Energy conservation direction and economic growth

Amnart Yasothorn[a], Pard Teekasap[b,*], Sombat Teekasap[c]

Rattanakosin College for Sustainable Energy and Environment (RCSEE)
Rajamangala University of Technology Rattanakosin
96 moo 3 Puthamonthon Sai 5, Salaya, Puthamonthon, Nakhon Pathom 73170, Thailand
Email: amnart.yas@at.rmutr.ac.th[a], pard.tee@rmutr.ac.th[b], sombat.teekasap@gmail.com[c]
*** Corresponding author**: pard.tee@rmutr.ac.th

Abstract

In this study, the system dynamics model with electricity consumption and economic growth is focused on Thailand. According to data from 1999-2012, we look at the case of how "reducing electricity consumption according to government policy", can effect economic growth. This study of electricity consumption was performed in 3 sections; Commercial, Industrial and Residential. This research investigated the effect of reducing electricity consumption due to government policy in 2 cases, "reserve" the savings that are left from electricity cost reduction (case 1) and "spend" the saving that are left from electricity cost reduction after subtracting the net saving (case 2), all economic growth was reduced in both cases. In the first case, economic growth was the most affected by industrial, followed by commercial and residential respectively. In the second case, all economic growth was also reduced. The industrial section was the most affected by short-term economic growth reduction followed by the commercial and residential sections. But for long-term economic growth reduction, the commercial section was the most affected, followed by industrial and residential sections. From this study of both cases, the research showed that "reserve" the savings that are left from electricity cost reduction was lowering economic growth more than "spend" the savings that are left from electricity cost reduction after subtraction of the net saving.

Keywords: *Economic growth, GDP growth, GDP, electricity consumption, system dynamics, simulation*

1. Introduction

Electricity consumption in Thailand has increased continuously due to the expansion of the population, habitat, industrial factory, commercial section and other sections. In 2015 the Energy balance of Thailand report, the net electricity consumption was 181,377 GWh, broken into four sectors which for Commercial section by 61,446 GWh (33.88%), Industrial section by 77,022 GWh (42.47%), Residential section by 41,443 (22.85%) and other for 1,466 GWh (0.81%), where from the domestic production 93.82% and imported for 6.18%. Thailand's electricity production in 2015 was derived from fossil fuel 87.87% (natural gas 67.52%, Coal 19.79% and petroleum products 0.56%) of electricity throughout the long periods and in 2015, 80.80% of natural gas resources were applied used for electricity production. Thailand imported natural gas for the first time in 1998 with increasing volumes every year. In 2015, Thailand produced only 71.18 % of net consumption and imported from 28.82% which cost 4,455.25 Million USD.

Electricity consumption in Thailand has continuously increased over time. Electric power in Thailand and Energy balance of Thailand report from 1999 – 2015, Thailand has averaged an electricity consumption growth rate of 5% per year or 6,245 GWh/year, but some power plants were in the process of retirement, new sources of electricity must be supplied. The Thailand power development plan 2015-2036 (PDP2015) contains several important issues e.g. Stabilization of power, lower risk in power outage, support of expanding electricity consumption in the whole country, meeting domestic electricity demand and the fair distribution of electricity production sources in the right proportion and finally reducing usage of natural gas while considering environmental impact.

The Thailand power development plan 2012-2030 (PDP2010: Revision 3 on June 2012) estimated the demand of electricity, that already cut off the energy consumption reduction from “The 20-year energy efficiency development plan (2011-2030)”, the average demand was still increasing more than 6% per year. But with the improved “Thailand power development plan 2015-2036 (PDP2015)”, which included the electricity demand from Electric trains (in exiting and 10 under construction plans) with the subtraction of electricity demand from the Energy Efficiency Plan for 2015-2036 (EEP2015) and electricity production from the Alternative Energy Development Plan 2015-2036 (AEDP2015) electricity demand still increases by 2.67% or higher than 4,000 GWh annually. Due to the situation, more electricity supplement needs to be supplied. But due to the inconvenience of increasing electricity production capacity and the lack of power, more electricity needs to be imported from abroad over the next 30 years and tends to increase over each year, which causes money loss and instability of domestic energy.

Depending on the type of power plant, construction takes 5 – 15 years (For example, coal power plants have 8 years of construction processes), but the power plant development in Thailand was in the critical dead-end situation by anti-power plant protesters.

To provide sufficient electricity the Thai government reacts to this situation in 2 ways; first by increasing electricity supply by adding more power plants to the system for sufficient consumption, purchasing electricity for domestic and abroad, increasing power plants generating efficiency to meet demand and second by reducing electricity consumption by promoting energy conservation campaigns.

