



Energy Efficiency: The Manufacturing Sector in Indonesia

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Abstract

Indonesia is involved in the global effort to alleviate the deterioration of the environment due to climate change. Given that the manufacturing industry accounts for the second-highest share of national energy consumption, efficiency energy in the industrial sector is crucial. This research examines which industrial subsector has to be prioritized to improve energy efficiency and what are the determinant factors that influence energy efficiency in Indonesia manufacturing. This study analyzes energy intensity as an approach to measure energy efficiency. Focusing on the 2010 - 2015 period, this research employs two methods, namely input-output and panel data regression analysis. The empirical finding shows that textiles and textile products; pulp, paper, paper products, printing, and publishing; and rubber and plastics sectors are the first priority subsectors that must implement green industry standards. The next priority is the subsectors at the second level but have no green industrial standards, namely electrical and optical equipment. Furthermore, there were four variables that statistically increase energy intensity, namely lagged energy intensity, technology intensity, lagged value added, and location of plant. However, other two variables, the price of electricity and company size, can reduce energy intensity.

Key words : Efficiency, Manufacture, Energy Intensity, Input – Output

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INTRODUCTION

The climate change issue has surfaced since the late 1980s. In 1995, the United Nations Framework Convention on Climate Change (UNFCCC) initiated the United Nations Climate Change Conferences which came to be known as the First Conference of the Parties (COP). The meeting was held in Berlin, Germany and the attending nations agreed to take joint action to protect the global climate. Two years later, several more countries joined the third COP which was held in Kyoto and agreed to a timetable of Green House Gases (GHG) emission reductions for the first emissions budget period 2008 to 2012. The target was to decrease emissions by 6 to 8% below the then 1990 levels. Defined as The Kyoto Protocol, it applied the UNFCCC idea to fight global warming by decreasing GHG intensities in the atmosphere. In the holding of COP 18 in Doha, Qatar, a second period was agreed between 2012 and 2020 despite the fact that many developing countries such as China, India and Brazil were not targeted for reducing emissions under the Kyoto Protocol.

At COP 21 held in Paris in 2015, a multinational agreement was signed entitled The Paris Agreement, namely an UNFCCC agreement to begin in the year 2020 that dealing with GHG mitigation, adaptation and funding. This agreement aims to counter the global climate change threat by maintaining a global temperature increase within this century to lower than 2 degrees Celsius above pre-industrial levels and to restrict the temperature rise even further to 1.5 degrees Celsius. Under the Paris Agreement, every country decides, organizes and regularly informs its own role to abate global warming. There is no procedure to press any country to agree to a given target by a specific period,

but each objective should go beyond previously set targets.

Indonesia, even though having no obligation to reduce GHG emissions, is involved in the global efforts to hinder the deterioration in the environment due to climate change. The then President of the Republic of Indonesia approved the Act of Ratification of the United Nations Framework Convention on Climate Change (UNFCCC) Number 6/1994 (*Undang-undang tentang Pengesahan Konvensi Kerangka Kerja PBB tentang Perubahan Iklim Nomor 6 Tahun 1994*). Ten years later Indonesia ratified the Kyoto Protocol through Law Number 17 of 2004. This commitment requires comprehensive efforts and concrete actions from all greenhouse gas emitters (*Kementerian Negara Lingkungan Hidup, 2007*) in Indonesia.

At the Leaders' Event at the opening of COP 21, the President of the Republic of Indonesia expressed his support for the success of the Paris Agreement. In 2015, Indonesia delivered an Intended Nationally Determined Contribution (INDC) with a target of reducing emissions by 2030 by 29% under its own efforts, and 41% with international assistance. Indonesian INDCs includes energy, industry, agriculture, usage and land use and land-use change and forestry sectors. Indonesia itself has signed the Paris Agreement in New York, USA, on 22 April 2016 by the Minister of Environment and Forestry.

The Government of Indonesia has developed and implemented an integrated program between climate change mitigation and adaptation, namely *Rencana Aksi Nasional Penurunan Emisi Gas Rumah Kaca (RAN-GRK)* or the National Action Plan for Reducing Greenhouse Gas Emissions. RAN-GRK is covered under Presidential Regulation Number 61 of 2011, NAP for Reducing Greenhouse Gas Emissions. RAN-GRK is a work plan document for the implementation of various activities that directly and indirectly reduce greenhouse gas emissions in accordance with national

development targets. The plans include reducing emissions in five areas, namely: industry, forestry and peat land, agriculture, energy and transportation, and waste management. This Regulation is a follow up to the commitment of Indonesia to reduce greenhouse gas emissions by 26% in 2020 from the condition in the absence of mitigation actions and up to 41% with international assistance (Sugiyono, 2014).

