Thailand's Energy Conservation Policy for Industrial Sector Considering Government Incentive Measures

Rittirong Intarajinda and Pornrapeepat Bhasaputra

Abstract— *This paper presents the simulation results of energy conservation potential for designated factories under incentive measures from Thailand's energy conservation policy. Historical campaigns and projects established from the past energy conservation policies have been reviewed. The investment cost of government and performance of energy conservation including energy reduction, participation of designed factories and financial indices are also investigated. Since the achievement of energy conservation policy for designated factories depends on several factors, the simulation has been taken internal factors of designated factories and external factor affected from economic situation into the consideration. The fuzzy inference system and regression analysis approach have been introduced to develop a hybrid model for evaluating benefits of energy conservation measures. In this approach, the benefit to cost ratio with different project life cycle and percentage of government incentives are investigated. In addition, multi-scenarios of worth obtained from energy conservation implementation with various sequential investments are evaluated. Finally, key success factors for promoting sustainable energy conservation policy in Thailand have been given.*

Keywords— **Designated factory, energy conservation, energy efficiency, incentive measures.**

1. INTRODUCTION

At the present, Thailand is one of developing country of which nation economy growth is driven by high energy-intensive. In 2010, a total value of energy import into Thailand was accounted of 911 billion Baht mainly caused by imported crude oil (751 billion Baht) [1]. During 1987-1997, prior to the (Asian) economic crisis, Thailand's expenditure on energy import at an average rate of 3% of the GDP as energy prices was then relatively low. However, after the economic crisis, crude oil prices sharply increased, causing an increasing loss of foreign currency to Thai currency; particularly in 2008 when the crude oil price was exorbitantly high, Thailand had to spend on imported energy as high as 12.8% of the GDP. In 2010, Thailand's expenditure on energy import accounted for 9.0% of the GDP. A large portion of energy import value results the country to be an imported energy dependency. Considering Thailand energy policy in the present time, not only the strategies have focused on distribution of energy resources and fuels, but the reducing imported energy especially crude oil and petroleum also attempt to implement with renewable energy and energy efficiency projects [2]. In addition the renewable energy development, the energy saving, energy conservation, energy efficiency and energy management from both supply and demand side are common terms used in the energy policy planning. Recently, Thailand has been formulated the long term energy efficiency planning called "the 20-Year Energy Efficiency Development Plan (2011-2030) or EEDP [3]. As shown in Fig. 1, this plan was set the target to reduce energy intensity by 25% in 2030 compared to 2005, or equivalent to reduction of final energy consumption by 20%. In order to achieve the policy target, the potential assessment approach is necessary to evaluate energy conservation potential at the national level and at the individual economic sector level.

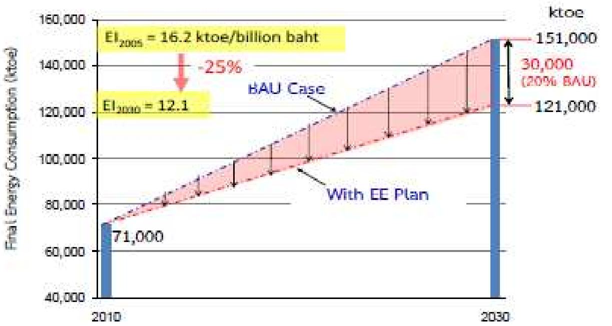

Fig. 1. Energy consumption in the past and future demand trend under business as usual case.

For industrial sector, the energy saving potential is divided into five main clusters, i.e. non-metal, food & beverage, basic metal, chemical and paper. These clusters account for the largest share of energy consumption, i.e. over 84% of the total energy consumption in the industrial sector in 2009. The energy conservation potential of each industrial cluster was roughly assessed by statistical and mathematical model. The approach can be made by comparing Thailand's current average specific energy consumption (SEC) with the best SEC or best practice in foreign countries or with the best practice in Thailand. The different value was set as the energy saving target for energy efficiency improvement in respective industrial cluster in the next

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20 years. Despite the need for increasing industrial energy conservation and efficiency, there were studied results indicated that cost-efficient energy conservation measures were not always implemented according to the company's investment criteria [4]. The actual energy reduction implemented by individual factory depends on several conditions, for example, the external factors such as the government promotion campaigns, the enforcement of energy conservation law, energy efficiency technology development and price trends which can impact to the energy conservation and efficiency. In the public policy making, economic parameters have also affected a potential of factories to perform energy conservation activities [5]. In addition to the external factor, the investment potential, energy policy of each organization, awareness of people, characteristic of plant operation, aging of equipment and machines, quantity and value of products were significant factors and strongly related to the implementation of the energy conservation project in each factory. In general, barriers to the success of energy conservation and efficiency can be summarized in various aspects such as economic barriers, behavioral barriers, organizational barriers, social barriers and driving market barriers [6-9]. Therefore, the characteristics of factories and driving forces from external factors should be taken into the energy saving potential assessment.

This paper presents the stochastic model using the hybrid fuzzy-regression method for examining the energy conservation potential of industrial sector. This approach was considered external factors and internal factors of each factory and projected the energy saving to the next 20 years. The benefits from energy saving potential are converted to monetary value in order to compare with the government supports. The information required to develop to model was provided from surveyed 380 factories. The development of these aspects will concern the cost-effectiveness in the project investment as well as feasibility of participation from all sectors. This paper also examined multi-scenarios of energy conservation policy for industrial sector based on various economic situations.

This article is organized as following aspects; the overview of energy conservation policy in Thailand was reviewed in Section 2 in order to address energy conservation policy in each period. The activities related to energy conservation policy, support and incentive measures for industrial sector have been described in Section 3. In order to assess the effectiveness of incentive measures for designated factories, the conceptual framework of modeling development using hybrid fuzzy-regression approach was described in Section 4. Then, the simulation results represented by worth of energy saving was presented in Section 5. In this section, direct-subsidy and tax incentive measures were selected to demonstrate the optimal subsidy criteria for promoting the energy conservation implementation of factories. In addition, multi-scenarios of government subsidy with sequential investment were also presented. Finally, in Section 6, we presented recommendations and conclusion of this study.

