

Key Management Factors Affecting Energy Control Capability in Small and Medium Scale Industries

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Abstract- The objective of this research was to figure out the key management factors affecting the energy control capability of small and medium scale industries. A number of factories, which participated and implemented in energy conservation project was only focused. The multiple linear regressions method was used to analyze the energy control capability of the factory. The capability was considered as a function of various management factors, and deduced by the determination coefficient of energy equation. The results declared that the role of top management played important role in which accounted to 33%, while the investment, motivation and organization were affected about 30%, 12% and 11% respectively. In term of, the qualification of energy management representative, the person who graduated in engineering area was affected by 14%. Nevertheless, the other management factors were not significantly affecting the energy control capability.

Keywords- Energy Control Capability / Energy Management System / Coefficient of Determination / Small and Medium Scale Industries / Criteria of Prime Minister Industry Award (Energy Management)

I. INTRODUCTION

Small and medium scales industries (SMIs) are one of the economic foundations of the country due to the number of enterprises in Thailand. As they are so crucial to economic and social development of the country, the implementation of projects and measures to improve the energy efficiency of enterprises will benefit the overall energy consumption of the country.

Since manufacturing industry is one of the greatest energy consumers, energy efficiency becomes a driver [1]. Although the projects and measures driven by many government agencies and affiliations for increasing energy efficiency of enterprises, even if they are promoted, it was found that there is a need to research to find appropriate solutions of how to develop the Energy Management System (EnMS) [2] with sustainable development thorough corporate by changing behavior of employee in the context of Thai culture.

Lacking of technical energy concerned management is a common barrier for SMIs to sustain energy efficiency and saving practices [3-6]. SMIs require a simplified methodology of assessment to monitor the progression of

projects and measures, and it could be implemented by present employee to hastily evaluate the accomplishment of such practices [7].

The index to assess energy monitoring and controlling has been applied as stated partly in the criteria of the Prime Minister Industry Award (Energy Management) [8]. Energy Control Capability (ECC) has been implied by deducing the coefficient of determination (R^2) of linear regression of the energy equation (EEQ), which constructed by regression of the relative data logging of the amounts of production yield and the amount of energy consumption, during the same each particular period of time.

The research is to figure out and investigate which of key management factors that affect, by applying the ECC of an enterprise for the analysis. The results of estimated figures show beneficial value. Never the less, further evaluation and related research of such methods shall require enhancing more reliability and validity.

II. ENERGY CONTROL CAPABILITY

Energy efficiency defines a ratio between an output of performance, service, goods or energy, an input of energy [9], means using less energy while maintain the same level of service [10], and provide at different levels. In process levels, it concern losses by physical mechanisms that are relative to the process itself, while in entire factory system, it does not result directly by the sum of individual parts or actions, and can be exploit only through a holistic view of the complex interactions of individual resources, processes and structures of a factory [1].

Improving energy efficiency means getting more work out from a given amount of energy put in [11], by various methods, and the key factors that affecting energy efficiency of the entire factory system are comprised of management and technology of its resources [1-7, 9-17] as shown in Figure 1.

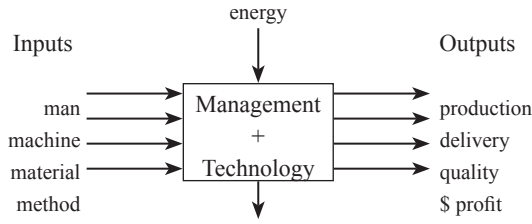


Fig.1 Management and Technology from an energy point of view

EnMS means systematic and continuous approach for sustainable energy improvements, and defines as the sum of totally integrated or interacting elements leading to the introduction of an energy policy and strategic energy goals, as well as processes and procedure to achieve these strategic objectives [2], as a system point of view shown in Figure 2.

