ภาคผนวก ง

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Energy conservation in Thai industry: reality or illusion

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Abstract

This paper presents the analysis in the energy consumption in Thai industry during 1987 to 2002 by decomposition method. The energy consumption was analyzed based on energy intensity, economic structure and economic growth factors. It was found that the mining and construction sectors saved energy equivalent to 171.68 thousand tons of oil equivalent (ktoe), while the manufacturing sector, which accounted for 98% of energy consumption in Thai industry, failed to save energy. Despite of the fact that many resources and infrastructure, both physical and institutional, were invested/established for energy saving in industry, Thai industry consumed about 1,401.95 ktoe more than it should, otherwise, have been.

Keywords: Energy model; Energy conservation; Decomposition method

Nomenclature

E	energy consumption (ktoe)
E_i	energy consumption in an economic sector (ktoe)
E^0	energy consumption in base year (ktoe)
E^t	energy consumption in year t (ktoe)
ΔE	change in energy consumption (ktoe)
GDP	gross domestic product (Billions of US dollars)
GDP^0	gross domestic product in base year (Billions of US dollars)
GDP^t	gross domestic product in year t (Billions of US dollars)
ΔGDP	change in gross domestic product (Billions of US dollars)
GDP_{effect}	energy consumption due to economic growth (ktoe)
I	energy intensity (kgoe/1000 US dollars)
I_i	energy intensity in an economic sector (kgoe/1000 US dollars)
I_i^0	energy intensity in an economic sector in base year (kgoe/1000 US dollars)
I_i^t	energy intensity in an economic sector in year t (kgoe/1000 US dollars)
I_{effect}	energy consumption due to energy intensity (ktoe)
ΔI	change in energy intensity (kgoe/1000 US dollars)
Q	sectoral gross domestic product (Billions of US dollars)
Q_i	sectoral gross domestic product in an economic sector (Billions of US dollars)
S_i	specific gross domestic product (decimal)
S_i^0	specific gross domestic product in an economic sector in base year (decimal)
S_i^t	specific gross domestic product in an economic sector in year t (decimal)
S_{effect}	energy consumption due to economic structure (ktoe)
ΔS_i	change in specific gross domestic product in an economic structure

Real	real energy consumption (ktoe)
Trend	trend (or predicted) energy consumption (ktoe)
ψ	energy saving (ktoe)
ψ_i	energy saving in a sector (ktoe)

1. Introduction

Countries where energy is used efficiently will have sound and sustained economic growth in the restricted international environmental agreement condition. Since energy is essential for economics advancement and competitiveness, there is a pressing need for improving energy efficiency, particularly for countries depending on importation of energy. In 2002 Thailand imported energy, which are mainly fossil-based fuel, amounting to 47,413 ktoe (DEDE, 2002). Fossil fuel, which contributes up to 82.9 % of total energy consumption, is the main source of energy in Thailand. Energy conservation and the use of indigenous energy sources become an important measure to decrease the dependency of imported energy for Thailand.

In 2002 the final energy consumption in Thailand was 52,979 ktoe. The major consumers are transportation (37.1%), industry (35.8%), and residential (14.9%). The average energy intensity in industry during 1987-2002 was 335.29 kgoe/1000 US$ (see Table 1); with an increasing trend. In order to be competitive, Thailand deserves energy efficiency management in industry. In 1992 the Parliament approved the Energy Conservation Promotion Act and the Energy Conservation Fund was established thereafter. Many public and private energy saving projects were supported by this Fund. Many evaluation reports were presented and resulted in public perception on the success of energy conservation measures. However, they are mainly project-based evaluation which lacks of concrete evidence to convince some energy experts that the country as a whole benefits from the energy conservation plan.

Many researchers have studied towards energy conservation in Thai industries. The cogeneration process based on the energy utility requirements of the plant is evaluated as the possible options (Tang and Mohanty, 1996). The DOE-2 simulation program was used to analyze energy in buildings and suggested many cost effective alternatives (Chirarattananon and Taweekun, 2003). The forecast of growth in energy demand and the corresponding emissions during 2003 to 2020 was studied by using a model based on end-use approach. The results showed that if all options are simultaneously implemented, the energy savings and CO_2 mitigation in 2020 are estimated to be 1,240 thousand toe and 3,622 thousand ton of CO_2 equivalent, respectively (Tanatvanit et al., 2003). These are fragmented studies which could not give holistic view of energy conservation of the country.

The convincing explanation should, perhaps, be obtained from the analysis of the energy saving by the decomposition method. The decomposition methodology has become a useful and popular tool not only in industry energy demand analysis but also in energy and environmental analysis (Ang and Zhang, 2000). It takes into account of the relationship between energy consumption and energy-related economy. It is a useful technique to give the broad view of the implementation of energy conservation measures. The forefront study of the application of the decomposition on energy conservation was that presented by Sun (Sun, 2003). However, most of the studies were limited to two economic dimensions such as energy intensity and *GDP*.

