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Estimation of Indonesia's Energy Demand to 2030 and Alternatives Scenario to Reduce Oil Dependence

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Abstract. The impacts of high dependence on oil on the economy have encouraged many countries to start eliminating or sharply reducing their dependence on oil consumption. As an oil importer as well as oil and gas producer country, Indonesia seeks to do the same thing by eliminating fuel subsidies, shifting to gas, and developing renewable energy. The oil price affects the economic and energy policies and impacts the efforts of reducing oil dependence.
Using an econometric model of Indonesia’s energy that is constructed based on its energy balance model, this paper will examine factors that influence the oil demand in Indonesia. It will estimate the country’s energy needs from 2017 to 2030 and simulate various alternative strategies to deal with oil dependencies, such as an increase in the refinery capacity, and a shift from oil to gas in the transportation sector.
This paper suggests that shifting from oil to gas in the transportation sector will be able to reduce oil dependency, while the alternative of increasing refinery capacity to 3 million barrel per day will be an opportunity to support greater short-term energy security and economic returns.

Keywords: Economy, econometric, energy, oil dependence, sustainable energy security

1. Introduction

The issue of oil has always been debated. While the world economy is highly dependent on oil, it is a limited non-renewable resource; and carbon emissions resulting from its use have a negative impact on the environment. Many efforts are being made by various countries to reduce the dependence on oil through diversification and conservation. European countries plan to become a carbon-free zone by boosting the use of non-fossil sources of power. The US encourages clean-coal technology, hydrogen, and biofuel. India plans to switch to gas and LNG imports and pursue nuclear power. China also plans to build more nuclear plants (Longmuir and Alhajj, 2007) in addition to expanding its investment in renewable energy and phasing out coal (Kejun and Woetzel, 2017). Nevertheless, the world projection of oil demand until 2040 is still high and dominated by transportation sector (Cordesman, 2015).

The effect of oil dependence and scenarios to reduce it vary between oil importing and exporting countries. They are influenced by various motivations, incentives, and political tension (Deniz, 2018). Cherfi and Kourbali (2012) explain four hypotheses in relation to energy consumption, economic growth, and strategies to reduce the dependency. *First*, the neutrality hypothesis states that there is no causality between economic growth and energy consumption. Under this hypothesis, the policies aimed at conserving energy resources fail to hinder economic growth (Asafu-Adjaye, 2000; Jumbe, 2004). *Second*, the feedback hypothesis states that there is a bidirectional causality running between economic growth and energy consumption. Energy consumption and economic growth are

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complementary, and the increase in energy consumption stimulates economic growth, and vice-versa. *Third*, conservation hypothesis determines the unidirectional causality running from economic growth to energy consumption. When causality runs from economic growth to energy consumption, an economy has less dependence on energy; thus energy conservation policies, such as phasing out energy subsidies, may not adversely affect economic growth (Mehrera, 2007). *Fourth*, the growth hypothesis evaluates the existence of the unidirectional causality running from energy consumption to economic growth (Narayan and Smyth, 2005; Ghosh, 2002). According to the growth hypothesis, a country's economy is energy dependent; in this case, the reduction of energy consumption will lead to a fall in economic growth because energy consumption is a prerequisite for economic growth (Ebohon, 1996).

The fluctuation of oil price compels economies to change their energy demand. For an oil importer, the increase in oil consumption and international oil price will affect the balance of trade, burden the currency depreciation (Restyani, 2012; Resosudarmo, 2002; Mishkin, 2001; Said et al., 2001), and cause higher cost of imports and lower value of exports, resulting in the decrease of real national income (Sukirno, 2011; Surjadi, 2006). The high cost of subsidy will burden the state budget (Sawitri, 2006), exacerbating fiscal balance (CSIS, 2011) and restricting the state budget for physical infrastructure development. The decline in oil price has an adverse impact on oil-exporting countries and a favorable impact on oil importers. For oil exporters, lower oil prices mean lower exports and lower revenue, and negatively impact its fiscal balance and economy. In contrast, oil importers get the benefits of lower energy cost via increased consumer spending, lower production costs for industries, and create an opportunity to reduce energy subsidies. There is a large number of papers examining how oil price affects the economy of oil exporter and/or importer countries, and what policies help to address the resulting consequences. Michelle Luk (2016) and Millington (2016) examine the effect of low oil price on oil-exporter countries, Albert and Gillet (2015) analyze both oil-exporter and importer countries.

As Indonesia is an oil importer as well as oil and gas producer country, oil plays two roles in its government finance: it is a source of revenue and an expense paying for fuel subsidy and crude oil imports. The fall in oil price since mid-2014 has had a multi-layered effect on Indonesia's economy. *First*, it created a momentum for reforming energy subsidies. *Second*, consumer spending increased in response to lower fuel cost, but it was also restrained by higher prices on imported goods and services due to the depreciation of the Indonesian rupiah. Second, the government collected less revenue from oil and gas sector, even though the spending on energy subsidies was reduced. *Third*, there has been an increase in investment in the non-resources sector as a result of reallocating energy subsidies to infrastructure. *Fourth*, investment and employment in the resources sector decreased, since oil price is commonly used by companies as a basis for approving and developing projects (Johnston, 2006). *Fifth*, cheaper oil price will make renewable energy sources such as solar and wind power less attractive. But Indonesia has set a target to have renewable energy provide 23% of total energy supply by 2025. The target is to be achieved through attractive incentives and easily available permits for renewable energy development, removal of fuel subsidies, energy conservation measures, energy diversification (Indonesia's Energy Outlook, 2016).