2. OVERVIEW OF ENERGY CONSERVATION POLICY IN THAILAND INDUSTRIAL SECTOR

In the past experience, the energy policy in Thailand had mainly focused on the supply side in order to meet the level of requirement while energy policy related to the demand side was less attention to consider. Since 1970s, energy efficiency and conservation have become one of key components to address energy security. During the crude oil shortage in 1973, the direction of energy policy in Thailand was changed with more consideration in the energy saving and energy conservation projects. The energy policy at that time had launched several measures to prevent the oil shortage and saving electricity. Some measures were temporarily required such as: reducing the public lighting by 50%, restriction on engine capacity not over 1,300 cc for the new official vehicle procurement, etc. All measures from government announcements had then been eliminated after the crisis was in a better situation. During 1977-1982, the problems of high rate of oil consumption and imported petroleum for electricity generation lead the government at that time to re-establish the campaign for energy saving measures covered transportation, industry and public sectors. Most were also temporary measures emphasizing on resolving the current problems such as: limit a driving speed of cars and truck, impose the bus lanes, prohibit the car parking along the main roads, forbid the electricity use in large factories during a peak load period, impose the opening-closing time of the services and entertainment places, reduce the TV broadcasting time in the evening, etc. In fact, the implementations of government campaigns were not capable of effective reducing the oil consumption and imported petroleum dependency because these measures were promoted with encouragement from the government sector while end-users were act as the reactive players for responding to the energy policy. For this reason, the strategic energy policy during 1982-1986 was reviewed from the previous plan and replaced by using the concept of maximum benefit to a country development. The government at that time had implemented the National Energy Saving Project for improving energy efficiency as well as the adjustment energy production structure. Industrial sector is the first target sector for providing energy efficiency promotion measures including energy audit, training in energy conservation technology, tax incentives, low interest loans and etc. The success of energy conservation implementation in National Energy Saving Project was expanded from the industrial sector to the commercial and residential sectors during 1987-1991. In 1986, the rapid economic expansion as well as the higher growth of commercial energy demand impacted to the energy supply adequacy. In addition, the achievement in energy conservation campaigns in several countries including Japan, Germany, and Canada which had enacted the Energy Conservation Act as a tool in energy conservation promotion to private sector lead the Thai government to firstly establish the Energy Conservation Promotion (ECP) Act in 1992. The ECP Act was expected to be sustainable energy conservation policy which helps Thailand to maintain the energy security onwards.

The strategic of energy conservation policy in Thailand has been more attention over a past of two decades because of the competitive market mechanism, energy conservation law and regulations and worldwide environmental concerns. Since the first enactment of energy conservation law in 1992, the government sector plays important roles for establishing the sustainable energy conservation policy especially in large energy consumer. Based on a period of policy planning, Thailand has been considered the energy conservation policy from 1992-2011 under short term planning (5-year period). Since 1992, three phases of the Energy Conservation Program have been completed: Phase 1 (1995-1995), Phase 2 (2000-2004) and Phase 3 (2005-2011). Although the target of each plan had focused in the similar way, the details and programmatic activities were different depending on politic direction, economic situation, oil price, energy resources availability and energy efficiency indicator. For practical planning of energy conservation policy, the industrial manufacturing sector, the largest energy consumer and economic contributor, is normally the dominate target sector for implementing energy conservation program when consider a proportional of energy consumption and a number of operating industry.

3. THE IMPLEMENTATION OF ENERGY CONSERVATION PROGRAMS AND INCENTIVE MEASURES IN THAILAND

The energy conservation programs implemented in Thailand can be classified by three perspectives: compulsory program, voluntary program and complementary program. For the compulsory program, the energy conservation program, a part of the ECP Act, put mandates on so-called designated factories and building to perform the energy conservation activities. Mandatory tasks for designated factories are:

- Appoint at least one Personal Responsible for Energy (PRE) or energy manager to regular work related energy conservation activities in an organization;
- Report energy consumption and production capacity in half a year period (Form Bor Por Ror 1);
- Determine the Energy Conservation Plan and Target and submit to DEDE at every three years;
- Conduct the energy audit funded by the Energy Conservation Program.

The successful implementation activities at initial state were primary driven by the Energy Conservation Promotion Fund (ENCON Fund). It was used as working capital and as grants or subsidy for energy conservation investment and operations, promotion of renewable energy utilization, public relations work, energy-related research and development, information dissemination, public awareness campaigns and expenses for management and monitoring of the energy conservation program. However, some activities of the energy conservation program were stopped such as mandatory energy auditing. From the mandatory tasks of designated factories, major problem findings for implementation in practical are;

- Reports on PRE appointment were delayed since the qualifications of the persons to be responsible for energy consumption in the facilities did not meet the criteria specified by laws, or it was difficult to find a qualified person for the task. Also, when the PRE of a facility resigned, a new one had to be hired and the new appointment had to be reported to the DEDE. This process was often delayed.
- The delivery of production data was delayed. This was due to the fact that a number of PRE did not clearly understand the way to fill in the energy consumption information in the given form, or some of the required information was not available. The production data in some designated factories is not preferred to reveal from its confidential information.
- The plan and target of energy conservation program was not directed assessed because of a number of energy expertise or specialists is limited when compared to the total number of designated factories.

For the government supports, there were several incentive measures which provide to the private sectors and social community. In this study, activities for energy efficiency implementation in the first two phases (1995-2007) were:

- Grants designated factories and buildings for conducting preliminary and detailed audits;
- Promote cost-based tax incentive program (direct subsidy) to encourage private sectors and enterprises to invest in high energy efficiency equipment. In the pilot phase, the government provided 10 million Baht for 25 factories and resulted the saving of 1.96 GWh/year. This measure has been extended a government budgetary of 100 million Baht to encourage energy conservation programs of private sector.
- Promote performance-based tax incentive program with financial support from the Energy Conservation Promotion Fund. In this measure, there were 219 companies received the subsidy contributed energy saving by 37.68 ktoe/year or 857.19 million Baht. Total project investment cost was 1322.91 million Baht while government supported in term of tax deductible of 62.65 million Baht.
- Promote a new energy business model in term of an energy service company (ESCO) by giving tax incentives from Board of Investment. Although the ESCO industry has been continued to promote for energy conservation programs, it is a limited number of company in Thailand. The services of ESCO for energy conservation activities are still not widely known from private sector.
- Promote Board of Investment (BOI) incentives for energy conservation that include corporate income

tax exemptions and import duty exemptions for energy conservation equipment;

- Provide energy revolving fund offered low cost loans for energy conservation and renewable energy projects. This measure contributed investment in energy conservation projects by 13815 million Baht while the government subsidy was accounted by 6,820 million Baht. The benefits of saving approximate with 300.84 ktoe/year or 4,698 million Baht/year;
- Support ESCO fund by one billion Baht through six activities: equity investment, venture capital, equipment leasing, carbon credit market, technical assistance and credit guarantee facility. However, this campaign was preferred by renewable projects while energy conservation is less attention.