In accordance with the government's efforts to implement sustainable economic development, the development of the industrial sector is also directed to maintain environmental sustainability through the green industry program. Green industry is any industry with a production process which places priority on efficiency and effectiveness in the sustainable use of resources, to enable harmonization between Industrial development and the preservation of environmental functions as well as to grant benefits to the community. Ministry of Industry has set 18 green industry standards implemented in each sector. The adoption of these green industry standards is voluntary and mandatory, depending on the readiness of each industry subsector. Green industry standards for other industrial subsectors are still in the preparation stage and cannot be determined at this same time due to limited funding for their preparation.

Agency for the Assessment and Application of Technology (BPPT) (2018) predicts that the national energy demand will continue to increase until 2050 (by 5.3% per year) in accordance with economic growth, population, energy prices, and government policies. An increase in the population accompanied by economic growth certainly must be anticipated by the government, with regards to energy consumption which can influence the environment.

Based on Enerdata (2019), Indonesia's energy intensity (0.077 KOE/\$ 2015p) is better than the energy intensity of several Asian countries such as South Korea (0.147), China (0.128), Thailand (0.111), Malaysia (0.094), and India (0.089). However, Indonesia is still lagging behind by developed countries in Europe such as the United Kingdom (0.059), Italy (0.064), Spain (0.069) and Germany (0.071). Furthermore, national energy efficiency can be observed through ratio between energy consumption growth and economic growth, recognized as energy elasticity. Indonesia's energy elasticity has decreased from 1.63 in 2013 to 1.08 in 2017. Though, the energy elasticity is above the target in National Energy Plan (RUEN), which is below 1 (the scenario in RUEN is 0.84 in 2025). To achieve the target, the government needs to improve energy efficiency in various sectors, especially energy intensive sectors.

According to the International Energy Agency (2018), the manufacturing sector accounted for the second highest share of global final energy consumption in 2016 (23%), just below transportation sector (36%). The similar pattern also occurs in Indonesia where the industrial sector is a productive sector that continues to be encouraged to expand in order to improve the national economy. The share of final energy consumption by industrial sector (not including transportation for industries) in 2017 is 30%. This sector is the second largest contributor after the transportation sector (47%).

As an energy-intensive sector, manufacturing converts raw materials into finished goods, primarily using heat in the production process. The largest sources of energy for the industrial sector are natural gas, by-products and waste fuels. Since this sector has a high energy consumption and generates serious environmental impacts, it is crucial to measure and optimize their total energy use to

determine the prospects for energy efficiency improvements and recognition of best standards (Azadeh et al., 2007).

Oil Shocks in the 1970s drove the development of energy efficiency indicators, which was emphasized by the concern about global warming in the last 25 years. Ang (2005) explains that the application of energy efficiency theories in many studies may involve various methods and objectives, creating no single definition of energy efficiency. Patterson (1996) characterizes the indicators as mainly four: thermodynamic, physical-thermodynamic, economic-thermodynamic, and economic. This research will explore the efficiency of energy from an economic perception computing the energy consumption and output from the industrial sector in Indonesia.

One approach to measuring energy efficiency in economics is energy intensity. Dasgupta & Roy (2017), Lam, et al. (2019), Shen & Lin (2020), and Faridzad, et al. (2020) use this indicator to measure how energy efficiency in the manufacturing sector. Bhatia (2014) explains that energy intensity is defined as units of energy per unit of GDP. High energy intensities indicate a high price or cost of converting energy into GDP and vice versa.

Energy intensity improvement is varied across industrial subsectors. Dasgupta & Roy (2017) found that during 1973 - 2012, aluminum, cement, and fertilizer industries in India improved their energy intensity while the opposite case was found in iron and steel and pulp and paper industries. Between 1970 and 2001, the highest energy-consuming sectors within US manufacturing (except primary metals) improved their efficiency in energy use (Mukherjee, 2008). During ten years of 1989 - 1998, the most marvelous Mexican manufacturers in energy intensity reduction were petrochemicals, iron and steel, sugar, cement, and pulp and

paper (Aguayo & Gallagher, 2005). Zhao et al. (2014) conducted a comparative study of energy efficiency in the manufacturing industries between China and Japan in the period 1980 to 2010. Their analysis illustrates that petroleum and coal products, iron and steel, and chemicals in Japan are constant as subsectors with the highest energy intensity. Different things occur in China where the ceramics and cement industries have higher energy intensities than the chemicals industry, even though iron and steel and petroleum and coal products remain the highest. Previous studies reveal how the energy intensity pattern in each country is different so energy policies in one country cannot necessarily be applied directly in other countries. Therefore, in determining the appropriate policy for Indonesia, it is necessary to evaluate its energy intensity configuration.

The industrial energy efficiency will have a direct impact on total energy utilization efficiency because the industrial sector is the second largest energy consumer in Indonesia. The implementation of the green industry program by Ministry of Industry (MoI) is expected to improve energy efficiency because this is one of the characteristics of the green industry. Given that the execution of the green industry standards is still limited to several of subsectors, it is necessary to examine which industry subsector has the greater opportunity to improve energy efficiency. This evaluation is carried out on the direct use of energy by the subsector, as well as the indirect energy usage caused by backward and forward linkage between industrial subsectors. In addition, it is also important to evaluate what factors drive industrial firms to make efficiency in terms of energy use. By doing both analyzes, it can be determined what subsector has the greatest potential for energy efficiency while providing an overview of how implementation and be appropriately carried out. Answering these issues is of vital importance for the government to understand energy consumption

characteristics of the industrial sector, to create effective policies to develop energy efficiency of the industrial sector, and ultimately to achieve energy saving and emission reduction targets.

