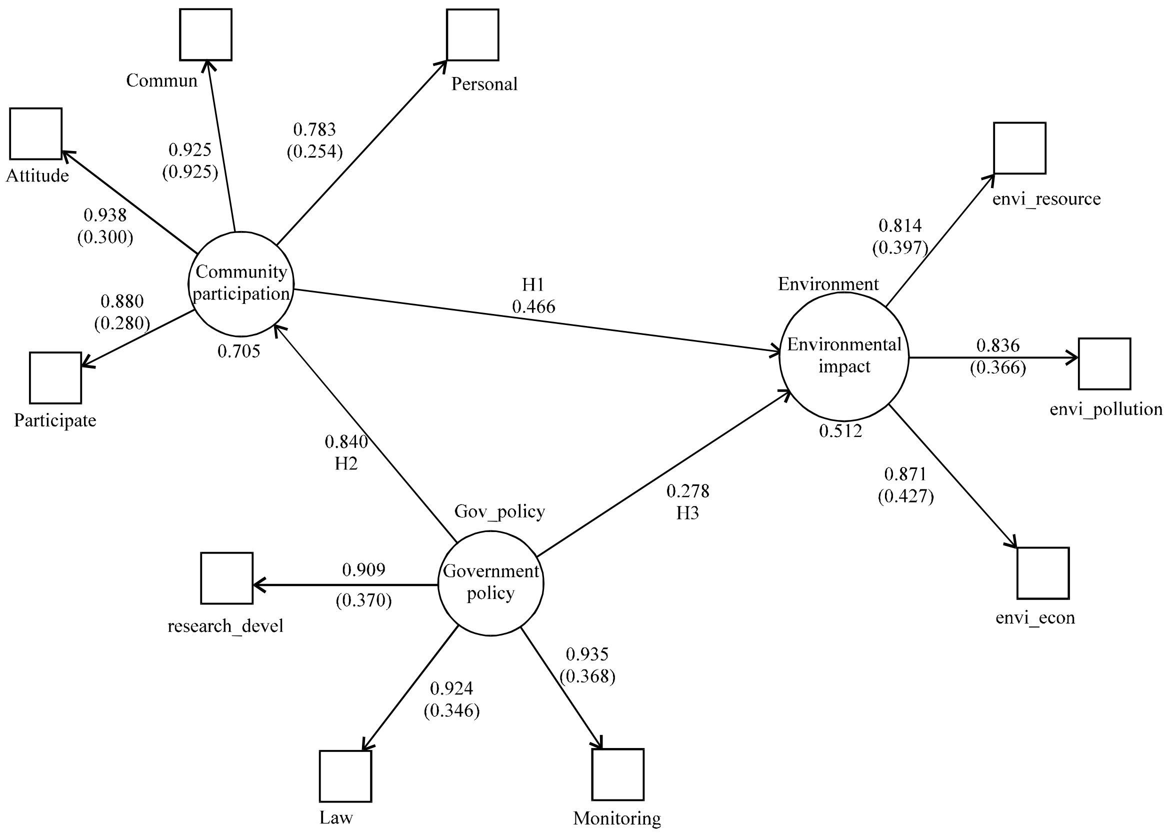

Fig. 6: Final model-analysis of factors that affect environmental impact on biomass energy

From the above conceptual review and development, the researchers have developed the following three hypotheses for this study on biomass energy (Fig. 6).

H1: Community participation influences environmental impact
H2: Government policy influences community participation
H3: Government policy influences environmental impact

METHODOLGY

This study was conducted from a sample population of community members residing in areas near biomass power plants across Thailand using both quantitative and qualitative research.

Data collection: For this research, the measurement instrument or questionnaires utilized were prepared from the literature. To gauge both the content validity and reliability of the survey, 5 specialists in their respective fields were chosen to evaluate the consistency of the content and confirm it was valid for the purposes of the research. Additionally, the index of Item-Objective Congruence (IOC) developed by Rovinelli and Hambleton (1977) was employed to carry out the screening of questions. The IOC is a procedure used in test development for evaluating content validity at the item development stage. This measure is limited to the assessment of unidimensional items or items that measure specified composites of skills. The method prescribed by Rovinelli and Hambleton (1977) results in indices of item congruence in which experts rate the match between an item and several constructs assuming that the item taps only one of the constructs which is unbeknownst to the experts. The research then proceeded to select items that with an IOC index higher than 0.5 which were considered acceptable.