The high dependence on oil and the negative impact on the economy raise concerns about Indonesia's energy security sustainability and its economy in the future. The purpose of this study is to present economic impacts on Indonesia's energy demand and oil dependence. Using an econometric model of Indonesia's energy that is constructed based on its energy balance model, this paper will examine factors that influence oil demand across all sectors in Indonesia. The model will estimate Indonesia's energy needs up to 2030, starting in 2017 and based on data from 1990 until 2016. Finally, it will simulate two alternative strategies to deal with oil dependency: a shift from oil to natural gas in transportation sector and an increase in refinery capacity.

A shift from oil to gas was chosen due to transportation sector being the largest user of oil fuel worldwide (Cordesman, 2015). Some countries have introduced various alternative mechanisms to reduce oil consumption in transportation sector, such as (Fergusson et al, 2006): (1) the use of more fuel-efficient vehicles, by means of hybrid car technology development, (2) the use of alternative fuels for vehicles, e.g. biofuels and compressed natural gas (CNG), (3) more efficient use of fuel in transportation system with emphasis on public transportation and infrastructure, and (4) using fewer vehicles to reduce the amount of fuel needed. In Indonesia, some efforts have been made to replace oil fuel with biofuel, natural gas in several big cities, electricity for electric trains, introduction of more buses and trains, and improvements in transportation infrastructure, especially in Jakarta. However, the impact of these measures remains low. Considering that Indonesia's gas reserves in 2015 were 150.4 trillion cubic feet (TCF), including 101.54 TCF of proven reserves and 48.85 TCF of potential reserves, and half of its production is used for exports, the use of natural gas for transportation sector should be maximized to reduce dependence on oil. Substituting oil fuel with CNG is a commonly used program in countries like Iran, Thailand, Pakistan, Bangladesh, and China.

The addition of refinery capacity was chosen as an alternative strategy to accommodate government regulation No.79/2014 on national energy policy related to operational reserves. According to the regulation, Indonesia's fuel stock is corresponding to less than 25 days' worth of domestic consumption. Therefore, Indonesia should pay more attention to the refining sector as an important component in achieving energy security by ensuring the total energy demand for petroleum fuels is met from domestic and import supplies. Indonesia should consider India's experience, which has been struggling to increase its domestic crude oil production and is positioning itself as a major refining hub. In 1985, Indonesia and India had the same refinery capacity of 867 thousand barrels per day (BPD). However, Indian refinery industry has expanded much faster to reach the current capacity of 5.3 million BPD, while Indonesia's utilized capacity is currently at 885 thousand BPD of total 1.16 million BPD. Indonesia's oil demand in 2016 was 1.6 million BPD with the difference between the refinery capability and the need being only 55%.

2. Methodology

This study developed Atty et al.'s (2013) previous study by adding research period data, from 1990 to 2016, and introducing some policy changes into the model. The research was conducted in four stages:

1. Building the energy balance model. Indonesia's energy model in figure 1 is constructed by modifying IEA's world energy model. Non-fossil energy sources (i.e., hydropower, geothermal, and biomass) were included into the model that reconciles the flow of energy supply, transformation, and the final demand which is disaggregated per sector of energy user and type of energy. In addition, policy changes variables are also included into the model, such as revocation of subsidies in 2015, changes in PSC sharing split on oil production forecast, etc. A total of 79 variables were included in 48 equations, consisting of 26 behavioral equations and 22 identities, as shown in table 3.
2. Solving the model using simultaneous econometric approach by employing two-stage least squares (2SLS) regression analysis. In this section, the relationship and correlation among different variables in the economy, energy, and policy were tested.
3. Validating the estimated simultaneous equation by generating an ex-post forecast (Greene, 2008) for the period of 2010 to 2016 to determine the model's ability to predict the variable. The forecast will be evaluated in terms of the accuracy and the ability to predict data changes by using the root mean square percentage error (RMSPE) and U-Theil's (measure of forecasting quality) tests. A lower RMSPE and U-Theil's indicate better performance in predicting turning points in the data.
4. Forecasting the baseline energy demand and simulating various alternative strategies to deal with oil dependency by changing the value of exogenous variables. Alternative strategies include an increase in refining capacity and optimization of the energy diversification in the transportation sector by switching from oil to gas. Building a baseline model assumption includes population growth, economic growth, energy price, policy and regulation change. The annual population rate is assumed to fall 0.6% until 2030; the growth trend continues to decline due to increasing public

awareness of prosperous, healthy and educated family. Considering declining economic growth in the last five years due to slowing global economic growth and current economic conditions, it is assumed that GDP will grow at an average of 5.4% per year until 2030. The energy price assumption is based on Southeast Asia Outlook by the International Energy Agency (IEA) from 2015; price increase of 1.2% per year for coal, 0.9% for gas, and 2.3% for fuel.

