Development of Natural Gas Infrastructure to Enhance National Energy Security in Indonesia

Agus Sugiyono¹ and Adiarso

Center for Assessment of Process Industry and Energy, Agency for the Assessment and Application of Technology (BPPT)
Building 720, Cluster of Technology Innovation and Business, Science and Technology Park, South Tangerang City, Banten, Indonesia

¹Email: agus.sugiyono@bppt.go.id

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Abstract. The current use of energy in Indonesia highly still depends on fossil-derived energy. Thus, policies to reduce the use of fossil energy towards the use of new and renewable energy (NRE), which is more environmentally friendly, receive great concern. The government encourages the use of low-carbon technology following up the Paris Agreement to reduce greenhouse gas (GHG) emissions by 29% (without assistance) and by 41% (with international assistance) under Business as Usual (BAU) by 2030. However, accelerating the utilization of renewable energy still faces some obstacles because the economic price of NRE is still more expensive than that of fossil energy. The most likely transition policy is to substitute the use of oil and fuel to natural gas through improving natural gas infrastructure. This transition is following the Sustainable Development Goal (SDG) which guides the achievement of global goals until 2030, namely to ensure access to affordable, reliable, sustainable, and modern energy for all. The development of natural gas infrastructure is currently in an early stage (point to point scheme) and is expected to develop into a hub and spoke scheme towards multiple networks. The more developed infrastructure will further enhance national energy security in the long run.

1. Introduction
Recently, the dependence on the use of fossil energy in Indonesia is very high. The supply of primary energy in 2018 reached 1533 million BOE, where the share of fossil energy reached 87% [1]. Crude oil and imported petroleum fuels are the largest primary energy used with a share of 37% followed by coal (32%) and natural gas (19%). Considering that fossil energy reserves, especially crude oil, are becoming scarce, it is necessary to immediately substitute the use of imported crude oil and petroleum fuels with other sources of energy. National proven reserves of oil currently only amount to 3.15 billion barrels and with the current oil production reaching 282 million barrels. Assuming without new reserves are found, it will estimate that these reserves will be exhausted in about 11 years. Meanwhile, natural gas has proven reserves of 96.06 TSCF, with production in 2018 reached 2.99 TSCF. It will estimate that it will run out in about 32 years.

Policies to reduce the use of fossil energy towards the use of renewable energy have been implemented. National Energy Policy (KEN), as stated in Government Regulation No. 79/2014, explicitly mandates to maximize the use of renewable energy by taking into account the economic level and minimizing the use of petroleum. The government has also signed a Paris Agreement to reduce...
greenhouse gas (GHG) emissions by 29% (without assistance) and by 41% (with international assistance) under business as usual (BAU) by 2030. This emission reduction target can achieve through the use of low-carbon technology. In developed countries, this kind of policy is called the energy transition policy, which makes various efforts to reduce GHG emissions [2]. Energy transition policies are long-term and sometimes require complex processes, including the creation of new market rules and support from investors. This policy faces a variety of challenges, such as technical feasibility, additional costs of the state budget, affordability or security of energy supplies, and the impact of the policy. The most likely implementation of policies related to the energy transition for the medium term in Indonesia is the substitution of oil with natural gas. Natural gas is more environmentally friendly energy than coal and oil, cheaper than oil and petroleum fuels, and also natural gas reserves are still relatively large [3]. Meanwhile, in the long term, the development of renewable energy is still needed. This energy transition is in line with the Sustainable Development Goal (SDG), which guides the achievement of global goals until 2030, namely ensuring access to affordable, reliable, sustainable, and modern energy for all.

The current energy policy is indirectly related to efforts to increase national energy security. Energy security can generally interpret as a condition for sustainably meeting people’s energy needs. Nugroho [4] and Permana, et.al. [5] discussed the problem of energy security with 4A indicators, which is availability, affordability, accessibility, and acceptability. The World Energy Council [6] through the energy trilemma index places Indonesia’s energy security in 2018 in the 71st position out of 125 surveyed countries. Indonesia’s ranking increased from the previous year which was in 75th place. The current first to third rankings are Denmark, Switzerland, and Sweden. The trilemma index contains at least three assessment variables related to global energy security i.e. energy security, energy equity, and environmental sustainability. Strategies to increase energy security include increasing crude oil production, reducing imports of crude oil and petroleum fuels, building natural gas infrastructure, and expanding energy access to outer and national border islands. This paper will focus on discussing one strategy to increase energy security by improving natural gas infrastructure.