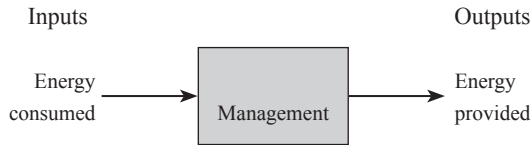


Fig.2 Energy Management System (EnMS)

Finding the energy optimization potential of the overall process or the total system [1], energy efficiency measurement and management that use widespread is Specific Energy Consumption (SEC), which mean the amount of energy used to produce 1 unit product, as shown by equation (1) [9].

$$SEC = \frac{\text{energy used}}{\text{products produced}} \quad (1)$$

Therefore, with the relative data logging of the amounts of production yield and the amount of energy consumption in same particular period of time, the EEQ can be constructed by the method of linear regression analysis, as shown by equation (2), and plotted as the graph shown in Figure 3.

$$y = mx + c \quad (2)$$

Whereas; y = amount of energy used (kWh); x = amount of product produced (kg); m = variable energy consumption (kWh/kg); and c = fixed energy consumption (kWh).

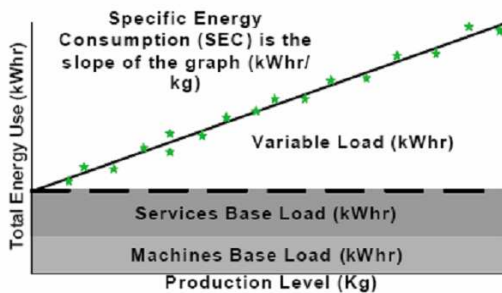


Fig.3 Graph of the Energy Equation (EEQ) [13]

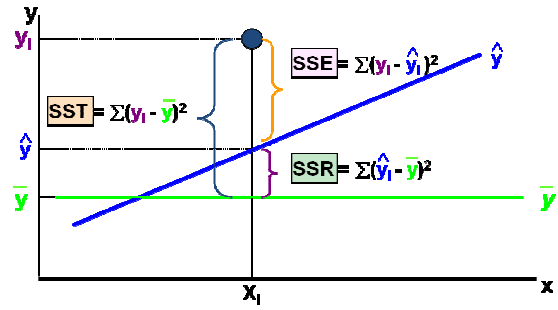


Fig.4 Coefficient of determination (R^2) of linear regression

$$R^2 = \frac{SSR}{SST} = \frac{\text{sum of squares explained by regression}}{\text{total sum of squares}} \quad (3)$$

The definition of R^2 , the coefficient of determination of linear regression, is the total portion of the total variation in the dependent variable (y) that is explained by the independent variable (x) as shown in figure 4 and equation (3). The highest value 1 mean 100% of the variation in y that is explained by variation in x. or may say the perfect linear relationship between y and x. In the contrary, the lowest 0 mean 0% of the explained variation between y and x, so R^2 can be used to imply efficiency of the regressed equation to determine expected value of y by known value of x.

Accordingly, as if the R^2 of EEQ would be brought to imply ECC, so it would mean the efficiency of the regressed EEQ to determine optimized energy consumption by expected producing product, and ECC would imply the capability of management to produce expected product with optimized energy used. Since management comprises controlling, so ECC would mean to be the capability of management for controlling energy consumption, and would be implied as the efficiency of EnMS of the firm in term of the capability to monitor and control energy consumption.

III. CONCEPTUAL FRAMEWORK

Several barriers prevent enterprises from implementing profitable energy projects and measures. They can be classified into related factors. The various factors are well-documented, economic for instance. The behavioural and organizational factors are increasing mentioned, but they are not yet well-documented [4]. Most of the entrepreneurs do not appear to aptitude, knowledge and dynamism required tackling technology-related problems such as energy efficiency. Meanwhile, key driving force for adoption of energy efficiency measures is the presence of individuals with ambition, and management role account in the context of sustainable development. [2-3, 11, 14-15].