Develop participatory approach for energy conservation that provides funding support for technical advice (<100,000 Baht) to factories on value engineering (VE) and energy management. This measure has been promoted for designated factories since the past decade. The success of implementation leads to introducing this measure for small and medium factories (SME). During 2002-2008, there were 1,036 designated factories had participated this campaign and it contributes the saving of 1,716.4 million Baht or 72.12 ktoe/year. In addition, the VE program for 1,068 SME factories can contribute the energy saving value of 561.6 million Baht/year.

4. THE HYBRID FUZZY-REGRESSION MODEL FOR ASSESSMENT ENERGY CONSERVSTION POTENTIAL

In order to study the implementation of energy conservation projects, the survey approach with questionnaire related to energy conservation activities in factories is used as a tool to collect information. Responded factories operating inside and outside industrial estates are shown in Table 1. The number of survey sample is 377 factories or 10.5% of total designated factories. Most are classified as the designated factory, the large energy consumer, while approximate 15% is the medium scale industries and expected to be a designated factories in the next few year. When classify a sample into the nine industrial categories, the survey shows that the factories under fabricated metal, machines and equipment (TSIC 38) has a largest number of respondent (107 samples), followed by chemical, petrochemical and chemical products (TSIC 35) with a number of 82 samples and food, beverage and tobacco (TSIC 31) with 77 samples, respectively.

In order to evaluate the energy conservation potential of factories with consideration external and internal factor, two methodologies have been employed to develop the hybrid model: fuzzy inference system and regression analysis technique. For the fuzzy inference system concept, it is used in two perspectives. First aspect, it is proposed for decision a feasibility of participation for designated factories to implement energy conservation project which presented in the energy management report. Second, the degree of membership function is represented as a confidential level of designated factories to implement energy conservation measures under different economic situation. For the regression analysis technique, it is employed to construct the model with two independent variables: an investment cost of designated factories and a number of supports for implementing energy conservation programs. The framework of hybrid model development for assessing energy conservation potential is shown in Fig.2. The following provides description of two approaches for model development.

Table 1 A number of sample classified into nine categories

category	number of sample	total number of designated factory	% of sample
Food, beverage and tobacco	77	727	10.60
textile	31	364	8.50
Wood and wood products	13	105	12.38
Pulp and papers	10	109	9.20
Chemical, petrochemical and chemical products	82	756	10.80
Non-metallic mineral	19	164	11.60
Basic metal	19	215	8.80
Fabricated metal, machines and equipment	107	1,011	10.60
Other manufacturing	19	70	27.10
total	377	3,521	10.50

4.1 Fuzzy inference system

A concept of fuzzy had introduced by Lotfi Zadeh in the mid of sixties to deal with a reality problems which contain more or less uncertain, vague and ambiguous. In general, the fuzzy concept is represented by fuzzy set and fuzzy logic to extend classical sets and mathematical logic which normally define by yes or no, white or black, true or false. Fuzzy sets and fuzzy logic deal with objects by using a fuzzy numbers which describe grade or degree of membership function between (0 to1). More details on fuzzy logic theory and applications are outlined in References [10-11]. A concept of fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. In this study, a concept of fuzzy set is employed to develop the decision model using a fuzzy logic or fuzzy rule.

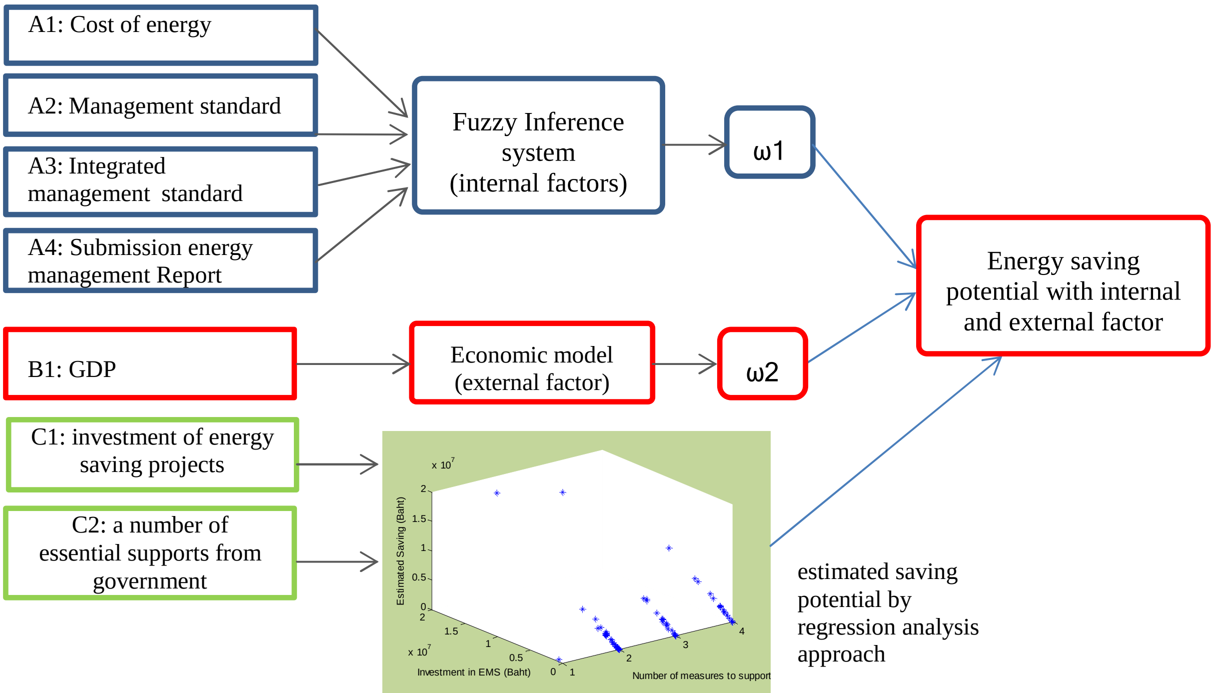

Fig. 2. Conceptual framework of the proposed model for estimating energy conservation potential.

4.2 Regression analysis technique

The regression analysis is a technique for modeling and analysing several variables, when the focus is on the relationship between a dependent variable and one or more independent variable. For this study, the multiple regression technique is used to develop for predicting the energy reduction target of nine industrial sectors with two independent variables: the cost of designated factories to invest in energy conservation projects and a number of support and measures which enhance the achievement of energy conservation project implementation.