Questionnaires were constructed to be a tool to measure concept definition and practice. The instrument or questionnaire used the 5-Point Likert Scale (Likert, 1972) as the measurement scale and the conceptual framework for determining the internal consistency measured by coefficient alpha (α-coefficient) of Akron BAC (Cronbach) to calculate the average value of the correlation coefficient. All values lower than 0.50 were eliminated from the measurement.

Dependent variable: Environmental impact analysis of the biomass power plant sector used a measurement instrument or questionnaires utilizing a 5-Point Likert Scale (Likert,1972) and have been constructed with the scales developed enabling measurement of resources (envi_resource), water and pollution (envi_pollution) and economic, social and human factors (envi_econ) (McKendry, 2002; Gavrilescua and Chisti, 2005; API, 2014).

Independent variables: Government policies analysis used a measurement instrument or questionnaires utilizing a 5-Point Likert Scale (Likert, 1972) and have been constructed with three aspects (Table 1) including R and D (research_devel), Legal (law) and Monitoring (monitoring). (Frost and Sullivan, 2012; NESDB, 2011; UNESCO, 2010; Bhattacharyya, 2007; Kolk and van den Buuse, 2012; Kangsanarak, 2001; Cohen and Uphoff, 1980).

Community participation analysis used a measurement instrument or questionnaires utilizing a 5-Point Likert Scale (Likert, 1972) and have been constructed with four aspects (Table 1) including Personal (personal), Community (commun), Attitude (attitude) and Participation (participate) (CEC, 2010; Flowers and Kelly, 2005; Lovins *et al*., 2002; Welsh, 2005; Cohen and Uphoff, 1980; Mohammad, 2010).

RESEARCH ANALYSIS AND RESULTS

Partial Least Squares has been applied for analysis of quantitative data by the researcher. It is data analysis for Confirmatory Factor Analysis (CFA) relating to the determination of Manifest Variable and Latent Variable and testing of research hypothesis exhibiting in structural model

Table 1: Statistic values presenting convergent validity of reflective scales of latent variables

Construct/item	Loading	AVE	t-stat
Community participation (participate)			
Personal factors (personal)	0.7832	0.781	22.1173
Community factors (commun)	0.9255		84.1485
Attitude (attitude)	0.9381		108.5072
Participation (participate)	0.8797		53.5740
Government policy (Gov_policy)			
R and D Research and Development (research_devel)	0.9086	0.851	65.9079
Legal (law)	0.9245		73.5503
Monitoring (monitoring)	0.9347		93.3154
Environmental impact (environment)			
Resource factors (envi_resource)	0.8137	0.706	31.6726
Waste and pollution factors (envi_pollution)	0.8358		32.9360
Economic, social and human factors (envi_econ)	0.8710		52.2450

analyzed by using the applications of PLS-Graph (Chin, 2001). According to the analysis result of scale validity and reliability, scale investigation was conducted using internal consistency measurement coefficient alpha (α-coefficient) of Akron BAC (Cronbach) to calculate the average value of the correlation coefficient, whose range was found to be highly reliable.

In case of measure variables with reflective analysis, convergent validity has been conducted. Loading is used as consideration criteria and must be positive quantity and indicator loading has been more than 0.707 and all values have been statistically significant ($|t|\geq 1.96$) representing convergent validity of scales (Lauro and Vinzi, 2004; Henseler *et al.*, 2009; Piriyakul and Wingwon (2010) and analysis results as shown in Table 1.

Government policy (Gov_policy) factors underlying the external variables influencing R and D (research_devel), Legal (law) and Monitoring (monitoring) with values loading from 0.707 and a significant level of confidence percentage 95 (t-.stat>1.96) which considers such factors highly reliable. It has a direct impact on environmental impact.

Community participation (Participate) factors underlying the external variables influencing Personal factors (personal), Community (commun), Attitude (attitude) and Participation (participate) with values loading from 0.707 and a significant level of confidence percentage 95 (t-.stat>1.96) which considers such factors highly reliable. It has a direct impact on environmental impact.

