Modelling and Optimization of Natural Gas Market in West Java Area to Maximize Consumer Social Welfare Value and Gas Producer Net Back Value

Abstract

Natural gas utilization is an important issue related to the demand and prices for the benefit of country and consumers. This study aims to optimize social welfare represents the interests of consumer and producer netback representing the interests of country. The scope of this research is the natural gas market in Western Java area having the biggest demand and integrated infrastructure. Multi-objective optimization is used to obtain the optimum value of both functions. Wholesale price formula of natural
gas at the optimum value is structured as a linear function of the price of crude oil with slope $\alpha$ and constant $k$. The values of $\alpha$ obtained in the range of 0.1079 to 0.1589 with $k$ in the range of 3.7 to 5.38.

**Keywords:** natural gas, social welfare, netback value, multi-objectives optimization

1. **Introduction**

Natural gas is one of the largest energy resources in Indonesia. This country is one of the biggest natural utilizer both as producer and consumer. The natural gas produced in Indonesia in 2012 reach 2.982 BSCF (BPS, 2014) with 1.445 BSCF domestic consumption (BPPT, 2014). In addition to fulfill domestic demands, natural gas produced in Indonesia also exported abroad through transmission pipeline and liquefied natural gas (LNG).

Natural gas demand in domestic market rise significantly this years along with the high economic growth in Indonesia. The domestic demand projected in 2035 reach 2.679 BSCF consisting of refinery-own use-loses, power generation, commercial, transportation, household and industry (BPPT, 2014). Meanwhile, the production in that period is only reach $\pm$ 1,600 BSCF resulting deficit of natural gas supply (BPPT, 2014). Therefore, domestic productions of natural gas have to optimize to fulfill its domestic demand.

Natural gas market in Western Java area is the biggest market in Indonesia having integrated infrastructure. In 2013, natural gas utilization in this area reach 36.25% of national utilization of natural gas. The sources of supply are obtained from local production in West Java, from South Sumatera through South Sumatera – West Java (SSWJ) pipeline and from Kalimantan and Papua through LNG.

The price of natural gas is become the most important factor in natural gas utilization. Currently, the price is still very competitive compared to the energy resources at the same unit. Natural gas price at consumer gate is influenced by netback value of this energy resources in producer side. In 2012, the average price of natural gas in Western Java area amounted to 6.85 USD/MMBTU (PGN, 2012). Besides, the price of high speed diesel (HSD) reach 30.76 USD/MMBTU (PGN, 2012). However, along with the competition
between domestic product and import product, the willingness to pay of natural gas consumers become affected because the price of energy abroad is quite low. In certain level, natural gas price is not accepted by consumers and choosing cheaper energy resources, such as coal.

Aside of being one of the energy resources for domestic usage, natural gas become one of commodity that generate revenue for Indonesia. The revenue generated from oil and gas sector in APBN-P 2014 is targeted to reach 29.7 billion US Dollar. This amount contribute to 18.71% of total revenue in APBN-P 2014. The revenue generated by natural gas is obtained from its sales both in domestically and abroad. Therefore, the higher netback value of natural gas in production side will give higher revenue for the country.

According to above, it is necessary to develop natural gas market models of Western Java area to obtain the optimum value of social welfare value representing domestic consumers’ interest and netback value of producer representing the interest of the country. The model developed by considering several factors in natural gas value chain. Optimization is then carried out to get optimum value for both social welfare and netback. Based on that value, a formula of natural gas price is developed for wholesale market of natural gas in Western Java area.

2. Material and Methods

2.1 Natural Gas Demand and Supply in Western Java Area

As on Figure 1, the natural gas supply and demand data arranged in a gas balance according to the fulfillment of the demand for natural gas scenarios developed. The natural gas demands rise from 2016 to 2030 as projected in Business As Usual (BAU) growth scheme used. BAU scheme growth is gas demand projection with existing economic growth.