4.3 Overview of the model development

4.3.1 Internal factor model

In general, industrial manufacturing sector intends to monitor and control business target based on company profits. The quantity and quality of products are the most important factors which impact to business growth. Without establishment energy conservation laws and regulations, the energy efficiency was expected to less attention by top management perspectives when compared to a quantity and quality of products. However, the energy conservation and energy efficiency projects have been more considered for large scale industries over a decade after the oil price crisis and energy conservation law enforcement. For this reason, internal factors of industry were strongly related to the success of energy conservation projects. In this study, four significant factors from large scale industrial survey were selected to be the input variables for the decision process with fuzzy inference system. The output of internal factor model in a range of 0 to 1 will indicate a level of confidential of an industry to achieve the energy reduction target as shown in the energy management report. For example, if an industry expected that annual energy reduction target by a project of high efficiency motor replacement to be 100,000 kWh. The proposed model will calculate a confidential level or participation factor of energy reduction target with input variables in FIS. Four significant variables for construction fuzzy inference system consist of energy cost (A_1), a number of management standards (A_2), integration of management standard (A_3) and energy management report submission (A_4). Assumption in each input variable can be described as following;

A1: the energy cost was derived from survey questionnaire. It consists of two cost elements including electricity and thermal energy. In fuzzy rule, a high energy cost industry was more expected to achieve energy reduction than a lower energy cost industry.

A2: a number of management standards were important factors for the success of energy conservation project implementation. In this study, the three worldwide standards (ISO 9001, ISO 14001 and OHSAS 18001) were considered. An industry with more standards was expected to achieve the energy conservation target higher than an industry without certified management standard.

A3: Not only a number of management standards, the integration of the existing standards was also expected to enhance the success of implementation of energy conservation projects.

A4: The submission of energy management report to the DEDE was expected to indicate the responsibility of an industry. In this report, the lists of investment plan and activities related to energy conservation project implementation were given.

Fig. 3 illustrates the model of participation factor estimated from internal factors of surveyed factories in TSIC 31 by FIS approach. Since a number of surveyed factories in TSIC 31 account by 10.6% of total designated factories in this sector, the boostrap technique, a statistical method for estimating the sampling distribution, was applied in order to represent to participation factor of all designated factories in each industrial category. Comparison the participation factor from FIS before and after resampling with boostrap technique is presented in Fig. 3. We can see that the a pattern of participation factor after using boostratp technique is normal distribution in a range of 0.91-0.97.

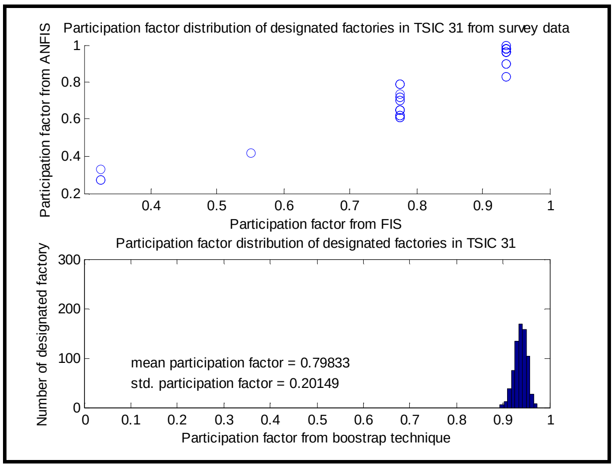

Fig. 3. Participation factor to implement the energy conservation programs of factory in TSIC 31.

4.3.2 External factor model

Manufacturing industry is the highest contributor for economic and social development in Thailand. The demand situation of global or local economy directly impact to the value added of industry which can be monitored by the growth rate of GDP. In this study, we formulated the participation factor of energy conservation implementation of factories under various conditions of national economy. The relationship between GDP growth rate and participation factor (B_1) of implementation was assumed as shown in Fig. 4.

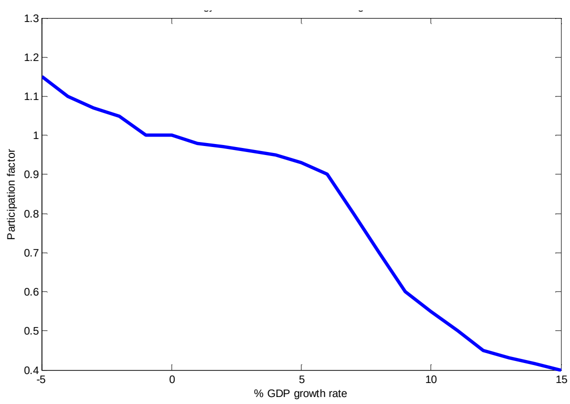

Fig. 4. Participation factor under economic situations.

4.3.3 Energy saving potential model

The model of energy saving potential (ES) has been developed by two input variables: the investment cost (C_1) of designated factories for implementing energy saving project and a number of measures (C_2) which factories requested a support from government sector. The data set of investment cost and a number of measures has been modelled by multiple regression technique to predict a potential of energy saving in each designated factory.

$$\log(\mathrm{ES}) = \log(\mathrm{C}_1) + \mathrm{C}_2 + \mathrm{k} \quad (1)$$

where k is constant number while ES is expressed in the unit of Baht/year. In this study, the ES was presented as the worth or benefits from energy conservation implementations in a year. The information of factory investment was based on the year of 2007-2009.

In the survey questionnaire, a number of measures and supports from government are limited by 5. Examples of measures from government support to enhance designated factories to implement energy conservation projects include technical expert assistance, financial assistance (soft loan), tax incentive with cost-based and performance-based, energy service company.

5 THE STUDY RESULTS

In this section, we provide the information related to the industrial preference for subsidy programs in order to implement energy conservation projects under presented in the energy management report. As is presented in Table 2, the percentage of respondent with seven options is significant to the benefits which factories can be obtained. In the industrial survey, the direct incentive, normally in range of 20-30% of investment cost for energy efficiency equipment, is the most preference option to obtain for implementing energy conservation project with 80.75% of total samples in this study. Then, the measure of tax incentive (cost based, performance-based) is also high level of preference by 63.06%, followed by the measure of soft loan financial assistance by 37.99% and ESCO program by 28.5%. It is also surprise that the measure of technical assistance is very low rate of preference which account by only 0.79%. In addition, there are significant portions by 20.05% of sample factories which not request for any supports from government sector. The feasible reasons to explain the option of expert and technical assistance is that the factories are not satisfy the previous performance of expert assistance from the past. The technical knowledge of factory's staff is sufficient to deal with the energy conservation project. The respondents are also indicated that this measure is non-monetary support directly. Furthermore, there are several reasons which factories not prefer measures and support from government to implement energy conservation projects. For examples, the quantity of production is more important than the energy saving aspect. The energy cost for some factories account by a small portion when compare with the labour and employee cost and raw material cost. Other possible reasons include the complex of subsidy procedure, unattractive rate of incentives and financial resource limitation to implement the energy conservation projects.