In this study, the 3 dimension complete decomposition models was formulated to analyze the energy saving in Thai industry. This technique includes the effect of energy intensity, economic structure and economic growth (*GDP*). This paper presents results of energy saving in Thai industry based on the complete decomposition method to disclose the fact of the acclaimed success in Thailand.

2. The energy saving model

The complete decomposition method was used to construct the energy saving model for Thai industry. The model starts with *GDP*-related energy intensity,

$$I = \frac{E}{GDP} \tag{1}$$

If the energy intensity is calculated for a particular sector having Q as its gross domestic product, equation (1) becomes,

$$I_i = \frac{E_i}{Q_i} \tag{2}$$

The aggregate *GDP*-related energy consumption can be decomposed as following.

$$E = \frac{E}{Q}\frac{Q}{GDP}GDP \tag{3}$$

Thus, energy consumption for n economic sectors can be obtained from equation (4)

$$E = \sum_i^n \frac{E_i}{Q_i}\frac{Q_i}{GDP}GDP \tag{4}$$

By defining S_i as the specific gross domestic product in each economic sector, equation (4) can be written as following

$$E = \sum_i^n I_i S_i GDP \tag{5}$$

The change of energy consumption over a period of t years is;

$$\Delta E = E^t - E^0 \tag{6}$$

$$= \sum_i^n I_i^t S_i^t GDP^t - \sum_i^n I_i^0 S_i^0 GDP^0 \tag{7}$$

Or can be rewritten as,

$$\Delta E = I_{effect} + S_{effect} + GDP_{effect} \tag{8}$$

Where, I_{effect}, S_{effect} and GDP_{effect} are the energy intensity effect, the economic structure effect and the effect of economic growth, respectively. Following the decomposition method (Sun, 2001), these three effects can be decomposed as below.

$$I_{effect} = \sum_i^n \Delta I_i S_i^0 GDP^0 + \frac{1}{2}\sum_i^n \Delta I_i (\Delta S_i GDP^0 + S_i^0 \Delta GDP) + \frac{1}{3}\sum_i^n \Delta I_i \Delta S_i \Delta GDP \tag{9}$$

$$S_{effect} = \sum_i^n I_i^0 \Delta S GDP^0 + \frac{1}{2}\sum_i^n \Delta S_i (\Delta I_i GDP^0 + I_i^0 \Delta GDP) + \frac{1}{3}\sum_i^n \Delta I_i \Delta S_i \Delta GDP \tag{10}$$

$$GDP_{effect} = \sum_i^n I_i^0 S_i^0 \Delta GDP + \frac{1}{2}\sum_i^n \Delta GDP (\Delta I_i S_i^0 + I_i^0 \Delta S_i) + \frac{1}{3}\sum_i^n \Delta I_i \Delta S_i \Delta GDP \tag{11}$$

The industry in Thailand categorized as 3 economic sectors namely, mining, construction and manufacturing. The aggregate change of energy consumption in industry is the summation of the change of three sectors, which can be calculated from equations (8)-(11).

From equation (6), the "real" energy consumption in the year t can be expressed as.

$$Real = E^t = \Delta E + E^0 \qquad (12)$$

The GDP_{effect} is used to predict the "trend" of the energy consumption in year t as appeared in equation (13).

$$Trend = GDP_{effect} + E^0 \qquad (13)$$

Energy saving is defined as the difference between the Real and Trend. Thus,

$$\psi = Real - Trend$$

$$= \Delta E - GDP_{effect} \qquad (14)$$

Energy saving is achieved only if $\psi \langle 0$, which indicates that the actual increase of energy consumption is less than that should have, otherwise, resulted from the growth of economy. This condition implies that the energy consumption has been comparatively reduced (saved), which is the indicator of the success of energy conservation plan. In contrast, if $\psi \rangle 0$, energy saving was not achievable. Finally, from equations (8)-(11) and (14), the energy saving model (ψ) can be written as,

$$\psi = I_{effect} + S_{effect}$$

$$\psi = \sum_i^n \Delta I_i S_i^0 GDP^0 + \frac{1}{2}\sum_i^n \Delta I_i (\Delta S_i GDP^0 + S_i^0 \Delta GDP) + \sum_i^n I_i^0 \Delta S_i GDP^0 + \frac{1}{2}\sum_i^n \Delta S_i (\Delta I_i GDP^0 + I_i^0 \Delta GDP) + \frac{2}{3}\sum_i^n \Delta I_i \Delta S_i \Delta GDP \qquad (15)$$

The energy saving from these models appear mathematically in minus sign. However, for the ease of perception the positive values are presented as "saving" in the results.