2.2 Natural Gas Infrastructure in Western Java Area

The existing infrastructure delivering natural gas from suppliers to customers in Western Java area consist of transmission pipeline, distribution pipeline and LNG Floating Storage Regasification Unit (FSRU). Each of the transportation facilities have certain throughput that include or separately from the natural gas price as shown in Table 1.
Table 1 Existing Natural Gas Infrastructure in West Java Area

<table>
<thead>
<tr>
<th>Transportation Facility</th>
<th>throughput</th>
<th>Fee</th>
<th>status</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Sumatera – West Java 1 (SSWJ 1) pipeline</td>
<td>Toll fee</td>
<td>1.47 USD/MSCF</td>
<td>open access</td>
</tr>
<tr>
<td>Pipa SSWJ 2</td>
<td>Toll fee</td>
<td>1.51 USD/MSCF</td>
<td>open access</td>
</tr>
<tr>
<td>PHE ONWJ – West Java Pipeline</td>
<td>N/A</td>
<td>N/A</td>
<td>upstream dedicated</td>
</tr>
<tr>
<td>SES – West Java Pipeline</td>
<td>N/A</td>
<td>N/A</td>
<td>upstream dedicated</td>
</tr>
<tr>
<td>Cilamaya – Cilegon Pipeline</td>
<td>Toll fee</td>
<td>1.40 USD/MSCF</td>
<td>open access</td>
</tr>
<tr>
<td>West Java Distribution Pipeline</td>
<td>Distribution fee</td>
<td>750 IDR/m³</td>
<td>downstream dedicated</td>
</tr>
<tr>
<td>LNG FSRU West Java</td>
<td>Regasification cost</td>
<td>3.03 USD/MMBTU</td>
<td>-</td>
</tr>
<tr>
<td>LNG FSRU Lampung</td>
<td>Regasification cost</td>
<td>3.43 USD/MMBTU</td>
<td>-</td>
</tr>
</tbody>
</table>
2.3 Crude Oil Price Projection

The crude oil price used to calculate substitute energy price is projected based on West Texas Index (WTI) crude oil price projection from U.S. Energy Information Administration as follow.

2.4 Natural Gas Market Modelling

Natural gas market in Western Java area is modelled as wholesale market consist of a locus market that supplied from multiple sources of natural gas supply as shown in Figure 3.

The demand of Western Java market is obtained from several sources, including existing gas supply through pipeline transportation, the gas supply through LNG using the existing
infrastructure and gas supply through LNG using new infrastructure to supply LNG from domestic and import. This model existing and projected natural gas supply in supply side and projected demand for natural gas market in demand side. The modeling time period is divided into 3 ranges period, ie 2016 to 2020 (Period 1), 2021 to 2025 (Period 2) and 2026 to 2030 (period 3).

The transportation scheme from gas sources to Western Java market describe as follow.

![Figure 4. Natural Gas Transportation Scheme to Western Java Area](image)

Western Java market is modelled as wholesale market which apply single price formula for all gas supply get into this area with exit point in the end of transmission pipeline. Meanwhile, distribution cost will be incurred in transporting natural gas from transmission pipeline to end customers through distribution pipeline.

Based on transportation scheme shown in Figure 4, producer netback and consumer social welfare value are formulated as follow.

**Table 2 Producer Netback and Consumer Social Welfare Value Formulation**

<table>
<thead>
<tr>
<th>Nilai</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Netback (NB)</strong></td>
<td>$NB = NB_{pipeline} + NB_{LNG}$</td>
</tr>
<tr>
<td></td>
<td>$NB_{pipeline} = \sum_{t=1}^{T} \sum_{i=1}^{I} (1 + r)^{-1} [(WP_{lt} - T_F^{ext} V_{it}^{oa} + (WP_{lt} - sLCGP_{lt}) V_{it}^{dh}]$</td>
</tr>
<tr>
<td></td>
<td>$NB_{lng} = \sum_{t=1}^{T} \sum_{i=1}^{I} (1 + r)^{-1} [(WP_{lt} - sLCLL_{lt} - sLCLS_{lt} - RC_{it}) V_{it}^{lngext}$</td>
</tr>
<tr>
<td></td>
<td>$+ (WP_{lt} - sLCLL_{lt} - sLCLS_{lt} - sLCRU_{lt}) V_{it}^{lngnew}]$</td>
</tr>
<tr>
<td><strong>Social Welfare (SW)</strong></td>
<td>$SW = \sum_{t=1}^{T} \sum_{i=1}^{I} (1 + r)^{-1} (ESP_t - WP_t - DF_{it}) V_{it}$</td>
</tr>
</tbody>
</table>
Netback value (NB) of natural gas in Western Java area consist of netback for pipeline and LNG. NB formulated in producer wellhead that obtained by offsetting wholesale price with transportation fee from wellhead to Western Java market both for pipeline and LNG. This value multiplied by the rate of natural gas ($V$) transported resulting NB as shown Table 2.