Table 2. Respondent related to the preference of supports

No	Subsidy programs	%
1	Not prefer	20.05
2	Tax incentive	63.06
3	Direct subsidy	80.75
4	Soft loan	37.99
5	ESCO	28.5
6	Expert, technical assistance	0.79
7	Other	1.85

Considering the incentive measures shown in Fig. 5 which classified energy cost of sample factories, the two incentives of tax incentive and direct subsidy programs are still most preference incenives for factories to implement energy conservation projects particularly industries with high energy cost. In contrast, an industry with low energy cost has less attention to consider energy conservation projects and the measure of expert/technical assistance not much prefers for all scales of factory. Therefore, the simulation of enery conservation potential assessed by the proposed hybrid model selected the measures of direct subsidy and tax incentives for investgating the optimal subsidy criteria from government sector. The project life cycle from 2 to 10 years has been varied in order to determine the sensitivity of financial performance as well as the rate of government subsidy.

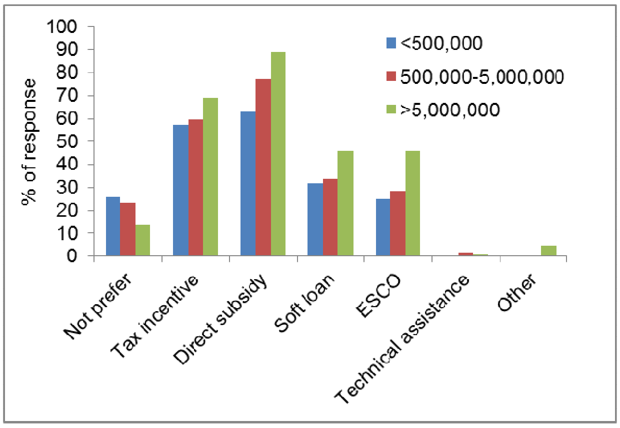

Fig. 5. Percentage of industrial response under subsidy programs preference considering energy costs.

Direct subsidy program

The energy conservation promotion with 30% direct subsidy incentive for industrial sector is one of the most successful programs in Thailand. The concept is based on the successful implementation in Denmark. The keypoint of this campaign is from the attractive rate of subsidy for industry to invest in a pre-approved list in high energy efficiency equipment. In the subsidy criteria, the government provides the 30% direct subsidy of equipment investment but not higher than 30% of standard price. The minimum subsidy is 15,000 Baht while the maximum support is limited at 2,000,000 Baht per factory. In the other word, the capital cost for investment in this project is in a range of 50,000-6,670,000 Baht. During the pilot project in 2000-2001, the 25 non-designated factories and buildings was selected as the target sector with project budgetary of 10 million Baht. In general approval criteria, the submited measure of energy conservation project should have a pay back period within 7 years. In general, this program is simple. The factories is not required to calculate financial or economic return and the procedures are not much complex for approval process. So, this campaign is attracted from many investors wich 11 standard measures are approved to receive the subsidy incentives: high frequency electronic ballast for lighting, variable speed drive on air compressor, insulation of pipes and surfaces, variable speed drive for pump, heat recovery equipment, controller of air supply for combustion, air to heat exchanger, high efficiency motors, luminaires reflectors, voltage regulator and power control for lighting system. However, the direct subsidy program was announced only in some periods and was stopped because from several reasons. The most important was the misperceptation that such a kind of subsidy is non macro-economically justifiable. In this study, the direct subsidy program is demonstrated for promotion in long term energy conservation policy which planned from 2011-2030. The project life cycle is expected in range 2-10 years. The variable of percentage for government subsidy to the industrial sector is varied from 20%-70%. The results of simulation in case of BAU scenario (GDP 3.5-6%), high economic growth rate situation (GDP >6%) and low economic growth situation (GDP <3.5%) are shown in Fig. 6 to Fig. 8, respectively.

The general results show that the benefit to cost ratio will be increased when the project life cycle is extended. Under the similar government budgetary, the benefit to cost ratio will be decreased if the percentage of government subsidy is increased because the investment from factories is minimized. As results of BAU scenario shown in Fig. 6, the optimal criteria for implementing energy conservation project is that the project life cycle must be longer than two years and the percentage government subsidy is lower than 50%.

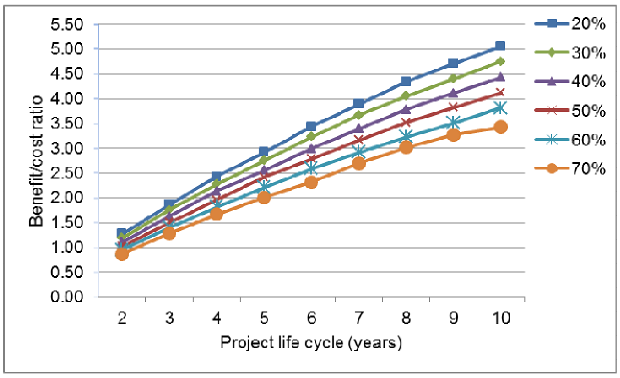

Fig. 6. Benefit to cost ratio for direct subsidy program with BAU scenario.

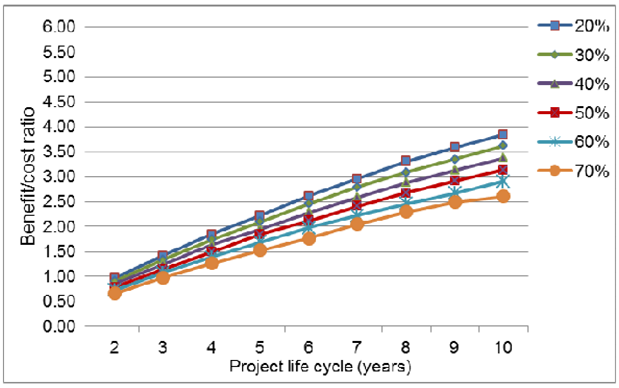

Fig. 7. Benefit to cost ratio for direct subsidy program with high economic growth rate scenario.

For the high economic growth rate, the energy conservation implementation is considered as the minor priority while the quantity of products is more important for factory profits. The government should provide the subsidy lower than 60% while the mimimum life time is expected with three years. The simulation results in this case is presented in Fig. 7. In the low economic growth rate or recesstion period, the energy conservation implementation is considered as the major policy for all factories in order to maintain their business operation profits. As the results shown in Fig. 8, the government should provide the subsidy lower than 70% while the mimimum life time is expected with two years. However, the results of this scenario may be reversed if factories counter a financial constraints from economic recession and result of investment capability for energy conservation project implementation. Therefore, the concept of value engineering with provision of enegy conservation experts or technical assistance is recommended. The low investment budgetary such as housekeeping measures are situated for this case.