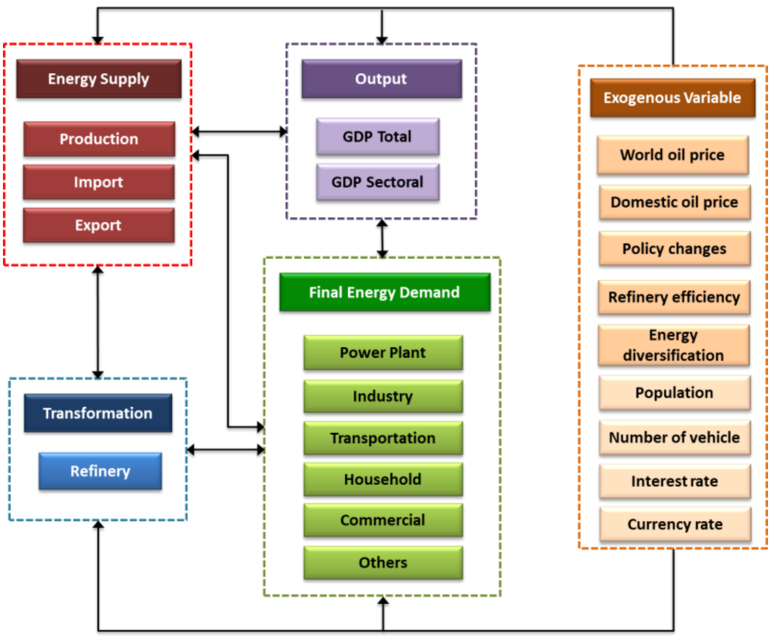

Figure 1. The energy balance model scheme

3. Results and Discussion

3.1. Model Estimation

The estimation results from econometric modeling of energy balance for Indonesia's oil demand in all economic sectors for the period of 1990 to 2016 are shown in table 1. It is concluded that domestic fuel price has a negative effect on oil demand in all sectors except power generation. This is because it is not easy to change the energy source due to price change, and the sector is still getting subsidies from the government. The declining world oil price since mid-2014, indirectly affected the oil fuel and energy demand because at the same time the government also revokes fuel and energy subsidies. In 2015-2016, domestic gasoline price decreased but its consumption slightly declined due to the slowing of Indonesian economy. The income affects the oil demand in the form of sectoral GDP and GDP per capita that has a significant correlation and positive effect on oil demand. The household sector is the only exception because people are already switching to subsidized LPG and obtaining Kerosene is difficult. The effect of natural gas switching program on oil demand is seen in several variables such as the ratio of fuel and gas demand, gas demand in the sector, and gas prices.

Table 1. The 2SLS estimation result of sectoral energy demand

Endogenous Variable	Exogenous Variable	Coefficient	Std. Error	t-Statistic	Probability	R^2
Oil demand in commercial sector,	C	-12725.7700	3518.8170	-3.6165	0.0003	0.9103
	GDP	18867.1300	4393.2110	4.2946	0.0000	

Endogenous Variable	Exogenous Variable	Coefficient	Std. Error	t-Statistic	Probability	R^2
COMOLT	Ratio oil to gas in commercial	0.4667	0.1259	3.7070	0.0002	
	COMOLT(-1)	0.0006	0.0005	1.2497	0.0920	
Oil demand in power generation sector, EGOLT	C	-192221.6000	43586.2600	-4.4101	0.0000	0.9172
	Diesel price	0.0031	0.0123	0.2503	0.0802	
	Gas demand in power generation sector	-0.6974	0.1534	-4.5449	0.0000	
	Population	1.2425	0.2395	5.1873	0.0000	
Oil demand in industrial sector, IDOLT	C	16420.5300	9515.9690	1.7256	0.0851	0.8534
	Diesel price	-0.0195	0.0131	-1.4909	0.0367	
	Gas demand in industrial sector	0.1485	0.1010	1.4704	0.0421	
	GDP industrial sector	0.0093	0.0412	0.2253	0.0218	
	IDOLT(-1)	0.7005	0.1249	5.6081	0.0000	
Oil demand in transportation sector, TROLT	C	14544.81	15873.18	0.9163	0.0027	0.9909
	Gasoline price	-0.1079	0.01338	-8.0649	0.3600	
	LGV price	0.2271	0.03047	7.4551	0.0000	
	GDP/capita	9686.9670	2796.9350	3.4634	0.0006	
	Number of vehicle	2.1995	0.2203	9.9842	0.0000	
Oil demand in residential sector, REOLT	C	-265602.0000	82903.6700	-3.2037	0.0015	0.8529
	LPG price	-0.0757	0.0215	-3.5157	0.0005	
	Ratio oil to gas	203334.8000	70114.8800	2.9000	0.0039	
	Number of household	4.2145	0.5332	7.9048	0.0000	
	GDP/capita	-4539.7100	3684.5450	-1.2321	0.0186	
Oil demand in other sector, OCOLT	C	6541.1930	5203.6090	1.2570	0.0094	0.8774
	Diesel price	-0.0025	0.0022	-1.1658	0.0443	
	GDP other sector	0.0091	0.0086	1.0621	0.0887	
	OCOLT(-1)	0.6015	0.1474	4.0814	0.0001	

