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What are the Key Drivers of Energy Intensity in Indonesia Manufacturing Sectors?

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Abstract. At present Indonesia manufacturing sectors consumes about half of total energy demand while its contribution to national growth is declining to about 24%. Both indicators show large room for improvement of manufacturing sectors by reducing the energy intensity which at the same time they will improve the value added contribution to GDP. This study will focus on six industry sectors of high energy consumption interestingly those sectors are also the major contributors to the total manufacturing value added. The decomposition method has been applied on the statistic data to identify the weight of each major driving force. The study result shows the technology-related factor accounts for the major driving forces of energy demand and energy intensity of most target industry where as the production output plays relatively smaller role. However, the structural factor is the notable determinant for the glass product and pulp industries.

Keywords: energy intensity; efficiency energy; decomposition analysis; manufacturing sectors

1. Introduction

Energy demands of the manufacturing sectors went up to 50% [1] of the total energy demand structures in Indonesia during 2008 while at the same period its value added contributions to GDP went down to different direction from well-above 25% level and steadily decline to the 24.5% level [2] in the last five years as shown in Fig. 1.

Like the other manufacturing sector in many countries, the energy-intensive manufacturer in Indonesia consists of Steel industry, Pulp and Papers, Chemical and non-metallic mineral industry (Cements and Glass industries).

However, since the food and textile industry have large population in Indonesia, then the energy demand of these sectors is quite considerable but distributed among thousands of small parcel that compose a big portion of demand.

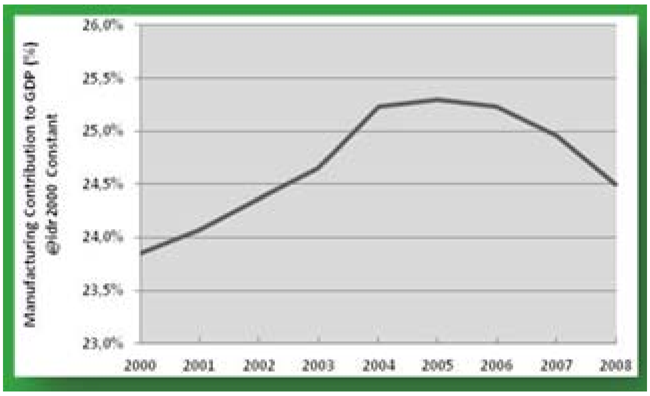

Fig. 1. Contribution of manufacturing value added to GDP (IDR constant 2000)

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The energy demand structure of the manufacturing sector in Indonesia shows that 80% of total energy consumption of this sector goes to only six industries as mentioned above. This is very clear early indication that a quantitative assessment on the various essential related-factors should be done to understand the energy consumption behaviors of these industries to control the future energy consumption.

There are three factors among the issues; Production Output level, Structural factors such as product mix, raw material, type of fuels and Energy Efficiency issue. The energy efficiency is described in three different units (thermodynamic unit, physical unit and monetary unit). Energy efficiency in thermodynamic terms is described as energy input divided by energy output (ex. Joule, BTU etc) while on the other term it can be described as energy input divided by physical units (Ton) or by monetary units ($), which can be defined as energy intensity. Efficiency energy indicator in thermodynamic unit and physical unit are less effective on the macro level compared to energy intensity approach.

These macro indicators of energy intensity and energy consumption of manufacturing sector that the room for improvements is widely available and the path forward to reduce it can be outlined by decomposing the driving-forces behind these macro indicators into various determinants as follows a.) efficiency-related factors and b.) factor that is not related or less-related to the efficiency issue.

The top-down approach through the energy intensity indicators and energy consumption will provide macro understanding and broad direction to explain the role of efficiency-related determinants compared to the industry structural and production output roles.

Decomposition is a method to access the driving forces of the changes of aggregate indicators. This method has been used in economic and environment studies prior to energy analysis. Boyd [3], Sun [4] , Albrecht *et al*. [5], Ang [6] and Liu [7] are among the many energy researchers who provide excellent study on the methodology and empirical study on the decomposition method for energy analysis. On his reports Ang [6] stated that the decomposition methodology has been used to study various energy fields such as: Energy supply/demand, Energy-related gas emissions, Material flows and dematerialization, National energy efficiency and monitoring as well as Cross-country analysis. Ang *et al*. [8] also reported the study on IDA methodology using both Divisia and Laspeyres indices with recommendation towards Log Mean Divisia Index (LMDI) in both additive and multiplicative forms.

