Measures Affecting Energy Conservation of Designated Factory in Thailand

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Abstract

The objective of this study was to examine the energy conservation measures conducted in designated factories over the past 10 years. The number of measures implemented, the energy-saving from the measures, the investment's cost-effectiveness for each sector, and the level of energy conservation measures were utilized to propose policy recommendations to related government agencies. Data were obtained from designated factories that submitted their energy management report over the past 10 years (2010 – 2019), encompassing all industrial sectors. From the research, it was found that the Non-Metallic group had the highest *Energy Intensity (*EI*)*, and the Paper group had an EI value that increased significantly. Analysis of energy conservation measures results was conducted, with the number of measures, the energy-saving from the measures, and the cost-effectiveness taken into account. The finding indicated that the most common measure was "Changing from fluorescent lamps (FL) to light-emitting diode (LED) lamps measure" for all. The measure with the highest amount of energy-saving was "Improving the efficiency of the production process measure" for a total of 3,324,943,687.80 MJ for the Non-Metallic group and "Switching to another type of fuel measure" for a total of 744,704,146 MJ for Paper group. The measure with the fastest payback period was "Measures to replacement of other lamps" with an average payback period of 0.01 years for the Non-Metallic group and "Changing the propeller size measure" with an average payback period of 0.02 years for the Paper group. Policy recommendations for the Department of Alternative Energy Development and Efficiency, Ministry of Energy include a recommendation to continuously promote the transition from fluorescent lamps to LED lamps, especially in those industrial sectors that have not implemented the measure. The efficiency of LED lamps should be performed and new energy efficiency standards should be regularly renewed at an appropriate time interval. Regulations concerning energy management should also be amended to, instead of prioritizing significant energy-consuming equipment, consider the overall production processes in various industrial sectors. Further analysis on the data concerning using Demand Controller to control the operation measure, changing the propeller size measure, using a high-efficiency motor measure and boiler replacement measure with fast average payback period but not implemented every year nor widely, should be performed and used as a guide toward more widespread implementation of such measures.

Keywords**:** *Energy intensity**,** Energy consumption, Energy conservation, Energy saving, Energy management*

1. Introduction

DEDE (2020) reported finding that energy is an important factor in the country's economic and social development. Due to the economic expansion of Thailand, energy demand tends to increase steadily every year. However, in 2020, Thailand's overall final energy consumption decreased by 9.8 percent from 2019, which is in line with the economic growth rate of Thailand (GDP) reported by the office of the National Economic and Social Development Council (NESDC). This was aligned with the 6.1% annualized decline in Thailand's Gross Domestic Product (GDP) reported by the office of the National Economic and Social Development Council (NESDC). The value of merchandise export fell by 6.6%, whereas private consumption and investment dropped by 1.0% and 4.8%, respectively. The average headline inflation was marked at -0.8% while the current account surplus in terms of GDP was at 3.3%. There is also a reduction in final energy consumption in all sectors of the economy, by which the final energy consumption in the transport sector accounts for the largest proportion of 38.4% of the total final energy consumption, followed by industrial fields, residential, commercial and agricultural businesses accounting for 37.3%, 13.1, 8.2, and 3.0, respectively.

GDP and energy use are directly proportional. Energy has a growth index from Energy Intensity (EI), that is, energy consumption per GDP, which is a measurement of energy efficiency per unit production of goods and services. The smaller the proportion of EI, the better energy efficiency. It means less energy is used in the production of goods and services. EI is a measure of a country's energy efficiency to compare with other countries or compare among the same industry groups but cannot be used to compare between different industry groups. EI is measured in terms of thermal units per million baht of GDP and can be obtained as the sum of all energy used in the group divided by the sum of all outputs in the industry. In Thailand, there are two types, namely primary energy intensity and primary energy, which is the energy in the form before it is used in the final form, such as natural gas and lignite used in the production of electricity. The other form is the final energy intensity, the energy in the form that we use in the final, such as electricity and refined oil. In 2020, the Thai EI was at 7.84 thousand tons, which was equal to crude oil per billion baht and tends to gradually continue to decline (Energy Policy and Planning office [EPPO], 2021).

For the reasons mentioned above, the researcher is interested in studying the energy consumption of industries that affect the EI value in order to study and analyze the energy conservation measures implemented by those industries in the past 10 years analyzing from the dimensions of the number of measures implemented in terms of energy-saving results from implementing measures and the value of an investment in implementing measures. The results obtained from the research will be a policy recommendation to the government agencies in the field of energy responsible for overseeing and promoting the implementation of energy conservation measures in the designated factories. to take into consideration the implementation of projects, activities, or measures to promote and support the owners of the controlled factory effectively.