3.2. Model Validation

The models which are built based on a historical period from 1990 to 2009 are validated by withholding six years of data (2010-2016) when specifying and estimating the model. This process generates an ex-post forecast to determine how well the models predicted the endogenous variables. Table 4 presents the validation result of the energy balance model, illustrating the validation indicators in 26 structural equations in the model, and suggests that the estimated model is good enough to provide an accurate estimation value. The analysis based on RMSPE shows that 24 out of 26 structural equations in the model have smaller RMSPE values of 20% with an average deviation of 7.4%. The smaller forecast error value indicates the model's reliability to make a prediction. The U-Theil's test shows that all structural equations in the model have values smaller than 0.15, indicating that the model can be used for the better forecasting simulation analysis. The small value of bias proportion (UB) below 0.2 indicates nonsystematic bias resulting from all equations, except the equation of GDP in the commercial sector (COMPt) which has a UB value above 0.2. However, higher determination coefficient value (R-square) of COMPt (97.1%) indicates that all exogenous variables have been able to explain the GDP in the commercial sector, so the revision of the equation will not be necessary. The small value of variance proportion (UV) below 0.3 indicates that the models have been able to replicate the fluctuation pattern of the actual series. Finally, the higher value of covariance proportion (UC) close to 1 indicates that the model is ideal for forecasting.

3.3. Forecast and Simulations

Currently, the share of Indonesia's oil reserves is only 0.2% of the total world oil reserves. Indonesia's oil production declined 4.3% in the last five years due to mature oil production wells and limited new production wells. At the beginning of 2017, the Indonesian government introduced PSC gross split under Ministry of Energy and Mineral Resource (MoEMR) law No. 08/2017 which changed the upstream fiscal terms to create a flexible PSC in order to account for uncertainties in field size, reservoir condition, oil price, production, economics, etc. This change is important for the government to encourage PSC operators to streamline and operate more effectively and efficiently. It will also increase state revenues by eliminating the cost recovery system and removing the need for related project budget scrutiny by the regulator. The regulation was then revised into MoEMR No.52/2017 to provide more economic benefits to the PSC contractors. It is assumed that the implementation of the new regulation will slow the production decline by 2.2% until 2030.

The drop in oil prices since mid-2014 followed by the world economic slowdown has had an impact on the slowing economic growth and energy consumption in Indonesia in the last two years. To support the average economic growth of 5.4% per year, it is estimated that energy demand needs to increase by 4.3% per year, or from 1,648 million barrels oil equivalent (BOE) in 2016 to 3,221 million BOE in 2030, as shown in figure 2. The lower rate of energy demand growth compared to GDP is due to the currently occurring shift where the commercial sector is the largest GDP producer (6.9% growth), and it consumes less energy.

In the 2030 energy mix, oil share is predicted to decline from 33% to 30%, and its position as the leading energy source is slightly changed by gas (17%) and coal (26%). Electricity share increases from 8% to 11% as the shift in lifestyle takes place along with the economic improvement and technology development. The increase in renewable's share is predicted to remain small under the 'business as usual' scenario, where their development is still constrained by bureaucratic licensing, investment and price.

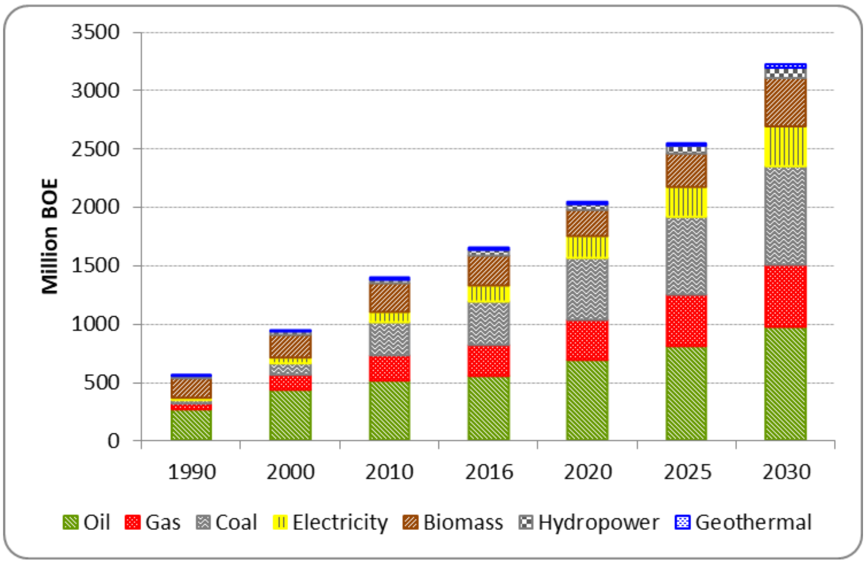

Figure 2. Chart of Indonesia's energy demand

Transportation still dominates oil use in Indonesia with a share of 79% in 2030 (figure 3) and grows 5.5% per year from 922 thousand BPD in 2016 to 2.2 million BPD in 2030 along with the increase of GDP per capita and a number of private vehicles. On the contrary, fuel consumption in other sectors (residential, industry, commercial, power generation, and others) decreases. Oil demand for electricity generation declines to 4% per year as well as oil demand for the commercial sector, which falls by 5.6% per year until 2030. In the household sector, Kerosene is fully replaced with LPG and city gas by 2021.