The EEP2015 was focusing on high efficiency and economical electricity consumption, but this policy can affect the domestic economic growth. According to this situation, the relation of energy conservation and economic growth must be studied.

The results from previous studies on the relationship between electricity consumption and the country's economy showed an inconclusive picture. Many researchers found that the electricity consumption were positively correlated with the economic growth, e.g. Yoo [1], Shiu and Lam [2], Yuan et al. [3], Shengfeng et al. [4], Altinay and Karagol [5] and whereas others research found insignificant relationship, e.g. New work by Chen et al. [6], Yoo and Kwak [7].

This relationship was utterly significant for the electricity conservation policy because without the clear understanding, electricity conservation policy can slow down the economy of the country and snowball to become a major economic crisis. Therefore, this study aims to shed more light on this topic by studying the effect of electricity conservation on the economic growth by using a different approach and show the direction of impact.

1.1 Data description

The study used the time series data from 1999 to 2012. Thailand’s GDP at current market prices from the Office of the National Economic and Social Development Board (NESDB), Office of the Prime Minister and net saving data from the World Bank. Number of businesses, number of factories, the number of households, electricity consumption data and unit price of electricity for Thailand were obtained from the Electric Power in Thailand years 1999 to 2011 and Energy balance of Thailand 2012 from Department of Alternative Energy Development and Efficiency, Ministry of Energy. All data used the average exchange rate per annum from the Bank of Thailand to change form Thai Baht into USD.

1.2 Literature review

Empirical studies on the relationship between electricity consumption and economic growth evidence provided mixed results due to different data, time period, economic structure and methodology.

The causal relationship of electricity consumption and economic growth in China by the error-correction model for the years 1971–2000 by Shiu and Lam [2] and methodology by the co-integration theory in the years 1978–2004 by Yuan et al. [3] were studied. The results showed the similarity of the real GDP and electricity consumption in China, which co-integrated and the presence of unidirectional Granger causality running from electricity consumption to real GDP without any feedback effect.

Yoo [1] studied the causal relationship between electricity consumption and economic growth in Indonesia, Malaysia, Singapore, and Thailand by Hsiao’s version of the Granger causality method covered the period of 1971–2002. The results showed the bidirectional causality between electricity consumption and economic growth in Malaysia and Singapore. Empirical findings reveal in Indonesia and Thailand the unidirectional causality running from economic growth to electricity consumption but not vice versa.

Chen, et al. [6] Studied the relationship between GDP and electricity consumption in 10 Asian countries covering the period of 1971–2001. The results from the panel data procedure showed the unidirectional short-run causality running from economic growth to electricity consumption and the bidirectional long-run causality between electricity consumption and economic growth. The results from a single country data set showed that Hong Kong, Indonesia, India, Korea, Singapore, Taiwan and Thailand were co-integration, but excluded China, Malaysia and Philippines. Empirical findings reveal that the unidirectional long-run causality running real from GDP to electricity consumption in Hong Kong and Korea. In Indonesia there is a long-run causal relationship running from electricity consumption to real GDP but not vice versa. India, Singapore, Taiwan and Thailand are not evidence to prove that long-run causality exists between real GDP and electricity consumption.

Mozumder and Marathe [8] studied the relationship between the per capita electricity consumption and the per capita GDP in Bangladesh by using co-integration and vector error correction model for the years 1971–1999. Empirical findings revealed that there is unidirectional causality running from per capita GDP to per capita electricity consumption but not vice versa. Onwards Ahamad and Islam [9] studied by the same methodology covered the period 1971–2008. The results for short-run show that there is unidirectional causality running from per capita electricity consumption to per capita GDP. The results for long-run show the bidirectional causality between per capita electricity consumption and per capita GDP.

Altinay and Karagol [5] studied the relationship between electricity consumption and real GDP in Turkey for the years 1950–2000. The results showed that unidirectional causality running from the electricity consumption to real GDP.

Yoo and Kwak [7] studied the causal relationship between electricity consumption and economic growth in seven South American countries, namely Argentina, Brazil, Chile, Columbia, Ecuador, Peru, and Venezuela by using co-integration and Granger causality method for the years 1975–2006. Empirical findings revealed that unidirectional short-run causality running from electricity consumption to economic growth in Argentina, Brazil, Chile, Columbia, and Ecuador. The results show bidirectional causality between electricity consumption and economic growth in Venezuela. In Peru there is not a causal relationship.

The study of Augustine and Damilola [10] investigated the relationship between energy consumption, oil price and economic growth in Nigeria by using the Granger causality method for the years 1970–2012. The results showed the bidirectional causality between energy consumption and economic growth and showed that bidirectional causality was found between electricity consumption and economic growth as well as between electricity consumption and electricity price.