Management factors including qualifications of person responsible for energy management (Energy Manager), corporate culture, energy management status, role of top management, participation of employee, and advisory of consultant [2, 11, 16-17], all of them are affecting ECC, which established a conceptual framework as shown in Figure 5

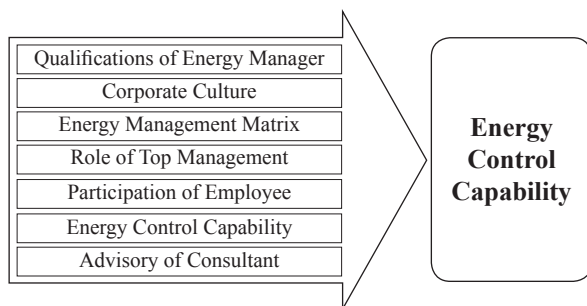


Fig. 5 Key Management Factors Affecting Energy Control Capability (ECC).

IV. RESEARCH METHODOLOGY

A. Target Group

The research targeted at small and medium-sized industries that had been participated in the energy efficiency and saving projects of 368 cases, with their EEQ were constructed by similar pattern of energy used data distributions which SEC were approximately between 1.374 - 8.529 kWh/kg.

Data collected by evaluating the qualifications of top management or owners or employee who had been designated and responsible for energy management of the enterprises, and the characteristics of the enterprises, which the 164 cases had fulfilled queries with accurate and complete information for the analysis.

B. Research Instrument

The instruments used in the research were evaluation form which was based on EnMS [17], and modified to comprise 16 variables in seven parts of components as follows;

Part 1: Qualifications of person who responsible for energy management including gender (X_1), age(X_2), work experience (X_3), level of graduation (X_4), and had been trained on energy management or related topic (X_5).

Part 2: Corporate culture (X_6 , X_7).

Part 3: Energy management status (X_8 - X_{13}).

Part 4: Role of top management (X_{14}).

Part 5: Participation of employee (X_{15}).

Part 6: Advisory of consultant (X_{16}).

Part 7: Amounts of production yield and relative amount of energy consumption with data logging during the same each particular period of time (Y).

Content validity testing of instruments with the objective characteristics defined in terminology by the index IOC (Index of item Objective Congruence) with each item is equal to or greater than 0.5 brings trial with a sample of 30 cases with a similar but unique to the cases used in the research. Then, test for consistency by using item-test correlation and Pearson product moment correlation coefficient, which of the value were 0.2 to 0.7 with significance at 0.05 levels, and a test of confidence by Cronbach's alpha coefficient was 0.87

C. Data processing and variables configuration

The data were processed to show the descriptive

statistics of the dependent variable and all independent variables used in the multiple linear regressions analysis to be summarized as detailed in Table 1.

The ECC, deducing by the R^2 of the linear regression of the EEQ which shown relationship between amounts of production yield with respected to energy consumption of an enterprise, were classified with the value of R^2 into five levels.

The R^2 value of 0.801 up to 1.000, with the inference of ECC, the enterprise was classified into grade A, and then converted grade into numerical values of 5. Hereby, the lower range values of R^2 , enterprises were classified into the lower grade B, C, D and E, respectively, and then converted those grade into the equivalent numerical scale with values of 4, 3, 2 and 1, respectively. The details are shown in Table 2.

D. Data analysis

Data were test the hypothesis by using t - test and ANOVA of significance at 0.05 levels and the correlations between each independent variable does not exceed 0.75 in Table 3.

TABLE 1
SUMMARY STATISTICS

Variables	Mean	Std. Dev.	Min	Max
Y - Energy Control Capability	3.012	1.009	1	5
X_1 - Gender	0.981	0.134	0	1
X_2 - Age	0.993	0.078	0	1
X_3 - Work experience	0.585	0.494	0	1
X_4 - Level of Graduation	0.945	0.228	0	1
X_5 - Trained on Energy Mgt.	0.774	0.419	0	1
X_6 - Acceptance of Uncertainty	0.622	0.486	0	1
X_7 - Planning time period	0.908	0.289	0	1
X_8 - Policy	3.554	0.609	1	5
X_9 - Organization	2.884	0.867	1	5
X_{10} - Motivation	2.756	0.665	1	5
X_{11} - Information	2.554	0.815	1	5
X_{12} - Public relation	2.865	0.795	1	5
X_{13} - Investment	2.902	0.485	1	5
X_{14} - Role of Top management	3.969	0.839	1	5
X_{15} - Participation of Employee	3.463	1.029	1	5
X_{16} - Advisory of Consultant	3.810	0.825	1	5