Researchers from various fields of science widely use the Input-Output Analysis for their studies. Using the World Input-Output Database, Feenstra & Sasahara (2018) analyze how imports and exports affected U.S. employment. Lee & Yoo (2016) analyze the economic effects of four transportation types in Korea using input-output analysis. Wang, et al. (2019) assess the essential effects of Brazil aviation biofuel production on employment, GDP, and trade balance. The method is also used by Bekó et al. (2019) to note the effect of the health system in Slovenia on its economy. Several studies on the environmental topic also used input-output analysis to evaluate global climate change. Chandrakumar, et al. (2019) computed New Zealand's GHG emissions based on their consumption and production using a global multi-regional input-output analysis. Input-Output Analysis has been employed by Alcántara & Padilla (2019) to determine the critical sectors in greenhouse gas emissions in Spain. Lam, et al. (2019) carried out an input-output analysis of energy use in Australia to examine the total energy intensity of the manufacturing sectors.

Some studies that utilized Indonesian data also use input-output analysis methods. Hayashi (2005) evaluated the manufacturing accomplishment in Indonesia and explains what the significant challenges are sustaining industrialization. Winarno & Freiberg (2016) study how low-rank coal utilization affected economic output and employment. Using Input-Output Analysis, Imansyah, et al. (2013) found that there is emission reduction in the fifteen main sectors during 1990-1995,

yet no significant change in the five key sectors as the highest polluters.

Using input and output analysis, both the direct and indirect energy induced by each sector can be estimated. Assuming that the output of a company does not change, therefore energy efficiency efforts automatically will reduce the energy intensity of the company. Furthermore, the implementation of energy efficiency will reduce the subsector energy coefficients and finally turn their direct energy induced to become lower. This analysis helps identify those subsectors with a high-energy intensity, which still has the potential to increase energy usage enormously. Thus, the government needs to prioritize those industrial sub-sectors in terms of conforming them into the green industry.

In order to formulate the right policies for the government to encourage industrial companies to directly or indirectly apply energy efficiency in the production process, we need to examine the factors that will drive energy efficiency in manufacturing. For that purpose, regression analysis will be used between energy intensity as a dependent variable and several independent variables namely energy price, technological renewal, value added, firm size, private capital, market share, number of products exported, and location of the plant.

METHOD

This research focuses on the energy efficiency of the manufacturing sector in Indonesia. How to accelerate industrial growth while improving energy efficiency is an issue confronting every developing country. In order to shed light on this issue, this study examines the energy intensity of the subsectors that would have a direct and indirect impact on national energy utilization. Furthermore, it will analyze those factors that affect energy intensity, i.e., energy price, technological

intensity, value added, firm size, private capital, market share, the number of products exported, and the location of the plant. According to Statistics Indonesia (BPS)'s classification, manufacturing industries are categorized into 24 two-digit subsectors. Since the Input-Output table provided by the Asian Development Bank (ADB) grouped manufacturing only into 14 subsectors, the authors adjust data from BPS in accordance with ADB category.

This study employs quantitative analysis to answer the research questions as the main objective of this research. Quantitative analysis is carried out using two methods, namely Input-Output Analysis and Panel Data Regression.

The Input-Output analysis will be applied to identify those industrial subsectors that induce high total energy consumption, which should be prioritized in terms of implementing energy efficiency in their production process.

Based on Leontief (1986), the quantity of the output of sector i absorbed by sector j per unit of its total output j is expressed as a_{ij} and is labelled the input coefficient of i product into sector j .

$$a_{ij} = \frac{x_{ij}}{x_j} \quad (1)$$

The structural matrix of that economy is a complete set of overall input coefficients of the economy in a rectangular table. The general solution of equilibrium equations for the "unknown" x 's in terms of the given final demand y 's can be illustrated as:

$$x_1 = A_{11}y_1 + A_{12}y_2 + \dots + A_{1n}y_n \quad (2)$$

The constant A_{ij} indicates by how much the output x_i of the i th sector would rise if one unit of y_j increased. The increase would affect sector i directly and indirectly if $i = j$. However, if $i \neq j$, the output x is only

indirectly affected. The matrix of A is the inversion of the coefficient (a) matrix known as the Leontief Matrix.

This study uses an annual input-output table during 2010-2015 to illustrate the pattern of changes in total energy induced in that period. The author uses a model approach conducted by Oliveira et al. (2013) in calculating the employment multiplier for sector. With a similar approach, the analytical model is as follows:

$$TE_j = \sum_{i=1}^m e_j b_{ij} \quad (3)$$

$$DE_j = e_j b_{jj} \quad (4)$$

Where TE_j is total energy induced per unit of final demand of sector j ; b_{ij} is elements of the inverse matrix $(I - A)^{-1}$; e_j is energy coefficients, the energy consumption of sector j divided by the total output of sectors j and DE_j is direct energy induced per unit of final demand of sector j .