Zaman et al. [11] investigated the relationship between electricity consumption, number of electricity customers, electricity prices and economic growth in Pakistan by using the Granger causality method for the years 1972 to 2012. The results showed the bidirectional causality between electricity consumption, economic growth and electricity customers except electricity prices which is exogenously determined.

Mohame [12] studied the relationships between private savings and economic growth in Bahrain by using the Granger causality method for the years 1990 to 2013. The results showed the bidirectional causality between the private savings and the economic growth.

2. Methodology

System dynamics (SD) was first created and developed by Jay W. Forrester of the Massachusetts Institute of Technology (MIT) in 1950. System Dynamics is a method for simulating the behavior of complex economic and social systems [13].

System dynamics was a method used to understand complex problems and the problem has changed over time by representing in the form of feedback loop [14].

System dynamics was a survey and analysis of the complex in the form of process, structure and strategies, which have replicated the problem and analysis to design a system structure and behavior [15].

System dynamics was used as a tool for understanding the behavior or the behavior of a complex system which changes over time. By studying the internal circuit and reverse delays effect on the behavior of the whole system. Development of ideas, events and problems are not caused by the impact of external events alone, but the relationship of the factors within the system itself. [16].

Analysis with system dynamics was focused on the relationship between each of the factors involved with the problem of the relationship between variables by presenting them as a causal loop diagram (CLD), feedback loop and stock and flow diagram.

System dynamics modeling links variables in the system and showed the relationship with a causal loop diagram to show the relationship between each factor. The curved arrows showed the causality. Tail of the arrow cause and the head of the arrow represented the results. The plus and minus symbols represented the displayed the directions of the effect at the head of the arrow. A plus sign represented a positive relationship and a minus sign represented a negative relationship. Identified as positive loop or reinforcing loop.

In this paper, system dynamics were used to explain the linked variables involved in the system and mapped relatively to facilitate the policy planning of the electricity conservation direction of Thailand for three main user groups; industrial, commercial, and residential sections.

2.1 System dynamics model

Electricity consumption can be divided in 3 sections; commercial, industrial and residential which showed their relationship to the GDP. Which were also reported by Shiu and Lam [2], Yuan, et al. [3], Shengfeng, et al. [4], Yoo [1], Chen et al. [6], Altinay and Karagol [5] and Yoo and Kwak [7] that showed unidirectional Granger causality running from electricity consumption to real GDP. Yoo [1], Chen et al. [6], Ahamad and Islam [9], Yoo [17] and Yoo and Kwak [7] reported the bidirectional causality between electricity consumption and economic growth.

GPD can be calculated in 3 approaches included production, expenditure and income. The results from all three approaches will be equal or similar. For Thailand, production is the primary approach [18], GDP in this research was considered in 3 groups; commercial GDP, industrial GDP and other GDP.

The presentation of the relationship between GDP and electricity consumption from the commercial, industrial and residential sections, the residential section will show only the influence part of GDP, which displayed only exogenous factors. Only the causal loop diagram is presented for the industrial and commercial sections.

Causal loop diagrams depict the structure clearly and accurately and also the function of a system. [16] Curved arrows represent the relationships between factors from causes (arrow tails) to results (arrowheads) with positive link (+) and negative link (-) labels at the arrowheads.

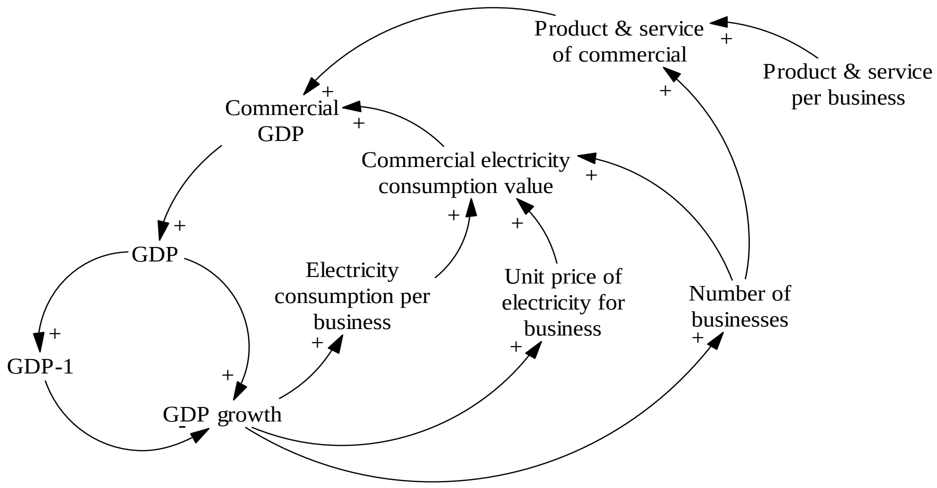

Figure 1 Causal loop diagram of commercial GDP (Commercial section).