2. Objectives

1) To study information on the economy and energy and the implementation of energy conservation measures in the Designated factory, consisting of the number of measures implemented, the energy-saving effect from the implementation of the measures, and the cost-effectiveness of the investment in implementing the measures in the past 10 years of the types of industries that have an impact on the economy with energy.

2) To analyze industry groups that have had an impact on the economy and energy as a whole over the past 10 years.

3) To analyze the highest number of energy conservation measures implemented including the highest operating energy-saving effect and analyze the value of the investment, implement conservation measures that are implemented with fast payback with the least value from industry groups that have had an impact on the economy and energy as a whole in the past 10 years.

4) To present guidelines to the Ministry of Energy and the Department of Alternative Energy Development and Efficiency To promote energy conservation measures for industrial groups that have an impact on the economy and energy.

3. Materials and Methods

Documentary Research from the Energy Management Report from the Energy Conservation Database (Database of Department of Alternative Energy Development and Efficiency) during 2010 - 2019 in terms of the number of measures implemented, energy management reports from the energy conservation database, and worthwhile investment.

4. Results and Discussion

The presentation of the study results is divided into 4 parts. The first part presents information on the economic and energy situation. The second part presents the 10-year Energy Intensity (EI) by manufacturing sub-sectors. The results are summarized in Table 1. The third section presents the results of the analysis of the Non–Metallic groups in 3 factors; the number of energy conservation measures, energy savings, and the payback

period. The results of the study are summarized in Tables 2-4 and the fourth section presents the analysis results of the Paper group in 3 factors: the number of energy conservation measures, energy savings, and the payback period. The study is summarized in Tables 5-7.

Thailand's Energy Situation and Energy Efficiency Situation

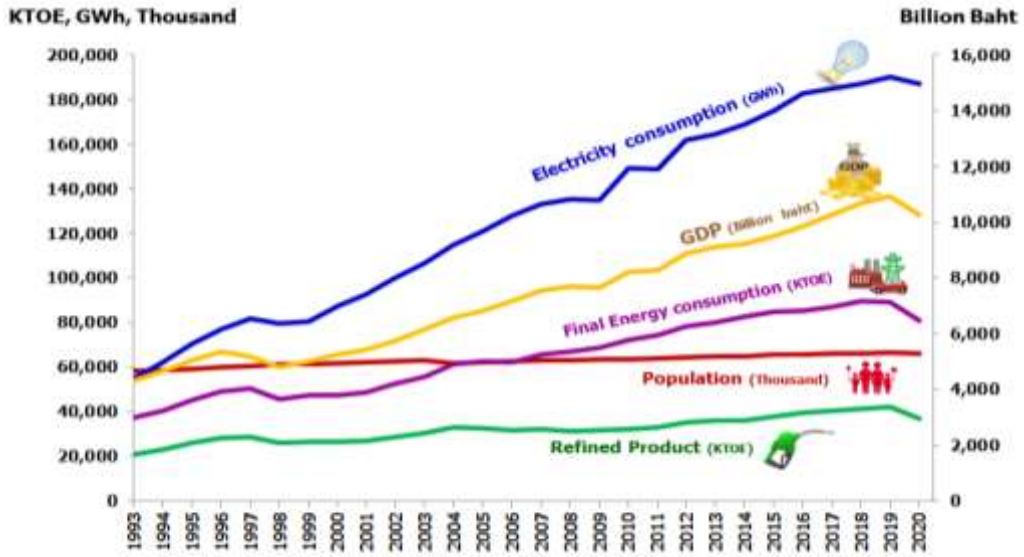

Figure 1 Energy consumption National Income and Population (Source from EPPO)

Figure 1 shows that the overall energy consumption has increased. and changes in the same direction as changes in GDP or economic expansion. From the graph, there will be a period of lower energy consumption in 1998 because the economic crisis that occurred in 1997 affected the following year. This caused the economy to shrink in 1998 and the energy consumption was also shrinking. In 2020, Thailand has faced the epidemic of Covid-19 and the government had passed measures to control the outbreak. As a result, the overall final energy consumption of the country decreased from 2019, resulting in the overall final energy consumption of the country decreased from 2019 as well.