TABLE 2
DEDUCING OF ENERGY CONTROL CAPABILITY (ECC) BY R^2

R^2	ECC Grade	ECC Scale
0.801 - 1.000	A	5
0.601 - 0.800	B	4
0.401 - 0.600	C	3
0.201 - 0.400	D	2
0.000 - 0.200	E	1

TABLE 3
MATRIX OF CORRELATION BETWEEN INDEPENDENT VARIABLES USED IN THE ANALYSES

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
X ₂	-0.0107	1													
X ₃	-0.0225	-0.0659	1												
X ₄	-0.0329	-0.0189	0.06893	1											
X ₅	-0.0737	-0.0423	0.10833	0.12616	1										
X ₆	-0.0126	0.10046	-0.0946	-0.0774	-0.0899	1									
X ₇	-0.0433	-0.0249	-0.0094	-0.0765	0.03117	-0.0293	1								
X ₈	-0.0251	-0.0574	0.25943	0.13197	0.32496	-0.0538	0.32467	1							
X ₉	-0.0709	-0.0105	0.28781	0.0915	0.24805	-0.1044	0.25086	0.50515	1						
X ₁₀	-0.0502	0.08923	0.19421	0.03247	0.19728	-0.0781	0.07462	0.22983	0.30116	1					
X ₁₁	-0.0747	-0.0429	0.11765	0.16438	0.38614	-0.102	0.26845	0.54928	0.63711	0.20551	1				
X ₁₂	-0.0231	-0.0133	0.13862	0.09433	0.33193	-0.0843	0.31989	0.43321	0.67073	0.2971	0.58829	1			
X ₁₃	-0.1215	-0.0158	0.11161	0.11735	0.37335	-0.0272	0.28559	0.49512	0.56978	0.38138	0.55554	0.49023	1		
X ₁₄	-0.1681	-0.0965	0.26514	0.18319	0.41615	-0.2839	0.26649	0.45314	0.45825	0.30498	0.42796	0.3891	0.51943	1	
X ₁₅	-0.027	0.03536	0.17499	0.13488	0.48531	-0.1993	0.30811	0.45801	0.49982	0.38968	0.45156	0.43613	0.63089	0.71924	1
X ₁₆	-0.0866	-0.1131	0.06234	0.10729	0.37225	-0.1943	0.28687	0.35609	0.32877	0.2839	0.37519	0.34425	0.48921	0.66433	0.66654

V. RESULTS

Independent variables, that affected ECC at 0.05 significant levels, has comprised seven variables including; X₅ - Trained on energy management; X₉ - Organization; X₁₀ - Motivation; X₁₃ - Investment; and X₁₄ - Role of top management, as details shown in Table 4-5 with statistical parameters in the Table 6-7. The model can be written by the Equation (4).

$$ECC = -2.33773 + 0.259226X_5 + 0.206915X_9 + 0.218076X_{10} + 0.541191X_{13} + 0.599720X_{14} \quad (4)$$