The causal loop diagram in figure 1 shows the relationship of commercial electricity consumption value, commercial GDP, GDP and GDP growth. While GDP growth has a positive relationship and changing GDP growth causes a positive effect on electricity consumption per business, unit price of electricity for business and the number of businesses. Commercial electricity consumption value is calculated from electricity consumption per business multiplied by the unit price of electricity for business and number of businesses. Product & service of commercial are calculated by product & service per business multiplied by the number of businesses. Commercial GDP comes from product & service of commercial and commercial electricity consumption value, which is consistent with the calculation of GDP for expenditure approach or income approach.

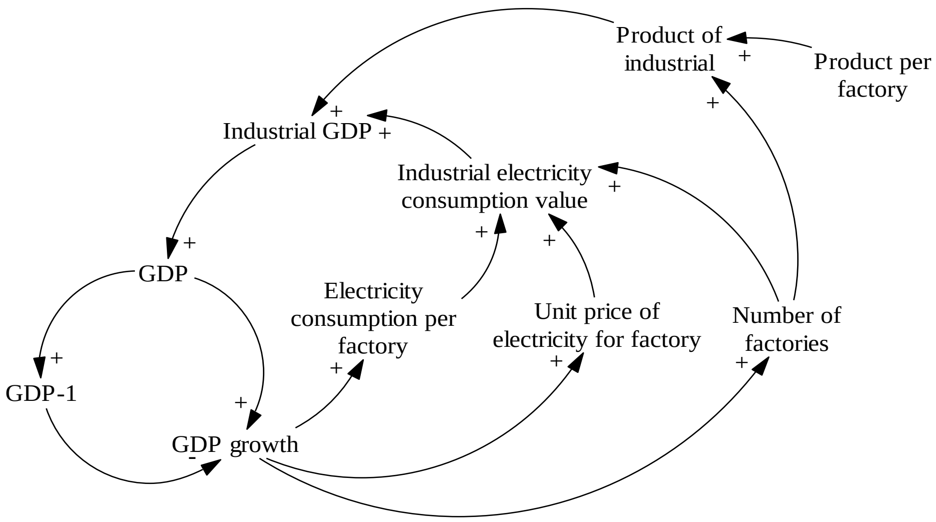

Figure 2 Causal loop diagram for industrial GDP (Industrial section).

Figure 2 displays the causal loop diagram for industrial electricity consumption value, industrial GDP, GDP and GDP growth. While GDP growth has a positive relationship and when changing with GDP growth caused a positive effect on electricity consumption per factory, unit price of electricity for factory and number of factories. The industrial electricity consumption value was calculated from electricity consumption per factory multiplied by unit price of electricity for factory and the number of factories. Industrial GDP value consists of product of industrial and industrial electricity consumption value, which is consistent with the calculation of GDP for expenditure approach or income approach.

2.2 System dynamics model (Stock & flow)

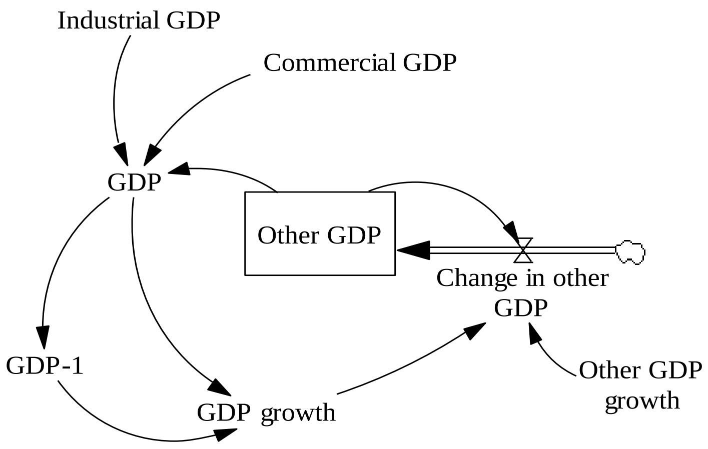

Figure 3 GDP and GDP growth.

System dynamics model in figure 3 shows that the GDP is the summary of industrial GDP + commercial GDP + other GDP. System dynamics investigated the GDP growth on the basis of economic growth to calculate growth rate by equation (1).

$$GDP\ growth = \frac{(GDP - GDP_{-1})}{GDP_{-1}} \tag{1}$$

While GDP is GDP in the current year which includes industrial GDP, commercial GDP and other GDP and GDP_{-1} is GDP in previous year.