2. Natural Gas Reserves and Utilization
Indonesia’s natural gas reserves are scattered in various regions as shown in Figure 1. The status of natural gas reserves on January 1 2018 is 135.55 trillion standard cubic feet (TSCF). The reserves consist of proven reserves (P1) of 96.06 TSCF and potential reserves of 39.49 TSCF. Potential reserves consist of probable reserves (P2) of 21.26 TSCF and possible reserves (P3) of 18.23 TSCF. From the total of proven natural gas reserves, 3.86 TSCF is in the form of associated gas and 92.20 TSCF of non-associated gas [7] [8] [9].

![Figure 1. Map of Natural Gas Reserves (Status 1.1.2018) [7]](image-url)

Natural gas production reached 2.99 TSCF in 2018 and is used both for export and to meet domestic demand. The utilization of natural gas was divide into three groups, namely fuel, raw material, and export commodity. Domestic natural gas utilization in 2018 was greater than exports with a share of 64.9% for domestic and the remaining 35.1% for exports. Domestic utilization as a fuel is quite large, namely for the industrial sector with a share of 26.0%, and power generation (13.7%) and fertilizer...
(12.1%). Figure 2 shows the use of natural gas for both domestic and export purposes. Natural gas as an export commodity can be in the form of LNG with export markets such as China, Japan, and South Korea, or exported to Singapore in the form of piped gas.

Figure 2. Natural Gas Utilization Share [8] [10]

LPG is a product that can be processed from oil and natural gas, although in statistics are included in gas production. The use of LPG has continued to increase since 2006 due to the policy of substituting the use of kerosene with LPG. Indonesia is not big enough as an LPG producer, so it has not been able to meet the current demand for LPG from domestic LPG production. LPG demand in 2018 reached 7.56 million tonnes and most of the supply was in the form of imports which reached 5.57 million tonnes or 73.6% of the total demand [1]. Most of the use of LPG is for subsidized fuel in the household sector. The use of subsidized LPG for the household sector must begin to be reduced and replaced with the use of city gas [11]. The price per unit of energy for city gas has still cheaper than other energy, and it comes from natural gas that produces domestically (Figure 3).

Figure 3. Comparison of Prices of Several Final Energy in Indonesia

Recently, there has been a paradigm shift in the management of natural gas, from previously acting as an export commodity, which was a source of foreign exchange for the country, become a driver of national economic growth. Natural gas has optimally utilized to meet domestic demand, both as fuel in

Note: compiled from [1] [11] [13] [14] and online media news
the industry sector and electricity generation as well as a raw material. The government continues to encourage the use of natural gas for domestic demand to accelerate economic growth and increase the competitiveness of national industries. The government regulates the price of natural gas for domestic use. The determination of natural gas prices takes into account several factors, including field economics, domestic and international gas prices, the purchasing power of domestic natural gas consumers, and the added value of domestic natural gas utilization [11] [12]. The availability of natural gas for domestic demand at an affordable price can create a beneficial chain effect on the economy as a whole.

3. Natural Gas Infrastructure Development

Natural gas has used as raw material for the fertilizer industry in the early 1960s. In 1977, Indonesia began to export natural gas as LNG and had become the largest LNG exporting country in the world. Currently, Indonesia is still exporting natural gas in the form of LNG and piped gas, therefore, the export will expect to decline in line with the increase in domestic gas demand [12]. The utilization of natural gas for the medium and long term (2025-2030) ranges from 8,000 MMSCFD, as discussed in the publication of the Ministry of Energy and Mineral Resources [12] [15] and BPPT [3]. Natural gas has proven to be safe, efficient, and environmentally friendly energy. Increasing the use of natural gas can create energy independence because it is energy from domestic production.