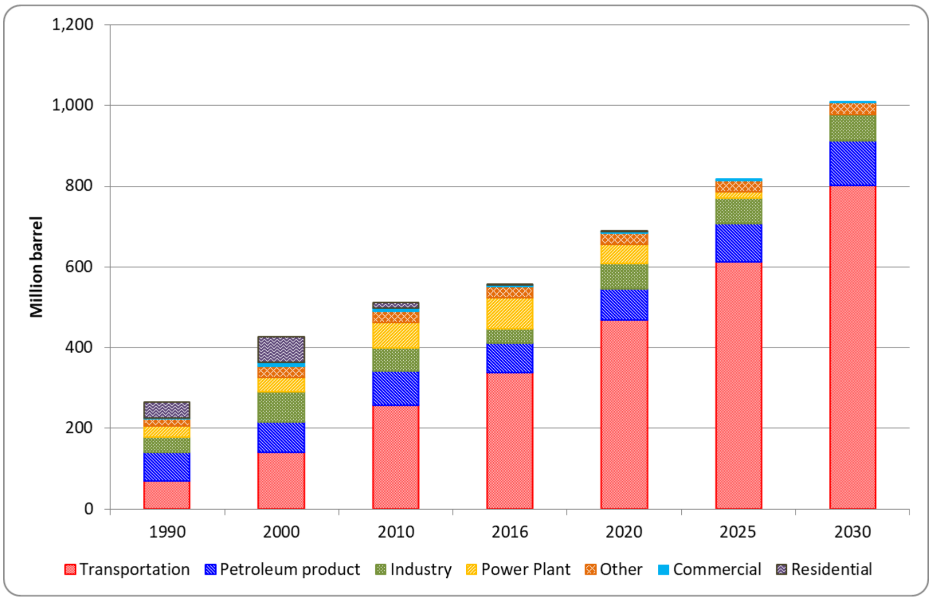

Figure 3. Indonesia Oil Demand 1990-2030

The number of vehicles is predicted to grow 5.6% per year. In Indonesia, car ownership is a symbol of prestige, and its ownership is associated with rising income and people's ability to afford higher-end private transportation. Furthermore, estimation results show that if it is assumed that oil price range is in \$60-80/barrel up to 2030, the government's efforts to build mass transportation facilities will fail to significantly reduce fuel consumption, given that taxi transportation is expected to continue to grow.

Without active energy diversification, the share of oil fuel in transportation sector will remain large, at 96%, while the rest of 3% and 1% will come from biodiesel and natural gas respectively. According to the simulation that examines intensive CNG conversion program until 2030 designed to gradually convert 10% of total vehicles, especially for public transportation (i.e., buses, taxies, and government vehicles). The fuel consumed by different transportation modes and activities may vary. Applying energy intensity in transportation sector from Sugiyono (2013) to the calculation, this program is projected to convert about 8 million vehicles in 2030 that would reduce consumption of total oil fuel demand in transportation sector by 9%, a decrease of about 205 thousand BPD of total 2.2 million BPD.

In addition to the necessary supply of gas, the availability of CNG fueling stations is also required. This scenario assumes that one CNG fueling station will serve 5,000 cars and buses. The simulation estimates that the government should add more than 63 gas stations in 2018 and increase this number to 1,600 gas stations in 2030. Therefore, the government is advised to immediately prepare a long-term plan of integrated and available gas infrastructure, such as fuel storage, pipelines, LNG receiving terminal units, mini LNG, and CNG carriers for delivery and distribution to fueling stations from gas sources in remote areas. Thus, real-sector economy will grow, create jobs, and reduce oil dependency.