TABLE 4
MULTIPLE LINEAR REGRESSION ANALYSIS

	Coefficient	SE	t Stat	P-value
C	-2.58003	0.652179	-3.95602	0.000118
X ₁	-0.01178	0.26497	-0.04444	0.96461
X ₂	0.511894	0.456309	1.121814	0.263771
X ₃	-0.09775	0.07737	-1.26338	0.208454
X ₄	0.026469	0.15575	0.169948	0.865285
X ₅	0.224687	0.100667	2.231995	0.027128*
X ₆	-0.12053	0.07516	-1.60364	0.11094
X ₇	0.015966	0.136342	0.117105	0.906936
X ₈	-0.00083	0.07513	-0.01107	0.991184
X ₉	0.211195	0.064908	3.253742	0.001413*
X ₁₀	0.206662	0.058711	3.519956	0.000575*
X ₁₁	0.019736	0.063291	0.311825	0.755615
X ₁₂	-0.0248	0.063362	-0.39137	0.696091
X ₁₃	0.490904	0.106571	4.606362	8.81E-06*
X ₁₄	0.544744	0.069174	7.874963	6.91E-13*
X ₁₅	0.102633	0.060785	1.688478	0.09344
X ₁₆	-0.02206	0.061831	-0.35676	0.721785

TABLE 5
MULTIPLE LINEAR REGRESSION ANALYSIS BY SELECTING SPECIFIC VARIABLES THAT ARE STATISTICALLY SIGNIFICANT

Variables	Coefficient	SE	t Stat	P-value
C	-2.33773	0.229331	-10.1937	4.55E-19
X ₅	0.259226	0.091554	2.83141	0.005238
X ₉	0.206915	0.049403	4.188316	4.66E-05
X ₁₀	0.218076	0.056236	3.877863	0.000154
X ₁₃	0.541191	0.095293	5.679253	6.33E-08
X ₁₄	0.599720	0.051214	11.71015	3.38E-23

VI. CONCLUSIONS

A. Summary

The investigation of key management factor whether makes a difference to the accomplishment of projects and measures implement in the firm. By applying the methods of multiple linear regression analysis, with implication of ECC by deducing R² of EEQ which used to determine energy used and product produced of the small and medium scale industries in target group, the results declared that key management factors affecting ECC as shown in table 8 with following details;

- Role of the top management, whose behavior inspires employee to participate in the implemented projects and measures, was the most effected at 33%.
- Investment for energy efficient technologies and process improvement was the second that effected 30%.
- Motivation to initiate employee enthusiasm affected 12%.
- Structure of organization affected 11%.
- Qualification of energy management representative with graduation in the field of engineering affected 14%.

The results also declared that others key management factors were not significantly affected.

The finding equation was verified that it was able to predict the ECC of enterprises with significant level of 76.2% and predicted value error by 11.3%.

B. Discussion

Despite the using of the ECC by deducing R² is found beneficial; the curtailed methods and interpretation may require enhancing more reliability and validity with further evaluation and related research. Because of the R² can be influence by other factors than ECC, such as the degree of freedom or the number of analyzed data. Nevertheless, the R² could declare the key management factors that affect the ECC are significant.

TABLE 6
STATISTICAL PARAMETERS OF MULTIPLE LINEAR REGRESSION ANALYSIS

Regression Statistics					
Multiple R					0.911324
R Square					0.830512
Adjusted R Square					0.812063
Standard Error					0.437455
Observations					164
ANOVA					
	df	SS	MS	F	Sig. F
Regression	16	137.8447	8.615295	45.01986	2.03E-48
Residual	147	28.13088	0.191367		
Total	163	165.9756			

TABLE 7
STATISTICAL PARAMETERS OF MULTIPLE LINEAR REGRESSION ANALYSIS BY SELECTING SPECIFIC VARIABLES THAT ARE STATISTICALLY SIGNIFICANT

Regression Statistics					
Multiple R					0.904946
R Square					0.818927
Adjusted R Square					0.813197
Standard Error					0.436134
Observations					164
ANOVA					
	df	SS	MS	F	Sig. F
Regression	5	135.922	27.18439	142.9156	9.44E-57
Residual	158	30.05363	0.190213		
Total	163	165.9756			

TABLE 8
THE RESULTS OF MULTIPLE LINEAR REGRESSION ANALYSIS OF THE VARIABLES THAT AFFECT ENERGY CONTROL CAPABILITY

Variables	Coefficient	Ratio
X ₅	0.259226	14%
X ₉	0.206915	11%
X ₁₀	0.218076	12%
X ₁₃	0.541191	30%
X ₁₄	0.599720	33%

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