Environmental impact (Environment) factors underlying the external variables influencing Resources (envi_resource), Water and Pollution (envi_pollution) and Economic, social and human factors (envi_econ) with values loading from 0.707 and a significant level of confidence percentage 95 (t-.stat>1.96) which considers such factors highly reliable. It has a direct impact on Environmental Impact.

The above reflective model in Table 1 shows the discriminant validity of the internal latent variables and the correlation of variables. It also depicts the scale reliability which has been analyzed from Composite Reliability (CR) as well as the Average Variance Extracted (AVE) and $R^{2.}$ The CR value should not go below 0.60 and the AVE values should also drop below 0.50 and R^2 values should not be under 0.20 (Lauro and Vinzi, 2004; Henseler *et al.*, 2009) quoted in Piriyakul and Wingwon (2010).

Table 2 below shows the results of factor analysis affecting Biomass Power Environmental Impact. The data also shows the CR values are higher than 0.60, with all AEV values higher than 0.50 for all values and R2 values higher than 0.20, representing the reliability of the measurement. It found that data sets in the $\sqrt{AVE}$ have higher values than all of the corresponding values in the 'Cross Construct Correlation' in the same column, representing discriminant validity of the measure

Table 2: Confirmatory factor analysis (CFA) of the independent variables of government policy and community participation and their effects on the dependent variable, environmental impact

				Cross construct correlation		
Construct	CR	R^2	AVE	Community participation	Government policy	Environmental impact
Community participation	0.934	0.7055	0.781	0.884		
Government policy	0.945		0.851	0.840	0.922	
Environmental Impact	0.878	0.5124	0.706	0.700	0.670	0.837

CR: Composite reliability, R^2: Square of the correlation, AVE: Average variance extracted. Statistical significance level is at 0.01 and diagonal figures mean $\sqrt{AVE}$

Table 3: Research hypotheses test results

Hypotheises	Coef.	t-test	Results
H1: Community participation has a direct and positive influence on environmental impact	0.466	4.7589	Supported
H2: Government policy has a direct and positive influence on community participation	0.840	39.9882	Supported
H3: Government policy has a direct and positive influence on environmental impact	0.278	2.8144	Supported

Coefficient refers to the Beta (β). t-stat is the t-value. 95% confidence level

in each construct and with a greater value than 0.50 of AVE as shown in Table 2. The samples were analyzed to answer the research hypotheses criteria in the three assumptions presented in Table 3.

Furthermore, the structural analysis model framework was used to research the t-test coefficients and their relationship of each path of the t-test hypothesis with significance greater than 1.96. This explains the results obtained from analysis as shown in Table 1 and 2 as well as the test results presented in Table 3.

CONCLUSION

Renewable energy is more than a passing fad or trend and is making deep inroads into both the global energy grid and Thailand's. With the stated objective since 1974 of Thailand's king for a "Sufficiency Economy" that has a "human development" component towards a well-being based on sufficiency, moderation, reasonableness and resilience, it is even more imperative to Thailand quickly and effectively move towards renewable energy including biomass.

Electrical utilities are essential for the development of Thailand and at current demand rates; the need is increasing yearly with power generation the assigned duty of the government to meet the demands and needs of its consumers and citizens. As has been shown however from 'A structural equation model of the environmental impact factors from Thailand's Biomass Power Plant Industry', although biomass is a viable and effective option in the renewable mix, it does have hurdles to overcome including technology, environmental and public perception amongst the Thai consumer market.

Renewable energy and especially biomass is a community effort with a much localized mix of problems and benefits. Many of the problems can be overcome with education and transparency but it will take time as most are fearful of what is new and what they don't understand but the problem of population growth along with soaring energy demands will not disappear.

So it therefore becomes critical that Thailand finds energy sources that are sustainable for the long haul and find a mix of renewable energy source for the long run. Fortunately, the research found that Thailand has ready sources for renewable energy because it has huge amounts of agricultural waste due to Thailand still being primarily an agriculture country. For small communities with rural populations, small biomass power plants could be a suitable solution for the localized power grid.

The environmental impact factors from Thailand's Biomass Power Plant industry using agricultural waste materials is small, whether it be from dust, noise or cooling water runoff. But the actual perceived impact on the environment or the socio-economic effects is really more dependent on the public perception of government policy and the involvement of the community. The results of this research show that guidance and education of those involved in the development of biomass power plants is an important component of the overall success or failure of a community project.

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