Total induced energy is the sum of direct and indirect energy induced by industries. The results will be used to determine which industry subsectors have the most substantial energy induced in total, direct and indirect.

In analyzing the driver of energy efficiency in Indonesia at the national level, this research used the quantitative method by applying panel data regression analysis over the 2010-2015 period. The factors that will be analyzed are energy price, technology, value added, firm size, private capital, market share, and products exported.

Panel data analysis provides both a spatial (countries, states, firms, sectors, groups or even individuals) and temporal (periodic observations in a particular time) dimension for regression (Yaffee, 2005). Hsiao (2003) notes several advantages of panel data analysis: 1) more precise interpretation of model parameters since the method contain more degrees of freedom and sample variability;

2) more capacity for creating more realistic behavioral hypotheses; 3) exposing dynamic relationships; 4) controlling the omitted variables effect; 5) estimating individual outcomes more accurately; 6) arranging micro-foundations for aggregate data analysis; and 7) simplifying computation and statistical interpretations.

Standard panel data focuses on individual outcomes which are affected by numerous factors. Assuming a common conditional probability density function of y conditional on x for all cross-sectional units i , at all times t is problematical (Hsiao, 2007). Suppose that in addition to x , unnoticed individual capabilities represented by α_i affect individual outcomes, so that the observed (y_{it}, x_{it}) , $i = 1, \dots, N$, $t = 1, \dots, T$, are generated by

$$y_{it} = \alpha_i + \beta'x_{it} + u_{it},$$

$$i = 1, \dots, N$$

$$t = 1, \dots, T \quad (5)$$

Adopting Huang, Lai, & Hu, (2020) model in exploring China's energy intensity, this research employ panel data regression analysis to determine how the relationship of energy intensity with the independent variables works. The authors adjust the model with some variables used by Sahu & Narayanan (2011), Ramstetter & Narjoko (2014), Costa-Campi et al. (2015), and Adom (2015) that are available in BPS's industrial survey data. The model used in this study is as follows:

$$IEI_{it} = \beta_{0i} + \beta_1 IEI_{it-1} + \beta_2 ITI_{it} +$$

$$\beta_3 ITI_{it-1} + \beta_4 IVA_{it-1} + \beta_5 LSZ_{it} +$$

$$\beta_6 PCO_{it} + \beta_7 MS_{it} + \beta_8 EXP_{it} + \beta_9 LOC_{it} +$$

$$u_{it}, \quad (5)$$

Where IEI_{it} is energy intensity, IEI_{it-1} is energy intensity in previous year; ITI_{it} is technology intensity; ITI_{it-1} is technology intensity in previous year; IVA_{it-1} is value added in previous year; LSZ_{it} is firm size; PCO_{it} is percentage of private capital; MS_{it} is percentage of market share; EXP_{it} is percentage of goods exported; LOC_{it} is location of plant; β_0 is constant; β is coefficient of independent variables; u_{it} is error term; i is subsector and t is year.

Since the energy consumption and economic growth are related, the static panel analysis create a biased estimation because energy intensity from the previous period may influence energy intensity in the following period (Huang, Lai, & Hu, 2020). Thus, the model (6) also includes the time lagged dependent variable to depict the time lagged impacts of the explanatory variables.

Logarithmic function (1) is also used because the value of goods produced is too large compared to the value of energy intensity together with the purchase of additional machinery and equipment. Additionally, the logarithmic function is useful for transforming random data into linear data.

To provide certainty that the regression equation obtained is not biased, but consistent and has accuracy in its estimation, a classic assumption test, i.e. multicollinearity and heteroscedasticity test is indispensable. A strong correlation among independent variables is called multicollinearity, which is problematic because it will have an impact on the accuracy of the regression coefficient in estimating the actual value. The heteroscedasticity test is used to learn whether the residuals of the models have constant variance or not. An appropriate model has a constant variance of each residual. The impact of heteroscedasticity is inefficiency on the estimation process, while the estimation results remain consistent and unbiased. If the regression model has indicated

heteroscedasticity and autocorrelation problems, it is necessary to use more advanced methods so that the resulting estimation is consistent and unbiased. The authors utilize the generalized method of moments (GMM) as suggested by Roodman (2009). The GMM model can avoid the potential effects of firm time-invariant, time-specific, and firm-specific by first differentiating the studied model. Alsaleh & Abdul-Rahim (2019) employ GMM to evaluate the determinants of bioenergy intensity in European.

This study uses the Indonesian input-output table for 2010 to 2015, accessible through the ADB, to estimate potential energy consumption induced by per unit of final demand of each sector. The table presents the input-output for 35 sectors including the service, education and health sectors. Of the total 35 sectors, only 14 can be classified as manufacturing sectors which are the focus of this study. Besides, as mentioned the panel data analysis employs BPS data, i.e. annual industrial survey. This survey is conducted in full for all large and medium industrial companies that are listed in the BPS industry directory. Macro level data can be downloaded from the BPS website, while firm level data can be obtained by formal request.

