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# Ammonia and Methanol as Energy Carriers Towards 2060 The Long-Term Plan Strategy: A Comparative Perspective of China and Indonesia Cases

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**ABSTRACT**
The objective of this paper was to review China's long-term carbon neutral 2060 policy and to compare with Indonesia's case in term of energy carriers such as Ammonia and Methanol. Topics regarding China and Indonesia's long-term carbon neutral 2060 policy and strategy are important to be discussed because it will open up issues related to the role of primary energy, chemical-energy nexus and the blue energy economy supported by technology innovation, and political will. The energy-chemical nexus on the background of the Ammonia & Methanol industries are the largest sources of CO2 emissions in China, so it will contribute significantly to emission reductions from the energy transition to carbon neutral energy. From the efforts made by China, it can provide information and considerations to Indonesian policy makers and researchers on their efforts regarding resource management optimization to reconcile the tradeoffs on resources protection and development of socioeconomic as well as to ensure a sustainable system..

***Keywords***: carbon neutral, Methanol, Ammonia, blue energy economy, energy-chemical nexus

**ABSTRAK**
Tujuan dari makalah ini adalah untuk meninjau kebijakan netral karbon jangka panjang Tiongkok 2060 dan membandingkan dengan kasus Indonesia dalam hal pembawa energi seperti Amoniak dan Metanol. Topik mengenai kebijakan dan strategi jangka panjang karbon netral 2060 Tiongkok dan Indonesia penting untuk dibahas karena akan mengangkat isu terkait peran energi primer, perhubungan energi kimia dan ekonomi energi biru yang didukung oleh inovasi teknologi, dan kemauan politik. Hubungan energi-kimia di latarbelakangi industri Amoniak & Metanol adalah sumber emisi $CO_2$ terbesar di Tiongkok, sehingga akan berkontribusi signifikan terhadap pengurangan emisi dari transisi energi ke energi netral karbon. Dari upaya yang dilakukan oleh Tiongkok, dapat memberikan informasi dan pertimbangan kepada pembuat kebijakan dan peneliti Indonesia tentang upaya mereka mengenai optimalisasi pengelolaan sumber daya untuk mempertemukan timbal balik perlindungan sumber daya dan pengembangan sosial ekonomi serta untuk memastikan sistem yang berkelanjutan.

**Kata kunci:** karbon netral, Metanol, Amoniak, ekonomi energi biru, perhubungan energi-kimia

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## 1. Introduction

The Paris Agreement on 2015 under the United Nations Framework of Convention on Climate Change (UNFCCC) on 1992 has come into force in November 2016. Based on the agreement, a new commitment has emerged from the Parties to reduce greenhouse gas (GHG) emissions escalation, and adapt to climate change's impact. The Agreement defines a long-term goal to limit global warming to below 2°C above pre-industrial level, and pursue efforts on limiting it to 1.5°C (Paris Agreement, Article 2).

To achieve the main purpose of the agreement, many nations have begun to undertake non-obligatory depletion of emissions with a Nationally Determined Contributions (NDCs) form. However, currently detail on evaluation informs that in an upcoming future without any strong constraints, the greenhouse gases (GHG) that is released towards the open air will result in an average global temperature to escalate up to more than two degrees Celcius by 2040 and 2050 (IPCC, 2018). For that reason, it is crucial for all nations to accelerate their actions to reduce GHG on curbing the heating level to beneath two degrees Celsius (Höhne et al., 2020).

Currently, the People's Republic of China (PRC) is the biggest polluter of GHG in a global rate, by producing 26% of global emissions (UNEP, 2019). However, the Country has also put an encouraging and

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dynamic part for the worldwide actions against changes on the climate. Under the Paris Agreement (PAg), China's NDCs has devoted to achieve $CO_2$ emissions peak target by approximately 2030 as well as put their greatest attempts to reach the pinnacle earlier, on reducing $CO_2$ excretion to 60%–65% per unit in Gross Domestic Product (GDP) based on the rate at 2005; as well as to improve non-fossil fuels share in primary energy consumption to around 20% (UNFCCC, 2018).