Energy Intensity (EI)

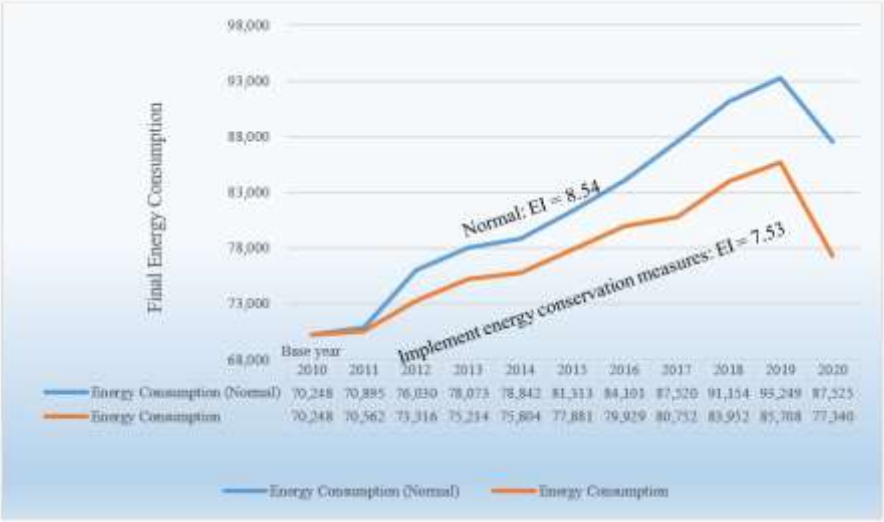

Figure 2 Performance on Energy efficiency in 2020 (Source from DEDE)

Figure 2shows that the blue line is the expected EI value under normal conditions. However, when the energy conservation measures are implemented in the orange line, it is found that, compared with the 2010 base year, the EI value is decreased by 11.8%, and the energy-saving effect is 10,185 ktoe. Therefore, if the controlled factory implements more energy conservation measures, it will help reduce the EI value.

Designated factory

The department of Alternative Energy Development and Efficiency (DEDE) classified the industries into 13 types of designated factories. There are a total of 6,271 factories, namely: Stone, Gravel, Soil, and Sand (81), Wood (101), Food, Beverage, and Tobacco (1,210), Non-metal (1,127), Textile (439), Chemical (439), Paper (187), Metals (380), Industrial metal products, Machinery and equipment (1,098), Electrical industry (233), Water supply industry (36), Gas industry (21), and Other manufacturing industries (919) (December 2021). The implementation of energy conservation measures can also be divided into 3 levels: Level 1-energy conservation in all 4 aspects, Level 2-energy conservation measures including 27 items, and Level 3-name of measures, a total of 461 measures.

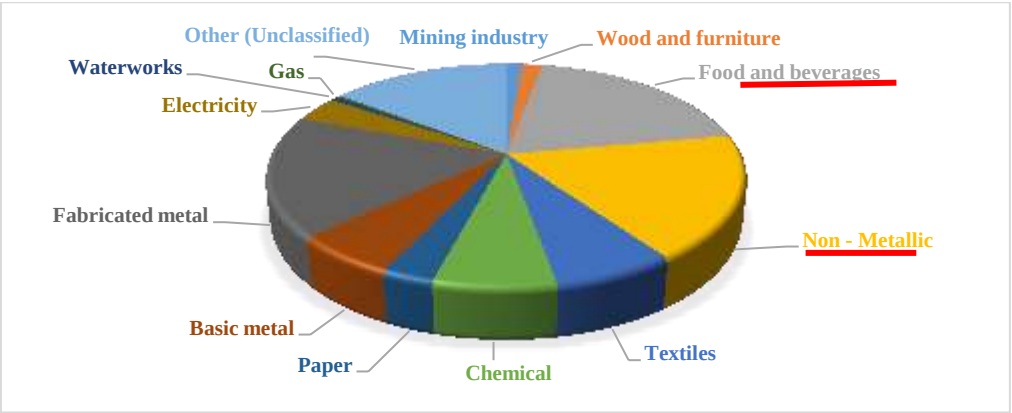

Figure 3 Proportion of the number of controlled factories (Information December 2021)

Table 1 Energy Intensity by manufacturing sub sectors (ktoe / thousand million baht)