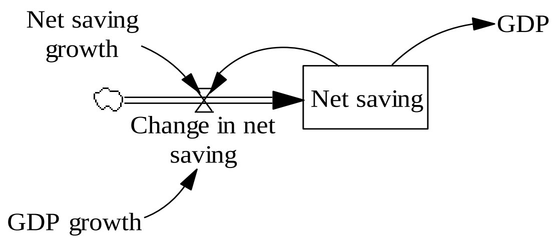

Figure 4 Net saving.

According to the World Bank, Thailand has an average gross saving (1999-2012) for 28% of GDP. Most of the saving has been invested as bank deposits, gold, government bond, mutual fund and etc. But some part of the saving was unspent, which have net saving (1999-2012) for 12 % of GDP. For calculation, the value was not fixed at the same value for every year, but represented as stock and flow diagram to get the most realistic value of each year.

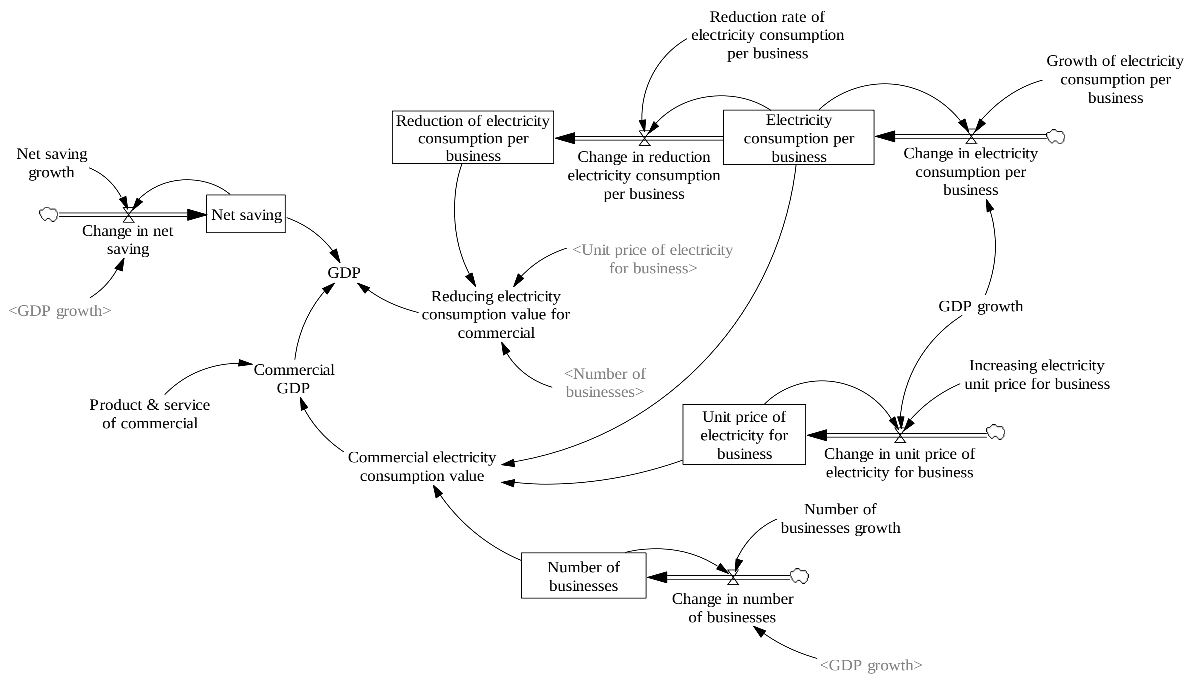

Figure 5 Commercial system dynamics model.

Figure 5 displays system dynamics model for commercial electricity consumption, commercial GDP, GDP and GDP growth followed the relationship as in the mentioned casual loop diagram of commercial GDP. (Figure 1) System dynamics model which shows in stock and flow pattern combined with electricity consumption reduction to determine the relationship and direction with GDP in both cases; reserved all savings from the reduction of electricity consumption (case 1) and spent after subtraction with net saving from the reduction of electricity consumption (case 2).