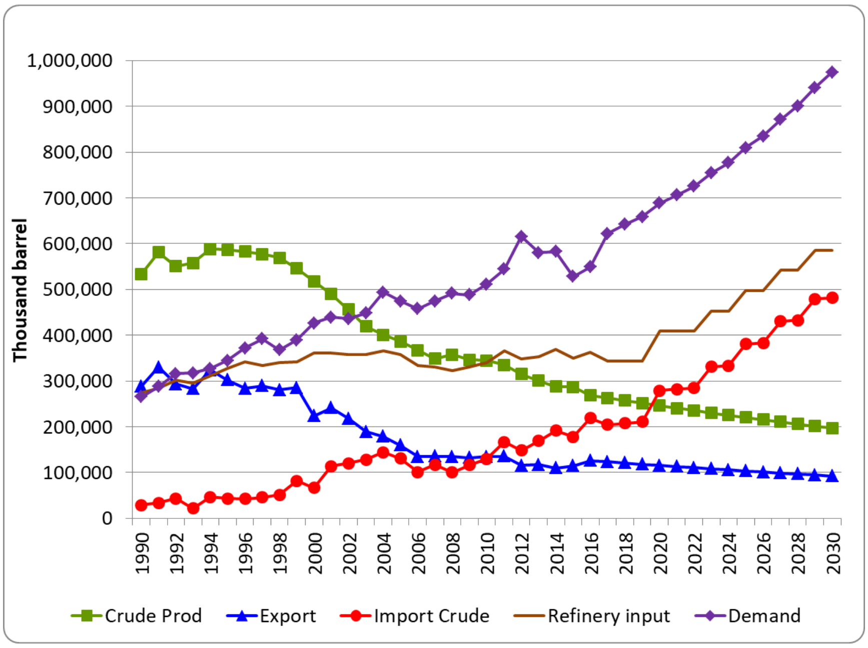

Figure 4. Crude oil and fuel supply and demand

The study also points out that although oil share is expected to decrease, the demand for fuel until 2030 continues to increase due to economic and population growth. At the same time, refinery capacity remains the same until 2019 causing an increase in both crude and fuel imports. Starting in the next three years, as shown in figure 4, additional refinery capacity is expected to reach 2 million BPD or 727 million barrels in 2030. Thus, increasing imports of both crude and fuel will contribute to meet the national fuel demand of 2.2 million BPD. The import dependency ratio will increase from 41% in 2016 for crude oil and 24% for fuel to 82% and 43% respectively for crude oil and fuel in 2030. This indicates that Indonesia is beginning to experience in high dependency on the crude oil supply from abroad, which greatly affects its national energy security.

Alternatively, by increasing the refinery capacity, Indonesia would reduce its dependence on the imported fuel and petroleum products by 2028. The expansion of crude oil refinery capacity to 3 million BPD (1,095 million barrels) would mean a 50% increase on the baseline, even though 90% of the crude or 2.7 million BPD would be obtained from imports in 2030. The simulation on table 2 estimates total import value from both fuel and crude import for this scenario in 2030 is 72,883 MM$

or 11% lower than its baseline 81,975 MM$. The value added from refining sector and the export of fuel and petroleum products also estimate to increase by more than 20%, which are economically beneficial. Thus, the addition of this refinery capacity calls for government action to immediately build crude oil storage facilities for refinery input as well as for strategic crude oil storage.

Table 2. Import estimation in 2030

Variable	Baseline	Case 2. Increase Refinery capacity
Crude import, Mbbls	481,709	990,631
Fuel import, Mbbls	420,596	-
Total oil import in value, MM$	81,975	72,883

To accommodate the increasing demand for electricity, in 2015, Indonesia set a target of 136 GW of power capacity by 2025 and 430 GW by 2050, compared with the current capacity of 55.5 GW. Based on the General Plan for National Electricity Development (RUKN), 80.5 GW of capacity will be added over the period of 2016-2025, dominated by coal (43% of total additional capacity), followed by natural gas (29%), hydro (18%), and geothermal (8%). This program is very ambitious considering that the additional capacity represents double Indonesia's installed power capacity. The emerging market of new power users is needed, including an expanding industrial sector, household sector switch to the electricity-based home appliances, and transportation sector developing the use of an electric vehicle. Delayed experiences of similar programs in 2005-2014 demonstrate that there are some challenges that need to be addressed. These include licensing, and land acquisition issues, lack of financing, delays in government-backed loans, grid infrastructure constraints, construction setbacks, and various technical difficulties (Cornot-Gandolphe, 2017). Therefore, excess capacity delays in achieving program targets are likely.

To support the additional 80.5 GW of power capacity supply that is expected to be on-stream in 2030 or an increase of 5.4 GW per year, the coal exports are expected to decline in the future, from 77% in the last five years to 66% in 2030 due to rising domestic demand.

4. Conclusion

Indonesia's energy demand is expected to double by 2030, from 1,648 million barrel oil equivalent (boe BOE) in 2016 to 3,221 million BOE in 2030. Coal and gas will replace oil fuel in the energy mix to meet the needs of power generation, industrial, and transportation sectors. There will also be an increase in electricity demand.

The average growth of oil demand by 3.5% per year has implications for Indonesia's dependency on both crude oil and oil product. This paper shows that shifting from oil to gas in the transportation sector will be able to reduce oil dependency, while the alternative of increasing refinery capacity to 3 million BPD will be an opportunity to support greater short-term energy security and economic returns.

A number of benefits derived from diversification program in transportation sector have implications in formulating integrated policy in energy sector and the automotive industry, some of which are ensuring the availability of gas supply and infrastructure, conversion facilities, and sufficient number of gas stations that would ease people to switch to natural gas vehicles (NGVs).