SECTOR	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Food and beverages	16.31	16.31	16.42	17.13	18.83	16.02	15.85	17.27	17.37	17.63
Textiles	2.87	3.05	3.74	3.94	3.69	4.13	4.31	4.63	4.89	5.86
Wood and furniture	9.08	9.22	9.73	11.70	12.22	11.79	11.35	8.68	9.05	10.80
Paper	22.60	21.33	20.73	33.05	31.90	36.61	37.61	41.21	51.68	47.01
Chemical	7.54	7.11	7.74	6.36	5.55	6.56	7.13	6.45	6.52	6.98
Non - Metallic	72.97	67.74	67.32	53.21	52.05	55.03	59.84	51.47	59.16	59.96
Basic metal	31.25	31.01	30.88	30.24	30.74	29.71	28.84	27.48	26.73	27.53
Fabricated metal	1.44	1.67	1.67	1.81	2.01	2.23	2.27	1.95	1.83	1.80
Other (Unclassified)	15.50	15.49	15.22	17.62	18.67	19.26	22.93	17.12	15.17	15.43

Data from Energy by the Department of Alternative Energy Development and Efficiency (DEDE)

From Table 1, it is found that for the entire 10 years from 2010 to 2019, the Non-Metallic group had the highest EI. Although from 2010 to 2019, it was significantly reduced but it can be noticed that in some years, the value has increased, especially in 2018 and 2019. However, for the Paper group, it was found that from 2010 to 2019, the EI value increased significantly. Therefore, the researcher is interested in the energy consumption of these two groups. To find important measures that are likely to be effective to reduce the EI value.

The researcher will study the data on the measures implemented by the two industrial groups, namely Non-Metallic and Paper, during the past 10 years, from 2010 to 2019. Data were analyzed on the results of the implementation of energy conservation measures in the designated factories in 3 factors: The number of Energy conservation measures, Energy saving, and Payback Period.

Non–Metallic Group

The Non-Metallic has 1,127 places, a total of implementing energy conservation measures for 10 years (2010-2019) has 12,556 measures, resulting in a total energy saving of 32,505,325,007.28 MJ and has an average payback period of 3.12 years as shown in Tables 2-5.

Table 2 The number of Energy conservation measures (Non – Metallic)

Year	System	Measures	Number
2010	Compressed air system	Reducing compressed air leaks	47
2011	Lighting system	Reducing the wattage of the lamp	67
2012	Lighting system	Reducing the wattage of the lamp	64
2013	Compressed air system	Reducing compressed air leaks	91
2014	Lighting system	Changing from fluorescent lamps (FL) to LED lamps	149
2015	Lighting system	Changing from fluorescent lamps (FL) to LED lamps	187
2016	Lighting system	Changing from fluorescent lamps (FL) to LED lamps	189
2017	Lighting system	Changing from fluorescent lamps (FL) to LED lamps	194
2018	Lighting system	Changing from fluorescent lamps (FL) to LED lamps	160
2019	Lighting system	Changing from fluorescent lamps (FL) to LED lamps	147

From Table 2, it is found that in 2017, Changing from fluorescent lamps (FL) to LED lamps measures were the most implemented measure (194 measure). The table also shows that lighting system measures had the highest implementation for 8 years, categorized as Changing from fluorescent lamps (FL) to LED lamps measured for 6 years and Reducing the wattage of the lamps measured for 2 years. When

considering the total number of all measures in 10 years, changing from fluorescent lamps (FL) to LED lamps measures were implemented the most, totaling 1,074 measures, or 8.55%.

Table 3 Energy saving (Non–Metallic)

Year	System	Measures	Energy-saving (MJ)
2010	Boiler fuel combustion system	Increasing efficiency of liquid fuel use	55,467,680.00
2011	Production process efficiency improvement system	Improving the efficiency of the production process	1,188,825,750.00
2012	Production process efficiency improvement system	Improving the efficiency of the production process	2,852,959,654.17
2013	Energy loss protection system	Other measures to prevent energy loss	733,593,714.00
2014	Energy loss protection system	Insulating steam pipes and fittings	77,272,531.93
2015	Another type of energy transition system	Other measures to switch to another type of energy	1,239,851,181.51
2016	Machine systems and other equipment	Proper maintenance measures	962,061,412.53
2017	Energy loss protection system	Other measures to prevent energy loss	983,602,462.21
2018	Other heat energy optimization systems	Other ways to increase the efficiency of other thermal energy	1,507,995,358.84
2019	The fuel combustion system of various industrial furnaces	Increasing the efficiency of the Furnace Reverberatory	397,176,276.73

From Table 3, It is found that in 2012 Improving the efficiency of the production process measure had the highest energy efficiency can save energy 2,852,959,654.17 MJ and also shows that the energy loss protection system has a total energy efficiency of up to 3 years, and data on the total energy efficiency of all measures in 10 years, it is found that the highest measures to improve the efficiency of the production process have been combined amounted to 3,324,943,687.80 MJ, representing 10.23% of total energy savings.