China's Methanol economy is too big to be ignored. Policy makers both inside and outside China must keep abreast of its developments, and responsive to policies in China and anywhere else that probably is necessary to manage the impacts (Yang et al., 2012). Methanol production has almost doubled in last decades, with most of the growth is located in China. Based on current trends, its production could increase up to 500 Mt per year by 2050, which releases 1.5 Gt $CO_2$ per year, if its only sourced from fossil fuels.

While concern in vehicles that are powered with Methanol ($CH_3OH$) is waning in most of advanced countries, PRC nowadays has been so vigorous in introducing CH30H to be used as transportation's propellant, extensively to reduce their vulnerability on fuels purchased from abroad. Many Chinese auto producers offer vehicles that are using $CH_3OH$, to run namely vans, cars, buses, and trucks that can be generated with M85 (eighty five percent of CH30H, and fifteen percent of petrol) as well as M100 (a sterling CH30H), as well as CH30H/petrol that mixes with a smaller amount of CH30H substance (SGS, 2020). There are also availability of another types of vehicles with flexible-fuels that can be generated with varieties on blends of CH30H as well as petrol that is named as GEM (Gasoline (petrol)/Ethanol/Methanol (CH30H)) fuels (IRENA, 2019; Olah et al., 2018; Schroder et al., 2020). These types of vehicles have the same price as regular cars.

The topic of China and Indonesia's long-term carbon neutral 2060 policy and strategy is important to be discussed because it can open up issues related to roles of primary energy, chemical-energy integration and economy of blue energy. The nexus of energy-chemical with the Methanol & Ammonia industry background is the largest source of $CO_2$ emissions in China, therefore it will contribute significantly to emission reductions of the transition to carbon neutral energy. From the efforts that have been made by China, it provided information and considerations to Indonesian policy makers and researchers on optimizing resource management to guarantee the system's sustainability also as a cross point of resources protection and development of socioeconomic as well as the surroundings.

The sustainable development goals (SDGs) that can be achieved from carbon neutral policy planning are very broad, including namely no. 7 (inexpensive, and pristine energy); no.8 (sufficient job fields along with a growing economy); no.9 ( innovation, infrastructure and industry); no.12 (responsible production as well as utilization of resources); no.13 (take the necessary actions to reduce GHG emissions, and to mitigate and adapt to the impacts of climate change); and no.17 ( cooperation to achieve the goals, both regionally and internationally). Thus, the objective of this paper is to review China's long-term carbon neutral 2060 policy and to compare with Indonesia's case in term of Ammonia & Methanol as energy carriers.

The objective of this paper was to review China's long-term carbon neutral 2060 policy and to compare with Indonesia's case in term of energy carriers such as Ammonia and Methanol. A review and development analysis are needed to answer the formulation of the research problem in order to achieve its objectives in a reference article, namely to provide an overview and the latest developments on the progress of long-term carbon neutral 2060 policies and strategies in China, in addition to present conclusions with recommendations for future research. Furthermore, this paper was structured to discuss the policies and strategies developed by the reference articles, which will then be evaluated through a critical review, on the optimization and limitations of its implementation if it applies in Indonesia. The commitment to reduce GHG emissions needs to be based on a strong political support, by paying close attention to resource sustainability, developing science and technology as well as regional and international cooperation.

## 2. Method

This paper used the method of a descriptive research by using secondary data from relevant sources. Furthermore, in the discussion, the long-term carbon neutral policies and strategies in China and Indonesia are reviewed in terms of the development of the Ammonia & Methanol industry as well as its utilization. By reviewing these two policies, inputs can be obtained for the long-term carbon neutral policies and strategies of Indonesia in 2060.