Future research is required to discuss the obstacles in the implementation of strategies to reduce oil dependency, and the long-term impact of additional refinery capacity on the environment, economy and crude supply.

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Appendix A

Table 3. Endogenous and Exogenous Variable

No	Code	Variable	Unit	No	Code	Variable	Unit
Endogenous Variable							
1	COMECT	Total Energy Consumption in Commercial Sector	Thousand Barrel	25	IDOLT	Consumption of Oil Fuel for Industrial Sector	Thousand Barrel
2	COMEGT	Consumption of Electricity in Commercial Sector	Thousand Barrel	26	IMOLT	Oil Import	Thousand Barrel
3	COMGT	Consumption of Gas in Commercial Sector	Thousand Barrel	27	INDPT	GDP of Industrial Sector	Trillion Rupiah
4	COMPT	GDP of Commercial Sector	Trillion Rupiah	28	OCOLT	Consumption of Oil Fuel in Other Sector	Thousand Barrel
5	COMOLT	Consumption of Oil Fuel in Commercial Sector	Thousand Barrel	29	OCPT	GDP of Other Sector	Trillion Rupiah
6	ECT	Total Final Energy Consumption	Thousand Barrel	30	OTPPRT	Refinery Ratio	%
7	ECGT	Gas Consumption	Thousand Barrel	31	OTPPT	Petroleum Refinery Transformation	Thousand Barrel
8	ECEGT	Electricity Consumption	Thousand Barrel	32	PDBT	Total GDP	Trillion Rupiah
9	EGGT	Consumption of Gas in Electr. Generation Sector	Thousand Barrel	33	RECLT	Consumption of Coal in Residential Sector	Thousand Barrel
10	EGPT	GDP in Electrical Generation Sector	Trillion Rupiah	34	REBIOT	Biomass Consumption	Thousand Barrel
11	EGECT	Total Energy Consumption in Electr. Gen. Sector	Thousand Barrel	35	REECT	Total Energy Consumption in Residential Sector	Thousand Barrel
12	EGCLT	Consumption of Coal in Electr. Generation Sector	Thousand Barrel	36	REEGT	Consumption of Electricity in Residential Sector	Thousand Barrel
13	EGGTT	Geothermal Consumption	Thousand Barrel	37	REGT	Consumption of Gas in Residential Sector	Thousand Barrel
14	EGHYT	Hydropower Consumption	Thousand Barrel	38	REOLT	Consumption of Oil Fuel in Residential Sector	Thousand Barrel
15	EGOLT	Consumption of Oil Fuel for Electricity Generation	Thousand Barrel	39	RFCRT	Crude Oil Input for Refinery	Thousand Barrel
16	EXGT	Gas Export	Thousand Barrel	40	TRECT	Total Energy Consumption in Transport Sector	Thousand Barrel
17	EXCLT	Coal Export	Thousand Barrel	41	TROLT	Consumption of Oil Fuel in Transport Sector	Thousand Barrel
18	EXOLT	Crude Oil Export	Thousand Barrel	42	TRPT	GDP of Transport Sector	Trillion Rupiah
19	FCCLT	Coal Consumption	Thousand Barrel	43	TRRTGT	Consumption of Gas in Transport Sector	Thousand Barrel
20	FCOLT	Oil Fuel Consumption	Thousand Barrel	44	VEHI	Number of Vehicle	Thousand
21	IDCLT	Consumption of Coal in Industrial Sector	Thousand Barrel	45	YBBMT	Oil Fuel Production	Thousand Barrel
22	IDECT	Total Energy Consumption in Industrial Sector	Thousand Barrel	46	YNBBMT	Non-Oil Fuel Production	Thousand Barrel
23	IDEGT	Consumption of Electricity in Industrial Sector	Thousand Barrel	47	SCRT	Crude Oil	Thousand Barrel
24	IDGT	Consumption of Gas in Industrial Sector	Thousand Barrel	48	SBBMT	Oil Fuel Supply	Thousand Barrel
Exogenous Variable							
No	**Code**	**Variable**	**Unit**	**No**	**Code**	**Variable**	**Unit**
1	CRBLNCT	Crude oil Stock Differences	%	8	JRT	Number of Residential	Thousand Barrel
2	EXCHT	Exchange Rate	Rupiah	9	OGR	Oil & Gas Cons. Ratio	%
3	IPCLT	Domestic Coal Production	Thousand Barrel	10	OGR_COM	Oil & Gas Cons. Ratio for Commercial Sector	%
4	IPGT	Domestic Gas Production	Thousand Barrel	11	OGR_EG	Oil & Gas Cons. Ratio for Electr. Gen. Sector	%
5	IPGTT	Geothermal Production	Thousand Barrel	12	OGR_IN	Oil & Gas Cons. Ratio for Industrial Sector	%
6	IPHYTT	Hydropower Production	Thousand Barrel	13	OGR_TR	Oil & Gas Cons. Ratio for Transport Sector	%
7	IPOLT	Domestic Crude Oil Production	Thousand Barrel	14	OWNT	Own use	Thousand Barrel