3. The mathematical model for sensitivity analysis

In order to understand the degree of parametric contribution in the energy saving, sensitivity analysis is carried out from equation 15. GDP^t is the summation of gross domestic products (Q^t) of the 3 sectors.

$$GDP^t = Q_1^t + Q_2^t + Q_3^t \tag{16}$$

Thus, for sector i equation 15 is reduced to,

$$\begin{aligned}\psi_i = &\frac{1}{3}\frac{E_i^t GDP^0}{(Q_1^t+Q_2^t+Q_3^t)} - \frac{1}{6}\frac{E_i^t Q_i^0 (Q_1^t+Q_2^t+Q_3^t)}{Q_i^t GDP^0} - \frac{1}{3}\frac{E_i^0 (Q_1^t+Q_2^t+Q_3^t)}{GDP^0} + \\ &\frac{1}{6}\frac{E_i^t Q_i^0}{Q_i^t} - \frac{1}{6}\frac{E_i^0 Q_i^t}{Q_i^0} + \frac{1}{6}\frac{E_i^0 Q_i^t GDP^0}{Q_i^0 (Q_1^t+Q_2^t+Q_3^t)} + \frac{2}{3}E_i^t - \frac{2}{3}E_i^0\end{aligned} \tag{17}$$

Parameters of the base year, which are represented by the superscript 0, are constants. Alternatively, the energy saving can be written as,

$$\psi_i = f(E_i^t, Q_1^t, Q_2^t, Q_3^t) \tag{18}$$

Total change of energy saving in industry can be written as

$$d\psi = d\psi_1 + d\psi_2 + d\psi_3 \tag{19}$$

$$= dI_{effect1} + dS_{effect1} + dI_{effect2} + dS_{effect2} + dI_{effect3} + dS_{effect3}$$

$$= \sum_i^3 dI_{effect_i} + \sum_i^3 dS_{effect_i} \tag{20}$$

From equations (9) and (10) the derivatives of energy intensity effect and economics structure effect in a particular sector are,

$$\begin{aligned}dI_{effect_i} = &\left(\frac{1}{3}\frac{Q_i^0}{Q_i^t} + \frac{1}{6}\frac{GDP^0}{GDP^t} + \frac{1}{6}\frac{Q_i^0 GDP^t}{GDP^0 Q_i^t} + \frac{1}{3}\right) dE_i^t + \\ &\left(\begin{aligned}&-\frac{1}{3}\frac{Q_i^0 E_i^t}{(Q_i^t)^2} - \frac{1}{6}\frac{GDP^0 E_i^t}{(GDP^t)^2} - \frac{1}{6}\frac{GDP^0 E_i^0 (GDP^t - Q_i^t)}{Q_i^0 (GDP^t)^2} \\ &-\frac{1}{6}\frac{Q_i^0 E_i^t (GDP^t - Q_i^t)}{GDP^0 (Q_i^t)^2} - \frac{1}{6}\frac{E_i^0}{GDP^0} - \frac{1}{3}\frac{E_i^0}{Q_i^0}\end{aligned}\right) dQ_i^t + \\ &\left(-\frac{1}{6}\frac{GDP^0 E_i^t}{(GDP^t)^2} + \frac{1}{6}\frac{GDP^0 Q_i^t E_i^0}{Q_i^0 (GDP^t)^2} + \frac{1}{6}\frac{Q_i^0 E_i^t}{GDP^0 Q_i^t} - \frac{1}{6}\frac{E_i^0}{GDP^0}\right)(dGDP^t - dQ_i^t)\end{aligned} \tag{21}$$

$$dS_{effect_i} = \left(\frac{1}{6}\frac{GDP^0}{GDP^t} - \frac{1}{6}\frac{Q_i^0}{Q_i^t} - \frac{1}{3}\frac{Q_i^0 GDP^t}{GDP^0 Q_i^t} + \frac{1}{3} \right) dE_i^t +$$

$$\left(\begin{array}{l} \frac{1}{3}\frac{GDP^0 E_i^0 (GDP^t - Q_i^t)}{Q_i^0 (GDP^t)^2} - \frac{1}{6}\frac{GDP^0 E_i^t}{(GDP^t)^2} + \frac{1}{6}\frac{E_i^0}{Q_i^0} + \frac{1}{6}\frac{Q_i^0 E_i^t}{(Q_i^t)^2} \\ -\frac{1}{6}\frac{E_i^0}{GDP^0} + \frac{1}{3}\frac{Q_i^0 E_i^t (GDP^t - Q_i^t)}{GDP^0 (Q_i^t)^2} \end{array} \right) dQ_i^t \qquad (22)$$

$$\left(-\frac{1}{3}\frac{Q_i^t GDP^0 E_i^0}{Q_i^0 (GDP^t)^2} - \frac{1}{6}\frac{GDP^0 E_i^t}{(GDP^t)^2} - \frac{1}{6}\frac{E_i^0}{GDP^0} - \frac{1}{3}\frac{Q_i^0 E_i^t}{GDP^0 Q_i^t} \right)(dGDP^t - dQ_i^t)$$