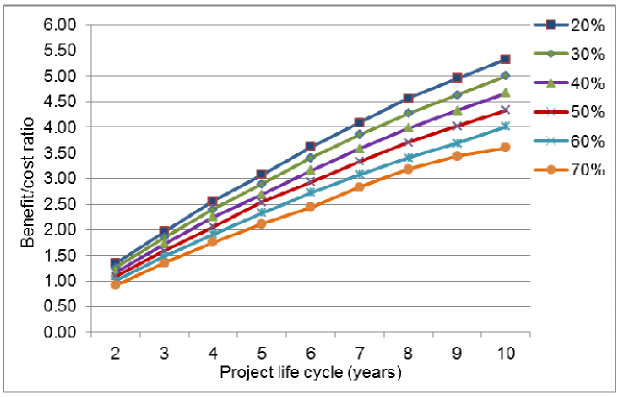

Fig. 8. Benefit to cost ratio for direct subsidy program with low economic growth rate scenario.

Tax incentive programs

For tax incentive measure, there are two programs considered in this study: cost-based tax incentive and performance based tax incentives. In the initial state, the campaign of cost-based tax incentive is firstly promoted because of government needs all energy intensive end-users invest in the proved energy efficiency technology. However, this measure leads to the large burden budgetary of government. Then, the performance-based tax incentive programs are introduced for reducing government constraint while the end-users are still received the incentive with acceptable value. For cost-based tax incentives, a 25% tax break is given to industrial sector for investing in projects that result in efficiency improvement. These tax breaks are applicable to the first 50 million Baht investment and spread over a 5-year period. In contrast to the cost-based consideration, the performance-based is introduced with 100% of tax deductible for all energy saving achieved. The maximum of this incentive measure is set at 2 million Baht. In this option, the procedure of pre and post energy saving audit is necessary to perform in order to certify the actual saving. Since two measures are related with tax, simulation results have been varied government subsidy from 15-85% while the project life cycle has a similar range with direct subsidy measure. The summary results of simulation obtained from the hybrid fuzzy-regression model for BAU, low growth rate GDP and high growth rate GDP are illustrated in Fig. 9-Fig. 11, respectively.

As shown in Fig. 9, we can investigate that overall results of benefit to cost ratio for the tax incentive measure are lower than direct subsidy program under the similar percentage of subsidy. If considering the case of BAU with the project life cycle of 2 years, the maximum percentage of subsidy for tax incentive measure should not higher than 25% in order to achieve the benefit to cost ratio at least 1.0. For the case of project life cycle is 3 years, maximum criteria of the tax incentive measure should not more than 55%. However, the economic situations can provide different results of cost-effectiveness for investment in energy conservation programs. Fig. 10 shows the simulation results of benefit to cost ratio for tax incentive measure in case of high growth rate of GDP. Our main finding results indicate that the tax incentive measure should not provide for the energy conservation projects with the life cycle less than 3 years in order to maintain the benefit to cost ratio at least 1.0. In addition, the optimal percentage of subsidy for the project life cycle between 5-7 years should not higher than 65% while the energy conservation projects with life cycle between 8-10 years should be received the incentives at maximum of 75%.

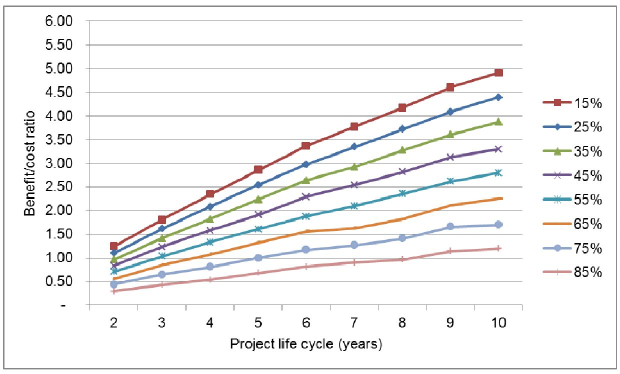

Fig. 9. Benefit to cost ratio for tax incentive program with BAU scenario.

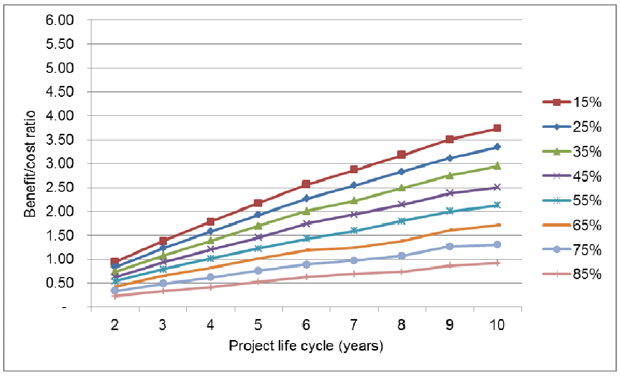

Fig. 10. Benefit to cost ratio for tax incentive program with high economic growth rate scenario.

For the situation of low economic growth rate, the trend of investment performance under various subsidy rates is shown in Fig. 11. The tax incetive measure has a maximum rate for subsidy by 25% if the project life cycle is at 2 years. The maximum subsidy of 75% is also possible if the project life time is at least 7 years. The simulatio results also indicate that the benefit to cost ratio in this case is more sensitive with the different rate of subsity and project life cycle.

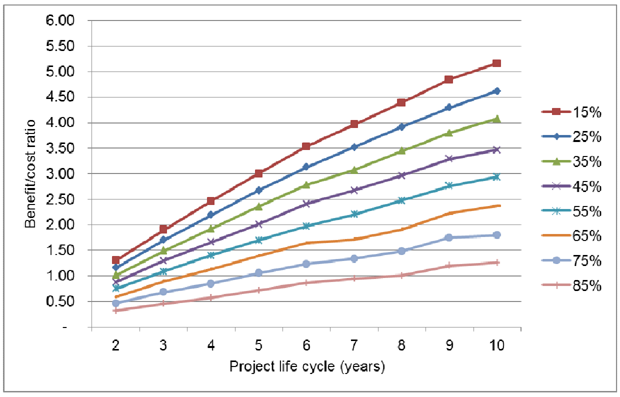

Fig. 11. Benefit to cost ratio for tax incentive program with low economic growth rate scenario.