Sun [4] has used the complete decomposition model where residuals are decomposed by the jointly created and equally distributed principle. Reddy and Ray [9] have applied this technique on the total decomposition approach and delivered an excellent result on the energy consumption and energy intensity analysis on the Indian manufacturing industries

Even the fact of energy issue in Indonesia manufacturing sectors as mentioned above, unfortunately there are not many studies on this particular subject. The few related studies are reported by Sitompul [10] on the CO_2 emissions in Indonesia Manufacturing sectors and by Irawan *et al* [11] which suggested that pulp and paper as well as non-metallic mineral industries with high energy intensity. Irawan also noted that the driving force behind the change of energy intensity on 2002 and 2006 are both economic factors (structural effects) and efficiency factor.

This study uses the annual industry statistic data that fall into three digits category of National Manufacturing Classification (KBLI 2005) adopted from ISIC 1990 REV 3.1 classifications for the medium and large manufacturers. We use these demand-side data from Central Statistic Agency (BPS) with no correction upon the supplier-side data to avoid any possibility of demand allocation approach and the unconsumed demand such as losses, thermal efficiency of central power generation, terminal inventory and any leakages does not representing the actual consumption of the target industry.

The impacts of efficiency-related factor as well as the structural and production factors on both energy intensity and consumption of the target industry are among the objective of this study. This information will sort out the industry sector with efficiency-related issues for further study and the decision making input on the energy policy.

2. Method

The total decomposition approach using Sun's complete decomposition model as explained by Reddy and Ray has been applied in this study with very minor modification by excluding the types of energy it has been used to map the target industry based on their efficiency-related factors. The energy intensity is described as the sum of energy consumption of each sector divided by its total value added:

$$e_t = \sum_{i=1}^{m} \frac{E_{it}}{P_t} = \sum_{i=1}^{m} \frac{E_{it}}{P_{it}} . \frac{P_{it}}{\sum_{i=1}^{m} P_{it}} = \sum_{i=1}^{m} e_{it} . A_{it} \tag{1}$$

The changes of energy intensity between two different periods of time can be explained as follows:

$$\Delta e_t = \sum_{i=1}^{m} \left[\Delta e_{it} . A_{it} + \frac{1}{2} \Delta e_{it} . \Delta A_{it} \right] + \left[e_{it} . \Delta A_{it} + \frac{1}{2} \Delta e_{it} . \Delta A_{it} \right] \tag{2}$$

Where:

E_{it} = Energy consumption of sector i
P_t = Total Value Added of manufacturing at time t (Rp)
P_{it} = Value added of sub sector i (Rp)
A_{it} = Value added contribution of sector i to total manufacturing
e_{it} = Energy Intensity of sector i

The first part of equation (2) explains the impact of Intensity changes caused by efficiency-related factors while the second part is related to the industry structural factor as follows:

$$\Delta e^{t}_{TMPeffect} = \sum_{i=1}^{m} \Delta e_{it} \left[A_{it} + \frac{1}{2} (\Delta A_{it}) \right] \tag{3}$$

This equation explains the energy intensity changes as the impact of technology changes and/or the Energy Management process.

$$\Delta e^{t}_{STeffect} = \sum_{i=1}^{m} \Delta A_{it} \left[e_{it} + \frac{1}{2} (\Delta e_{it}) \right] \tag{4}$$

While equation (4) above explains the changes of energy intensity as the impact of industry structural changes.

This study also decomposes the energy consumption with this following equation to segregate the efficiency-related factor with Structural and Production factors:

$$E_t = \sum_{i=1}^{m} E_{it} = \sum_{i=1}^{m} \frac{\sum_{j=1}^{n} E_{it}}{P_{it}} . \frac{P_{it}}{\sum_{i=1}^{m} P_{it}} . \sum_{i=1}^{m} P_{it} \tag{5}$$

The first part of above equation is related with the Energy Intensity factor, the second part is related with the Structural factor and the third part is related with the Production output factor.