The overall change of energy saving in industrial sector can be calculated by substituting equation (21) and (22) into equation (20)

Alternatively, by substituting derivatives of equation (17) into equation (18), the change of energy saving in a particular sector is,

$$d\psi_i = \left(\frac{1}{3}\frac{GDP^0}{(Q_1^t + Q_2^t + Q_3^t)} - \frac{1}{6}\frac{Q_i^0 (Q_1^t + Q_2^t + Q_3^t)}{Q_i^t GDP^0} + \frac{1}{6}\frac{Q_i^0}{Q_i^t} + \frac{2}{3} \right) dE_i^t +$$

$$\left(\begin{array}{l} -\frac{1}{3}\frac{E_i^t GDP^0}{(Q_1^t + Q_2^t + Q_3^t)^2} + \frac{1}{6}\frac{E_i^t Q_i^0}{GDP^0}\left(\frac{GDP^t - Q_i^t}{(Q_i^t)^2} \right) - \frac{1}{3}\frac{E_i^0}{GDP^0} - \frac{1}{6}\frac{E_i^t Q_i^0}{(Q_i^t)^2} \\ -\frac{1}{6}\frac{E_i^0}{Q_i^0} + \frac{1}{6}\frac{E_i^0 GDP^0}{Q_i^0}\left(\frac{GDP^t - Q_i^t}{(Q_1^t + Q_2^t + Q_3^t)^2} \right) \end{array} \right) dQ_i^t + \qquad (23)$$

$$\left(\begin{array}{l} -\frac{1}{3}\frac{E_i^t GDP^0}{(Q_1^t + Q_2^t + Q_3^t)^2} - \frac{1}{6}\frac{E_i^t Q_i^0}{Q_i^t GDP^0} - \frac{1}{3}\frac{E_i^0}{GDP^0} \\ -\frac{1}{6}\frac{E_i^0 Q_i^t GDP^0}{Q_i^0 (Q_1^t + Q_2^t + Q_3^t)^2} \end{array} \right)(dGDP^t - dQ_i^t)$$

The overall energy saving in industrial sector can be calculated by substituting equation (23), for i = 1 ,2, 3, into equation (19)

Thailand energy consumption (DEDP, 1996; DEDP, 1999; DEDP, 2000; DEDP, 2001; DEDE, 2002) and the sectoral GDP during 1987 to 2002 (NESDB, 2002; NESDB, 2004) are given in Table 1. They were used to calculate the energy saving in Thai industry. The starting base year is 1987. The gross domestic product data come from Thai Baht constant at 1988 price and then converted to US dollars using the yearly average 1988 exchange rates (IMF, 2002).

4. Results and discussion

The results show that, during the period of 1988-2002, the total energy saving in Thai industry was -1,401.95 ktoe. This accounted for the saving in mining, construction and manufacturing sectors of 25.84, 145.84 and -1573.62 ktoe respectively. Since the energy consumed by mining sector was only 0.67% of the total energy consumption in industry, its role in energy saving is minimal. For the construction sector the energy consumption increased continuously to the peak of 369 ktoe in 1997 (see Table 1), when the economic crisis hit the country and the real estate was the first to be suffered. As a consequence, the share of the construction sector in industry economic structure decreased since 1997 (see Fig. 1). It is interesting to point out that after 1993, the year that Thailand implements Energy Conservation Act, the energy saving in construction sector has been heavily fluctuated (see Fig. 2). It indicates that Thailand has not yet taken proper action in energy management in the construction sector.

As the manufacturing sector consumes great amount of energy and it contributes to the economic development substantially, the energy conservation activities has been targeted for this sector since the inception of Energy Conservation Promotion Act in 1993. Energy consumption in this sector during 1987-2002 was 202,907 ktoe (see Table 1). It accounted for 97.75% of the total energy consumption in industry. Hence, energy conservation in this sector is very vital. Emphasis will be placed on analyzing energy saving in this particular sector. Table 2 and Fig 3 show that, despite of the implementation of many energy saving measures, energy saving did not actually occur in this sector at all. It indicates that the over-energy consumption comes from the structural change 1,713.61 ktoe while the change in sectoral energy intensity saved -139.99 ktoe of energy. This is the evidence of energy inefficiency of this sector which, as a result, over consumption of -1,573.62 ktoe was apparent. From 1994 to 1996, before the economic crisis started, Thai manufacturing sector failed to save energy every year.