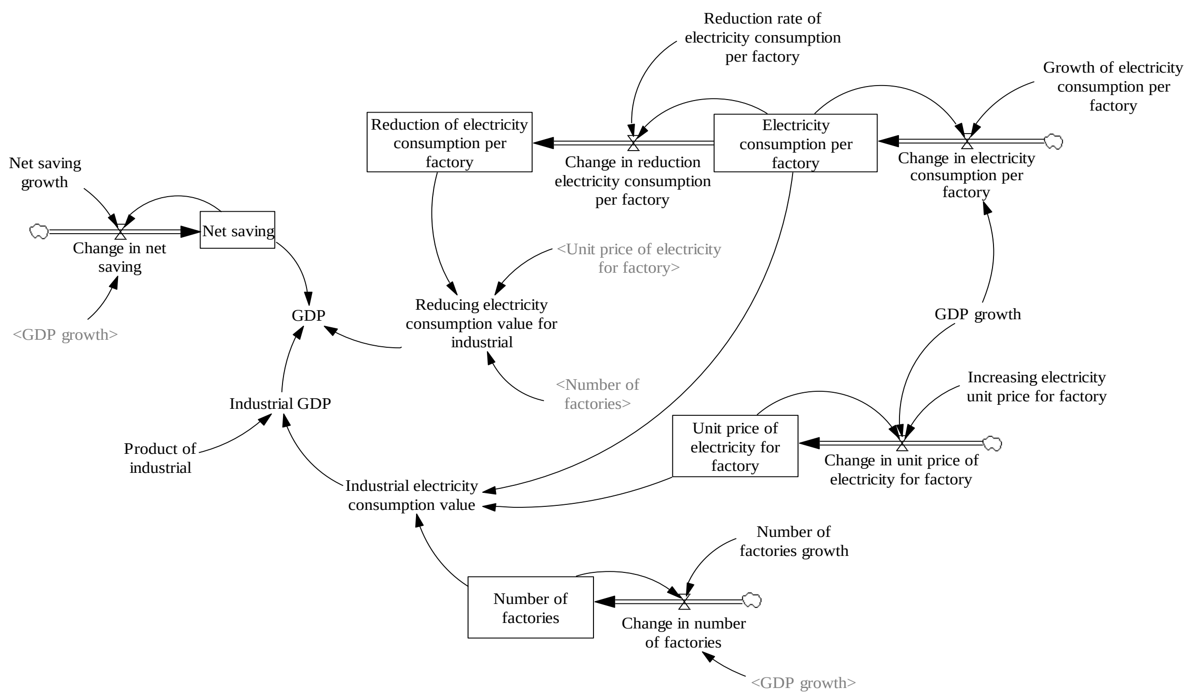

Figure 6 Industrial system dynamics model.

Figure 6 represents the industrial system dynamics model which shows the relationship of industrial electricity consumption value, product of industrial, Industrial GDP, GDP and etc. The industrial system dynamics model shows a similar pattern to the commercial system dynamics model.

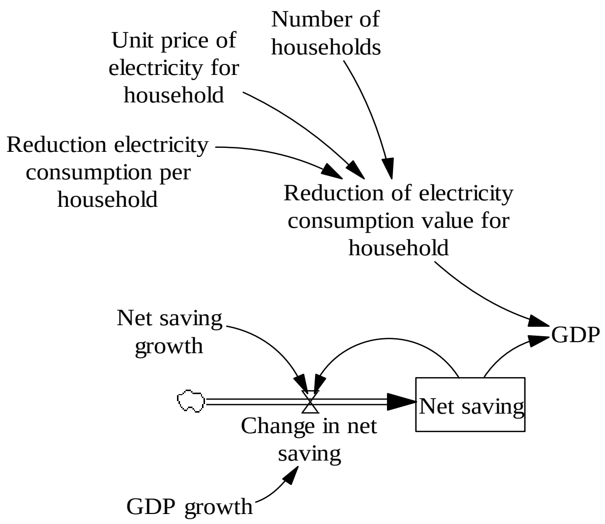

Figure 7 Residential systems dynamic model

Figure 7 shows the systems dynamic model relationship between the residential section and GDP by being shown as exogenous only in the case of residential electricity reduction.

2.3 Measuring error of the actual value and the value of system dynamics model.

Mean forecast error (MFE), mean absolute deviation (MAD), mean absolute error (MAE), mean squared error (MSE), root mean squared error (RMSE) and mean absolute percentage error (MAPE). The values depended on the size of the data and no base comparison. A larger size in the data or discrepancy can cause higher error except MAPE. Measurement error was regularly calculated by MAD, MSE and MAPE [19].

In this research, measurement error was calculated by MAPE, because MAPE is a measure of deviation by comparing the real data with the data obtained from the system dynamics model regardless of the positive or negative calculation. The calculation of MAPE, which is the lowest, provides the highest accuracy. A MAPE value less than 10% is highly accurate, 10% to 20% is good, 21% to 50% is reasonable and more than 51% is inaccurate [20]. MAPE value was calculated by the equation (2).

$$MAPE = \frac{\Sigma\left(\frac{|R-D|}{R}\right)}{n} \times 100 \qquad (2)$$

Where R is real data, D is data from the system dynamics model and n is the number of all data. To provide assurance the System dynamics model was measured by MAPE the results are as shown in table 1.

According to measuring error value between the actual value and systems dynamic model by MAPE, item 1-6, 8-14 and 16-22 had MAPE values less than 10% which are considered as highly accurate. Item 15 had MAPE values between 10% – 20%, which are considered as good and item 7 has MAPE values between 21% - 50%, which are considered as reasonable. This system dynamics model can be considered as a suitable analyzing tool for the relationship between GDP and electricity consumption in all sections (commercial, industrial and residential).