Table 4 Payback period (Non–Metallic)

Year	System	Measures	Average payback period (year)
2010	Lighting system	Using compact fluorescent lamps (CFLs) instead of HID lamps	0.38
2011	Lighting system	Switching from incandescent lamps to compact fluorescent lamps (CFLs)	0.06
2012	Lighting system	Replacement of other lamps	0.01
2013	Pump and Fan System	Using a high-efficiency fan	0.16
2014	Pump and Fan System	Using a smaller water pump	0.08
2015	Industrial loading and unloading systems	Using a high-efficiency loading and unloading system	0.18
2016	Lighting system	Replace the electronic ballast for the moonlight lamp.	0.01
2017	Utility System	Using Demand Controller to control the operation	0.05
2018	Lighting system	Replace the electronic ballast for the moonlight lamp.	0.01
2019	Electric motor system	Hanging the motor size in the water cooling system	0.28

From Table 4, It is found that the Replacement of other lamps measure in 2012, Replace the electronic ballast for moonlight lamps measured in 2016 and 2018 have the lowest average payback period

of 0.01 years. Secondary measure, Using Demand Controller to control the operation, has an average payback period of 0.05 years.

Paper Group

The Paper has 187 places, a total of implementing energy conservation measures for 10 years (2010-2019) has 2,394 measures, resulting in a total energy saving of 5,789,449,703.27 MJ and has an average payback period of 2.49 years as shown in Tables 6-9

Table 5 The number of Energy conservation measures (Paper)

Year	System	Measures	จำนวน
2010	Machine systems and other equipment	Optimizing the speed of the device	10
2011	Compressed air system	Reducing compressed air leaks	16
2012	Lighting system	Reducing the wattage of the lamp	16
2013	Utility System	Setting the time to turn off and turn on the device appropriately	13
2014	Lighting system	Changing from fluorescent lamps (FL) to LED lamps	22
2015	Lighting system	Changing from fluorescent lamps (FL) to LED lamps	23
2016	Lighting system	Changing from fluorescent lamps (FL) to LED lamps	24
2017	Lighting system	Changing from fluorescent lamps (FL) to LED lamps	36
2018	Lighting system	Changing from fluorescent lamps (FL) to LED lamps	42
2019	Lighting system	Changing from fluorescent lamps (FL) to LED lamps	21

From Table 5, it is found that in 2018 Changing from fluorescent lamps (FL) to LED lamps measure was 42 measures. The table also shows that the lighting system measures had the highest implementation each year for 7 years. Divided into Changing from fluorescent lamps (FL) to LED lamps measure for 8 years and Reducing the wattage of the lamp measure for 1 year. When considering the total number of measures, 176 Changes from fluorescent lamps (FL) to LED lamps measure were implemented in 10 years, accounting for 7.35% of the total measures implemented.

Table 6 Energy saving (Paper)

Year	System	Measures	Energy-saving (MJ)
2010	Hot oil boiler fuel combustion system	Switching to another type of fuel	668,736,000.00
2011	Machinery and equipment systems (heating)	Use of other high-performance machinery and equipment	49,885,166.40
2012	Machinery and equipment systems (heating)	Use of other high-performance machinery and equipment	270,226,800.00
2013	Management and control system	Other measures to manage and control	144,892,498.53
2014	Compressed air system	Other Ways to Maintain a Compressed Air System	190,158,240.77
2015	Hot oil boiler fuel combustion system	Increasing efficiency of liquid fuel use	121,197,756.41
2016	System for recycling the remaining energy from being used	Optimizing the use of steam	69,285,315.00
2017	Machinery and equipment systems (heating)	Use of other high-performance machinery and equipment	114,747,140.00
2018	Power Factor System	Proper maintenance measures	62,929,936.62
2019	System for recycling the remaining energy from being used	Optimizing the use of steam	117,302,245.15

From Table 6, it was found that in 2010, Switching to another type of fuel measure has the highest energy-saving effect. Energy savings of 668,736,000 MJ. The table also shows that the mechanical and equipment (heat) system measures have a total energy savings of up to 3 years. The measure with the highest amount of energy-saving was Switching to another type of fuel for a total of 744,704,146 MJ, accounting for 12.86% of total energy savings.