In natural gas transportation through pipeline, transportation fee is using toll fee (TF) which applicable under current contract ($ext$) for open access pipeline (oa) and simplified levelized cost gas pipeline (sLCGP) calculation for upstream dedicated pipeline. Meanwhile, for transporting natural gas through LNG, the transportation fee consist of liquefaction cost, shipping cost and regasification cost. Liquefaction cost is calculated with simplified levelized cost LNG liquefaction (sLCLL), while shipping cost is calculated with simplified levelized cost LNG shipping (sLCLS). Regasification cost is distinguished between existing facilities and projected facilities to be built. Regasification cost under current contract is used for existing facilities, while projected facilities are using simplified levelized cost regasification unit (sLCRU). $RC$ is regasification cost for existing regasification facilities, while $lng_{ext}$ representing notation for current regasification facilities. In the model, it is assumed that the additional supply for the foreseeable future is obtained through LNG only. $lng_{new}$ notation is used for projected LNG facilities capacity.

Social welfare (SW) calculation is develop based on basic concept used in Gas Trade Model (GTM) developed by Beltramo and Manne. The value describe as willingness to pay minus production cost and transportation cost boundered by price and volume traded. Willingness to pay is modelled as the price of energy substitute of natural gas, diesel oil. The energy substitute price is modelled as index of crude oil price projected along the modelling period, while production cost plus transportation cost is modelled in form of wholesale price plus distribution cost.

In the social welfare equation shown in Table 2, $WP_t$ represents wholesale price in year $t$, while $DF_{it}$ represents distribution cost of each supply source $i$ in year $t$. $V_{it}$ represents the rate of natural gas transported from each supply source $i$ in year $t$. $r$ is discount rate, $t$ is time period and $i$ is gas supply source. Discount rate $r$ is assumend in constant value during periode $t=1$ to $t=T$ in the model.
There are three scenarios developed in the model that affect the overall modeling as shown in the following table.

<table>
<thead>
<tr>
<th>No</th>
<th>Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Natural gas deficit is fulfilled by domestic LNG supply. If still not sufficient, it will be met from imported LNG supply.</td>
</tr>
<tr>
<td>2</td>
<td>Natural gas deficit is fulfilled by domestic LNG supply and imported LNG supply with proportion 50% : 50%</td>
</tr>
<tr>
<td>3</td>
<td>Natural gas deficit is fulfilled by 100% imported LNG supply.</td>
</tr>
</tbody>
</table>

The result of the modelling scenario is natural gas balance in Western java area for each scenario developed.

2.5 Multi-objective Optimization

In order to solve the research problem, multi-objective optimization is used to meet the trade off between social welfare and netback value as the objective function. $f_1$ is the first objective function aiming to maximize producer netback value of natural gas in upstream sector, while $f_2$ is the second objective function aiming to maximize consumer social welfare value in downstream sector. The method use in the multi-objective optimization is graphical method. The wholesale price is trialed from 8 USD/MMBTU to 24 USD/MMBTU resulting the curve of netback and social welfare. The intersection between netback curve and social welfare curve resulting the optimum value for both objective function. At that point, the value of netback is equal to the value of social welfare so that the determination of wholesale price at that point not to burden either consumers or producers.