Then the equation (5) can be rewritten:

$$E_t = \sum_{i=1}^{m} e_{it} A_{it} P_t \tag{6}$$

Where the changes of energy consumption between two different periods of time and which according to the jointly created and equally distributed principle the equation (6) can be written as follows:

$$\Delta E_t = \Delta e_{effect} + \Delta A_{effect} + \Delta P_{effect} \qquad (7)$$

Where:

Δe_{effect} is the change on the Energy Consumption as the impact of the changes of energy intensity

ΔA_{effect} is the change on the Energy Consumption as the impact of structural changes

ΔP_{effect} is the change on the Energy Consumption as the impact of production changes.

The analysis divided the data into three different time periods, i.e. of 2001-2002, 2002-2005 and 2006-2007. Three different time frames are reflecting the consumption trends and also to avoid the data bias in 2006 as the result of national industry census that add 9000 new additional industries into the category of medium and large scale manufacturers. The total populations of industry within this category which is about 28000 by end of 2007 which according to ISIC REV 3.1 belongs to 23 industry sectors and mostly are food processing and garment industry.

The six energy intensive industry sectors that are the object of this study are composed of 26 subsector industry. The energy demand structure as well as the structure of value added contribution to the total value added of these six industry sectors mostly come from only 13 subsectors, while the other subsectors contribution to added value is about 20% or less.

3. Results and Discussion

Fig. 2 shows the energy intensity of six target industry sectors are remarkably well above the average of total manufacturing sector. This high energy intensity could be driven by either efficiency factors or non related efficiency factors.

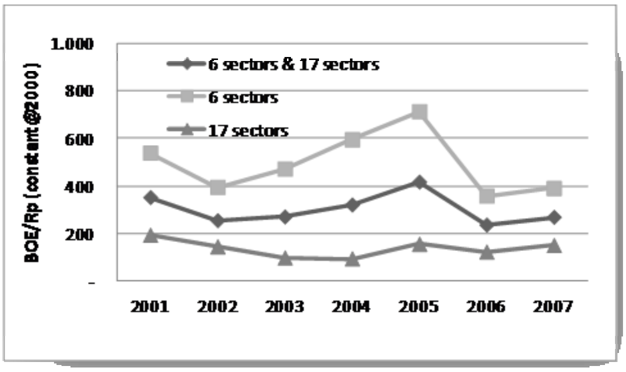

Fig 2. Energy intensity of six sectors compares to total manufacturing sectors

The energy consumption in the period 2001 – 2002 was declining and the production output effect (P effect) as shown as arrow markers on Table 1 mostly shown downward direction. This massive production decline indicates that all industry has been pressured by economic circumstance. Although the production effect has less impact compared to both of Energy Intensity effect and Structural effect during this period, the decline on production output has forced the industry to do significant structural changes (A effect) resulting in low energy intensity. This change effect analysis explains that the small changes on production output effect has triggered even bigger response on the energy intensity factors (e effect). In the other words the energy intensity decline during this period may not only related to efficiency when we combined it with the other two indicators of structural effect and Production output effect.