When consider the whole industry, the over-consumption of energy in the manufacturing sector out-weighted the other two sectors and resulted in wasteful use of energy by -1,401.95 ktoe (see Table 3and Fig 4). During the first year of economic crisis (1997) it seemed that Thailand could save energy consumption in the industry sector. Because the energy consumption in the manufacturing sector was decreased affecting from economic downturn, the energy intensity in manufacturing sector gave the sign of success of energy saving (I_{effect} =-1,651.36 ktoe in Table 2 for 1997) while the structural change indicated the over-consumption (S_{effect}= +619.22 ktoe). The positive sign in S_{effect} is partly due to the increasing share of the manufacturing sector (structure change) as appeared in Fig.1. Because of the decrease of the GDP, it resulted in energy saving with respect to the change of GDP. Therefore, in 1997 it seemed that Thai industry saved energy 963.54 ktoe (see Table 3) and the major contributor was the manufacturing sector (1,032.14 ktoe while the mining and construction sectors over-consumed by 6.65 and 61.95 ktoe, respectively). This might be an illusion because the negative change in energy consumption was due to the slow-down of the large and energy-intensive industries (gives negative I_{effect} and GDP_{effect}) not because of good management for energy saving.

In 1997 when Thailand faced economic crisis, the excessive foreign debt was blamed for the collapse of many industries. But how well the industry performed regarding to energy-related production cost is still a myth to the industrial executives (and also the Energy Conservation Fund). It is interesting to note that seven years before the enforcement of energy conservation promotion act (1988-1994) Thai industry had an energy saved-consumption of 297.66 ktoe. But, for the same period of eight years, after the full implementation of the law (1995-2002) the corresponding figure has jumped to 1,699.60 ktoe. Obviously, three years before the crisis (1994-1996) Thailand enjoyed her double-digit economic growth, without realizing that the industry was at the brink of uncompetitive cost (heavily over-consumed energy and fluctuating oil price). During these three years Thai industry consumed 2085.54 ktoe more than what it should have been (see Table 3). In conclusion, for the last 15 years Thai industry has over consumed energy by 1,401.95 ktoe.

5. Sensitivity of energy saving

The sensitivity analysis of energy saving model is shown in Table 4. The energy consumption and GDP of 2001 were used as the reference year for the sensitivity analysis of year 2002. The parameters governing energy saving (E_i^t, Q_1^t, Q_2^t and Q_3^t) were varied by 1% to reveal the influence of the parameters.

Equation (20) reveals that the energy saving in industry is a function of the energy saving in energy intensity and the economic structure. The total saving of 183.61 ktoe was mainly a contribution from the manufacturing sector (180.70 ktoe). It appears in construction and manufacturing sector that the effect of the energy intensity is higher than that of the economic structure when increasing or decreasing energy consumption. It further demonstrates that the influence from energy consumption (E_i^t) overwhelms the influence from the GDP (Q_i^t).

Table 4 confirms general trend that energy saving occurs when decreases energy consumption and increases GDP in each economic sector. The increment of 1% of energy consumption in the manufacturing sector results in 180.70 ktoe of energy inefficiency. The change in one sector affects the others. For example, if the GDP of the construction sector (Q_2^t) changes by +1%, the saving in manufacturing by 10.71 ktoe is achieved. The most influential sector is the manufacturing as its change (Q_3^t) will impose substantial change in other sectors. However, the change of 1% of all parameters will result in only 2.97 ktoe energy saving difference.

One of the most important points is that the success of energy conservation in the Thai industry depends wholly on the manufacturing sector. The manufacturing sector comprises of 9 sub-sectors namely, food and beverages, textile, wood and furniture, paper, chemical, non-metallic, basic metal, fabricated metal and others (unclassified). There is a need, therefore, to examine closely in each sub-sector in order to identify the potential ones for policy recommendation and proper energy conservation plan. Such study is in progress and the results will be reported in due course.

6. Conclusions

This paper presents the detailed study of energy saving in Thai industry. It can be concluded that,

(1) Thai industry has an energy over-consumption by 1401.95 ktoe during 1987-2002. Although having the Energy Conservation Promotion Act and Energy Conservation Fund as the tools, the success

of energy saving in Thai industry was not yet visualized. The energy conservation plan did not function as was expected.

(2) The manufacturing sector is the major player in Thai industry. Emphasis of energy conservation plan should be placed on this sector. Detailed study is needed for proper policy recommendation and measures implementation.