The explanation of each data is as follows: 1) Energy consumption is the quantity of fuel and lubricants used in a year. According to industrial surveys of BPS, energy consumption consists of several fuel types, i.e., gasoline, diesel fuel, kerosene, coal, briquettes, gas, electricity, and lubricants. Every type of fuel has a different measurement unit, for instance, liquid fuel (gasoline, diesel, kerosene and lubricants) are measured in terms of liter unit, while coal is quantified in terms of kilogram unit. Therefore, a conversion unit is a must to aggregate all the types of fuels in one-unit

measurement. The author uses the conversion factor provided by the Ministry of Energy and Mineral Resources (2018) to change all fuel units into BOE; 2) Energy price is the price of electricity that is set by the state electricity company, especially for the manufacturing sector. This value is the average value of electricity prices for one year. Other types of energy prices cannot be included in the model due to data limitations; 3) Technology intensity is the estimated value (in rupiah) of machinery and equipment added during a year divided by output produced. The purchase of new machinery and equipment is considered a technological renewal that can make a company's production process more efficient; 4) Value added is the difference between company revenue and total costs incurred for one year. This value can be assumed as a profit gained by the company; 5) Firm Size is measured by the total number of workers employed by the company, both production and non-production (administrative) workers; 6) The private capital variable is the percentage of capital from foreign private companies and domestic private companies. In industrial survey, capital investment is categorized into four types of capital, namely from the central government, from the local governments, from foreign private companies and from domestic private companies; 7) Market Share is the ratio of the total output produced by the company to the total output of the entire 5-digit subsector level, in percentage value. This variable is to determine the condition of market control by a company; 8) Exporting status is the percentage of its products exported to other countries. A value of 100% indicates that all goods produced by the firm in one year are traded to the global market; 9) The location of the plant uses a dummy variable, namely where industries located inside industrial estates are valued at 1, and industries located outside industrial estates are valued at 0. The variables and data used in panel data analysis are explained in Table 1.

Table 1. Variable Data and Measurement Unit

No	Variables	Description	Unit
1	EI	Energy intensity, defined as energy consumption divided by output	BOE / Rupiah
2	EP	Average price of electricity in a year	Thousand Rupiah/BOE
3	TI	Technology intensity, ratio of additional machinery and equipment cost and output produced by the companies	unit
4	VA	Value added, company revenue reduced by costs incurred for one year	Rupiah
5	SZ	Firm Size, the number of workers employed by the company	Person
6	PCO	Private capital, the percentage of private ownership of capital	%
7	MS	Market share, the percentage of the firm's output to the total subsector output	%
8	EXP	Percentage of goods exported by the companies	%
9	LOC	Plant location, inside or outside industrial estate	dummy

RESULTS AND DISCUSSION

The MoI has established 18 green industry standards that are implemented for certain subsectors. Table 2 shows the number of green industry standards based on the industry subsector that was the focus of this study. Food, beverages, and tobacco (FBT) and ONM are the sectors with the highest number of standards, each with four standards. Conversely, there are six sectors that do not have green industrial standards yet, i.e. wood and products of wood and cork (WPC); CRP; basic metals and fabricated metal (BFM); machinery, n.e.c. (MCH); electrical and optical equipment (EOE); and manufacturing, n.e.c. recycling (MFR).

Table 2. Green Industry Standards by Sector

Code	Sector	Number of Standard
FBT	Food, beverages, and tobacco	4
TXT	Textiles and textile products	2
LPF	Leather, leather products, and footwear	1
WPC	Wood and products of wood and cork	-
PPP	Pulp, paper, paper products, printing, and publishing	2

Code	Sector	Number of Standard
CRP	Coke, refined petroleum, and nuclear fuel	-
CHP	Chemicals and chemical products	2
RUP	Rubber and plastics	2
ONM	Other nonmetallic minerals	4
BFM	Basic metals and fabricated metal	-
MCH	Machinery, n.e.c.	-
EOE	Electrical and optical equipment	-
TRE	Transport equipment	1
MFR	Manufacturing, n.e.c.; recycling	-
	Total	18

Source: Ministry of Industry

Energy consumption and output of the manufacturing sector of Indonesia experienced a significant increase in the period 2010 - 2015. Within a 6-year period, there was an increase of 148% and 25% respectively. Energy intensity, the ratio of energy consumption to output, also rose by 99% during the same period. However, there was a decrease in energy intensity in the period 2012 - 2013. The fluctuation in intensity is the result of very heterogeneous sectoral dynamics. Nine subsectors have decreased energy intensity, while the remainder show the opposite trend. The historical data of the average annual growth shows that the transport equipment (TRE) sector experienced the highest increase in energy intensity.

The energy induced of each subsector is computed using the Leontief inverse matrix and energy coefficient. The results of these calculations can be seen in Table 3.