Table 1 MAPE

No.	Description	MAPE	Remark
1	Commercial electricity consumption value	8.61%	Highly accurate
2	Commercial GDP	5.54%	Highly accurate
3	Electricity consumption per business	2.38%	Highly accurate
4	Electricity consumption per factory	5.55%	Highly accurate
5	Electricity consumption per household	2.78%	Highly accurate
6	GDP	6.03%	Highly accurate
7	GDP growth	29.92%	Reasonable
8	GDP-1	6.27%	Highly accurate
9	Industrial electricity consumption value	9.91%	Highly accurate
10	Industrial GDP	6.47%	Highly accurate
11	Net saving	9.17%	Highly accurate
12	Number of businesses	4.51%	Highly accurate
13	Number of factories	5.63%	Highly accurate
14	Number of households	1.80%	Highly accurate
15	Other GDP	12.95%	Good
16	Product & service of commercial	5.58%	Highly accurate
17	Product and service per business	5.31%	Highly accurate
18	Product of industrial	6.75%	Highly accurate
19	Product per factory	8.41%	Highly accurate
20	Unit price of electricity for business	9.81%	Highly accurate
21	Unit price of electricity for factory	4.37%	Highly accurate
22	Unit price of electricity for household	4.84%	Highly accurate

2.4 Extreme condition test

The extreme test is testing under critical conditions, which do not have a possibility of happening for the estimate of the performance of the model. GDP growth was set to 0 and also set exogenous input factors, which was product per factory growth and product and service per business growth both to 0 to test the integrity of the model. The results showed no GDP growth, which allowed the model to investigate the relationship between GDP and electricity consumption in all sections (commercial, industrial and residential).

3. Scenario

This paper investigated the relationship between electricity consumption and GDP in Thailand by the system dynamics model. The system dynamics model is based upon annual information of GDP, electricity consumption (commercial, industrial and residential), electricity price and etc. from 1999 to 2012 in Thailand.

The electricity consumption reduction from EEP2015 contained 2 implied meanings; 1. Saving or reducing the unnecessary electricity consumption and 2. using energy efficiently by achieving the regular result while reducing energy usage such as lighting, heating, cooling, transportation or running machines in a production line. Using electricity efficiently and economically was an important part of energy sustainability, reducing household expenses, reducing production and service cost, reducing the trade deficit and to increase competitiveness, including the reduction of greenhouse gases and pollution emissions, which is a cause of global warming and climate change.

This research proceeded under the electricity consumption reduction policy after the EEP 2015, which aimed to reduce the electricity consumption in 2015-2036 to total 89,672 GWh or 4,076 GWh per year. In comparison with electricity consumption under PDP2015, which has to reduce the electricity by 2% per year. Therefore, this research will be conducted under the electricity consumption reduction condition for 2% per year for the commercial, industrial and residential sections which consisted of 2 Scenarios;

Scenario 1: Keep all saving from the reduction of electricity consumption.

Scenario 2: Spend leftover saving from the reduction of electricity consumption after subtraction of net saving.

4. Results of scenario

According to the results of scenario 1, electricity consumption has been reduced by 2% and keep all the savings from the reduction of electricity consumption. The Industrial section had the most negative affect on GDP, followed by the commercial and residential sections respectively.

As the result of scenario 2 showed electricity consumption has been already reduced by 2%, but spend after subtraction of net saving with the saving from reduction of electricity consumption. Economic growth was reduced in all sections. For short-term effect, the industrial section has the highest affected on GDP, followed by the commercial and residential sections respectively. But for long-term effect, the commercial section has the most effect on GDP, followed by industrial and residential sections respectively.

The results from scenario 1 and 2 have been compared. According to the results, reserve or keep all saving from the reduction of electricity consumption caused more economic growth reduction (Scenario 1) than expense the saving from the reduction of electricity consumption after subtraction with the net saving (Scenario 2) in all conditions.

5. Conclusions

Electricity demand was increasing steadily. Reducing electricity consumption can help the government reduce the electricity supply provision, which also saves the foreign exchange from electricity import and reduce electricity production cost, including extending the time gap from building additional power plants. An energy saving policy by reducing electricity consumption was considered as the appropriated and suitable policy.

According to the study of the electricity consumption reduction plan under government policy, the results showed for both scenario 1 and scenario 2, economic growth had been reduced in all sections. But for scenario 2 in case of short-term effect, the industrial section has the most affected on economic growth, then the commercial and residential sections respectively, whereas in terms of long-term effected, the commercial section has the most effect on economic growth followed by the industrial and residential sections. After both Scenarios were considered, the results showed that Scenario 1 caused more economic growth reduction than Scenario 2 in all conditions.