Table 1 Decomposition result of energy consumption

	2001-2002			2002-2005			2006-2007		
	e effect	A effect	P effect	e effect	A effect	P effect	e effect	A effect	P effect
Food processing & preservation (151)	↑ 3.235.120	↓ (307.371)	↓ (713.500)	↓ (9.537.619)	↑ 1.763.122	↑ 929.102	↑ 914.599	↑ 337.483	↑ 258.797
Spinning, Weaving & Finishing Product (1	↓ (12.622.189)	↑ 1.335.545	↓ (311.636)	↑ 11.130.155	↓ (15.732.691)	↑ 3.521.542	↑ 1.759.996	↓ (1.343.733)	↑ 387.315
Chemical Product (242)	↓ (1.019.437)	↑ 90.989	↑ 329.554	↑ 990.636	↓ (587.331)	↑ 866.191	↑ 389.414	↑ 642.293	↑ 301.698
Basic Chemical (241)	↓ (1.340.862)	↓ (425.345)	↓ (91.736)	↑ 5.941.811	↑ 4.264.020	↑ 2.259.822	↑ 1.609.342	↓ (407.252)	↑ 294.095
Other food products (154)	↓ (1.797.166)	↑ 102.945	↓ (136.084)	↑ 524.889	↓ (438.027)	↑ 618.291	↑ 922.434	↓ (449.788)	↑ 209.188
Pulp (21011)	↓ (2.130.529)	↑ 101.426	↓ (39.026)	↑ 1.353.412	↓ (9.636.789)	↑ 307.329	↑ 588.229	↓ (3.648.465)	↑ 80.013
Basic iron and Steel (271)	↑ 2.210.415	↓ (185.093)	↓ (433.695)	↑ 2.015.382	↓ (9.962.345)	↑ 688.152	↑ 7.218.922	↓ (611.313)	↑ 543.162
Paper (2101)	↓ (411.995)	↓ (70.484)	↓ (72.059)	↓ (1.528.344)	↑ 1.487.240	↑ 496.918	↑ 1.597.140	↑ 625.019	↑ 220.507
Cement (264)	↑ 459	↓ (2.903.365)	↓ (2.394)	↑ 13.422.993	↑ 14.228.820	↑ 4.480.165	↓ (15.313.583)	↓ (647.445)	↓ (142.575)
Grainmill, Strarches & Animal feed (153)	↓ (421.555)	↓ (55.771)	↓ (78.260)	↑ 902.714	↓ (2.216.491)	↑ 310.515	↑ 1.138.591	↓ (1.210.413)	↑ 99.869
Non Ferrous Metal (272)	↓ (16.094)	↓ (390.475)	↓ (5.869)	↑ 1.162.705	↑ 1.276.445	↑ 460.230	↓ (232.630)	↑ 213.478	↑ 66.264
Knitting (173)	↓ (336.903)	↓ (76.538)	↓ (20.323)	↑ 148.675	↑ 497.766	↑ 241.863	↑ 1.650.268	↓ (99.986)	↑ 132.141
Glass and Glass product (261)	↓ (72.079)	↓ (845.875)	↓ (22.623)	↑ 210.386	↑ 1.337.237	↑ 503.066	↓ (101.368)	↓ (519.236)	↑ 8.340

Table 2 Decomposition result of energy intensity

	2001-2002		2002-2005		2006-2007	
	TMP effect	ST effect	TMP effect	ST effect	TMP effect	ST effect
Food processing & preservation (151)	↑ 32,91	↓ (3,13)	↓ (71,49)	↑ 13,54	↑ 5,98	↑ 2,21
Spinning, Weaving & Finishing Product (1	↓ (128,66)	↑ 13,38	↑ 84,48	↓ (117,64)	↑ 11,51	↓ (8,78)
Chemical Product (242)	↓ (10,38)	↑ 0,92	↑ 7,48	↓ (4,40)	↑ 2,54	↑ 4,20
Basic Chemical (241)	↓ (13,62)	↓ (4,30)	↑ 44,54	↑ 31,91	↑ 10,52	↓ (2,66)
Other food products (154)	↓ (18,29)	↑ 1,04	↑ 3,96	↓ (3,29)	↑ 6,03	↓ (2,94)
Pulp (21011)	↓ (21,70)	↑ 1,01	↑ 10,73	↓ (71,96)	↑ 3,87	↓ (23,83)
Basic iron and Steel (271)	↑ 22,49	↓ (1,89)	↑ 15,58	↓ (74,54)	↑ 47,20	↓ (3,99)
Paper (2101)	↓ (4,19)	↓ (0,72)	↓ (11,43)	↑ 11,26	↑ 10,44	↑ 4,08
Cement (264)	↑ 0,00	↓ (29,55)	↑ 100,35	↑ 106,41	↓ (100,03)	↓ (4,16)
Grainmill, Strarches & Animal feed (153)	↓ (4,29)	↓ (0,57)	↑ 6,89	↓ (16,58)	↑ 7,46	↓ (7,90)
Non Ferrous Metal (272)	↓ (0,16)	↓ (3,97)	↑ 8,70	↑ 9,56	↓ (1,52)	↑ 1,40
Knitting (173)	↓ (3,42)	↓ (0,77)	↑ 1,11	↑ 3,74	↑ 10,79	↓ (0,65)
Glass and Glass product (261)	↓ (0,72)	↓ (8,60)	↑ 1,57	↑ 10,05	↓ (0,67)	↓ (3,40)