It is possible to take decision which tend to one of the objective function. Tendency to producer is shown by increasing netback value, while tendency to consumers is shown by increasing social welfare value. The decision making process (DM) use weighted method as follow.

$$f_3 = w_1 f_1 + w_2 f_2, \text{ where } w_1 + w_2 = 1$$

Weighted factor used in the model is varied at $w_1 = 0.00; 0.25; 0.50; 0.75; 1.00$. 
2.6 Wholesale Price Formulation

The wholesale price of natural gas in Western Java area is formulated as index of crude oil price as follow.

\[ WP_t = \alpha \times \text{Crude Oil Price} + k \]

Where \( WP_t \) is wholesale price of natural gas in Western Java area at year \( t \) and \( \alpha \) is wholesale price index to crude oil price, while \( k \) is constant in USD/MMBTU. The value of \( \alpha \) is obtained in optimum value of netback and social welfare, while \( k \) is obtained at minimum value of netback.

3. Result and Discussion

3.1 Netback and Social Welfare Value

The trade off curve between netback and social welfare resulted from the modelling shown in Figure 5. Based on the result, it can be seen that the escalation of wholesale price will increase producer netback value developing a positive linear curve. Along with period of the modelling, there are degression of netback value caused by throughput escalation affected by inflation rate.

Additional volume from import didn’t have any effect to netback value because the import LNG didn’t give any value added to domestic producer. Therefore, the highest netback value is in scenario 1 compared to other scenario at the same period.

Meanwhile, escalation of wholesale price decrease the consumer social welfare value, developing a negative linear curve. The escalation of wholesale price give less gap between wholesale price and energy substitute price as representation of willingness to pay. Along the period, it can be seen that consumer social welfare value increasing because of escalation of crude oil price.

3.2 Multi-objective Optimization Result

Based on the result shown in Figure 5, the curve between social welfare value and netback value has an intersection resulting a wholesale price at optimum value of both function. The wholesale prise resulted as follow.
Figure 5 Modelling Result – A. Scenario 1; B. Scenario 2; C. Scenario 3
Based on the result shown in Table 5, it seen that wholesale price at optimum value increasing along the period of modelling. It caused by increasing of substitute energy price due to projection of crude oil price. The increasing of gas supply using LNG also become one of factor that increase the wholesale price of natural gas. Additional volume from import didn’t have any effect to netback value because the import LNG didn’t give any value added to domestic producer but giving additional value to consumer social welfare. The intersection of both function resulting higher wholesale price of natural gas.

### 3.3 Decision Making Process with Tendency to One of Objective Function

The optimum point resulted in optimization process is a point where both function have the same weight, $w_1 = w_2 = 50\%$. In decision making process, it is possible to have a tendency to one of the objective function. The tendency will effect both social welfare value and netback value as shown in Figure 6.

In Figure 7, it can be seen that tendency to netback value ($f_I$) where $wI > 0.5$ resulting the increasing of netback value and decrease social welfare value and vise versa. It is happened because the increasing of wholesale price has to be done in order to increasing netback. The increasing of wholesale price will lower the netback value.
In the decision making process where one of the objective function reach value of zero ($w1$ or $w2 = 0 = 0$), it will obtain the maximum or minimum prices that limit the determination of the wholesale price of natural gas. The limit is known as the ceiling price to the upper limit of the price and the floor price for the lower limit of the price. The values of floor price and ceiling price for all scenarios at each period are shown in the following table.

### Table 5 Ceiling Price and Floor Price

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Period</th>
<th>Floor Price (USD/MMBTU)</th>
<th>Ceiling Price (USD/MMBTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2016-2020</td>
<td>3.77</td>
<td>18.67</td>
</tr>
<tr>
<td></td>
<td>2021-2025</td>
<td>4.21</td>
<td>20.83</td>
</tr>
<tr>
<td></td>
<td>2026-2030</td>
<td>4.79</td>
<td>24.11</td>
</tr>
<tr>
<td>2</td>
<td>2016-2020</td>
<td>3.72</td>
<td>18.67</td>
</tr>
<tr>
<td></td>
<td>2021-2025</td>
<td>4.19</td>
<td>20.83</td>
</tr>
<tr>
<td></td>
<td>2026-2030</td>
<td>4.88</td>
<td>24.11</td>
</tr>
<tr>
<td>3</td>
<td>2016-2020</td>
<td>3.65</td>
<td>18.67</td>
</tr>
<tr>
<td></td>
<td>2021-2025</td>
<td>4.15</td>
<td>20.83</td>
</tr>
<tr>
<td></td>
<td>2026-2030</td>
<td>5.38</td>
<td>24.11</td>
</tr>
</tbody>
</table>