Based on the results, the energy saving policy should be applied to all sections. Focusing on the residential section, which has the least impacted on the economic growth and focuses on the target with money left over from electricity consumption reduction. And with the policy for importing electrical products which allow only energy saving of eco-friendly devices. This will be an indirect obligation to the public to buy or use energy saving devices. The government had to be support and control the prices (to close to the old prices) of equipment

The short-term effect had the most impact on the industrial section and long-term effect had the most impacted on the commercial section and caused the highest reduction in economic growth for both cases and showed slight differences to keep the accessibility for low-income populations. Thailand averaged electricity consumption in 1999 – 2012, the industrial section shared 44.37%, commercial section shared 32.98% and residential section shared 21.92% and in 2015 the industrial section shared 77,022 GWh (42.47%), commercial section shared 61,446 GWh. (33.88%) and the residential section shared 41,443 GWh. (22.85%). The commercial usages of electricity less than industrial usages to 8.59% in 2015. Therefore, the electricity consumption reduction policy should focus on the industrial section and commercial sections for the suitable proportion to minimize the impact on economic growth. In addition; energy saving equipment or products should have been encouraged in both production and distribution by investment promotions, tax reduction and lower import duties.

References

[1] Yoo, S. H. (2006). The causal relationship between electricity consumption and economic growth in the ASEAN countries. *Energy policy*, *34*(18), 3573-3582.

[2] Shiu, A., & Lam, P. L. (2004). Electricity consumption and economic growth in China. *Energy policy*, *32*(1), 47-54.

[3] Yuan, J., Zhao, C., Yu, S., & Hu, Z. (2007). Electricity consumption and economic growth in China: integration and co-feature analysis. *Energy Economics*, *29*(6), 1179-1191.

[4] Shengfeng, X. (2012). The relationship between electricity consumption and economic growth in China. *Physics Procedia*, *24*, 56-62.

[5] Altinay, G., & Karagol, E. (2005). Electricity consumption and economic growth: evidence from Turkey. *Energy Economics*, *27*(6), 849-856.

[6] Chen, S. T., Kuo, H. I., & Chen, C. C. (2007). The relationship between GDP and electricity consumption in 10 Asian countries. *Energy Policy*, *35*(4), 2611-2621.

[7] Yoo, S. H., & Kwak, S. Y. (2010). Electricity consumption and economic growth in seven South American countries. *Energy Policy*, *38*(1), 181-188.

[8] Mozumder, P., & Marathe, A. (2007). Causality relationship between electricity consumption and GDP in Bangladesh. *Energy policy*, *35*(1), 395-402.

[9] Ahamad, M. G., & Islam, A. N. (2011). Electricity consumption and economic growth nexus in Bangladesh: Revisited evidences. *Energy Policy*, *39*(10), 6145-6150.

[10] Osigwe, A. C., & Arawomo, D. F. (2015). Energy consumption, energy prices and economic growth: causal relationships based on error correction model. *International Journal of Energy Economics and Policy*, *5*(2).

[11] Zaman, M., Shaheen, F., Haider, A., & Qamar, S. (2015). Examining Relationship between Electricity Consumption and its Major Determinants in Pakistan. *International Journal of Energy Economics and Policy*, *5*(4).

[12] Mohamed, E. S. A., (2014). Testing the relationship between private savings and economic growth: case study of Bahrain. *G.J.C.M.P*, *Vol.3(1)*, 38-44.

[13] Forrester, J. W., (1961). *Industrial Dynamics*. MIT Press: Cambridge, MA.

[14] Richardson, G. P., & Pugh III, A. I. (1981). *Introduction to system dynamics modeling with DYNAMO*. Productivity Press Inc.

[15] Wolstenholme, E. F. (1990). *System enquiry: a system dynamics approach*. John Wiley & Sons, Inc.

[16] Sterman, J. D. (2000). *Business dynamics: systems thinking and modeling for a complex world* (No. HD30. 2 S7835 2000).

[17] Yoo, S. H. (2005). Electricity consumption and economic growth: evidence from Korea. *Energy Policy*, *33*(12), 1627-1632.

[18] National accounting statistics processing hand book, Office of the National Economic and Social Development Board, Office of the Prime Minister, Thailand. [online] Available : www.nesdb.go.th/ewt_dl_link.php?nid=3521

[19] Stevenson, W. J., & Sum, C. C. (2002). *Operations management* (Vol. 8). New York, NY: McGraw-Hill/Irwin.

[20] Lewis, C. D. (1982). *Industrial and business forecasting methods: A practical guide to exponential smoothing and curve fitting*. Butterworth-Heinemann.