(3) The analysis incorporating economic factors by decomposition method reveals that the success of energy saving in Thai industry reported previously is an illusion.

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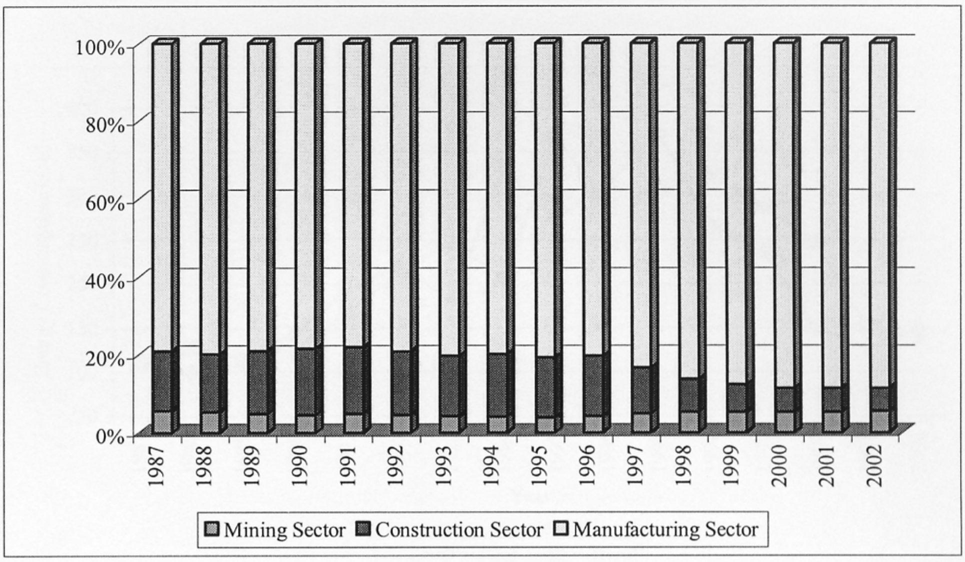

Fig. 1. The share of structural change in Thai industry (mining, construction and manufacturing sector) during 1987-2002.

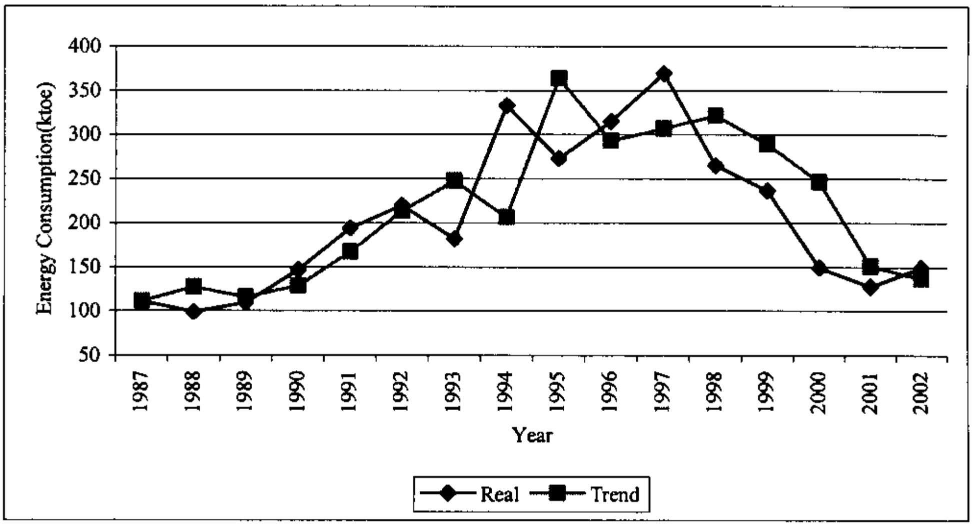

Fig. 2. The trend and real change of energy consumption in Thai construction sector during 1987-2002.