Floor price is set to protect producers by limiting the decline in wholesale prices at the point that not giving negative netback to producers. Instead, the ceiling price is set to protect consumers by limiting the increase in the wholesale price at the point where that not giving negative social welfare to consumers.
3.4 Wholesale Formula of natural Gas in Western Java Area

Wholesale price formulated in the form of pricing formula linked to crude oil price with the following basic formulation:

\[ \text{Wholesale Price (WP)} = \alpha \times \text{crude oil price} + k \]

The \( \alpha \) value is calculated based on the wholesale price of natural gas at the optimum point of netback and social welfare, compared to the average price of oil in the same period. The value of constant \( k \) is determined with the aim to protect the manufacturers, the value of \( k \) is set equal to the floor price for all scenarios in each period. Values \( \alpha \) generated in this study are shown in the following table.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Period</th>
<th>( k )</th>
<th>( \alpha )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2016-2020</td>
<td>3.77</td>
<td>0.1079</td>
</tr>
<tr>
<td></td>
<td>2021-2025</td>
<td>4.21</td>
<td>0.1039</td>
</tr>
<tr>
<td></td>
<td>2026-2030</td>
<td>4.79</td>
<td>0.1121</td>
</tr>
<tr>
<td>2</td>
<td>2016-2020</td>
<td>3.72</td>
<td>0.1137</td>
</tr>
<tr>
<td></td>
<td>2021-2025</td>
<td>4.19</td>
<td>0.1215</td>
</tr>
<tr>
<td></td>
<td>2026-2030</td>
<td>4.88</td>
<td>0.1261</td>
</tr>
<tr>
<td>3</td>
<td>2016-2020</td>
<td>3.65</td>
<td>0.1223</td>
</tr>
<tr>
<td></td>
<td>2021-2025</td>
<td>4.15</td>
<td>0.1463</td>
</tr>
<tr>
<td></td>
<td>2026-2030</td>
<td>5.38</td>
<td>0.1589</td>
</tr>
</tbody>
</table>

To determine the effect of the value of constant \( k \) and the slope \( \alpha \) to the wholesale price of natural gas, a sensitivity analysis is performed. The results of the sensitivity can be seen in Figure 7. It can be seen that the wholesale price of natural gas is more sensitive to the changes in the slope \( \alpha \) compared to the constant changes of constant \( k \). In other words, changes in slope \( \alpha \) will result a more significant decrease or increase in the wholesale price of natural gas. It need to be considered in the negotiations of wholesale gas pricing formula determination.
Figure 7 Sensitivity Analysis of Constant $k$ and Slope $\alpha$ to Wholesale Gas Price – A. Scenario 1; B. Scenario 2; C. Scenario 3 – I. Period 2016–2020; II. Period 2021–2025; III. Period 2026–2030
4. Conclusion

Producer netback value from period to period decreased related to the increase in throughput which affected by the inflation rate constant. The additional portion of LNG imports volume giving an impairment in producer netback value as because imports do not provide added value for domestic producers. Social welfare value from period to period increase influenced by the increase in projected crude oil price as an index of energy substitution price.

The wholesale prices at the optimum point $f_1$ and $f_2$ higher from period to period. This is caused by increasing of substitute energy prices associated with crude oil price projection whose price continues to rise. In addition, it is also influenced by the increase in transportation costs associated with inflation. The portion of the gas supply through LNG growing along the period also become one of the factors increasing the wholesale price of natural gas. The increase in the portion of the volume of LNG imports caused the wholesale price of natural gas also increased because additional volume of imports did not provide additional value to netback but still provide additional value to social welfare. So that the intersection of the second objective function resulting a higher wholesale price.

At the optimum point between the social welfare of consumers and producers of natural gas netback value, the wholesale price of natural gas is obtained which is then formulated related to oil prices. Wholesale price formula of natural gas at the optimum point is structured as a linear function of the price of crude oil price with slope $\alpha$ and the constant $k$. $\alpha$ values is obtained in the range of 0.1079 to 0.1589 with k in the range of 3.7 to 5.38.
Reference