The government continues to aggressively encourage the use of domestic natural gas through the development of natural gas infrastructure [13] [15]. Accelerating the development of natural gas infrastructure is imperative for equitable distribution and fulfillment of gas supplies throughout the region. Indonesia faces many challenges in the use of natural gas due to the geographical conditions as an archipelago. Many natural gas reserves have located far from the users. Several large gas reserves, such as Tangguh in Papua, Jangkrik in Kalimantan, Masela in the Timor Sea, and Natuna D-Alfa are far from the users, therefore the infrastructure must be prepared. Natural gas is not as easy to store as crude oil, it requires a well-established infrastructure and long-term contract that can provide business certainty for producer and consumer. In line with this plan, the government in April 2018 formed a holding company of oil and gas state-owned enterprises. Pertamina (national energy company) as the holding company and PGN (national gas company) as the sub-holding have full responsibility for regulating the gas business. This holding has arranged for Pertagas to be under PGN's control so that the development of gas infrastructure will be more well managed and the ability to invest becomes greater.

Current natural gas infrastructure and development plans are shown in Figure 4.

Natural gas transmission and distribution systems from sources to consumers have been briefly discussed in Permana, et. al. (2009) [17]. This system contains various natural gas infrastructures that are still in the developing phase with a point to point scheme. In the energy transition period, natural gas infrastructure is expected to be able to enter a growth phase with a hub and spoke scheme. The utilization of natural gas is more flexible along with the development of the market, therefore in the future it can enter a maturity phase with a multiple network scheme [16]. Figure 5 shows the natural gas infrastructure development phase. The utilization of natural gas can develop if there is sufficient infrastructure so that it can be more efficient and cheaper than other fossil energies. Government policies need to support technological innovations that can improve the safety and security of natural gas utilization.

Natural gas infrastructure can be categorized into three categories, i.e. pipelines, liquefied natural gas (LNG), and compressed natural gas (CNG) infrastructure [15] [19]. Until now, the natural gas infrastructure, whose largest share is pipelines. This infrastructure is in the form of natural gas transmission and distribution pipelines, which are mostly located in Java and Sumatra. LNG infrastructure is the transportation of natural gas in the sea using a ship. This network makes it possible to transport large volumes of natural gas by processing natural gas into LNG. International LNG trade is expected to continue to increase during this decade. Meanwhile, CNG infrastructure has a relatively small volume of gas transportation by compressing the natural gas into CNG and transporting it by truck, train, or other transportation modes.
Figure 4. Natural Gas Infrastructure Development Plan [12] [16]

Note: S - Supply, D - Demand, compiled from [13] and [18]

Figure 5. Natural Gas Infrastructure Development Phase

3.1. Pipelines Infrastructure
The gas pipeline system is a means of transporting natural gas from the producers to the consumers and most commonly used. The government has made a natural gas pipeline development plan since 2010, based on the Minister of Energy and Mineral Resources Decree No. 0225.K/11/MEM/2010. This plan was later revised by the Minister of EMR Decree No. 2700.K/11/MEM/2012 concerning the Master Plan for National Natural Gas Transmission and Distribution Network 2012-2025. The development of natural gas pipeline transmission and distribution networks is still slow. Natural gas pipeline transmission and distribution infrastructure serve all customer segments from power generation, industrial, commercial, household, and transportation sectors.

The transmission and distribution of gas pipelines are divided into five categories, i.e. open-access, dedicated upstream, dedicated downstream, own utilization, and city gas network. The open-access system has been introduced since 2008 that natural gas pipeline owners open access to other parties to participate in using the natural gas network. Dedicated upstream is intended for field operations as a facility for transporting natural gas in upstream business activities. Dedicated downstream is used to transport natural gas to certain end-used consumers. Own utilization if the construction and operation is carried out by consumers to distribute gas for their own use. Meanwhile, the city gas network is used
for the household sector. City gas networks for household consumers have existed since colonial times. In 2009 the government began collaborating with PGN and Pertamina to build household gas networks in various cities. The construction of city gas pipelines is intended to diversify energy to substitute the use of petroleum fuels and LPG. The government seeks to optimize the development of natural gas distribution networks for the household to achieve energy security and improve community welfare.