ONM and TXT are the two subsectors with the highest energy induced in the manufacturing sector. While CRP and MCH has lower energy induced compared to other subsectors, the proportion of direct and indirect energy induced also varies between subsectors. CRP are the sectors with the largest portion of indirect induced energy, 59%, whereas ONM only have 2.2% of indirect induced energy compared to their total induced energy.

Table 3. Energy Induced by Subsectors

2010 - 2015		
Sector Code	Total	Indirect
FBT	112.07	7.95
TXT	357.55	23.73
LPF	142.74	29.16
WPC	157.51	20.29
PPP	354.74	17.83
CRP	9.04	5.37
CHP	309.01	9.33
RUP	303.54	44.96
ONM	924.16	20.16
BFM	137.93	21.77
MCH	68.27	12.87
EOE	212.11	25.25
TRE	173.99	16.50
MFR	114.36	50.38

Analyzing the energy induced for each subsector, the annual growth trend of induced energy can be compared with the annual growth of energy intensity, as shown in Figure 1. Generally, the energy induced annual growth of each subsector is directly proportional to the change in energy intensity. Transport equipment (TRE), the sector that has the highest energy induced annual growth, occupies the first position as a sector with energy intensity that rises rapidly from year to year.

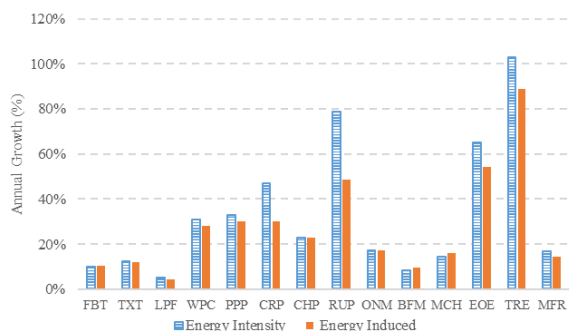


Figure 1. Energy Intensity and Energy Induced Annual Growth (%), 2010-2015

Furthermore, the authors categorize subsectors based on annual energy intensity, energy induced, and output growth. Figure 2 illustrates the position of subsectors in the group based on annual energy intensity and energy induced. Each subsector is classified into four groups, (1) upper right, both energy intensity and energy induced are high; (2) upper left, low energy intensity but high energy induced; (3) lower right, high energy intensity but low energy induced; and (4) lower left, both energy intensity and induced energy are low.

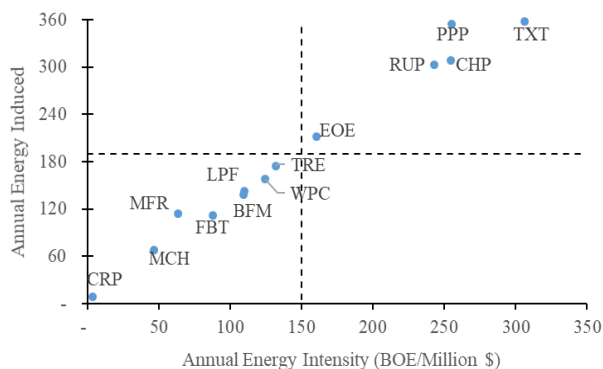


Figure 2. Categorizing based on Annual Energy Intensity and Energy Induced, 2010 - 2015

In an effort to increase national energy efficiency, the upper right group is the subsectors that need special attention since the increase in energy consumption has a greater chance of increasing energy intensity on a national scale. In Figure 2, most of the

subsectors stay at the lower left group, which shows that these subsectors are notable in terms of energy efficiency compared to other subsectors. Figure 3 is also categorizing of subsectors using the same method, but based on annual energy intensity and output growth. In contrast to Figure 2, the best group in Figure 3 is the upper left, where the subsector in the group gives a significant contribution in the economy with high output growth but accompanied by low energy intensity.

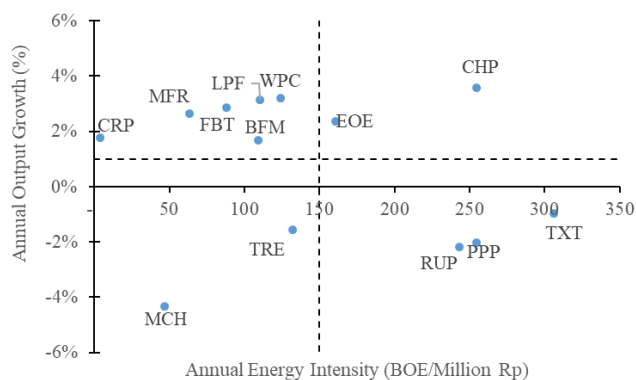


Figure 3. Categorizing based on Annual Energy Intensity and Output Growth, 2010 - 2015

Conversely, in an effort to obtain energy efficiency nationally, the government needs to focus on the lower right group. In regard to the high value of energy intensity, ONM sector is exceptional from Figure 2 and 3. However, this sector belongs to the upper right group in both of these figures.