The relationships between the investment performance index (benefit to cost ratio) under several conditions of economic situation, percentage of incentive subsidy and project life cycle have already presented. However, in fact, the decision making for implementing energy conservation project in industrial process are sequenctial investment. The factories need to choose the optimal timing for thier investment program based on thier specific industrial prioritie rather than the financial internal rate of return of the investment project alone. The multi-scenario of goverment investment with several time sequential for promoting energy conservation measures to the designated factories is presented in this section. The incentives of 30% direct-subsidy and 25% cost-based tax incentives are selected for comparison the results. In this calculation, the investment constraints of government budget for the 30% direct-subsidy program is 100 million Baht a year while the tax incentives is set the budget with 60 million Baht a year. In order to investgate the sensitivity of financial investment index, four scenarios with varying the time sequential of investment in each subsidy measure is assumed while the project life time is estimated in a range of 3-5 years. The annual worth of energy saving with the interest rate of 5% is ploted according to the sequential investment from government. The assumption in each scenario and simulation results are given as follow;

Scenario 1: promoting direct subsidy measure with 5-year period and the tax incentive measure with 2-year period.

This first scenario has been examined on the fact that 30% direct subsidy is the most attractive for designated factories. Therefore, the strategic planning for promoting this incentive is setting 30% direct subsidy program as the first priority, followed by 25% cost-based tax incentive. In this scenario, direct subsidy measure has been scheduled in the five years period while tax incentive has planned to promote in every two years. The time sequential of two subsidy programs within 20 years long term planning is shown in Fig. 12. The annual worth derived energy saving potential over 20 years with 5-year project life cycle is also illustrated. The net present value (NPV) of this scenario is calculated by 8,597.14 million Baht. However, the government investment is also high which accounted by 400 million Baht for direct-subsidy and 600 million Baht for tax incentive program.

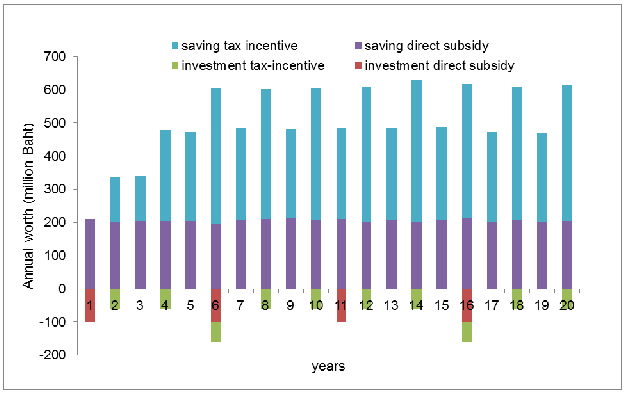

Fig. 12. Annual worth of scenario 1.

Scenario 2: promoting direct subsidy and tax incentive measures with 5-year period

This second scenario is based on the similar schedule for two incentive measure programs. The direct-subsidy and tax incentive is expexted to promote in every 5-year period. This scenario provides designated factories to have two options for energy conservation projects. The time sequencial of government support over 20-year is shown in Fig. 13. The expected saving from two subsidy measure presented by annual worth have a similar trend. The NPV of this scenario is calculated by 5,873.09 million Baht and the government investment is lower than the first scenario. Overall investment burden from government subsidy is 640 million Baht which 400 million Baht is from direct subsidy and 240 million Baht from tax incentive measures.

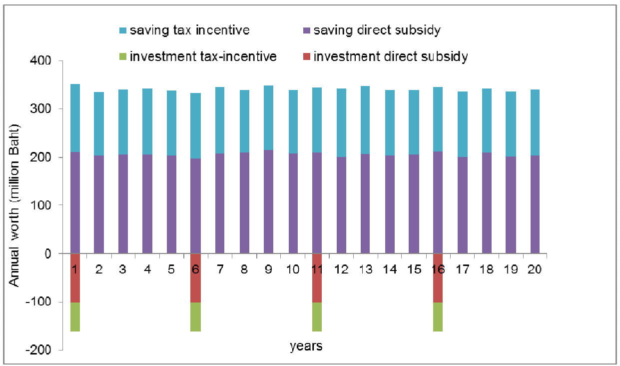

Fig. 13. Annual worth of scenario 2.

Scenario 3: promoting direct subsidy and tax incentive measure with 4-year period, the tax incentive measure lack the direct subsidy by 1 year

This third scenario is set the interval for subsivy shortter than the first scenario while the direct subsidy is still considered as the first priority for announcement. In this scenario, the direct-subsidy is placed on the order of 1st, 5th, 9th, 13th and 17th-year while tax incentive is set on the 2nd, 6th, 10th 14th and 18th-year. The sequential of subsidy programs and the saving potential is illustrated in Fig. 14. The NPV of this scenario is calculated by 6,878.06 million Baht. The government investment to promote this campaign is about 800 million Baht which the 500 million Baht is nessessary for direct subsidy and 300 Baht is required by tax incentive program.

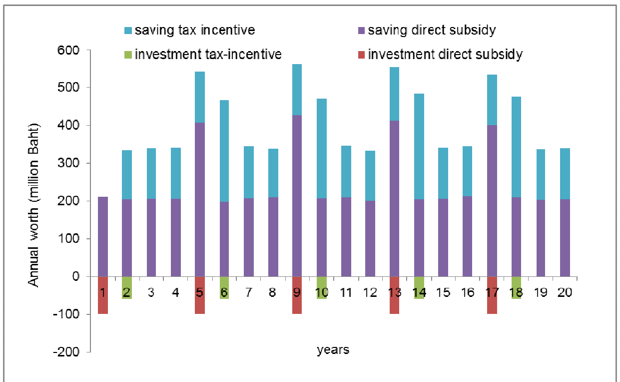

Fig. 14. Annual worth of scenario 3

Scenario 4: promoting direct subsidy and tax incentive measure with 3-year period, the tax incentive measure lack the direct subsidy by 1 year

This last scenario is established with the 3-year period of two subsidy programs. This scenario is based on the law enforcement for designated facories to performance the energy conservation projects and these require financial support from government frequently. Fig. 15 illustrates the government investment sequential over the 20-year planning period. The direct subsidy is still considered as the first priority for announcement and followed with the tax incentive measure program delayed by 1-year. In this scenario, the direct-subsidy is placed on the order of 1st, 4th, 7th, 10th, 13th,16th and 19th-year while tax incentive is set on the 2nd, 5th, 8th,11th 14th,17th and 20th-year. The NPV of this scenario is calculated by 9,019.26 million Baht. The government burden to promote this campaign is in the highest level compared to the onther scenarios. In this option, overall investment from government is about 1,120 million Baht which the first 700 million Baht is from direct subsidy program and 420 Baht is required by tax incentive program. It is noted that the simulation results is calculated based on the constant price of energy while the factory investment is obtained from survey. In case of energy prices is higher than the present situation, there are more opportunities for promoting the subsidy program with short sequential period of investment.