Table 7 Payback period (Paper)

Year	System	Measures	Average payback period (year)
2010	Boiler fuel combustion system	Switching to another type of fuel	0.36
2011	Boiler fuel combustion system	Switching to another type of fuel	0.16
2012	Air conditioning or cooling system and ventilation (HVAC)	Use of a new high-efficiency air conditioner to replace the old one	0.66
2013	Pump and Fan System	Changing the propeller size	0.24
2014	Lighting system	Switching from incandescent lamps to compact fluorescent lamps (CFLs)	0.18
2015	Lighting system	Changing from incandescent bulbs to LED bulbs	0.1
2016	Machine systems and other equipment	Using a high-efficiency motor	0.06
2017	Boiler fuel combustion system	Boiler replacement	0.06
2018	Lighting system	Switching from compact fluorescent lamps (CFLs) to LEDs	0.53
2019	Pump and Fan System	Changing the propeller size	0.02

From Table 7, It is found that Changing the propeller size measure in 2019 has the lowest average payback period of 0.02 years. Secondary measures, using a high-efficiency motor measure in 2016 and a Boiler replacement measure in 2017 have an average payback period of 0.06 years.

5. Conclusion

From the research of Measures Affecting Energy Conservation of Designated Factory in Thailand. The results of the analysis are as follows:

1. DEDE categorizes industries of designated factories into 13 industries, but 9 industries are the final energy consumption for the manufacturing sector by sub-sector. The Non-Metallic group has the highest EI of all industries and the EI value of The Paper group tends to increase every year.

2. The Non-Metallic group has 1,127 places, a total of implementing energy conservation measures for 10 years (2010-2019) have 12,556 measures, resulting in a total energy saving of 32,505,325,007.28 MJ and have an average payback period of 3.12 years.

2.1 Changing from fluorescent lamps (FL) to LED lamps measure has the most implementation with 194 measures, and in the 10 years, this measure has the most combined implementation, with 1,074 measures, accounting for 8.55% of the total number of measures implemented.

2.2 Improving the efficiency of the production process measure is the maximum energy-saving measure, and in 10 years, this measure has the most combined implementation, 3,324,943,687.80 MJ, accounting for 10.23% of the total energy saving.

2.3 Replacement of other lamps measure and Replacing the electronic ballast for moonlight lamps measure have the lowest average payback period of 0.01years. Secondary measure, Using Demand Controller to control the operation, has an average payback period of 0.05 years.

3. The Paper group has 187 places, a total of implementing energy conservation measures for 10 years (2010-2019) has 2,394 measures, resulting in a total energy saving of 5,789,449,703.27 MJ and has an average payback period of 2.49 years

3.1 Changing from fluorescent lamps (FL) to LED lamps measure has the most implementation with 42 measures, and in the 10 years, this measure has the most combined implementation, with 176 measures, or 7.35% of the total number of measures implemented.

3.2 Switching to another type of fuel measure has the maximum energy efficiency measure. Energy savings of 668,736,000 MJ is also the measure that, in 10 years, is the most combined total of 744,704,146 MJ, accounting for 12.86% of the total energy savings.

3.3 Changing the propeller size measure has the lowest average payback period of 0.02years. Secondary measures, using a high-efficiency motor measure and Boiler replacement measure have an average payback period of 0.06years.

Suggestion

Ministry of Energy by the Department of Alternative Energy Development and Efficiency as a regulatory agency. The appropriate measure for industry groups should be promoted to reduce EI as follows:

The Non-Metallic group: DEDE should establish a project to support 573 factories that have not yet implemented Changing from fluorescent lamps (FL) to LED lamps measure (50.84%) and 1,005 factories that have not yet implemented Using Demand Controller to control the operation measures (98.05%) because this measure has an average payback of 0.05 years. Regulations concerning energy management should also be amended to, instead of prioritizing significant energy-consuming equipment, consider the overall production processes in various industrial sectors.

The Paper Group: DEDE should establish the project to support 147 factories that have not yet implemented Changing or using a high-efficiency motor measure (78.61%), by providing knowledge or financial support. And should create the project to encourage factories to install or replace high-efficiency motors for this industry group.

6. Acknowledgements

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