Table 4 summarizes the subsectors categorized based on Figure 2 and 3. From the results of the grouping, we can determine the priority level of each subsector in accordance with the necessities of implementing green industrial standards. The sub-sector sorting is based on energy intensity, energy induced and output growth, with the criteria as follow: First priority, industries with high energy intensity and energy induced but have low output growth; Second priority, industries with high energy intensity, but low energy induced or

high output growth; Third priority, industries with low energy intensity, but high energy induced or low output growth; and Fourth priority, industries with low energy intensity and energy induced, but have high output growth.

Based on the results of classifying, most of the industrial subsectors are at fourth priority levels with including eight subsectors. While the remaining three subsectors is at the first priority level and three subsectors at the second priority level.

TXT, PPP and RUP is the very subsectors as the top priority in implementing green industry standards. Recently, the above subsectors only have two green industry standards each, so the government needs to provide and apply more standards on these subsectors. The subsectors that currently have the highest number of standards are ONM and FBT, which are at the second and fourth priority levels, respectively.

However, there are one subsector at the second priority level that do not have green industry standards, namely EOE. This subsector need to be promoted to implement green industry standards as part of the government's efforts to implement energy efficiency at the national manufacturing sector. Although all sub-sectors are expected to implement green industry standards, the first and second priority level industries must be prioritized among other levels.

In addition to mapping the priority subsectors, the factors that influence manufacturing energy intensity also needs to be analyzed. By identifying these factors, we can formulate an appropriate pattern to accelerate the implementation of energy efficiency in the manufacturing sector. Panel data regression analysis is employed to determine what variables affect energy intensity significantly. The authors use ten independent variables (including three lagged variables) which allegedly affect energy intensity as the dependent variable. Analysis was conducted using data from 8,215 manufacturing companies over a 6-year period, from 2010 to 2015.

The classic assumption test of the regression results is performed to confirm indications of multicollinearity, heteroscedasticity, and autocorrelation. The author uses the variance inflation factor (VIF) as an indicator of multicollinearity. Based on the calculation results, all variables have a VIF value below 10 so it can be assumed that the model used is free of multicollinearity problem. Furthermore, the author used the modified Wald statistics test to verify the existence of heteroscedasticity, and the Wooldridge test for autocorrelation. The results of both tests indicate the existence of heteroscedasticity and autocorrelation problems in the fixed effect model used previously.

Table 4. Classifying based on Priority Level

Code	Sector	First Grouping	Second Grouping	Priority for Green Industry	Number of Existing Standard
FBT	Food, beverages, and tobacco	LL	UL	Fourth	4
TXT	Textiles and textile products	UR	LR	First	2
LPF	Leather, leather products, and footwear	LL	UL	Fourth	1
WPC	Wood and products of wood and cork	LL	UL	Fourth	-
PPP	Pulp, paper, paper products, printing, and publishing	UR	LR	First	2
CRP	Coke, refined petroleum, and nuclear fuel	LL	UL	Fourth	-
CHP	Chemicals and chemical products	UR	UR	Second	2
RUP	Rubber and plastics	UR	LR	First	2
ONM	Other nonmetallic minerals	UR	UR	Second	4
BFM	Basic metals and fabricated metal	LL	UL	Fourth	-
MCH	Machinery, n.e.c.	LL	LL	Fourth	-
EOE	Electrical and optical equipment	UR	UR	Second	-
TRE	Transport equipment	LL	LL	Fourth	1
MFR	Manufacturing, n.e.c.; recycling	LL	UL	Fourth	-

Note: UR = upper right; UL = upper left; LR = lower right; LL = lower left

To obtain consistent and unbiased estimation results, the authors use the generalized method-of-moments (GMM) estimator system to eliminate the problem of heteroscedasticity and autocorrelation in the model.

The regression results are shown in Table 5. Heteroscedasticity and autocorrelation problems that arise in the

model can be removed with the GMM system which can be seen in the p-value AR and Hansen tests (both p-values above 0.1). This regression produces six out of ten significant independent variables, while the other four variables are not significant.

Table 5. Estimation Result of Dynamic Panel Data Models

Variable	System GMM
Lag lnEI	0.5069*** (0.0627)
lnEP	-2.0009*** (0.4338)
lnTI	0.4750** (0.2330)
Lag lnTI	-.01893 (0.0922)
Lag lnVA	1.0682*** (0.2792)

Variable	System GMM
lnSZ	-1.9040*** (0.7209)
PCO	0.1538 (0.1586)
MS	-0.2296 (0.2189)
EXP	0.0014 (0.0034)
LOC	6.7699*** (1.9583)
CONS	- 8.9670 (14.8507)
<i>Diagnostic test</i>	
No. of Obs.	41,075
No. of Groups	8,215
No. of Instrument	20
AR (2) test <i>p</i> -value	0.483
Sargan test <i>p</i> -value	0.181
Hansen test <i>p</i> -value	0.470

Note: *** significant at 1%; ** significant at 5%; * significant at 10%

Source: Stata Output

Empirical outcomes present that the electrical price has a negative effect on the energy intensity of a company. This finding is in accordance with the results of research obtained by Kartiasih, et al. (2012) and Adom (2015). Theoretically, rising energy prices will increase the costs incurred to produce the same number of outputs. This condition will force companies to consume energy more efficiently so that production costs can be as minimum as possible.