During the period 2002-2005 and 2006-2007 demand of total energy increased. The production effect marker of all industries (except cement in 2006-2007) has shown the increasing direction that related to the raise of the production output. While the markers of the other two determinants shown various directions for each industry sector and indicated substantial rule on the demand increase compared to the production factor.

The result of decomposition on the energy intensity into efficiency-related factor and Structural factor is shown in Table 2. The results show various combinations of Intensity and Structural effects. Some industries are strongly affected by either Intensity effect or by both Intensity and Structural effects and only very few industries that strongly determined by the Structural effect.

The result of these two decomposition approaches gives guidance to split these industries into three different groups regarding to their efficiency-related factor and Structural factor.

The industry with higher efficiency-related factor compared to the Structural factor belongs to the first group. For those with high Structural impact goes to the third group, while the industries in which both impact are quite comparable are grouped in between as the second group.

Most of industries fall into the first group. Those industries consist of Food Processing (151), other food industry (154), Knitting (173), Paper (2101), Basic Chemical (241), Chemical product (242) Cement (264) and Basic Metal and Steel (271). There are only few industries falls into the third group which are strongly impacted by the structural factor. These industries consist of Pulp industry (21011) and Glass Product (261). Industries that have comparable impact from both Intensity and structural factors are Grain mill, Starches & Animal feed (153), Spinning, Weaving & Finishing Product, (171) and Non-Ferrous Metal (272).

Each figure below represents each group that already discussed on the above paragraph. Fig. 3.(a) shows the Efficiency-related factor consistently as the main driver for food processing industry (151) while Fig. 3.(b) and Fig. 3.(c) show the comparable impact from both factors and the very strong impact from Structural factors. Fig. 3.(a) is represents industries with strong efficiency impact on energy intensity, Fig. 3.(b) industries with comparable impact from both efficiency and structural factor on the energy intensity while Fig. 3.(c) industries with strong structural impact on energy intensity.

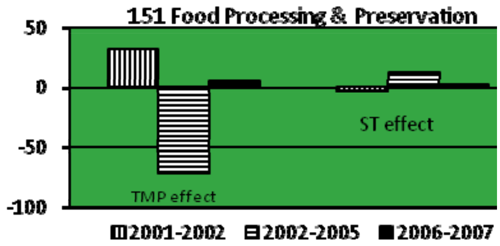

Fig. 3. (a) Strong Efficiency Impact

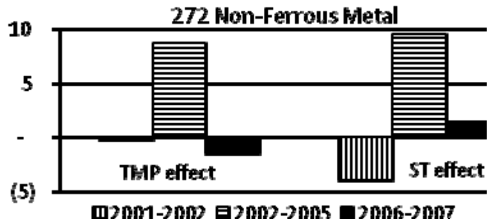

Fig. 3. (b) Comparable impact from both Efficiency and Structural

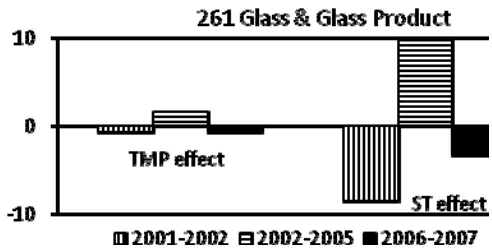

Fig. 3. (c) Strong Structural impact

4. Conclusion

The industries sector with strong impact by the intensity factors as well as those with comparable impact by both intensity and structural factors have big room for technology and energy management improvements. While both glass and pulp industries are among the highest energy intensity and these industries are strongly impacted by the structural factor instead of efficiency related factors. Substantial structural approach should be applied significantly the overall energy intensity of manufacture sector to these industries on the top of efficiency aspect consequently reduces.

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