No	Code	Variable	Unit	No	Code	Variable	Unit
8	POPT	Population	Thousand ppl	24	RPGASIT	Price of Gas for Industrial Sector	Rupiah/BOE
9	POILWDT	World Oil Price	Rupiah/BOE	25	RPGASLT	Price of LPG	Rupiah/BOE
10	PPBLNCT	Oil Fuel Stock Differences	%	26	RPHYT	Price of Hydropower	Rupiah/BOE
11	RCCRT	Refinery Capacities	Thousand Barrel	27	RPOILDT	Price of Diesel	Rupiah/BOE
12	RFCICRT	Refinery Capacity and Input Ratio	Thousand Barrel	28	RPOILMTT	Price of Kerosene	Rupiah/BOE
13	RFUTT	Refinery Utility	%	29	RPOILPT	Price of Gasoline/Premium	Rupiah/BOE
14	RPCOALT	Price of Coal	Rupiah/BOE	30	RPOILST	Price of Diesel	Rupiah/BOE
15	RPELRT	Price of Electricity	Rupiah/BOE	31	SKBRT	Interest Rate	%
16	RPEXOLT	Crude Oil Production and Export Ratio	%				

Table 4. Validation Analysis of Structural Equations on Energy Model

No	Endogenous Variable	Code	RMS Error	Mean Abs Error	Mean Abs. % Error	Bias (UB)	Variance (UV)	Covar (UV)	U
1	Consumption of oil fuel at Electr. Generation sector	EGOLT	4,498.05	3,279.18	6.95	0.00	0.02	0.98	0.0457
2	Consumption of oil fuel at Industrial sector	IDOLT	2,943.78	2,355.11	3.84	0.00	0.02	0.98	0.0239
3	Consumption of oil fuel at Residential sector	REOLT	2,309.19	1,354.51	3.73	0.00	0.01	0.99	0.0248
4	Consumption of oil fuel at Transport sector	TROLT	16,284.91	15,561.51	12.45	0.00	0.00	1.00	0.0538
5	Consumption of oil fuel at Commercial sector	COMOLT	740.07	594.72	8.44	0.00	0.14	1.00	0.0531
6	Consumption of oil fuel at Other sector	OCOLT	1,979.96	1,682.38	6.18	0.00	0.15	0.85	0.0239
7	Consumption of gas at Electricity Generation sector	EGGT	1,600.13	1,295.16	8.04	0.00	0.01	0.99	0.0244
8	Consumption of gas at Industrial sector	IDGT	7,406.86	5,496.25	6.72	0.00	0.01	0.99	0.0447
9	Consumption of gas at Residential sector	REGT	1,206.00	848.81	13.18	0.00	0.02	0.98	0.0487
10	Consumption of gas at Transport sector	TRRTGT	23.57	17.92	19.64	0.00	0.11	0.89	0.1049
11	Consumption of gas at Commercial sector	COMGT	249.93	212.01	12.78	0.00	0.09	0.91	0.0794
12	Consumption of coal at Electricity Generation sector	EGCLT	7,473.66	5,995.19	18.68	0.00	0.01	0.99	0.0392
13	Consumption of coal at Industrial sector	IDCLT	12,454.91	9,579.75	67.33	0.00	0.02	0.98	0.0906
14	Consumption of coal at Residential sector	RECLT	7.43	6.07	48.40	0.00	0.04	0.95	0.0509
15	Consumption of electricity at Industrial sector	IDEGT	1,130.19	783.91	3.47	0.00	0.00	1.00	0.0251

No	Endogenous Variable	Code	RMS Error	Mean Abs Error	Mean Abs. % Error	Bias (UB)	Variance (UV)	Covar (UV)	U
16	Consumption of electricity at Residential sector	REEGT	3,715.87	2,755.25	9.56	0.11	0.22	0.66	0.0780
17	Consumption of electricity at Commercial sector	COMEGT	369.65	303.61	4.03	0.04	0.09	0.87	0.0148
18	Consumption of biomass at Residential sector	REBIOT	6,739.16	3,537.39	1.59	0.00	0.02	0.98	0.0160
19	Consumption of geothermal at Electr. Generation sector	EGGTT	0.22	0.18	0.00	0.00	0.00	1.00	0.0000
20	Consumption of hydropower at Electr. Generation sector	EGHYT	1,756.10	1,509.56	6.34	0.00	0.05	0.95	0.0348
21	GDP at Electricity Generation sector	EGPT	103.14	82.47	1.42	0.09	0.01	0.99	0.0073
22	GDP at Industrial sector	INDPT	10,550.19	8,988.45	2.21	0.01	0.28	0.71	0.0120
23	GDP at Transport sector	TRPT	1,753.20	1,452.50	2.89	0.00	0.31	0.69	0.0151
24	GDP at Commercial sector	COMPT	87,041.48	70,711.32	13.15	0.69	0.02	0.29	0.0724
25	GDP at Other sector	OCPT	44,608.56	35,924.27	6.17	0.10	0.20	0.70	0.0383
26	Number of vehicle	VEHI	8,309.35	7,735.02	6.43	0.00	0.04	0.95	0.1109