Interesting results can be seen in the technology intensity variable which has varying coefficient values. Technology intensity in the current year tends to increase energy intensity in that year, and vice versa will decrease energy intensity the following year. The purchase of new machinery and equipment can be categorized not only as an energy efficient technology transfer, but also as an effort to replace machines with a level of efficiency that is almost the same as the existing technology. Based on the value of the technology intensity coefficient, where the current value is greater than the lagged

value, it can be assumed that the procurement of new machinery and equipment by industrial companies is more towards technology renewal that has similar energy efficiency levels as before. Sahu & Narayanan (2011) obtain similar results when studying energy intensity in Indian manufacturing. Repair intensity variable, the term they choose besides technology intensity, is positively correlated with energy intensity. In addition, they also discovered that company profits were positively correlated to energy intensity, although not statistically significant. In Table 5, the variable value added has a positive coefficient with a significant *p*-value for energy intensity. Rising profits of a company, as seen from the increase in the variable value added in the previous year, is expected to increase the company's energy intensity. As long as the company's profits are still at the same level as the previous year, the energy efficiency effort tends to be minimum.

The firm size, which is represented by the number of workers, has a negative effect on energy intensity. This shows that the larger the company is, the higher the energy efficiency efforts undertaken. This is certainly related to energy loss which will add to the manufacturing company's production costs. Because the greater the capacity of production or output, the higher the possibility of energy loss, large companies tend to efficiently consume energy in their production process. Costa-Campi et al. (2015) revealed identical results when investigating energy efficiency determinants in the nonmetallic mineral industry, even though on the aggregate the manufacturing sector has the opposite trend.

Another significant variable to energy intensity is the location of the industrial plant. Estimation results show that companies located in industrial estates tend to have greater energy intensity compared to companies outside. This could be due to the availability of energy supply facilities that are relatively easily accessed in industrial estates so that the use of energy for the production process is easier and more affordable, which causes weak energy efficiency efforts. In their research, Gerlagh & Mathys (2012) concluded that energy abundance is positively correlated with industrial energy consumption. Assuming that the industrial estate has a greater stable energy supply, it can be concluded that the use of energy by companies in the estate tends to be large.

However, the regression results indicate that the market share variable is negatively correlated with energy intensity, while the private capital owned and exporting status has a positive relationship. Nevertheless, the three variables are statistically insignificant for the dependent variable.

CONCLUSION

The research examines the energy efficiency of the manufacturing sector in Indonesia during the period 2010 - 2015. To obtain a fair understanding of the energy efficiency conditions of each subsector and the determinants of energy efficiency, this study uses two methods, namely input output analysis and panel data regression analysis.

The authors categorize subsectors based on annual energy intensity, energy induced, and output growth from the standpoint of determining the priority level of each subsector in accordance with the necessities of implementing green industrial standards. The result shows that most of the industrial subsectors, eight subsectors, are at fourth priority level. While the remaining subsectors is at the first and second priority level. Textiles and textile products; pulp, paper, paper products, printing, and publishing; and rubber and plastics is the very subsectors as the top priority in implementing green industry standards. The number of green industry standards implemented in these sectors needs to be increased, where currently only two standards have been set each sectors. The next priority is the subsectors at the second level, but do not have the green industrial standards, namely electrical and optical equipment. The implementation of green industrial standards in these sub-sectors is expected to accelerate energy efficiency efforts nationally, in line with the target of reducing greenhouse gas emissions in Indonesia.

This study also employs panel data regression to map the factors that influence energy intensity in the manufacturing sector. The analysis showed that statistically, there were four variables that reduce energy efficiency, namely lagged energy intensity, technology intensity, lagged value added, and

location of plant. Unpredictably, empirical results show that the increase in energy intensity in the previous year and technology intensity triggered an increase in energy intensity in the current year. This shows that the company did not give attention to the energy intensity in previous year as their consideration in determining the energy consumption, and the purchase of new machines and equipment is more focused on maintaining the old production process rather than the transition to technology that is more efficient in consuming energy. It is very important for the government to encourage the industry to upgrade technology that is more environmentally friendly, especially in terms of energy consumption.

However, there are two variables that can increase energy efficiency, namely the price of electricity and company size. The increase that occurs in these two variables will reduce energy intensity in the manufacturing sector. The authors assume that changes in energy prices also affect the price of the final product, while on the other hand the purpose of energy prices by the government can significantly reduce energy intensity, but does not reduce the competitiveness of industrial companies. Therefore, the energy price management is important for the government to improve energy efficiency in the industrial sector. With the mapping of these determinants, company characteristics that are a priority in implementing green industrial standards can be better directed.

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