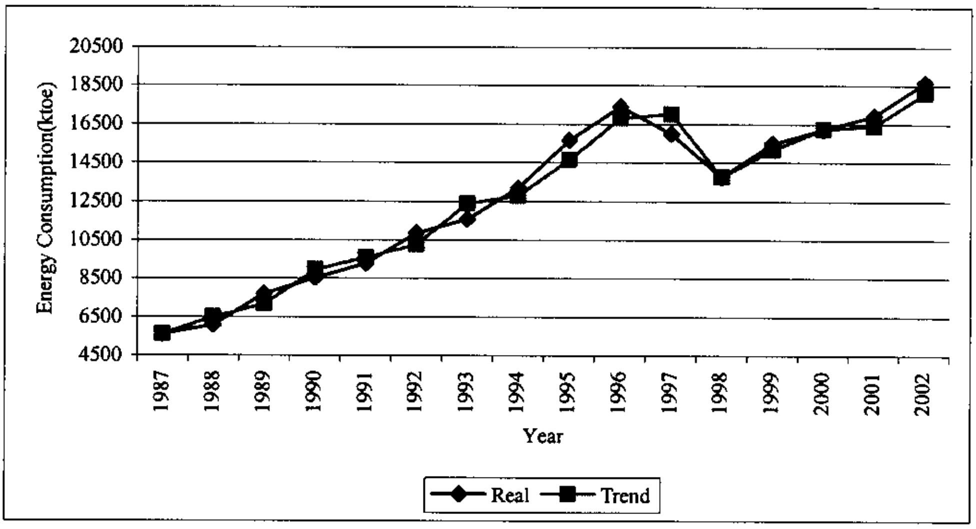

Fig. 3. The trend and real change of energy consumption in Thai manufacturing sector during 1988-2002.

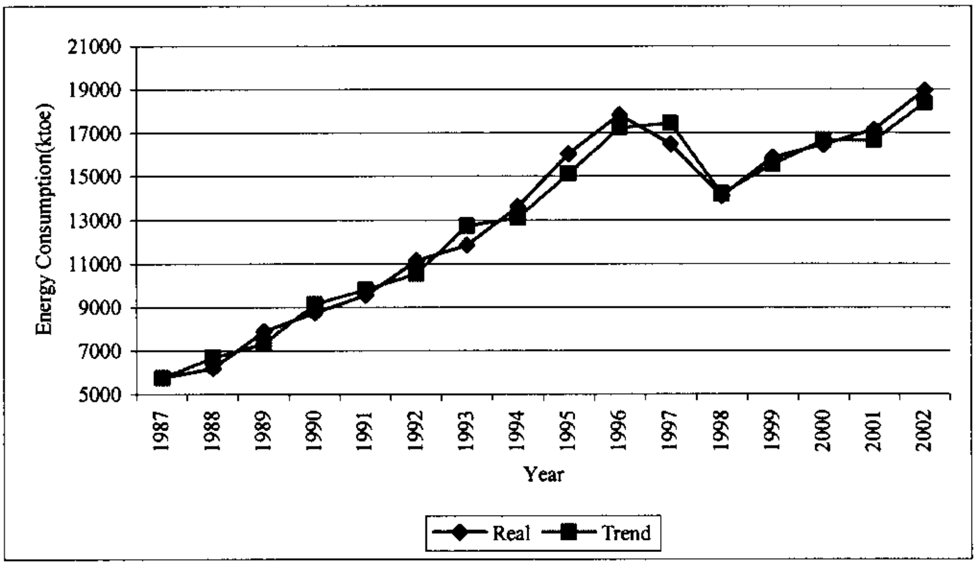

Fig. 4. The trend and real change of energy consumption in Thai industry during 1987-2002.

Table. 1.

Energy consumption (ktoe), GDP of sectors (Milions of US dollars at 1988 price levels and exchange rates of 1988) and energy intensity of industry (kgoe per 1000 US$) in Thai industry during 1987-2002

Year	Mining		Construction		Manufacturing		Industry		
	Energy Consumption	Q_1	Energy Consumption	Q_2	Energy Consumption	Q_3	Energy Consumption	*GDP*	Energy Intensity
1987	49	953.07	111	2611.69	5599	13511.11	5759	17075.87	337.26
1988	49	1051.59	99	2943.35	6062	15933.98	6210	19928.92	311.61
1989	56	1115.96	109	3777.73	7712	18487.86	7877	23381.55	336.89
1990	58	1227.68	147	4610.03	8541	21385.78	8746	27223.49	321.27
1991	60	1426.62	194	5238.16	9293	23892.50	9547	30557.29	312.43
1992	84	1500.71	220	5483.51	10847	26592.71	11151	33576.94	332.10
1993	92	1611.84	182	5958.33	11580	30911.09	11854	38481.26	308.05
1994	95	1733.26	333	6801.45	13174	33863.64	13602	42398.36	320.81
1995	104	1769.12	273	7258.64	15664	37889.38	16041	46917.13	341.90
1996	114	2091.09	315	7770.22	17398	40381.87	17827	50243.18	354.81
1997	118	2371.04	369	5777.58	15986	40964.34	16473	49112.95	335.41
1998	94	2223.61	265	3567.45	13754	36514.67	14113	42305.72	333.60
1999	139	2406.30	237	3323.32	15488	40856.76	15864	46586.38	340.53
2000	85	2539.18	149	3008.66	16208	43329.17	16442	48877.01	336.40
2001	93	2554.48	128	3017.20	16922	43925.32	17143	49497.00	346.34
2002	106	2833.95	149	3187.75	18679	46928.05	18934	52949.75	357.58
7-2002	1396	29409.50	3280	74335.06	202907	515368.23	207583	619112.79	335.29

Source: DEDE(2002), DEDP(1996, 1999, 2000, 2001), NESDB(2002, 2004)

Table. 2.