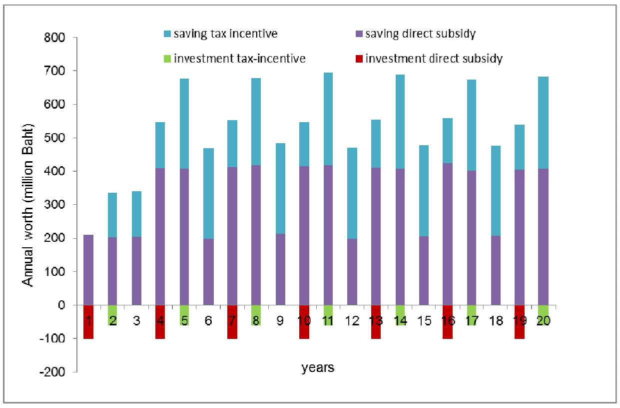

Fig. 15. Annual worth of scenario 4

In order to compare the cost-effectiveness of investment in each promotion campaign, Table 3 summarizes the NPV of four scenarios under the project life time of 3-5 years. This analysis considers both the NPV which derived from energy saving potential in a year and the burden from government investment. Thus, we define the cost-effective investment index with NPV and divided by government investment to represent the term of effectiveness. Based on the analytical results in Table 3, the results show that scenario 2 is the most efficient for promoting subsidy of energy conservation projects with the NPV/government investment of 9.18, followed by scenario 1 and scenario 3 with the NPV/government investment of 8.60. These imply that the effective promotion is from the announcement of two incentive measures in the similar period. In contrast, the scenario 4 provides the lowest feasibility for proposing the factories to implement the energy conservation projects although it contributes the result in term of highest energy saving return. In this case, the scenario 4 provides the NPV/government investment of 8.05.

The results of four scenarios imply that the strategy of investment to promote energy conservation programs based on long term period is strongly affected to the burden of government as well as the worth of energy saving. In practical, factory ability for replacement equipment from the existing system to the high efficiency technology is different from each other although they are classified within the similar category.

In this aspect, the large scale factory (large production volume or large energy consumption) has limitations higher than a small scale factory for investment in equipment with contributes a major impact of energy efficiency. Thus, our recommendation is that the percentage of subsidy should be considered the size of project investment. A factory required to change a major (major impact to the energy saving or energy efficiency) should be received more percentage of subsidy. Our further recommendation for sustainable and effective policy for energy conservation is that the person in an organization who is aggressive to energy conservation implementation should be received benefits from the worth of saving in order to encourage awareness and the responsibility of energy conservation in mind.

Table 3 Financial index from four investment scenarios

Scenario	Project life time	NPV ($x10^6$ Baht)	Investment	NPV /Investment
1	5	8,597.14	1000	8.60
	4	6,731.11		6.73
	3	5,008.91		5.01
2	5	5,873.09	640	9.18
	4	4,551.31		7.11
	3	3,402.79		5.32
3	5	6,878.06	800	8.60
	4	5,543.33		6.93
	3	4,096.78		5.12
4	5	9,019.26	1120	8.05
	4	7,158.64		6.39
	3	5,299.14		4.73

6 CONCLUSION

For the past decade, the investment for energy conservation policy in Thai industries has been promoted with several government measures. However, the uncertainty of manufacturing operation and investment limitations lead the actual energy reduction from energy conservation implementations to difficulty to assess in practical. This article presents the approach for estimating energy reduction potential using the hybrid fuzzy-regression model. The fuzzy concept is introduced to deal with the uncertainty of project implementation while the regression is used to describe the relationship of investment and energy reduction potential of factories. The internal factors of factories obtained from survey and various economic situations which significantly impact to the success of energy conservation projects are considered as the inputs for model development. After the model is already set up, the investment of factories related to energy conservation project with different subsidy options and project life time have been simulated. The benefit derived from energy saving to total cost of government investment is investigated. The simulation results indicate that the mechanism of direct subsidy measure can contribute the higher benefits than the tax incentive under the different government subsidy and project life time. In addition, the proposed model has been studied with the multi-scenario of government investment for promoting energy conservation policy. The sequential timing of government subsidy for direct subsidy and tax incentive programs results to the different investment performance index. Because of the factory can request the subsidy of energy conservation measure only one time per subsidy program, sustainable policy should be based on the project with long life time while the investment is in an acceptable range. Furthermore, our findings from survey clearly display that company policy and management understanding are the key driver for effective implementation of energy conservation activities. Finally, the direct subsidy and tax incentive are the most industrial preference for enhancing the energy conservation policy in Thailand.

REFERENCES

[1] Energy Statistic of Thaland 2011, Energy Policy and Planing Office (EPPO), Ministry of Energy.

[2] Energy Strategy, Ministry of Energy, Retrieved May 15, 2012 from the World Wide Web: eppo.go.th/doc/index.html

[3] Thailand 20-Year Energy Efficiency Development Plan (2011-2030), Ministry of Energy.

[4] Rohdina, P., Thollandera, P., Solding, P. 2007. Barriers to and drivers for energy efficiency in the Swedish foundry industry. *Energy Policy* 35: 672-677.

[5] Oikonomou, V., Becchis, F., Steg, L., Russolillo, D. 2009. Energy saving and energy efficiency concepts for policy making. *Energy Policy* 37: 4787-4796.

[6] SPRU (Science and Technology Policy Research), 2000. Reducing Barriers to Energy Efficiency in Public and Private Organizations. Brighton.

[7] Blumstein, C., Krieg, B., Schipper, L., York, C., 1980. Overcoming social and institutional barriers to energy conservation. *Energy* 5: 335–349.

[8] De Canio, S. 1993. Barriers within firms to energy-efficient investments. *Energy Policy* 1 (9): 906–914.

[9] de Groot, H., Verhoef, E., Nijkamp, P. 2001. Energy saving by firms: decision-making, barriers and policies. *Energy Economics* 23 (6): 717–740.

[10] Zadeh, L. 1965. Fuzzy sets. Information Control 8, 338–353.

[11] Bojadziev, G., Bojadziev, M. 1995. Fuzzy sets, fuzzy logic, applications. Advances in fuzzy systems-Applications and theory, Vol. 5.