3.2. LNG Infrastructure

The mode of gas transportation using LNG ships is applied for the delivery of natural gas over long distances. The construction of long-distance gas pipelines with archipelagic geographical conditions can no longer be carried out because they do not meet economic aspects. Natural gas needs to be processed into LNG in the LNG plant. Liquefaction is intended that natural gas can be stored and transported to users easily. Based on their capacity, the LNG plant can be classified into: large plant (capacity more than 50 MMSCFD), mini plant (between 5 MMSCFD - 50 MMSCFD), and micro plant (less than 5 MMSCFD). Indonesia currently has three LNG plant facilities, i.e. Bontang (East Kalimantan), Tangguh (West Papua), and Donggi Senoro (Central Sulawesi).

LNG transportation in the sea for export and domestic needs can use LNG tankers. LNG at the destination must be regasified. Regasification is intended to convert back LNG into natural gas that can be distributed or utilized further. Regasification terminal can be in the form of floating storage regasification unit (FSRU) and land-based storage and regasification (LBSR). From the FSRU, it is then distributed to the terminal on land, which can then be distributed via natural gas pipelines or other transportation modes. Currently, there are four regasification facilities, i.e. LBSR Arun-Belawan in Aceh, FSRU in Lampung, FSRU Nusantara Regas in West Java, and FSRU Tanjung Benoa in Bali [20]. The next FRSU development plan will be in Gresik and Cilacap territory.

3.3. CNG Infrastructure

Transportation infrastructure for CNG is also being developed in Indonesia. CNG is a natural gas storage technology by compressing it at high pressure up to 250 bar. The CNG is then stored in high compression tubes and can be distributed by consumers such as the industrial sector, transportation sector, and power generation. The CNG plant is a unit for compressing natural gas which also functions for CNG storage. CNG can be distributed from the CNG plant to consumers using roads and rails mode. CNG that has been stored in a high-pressure tube can be distributed using specially designed trucks, which can be in the form of a mobile refueling unit (MRU). The transportation of CNG using the train is faster, without obstacles on the way such as traffic jams. However, transportation by train can only be done in areas that have a rail network. Since mid-2014, PLN has distributed CNG to supply gas engine power plant on Kijang Island (Bintan) and Bawean Island (Gresik) using special CNG carriers. Pertamina has introduced CNG for vehicle fuel under the Pertamina Envgas brand since 1986. The program to convert petroleum fuels to CNG has been continued since 2012, however there are still many obstacles faced due to the lack of infrastructure for gas refueling stations for vehicle refueling.

4. Conclusions and Recommendations

Domestic use of natural gas has begun to develop and will gradually reduce the share of natural gas exports. Natural gas is expected to play a major role in the energy transition period towards utilizing renewable energy. Natural gas is a kind of energy that is more environmentally friendly than coal and petroleum fuels. The use of natural gas in the industrial sector can increase the added value of natural gas commodities as an industrial raw materials, while for power generation fuel it is an effort to use more environmentally friendly energy. The price of natural gas is also relatively cheaper compared to petroleum products and its reserves are still larger than oil. During this energy transition period, natural gas infrastructure needs to be continuously developed to maintain energy security. Good energy security can have an impact on increasing economic growth and national resilience.

The natural gas infrastructure that is the focus of development at this time is pipelines, LNG, and CNG. Other modes of gas transportation and distribution may emerge in line with the increasing gas demand and the economy of new infrastructure technologies. This infrastructure development enables natural gas reserves in remote areas to be processed and gradually connected to demand centers. The
geographical condition of Indonesia as an archipelagic country is a challenge in developing natural gas infrastructure. The growth of natural gas infrastructure can create greater flexibility in energy access, which in turn encourages further growth. A more massive infrastructure contributes to making energy systems stronger and more resilient to disruption.

Contribution
All authors contributed equally to this work. All authors discussed the result and implications and commented on the manuscript at all stages.

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