Decomposition of the change in energy consumption and energy saving in Thai manufacturing sector during 1988-2002 (ktoe)

Year	I_{effect}	S_{effect}	GDP_{effect}	Real change	Energy saving
1988	-499.77	60.97	901.80	463.00	438.80
1989	631.72	-76.41	1094.70	1650.00	-555.30
1990	-354.16	-53.06	1236.22	829.00	407.22
1991	-236.08	-41.80	1029.88	752.00	277.88
1992	478.08	129.10	946.81	1554.00	-607.19
1993	-956.29	158.90	1530.39	733.00	797.39
1994	466.68	-70.66	1197.98	1594.00	-396.02
1995	874.62	159.17	1456.21	2490.00	-1033.79
1996	681.89	-79.02	1131.13	1734.00	-602.87
1997	-1651.36	619.22	-379.86	-1412.00	1032.14
1998	-526.19	509.05	-2214.85	-2232.00	17.15
1999	93.20	233.41	1407.39	1734.00	-326.61
2000	-211.02	170.44	760.58	720.00	40.58
2001	487.67	17.56	208.78	714.00	-505.22
2002	581.02	-23.25	1199.23	1757.00	-557.77
1987-2002	-139.99	1713.61	11506.38	13080.00	-1573.62

Table. 3.

Decomposition of the change in energy consumption and energy saving in Thai industry during 1988-2002 (ktoe)

Year	I_{effect}	S_{effect}	GDP_{effect}	Real change	Energy saving
1988	-529.25	54.52	925.73	451.00	474.73
1989	619.58	-72.33	1119.75	1667.00	-547.25
1990	-344.90	-50.32	1264.22	869.00	395.22
1991	-217.61	-37.67	1056.28	801.00	255.28
1992	515.01	115.93	973.06	1604.00	-630.94
1993	-1009.42	142.42	1569.99	703.00	866.99
1994	580.30	-63.93	1231.63	1748.00	-516.37
1995	801.76	140.12	1497.13	2439.00	-941.87
1996	695.67	-68.37	1158.70	1786.00	-627.30
1997	-1504.10	540.56	-390.46	-1354.00	963.54
1998	-495.17	413.09	-2277.91	-2360.00	82.09
1999	118.82	189.37	1442.81	1751.00	-308.19
2000	-340.15	142.92	775.23	578.00	197.23
2001	473.74	15.62	211.64	701.00	-489.36
2002	597.10	-21.36	1215.26	1791.00	-575.74
1987-2002	-38.61	1440.56	11773.05	13175.00	-1401.95

Table. 4.

Sensitivity analysis of 3 dimensional model in Thai industry during 2001-2002

Parameters	Parameter Variation	Influence of each parameter (ktoe)											
		I_{effect_1}	S_{effect_1}	ψ_1	I_{effect_2}	S_{effect_2}	ψ_2	I_{effect_3}	S_{effect_3}	ψ_3	I_{effect}	S_{effect}	ψ
E_i^t	+1	-1.01	-0.02	-1.03	-1.45	0.01	-1.44	-180.82	0.12	-180.70	-183.27	0.11	-183.16
	-1	1.01	0.02	1.03	1.45	-0.01	1.44	180.82	-0.12	180.70	183.27	-0.11	183.16
Q_1^t	+1	0.99	-0.94	0.05	0.00	0.07	0.07	0.00	9.52	9.52	0.99	8.66	9.65
	-1	-0.99	0.94	-0.05	0.00	-0.07	-0.07	0.00	-9.52	-9.52	-0.99	-8.66	-9.65
Q_2^t	+1	0.00	0.06	0.06	1.38	-1.30	0.08	0.00	10.71	10.71	1.38	9.47	10.85
	-1	0.00	-0.06	-0.06	-1.38	1.30	-0.08	0.00	-10.71	-10.71	-1.38	-9.47	-10.85
Q_3^t	+1	0.00	0.88	0.88	0.00	1.23	1.23	177.82	-20.24	157.59	177.82	-18.13	159.69
	-1	0.00	-0.88	-0.88	0.00	-1.23	-1.23	-177.82	20.24	-157.59	-177.82	18.13	-159.69
Total	+1	-0.01	-0.02	-0.03	-0.07	0.01	-0.06	-3.00	0.12	-2.88	-3.09	0.11	-2.97
	-1	0.01	0.02	0.03	0.07	-0.01	0.06	3.00	-0.12	2.88	3.09	-0.11	2.97