The basic research methodology in this study is by literature review and comparative dimensions. Critical review is a qualitative research method that may be used to accelerate certain aspects of a research. This method can also combine data analysis methods along with data collection to present current findings (Padros et al., 2020).

The systematic stages of critical analysis are consist of few stages, with its first stage, namely search for articles that meet criteria according to the themes that are raised in the study. Each article is reviewed in depth and the results of the research are identified to be proceeded to a second stage. The second stage is to review the results of the identification of the articles that are mentioned in the first stage, that may obtain new findings. In third stage, it discusses the results of each article review, and put in to consideration of the obtained findings to reach conclusions (Tricco et al., 2017).

This paper identified articles that related to the targets towards carbon neutrality 2060 in China and Indonesia. Then in the second stage, regarding the relationship between the dominant energy source reserves, production capacity of Ammonia & Methanol and the scenario of the energy-chemical relationship policy had been be carried out to obtain critical study articles that show the development and implementation of carbon neutrality strategies and the policies in China and Indonesia. Afterwards, the blue energy economy development strategy is concluded in the third stage, after conducting a critical study of each article as references for this writing.

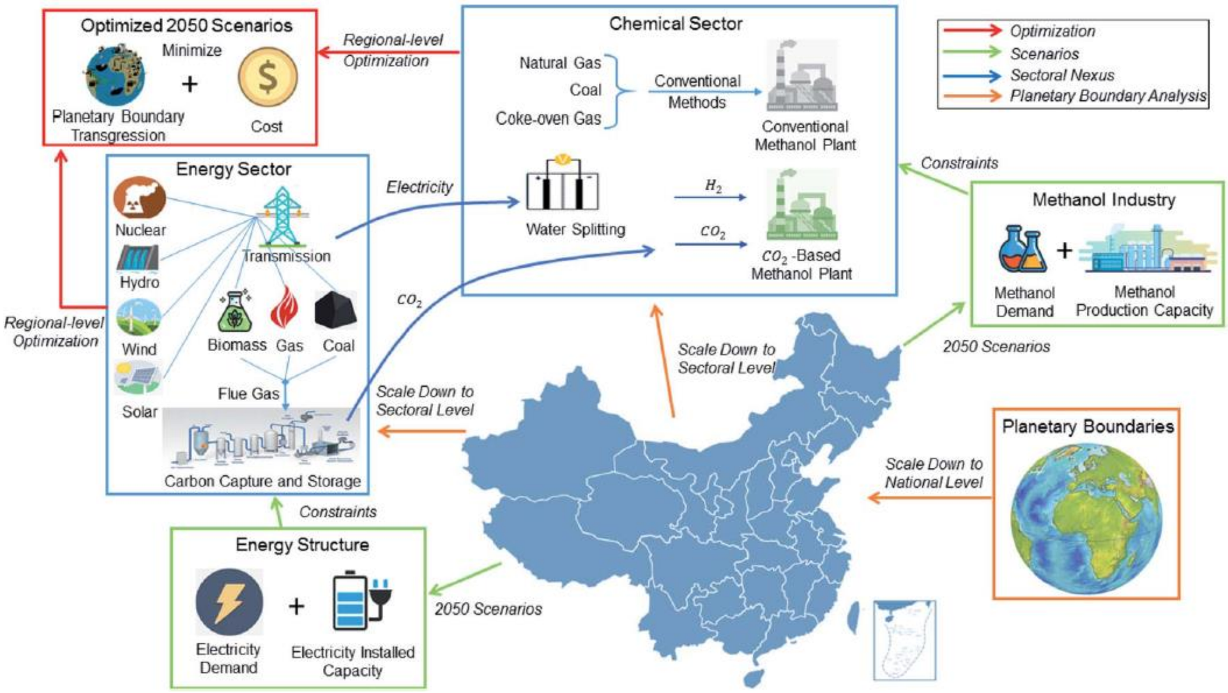


Fig. 1. Concept and research methodology of the energy-chemical nexus for Methanol production in China. Li et. al. (2020)

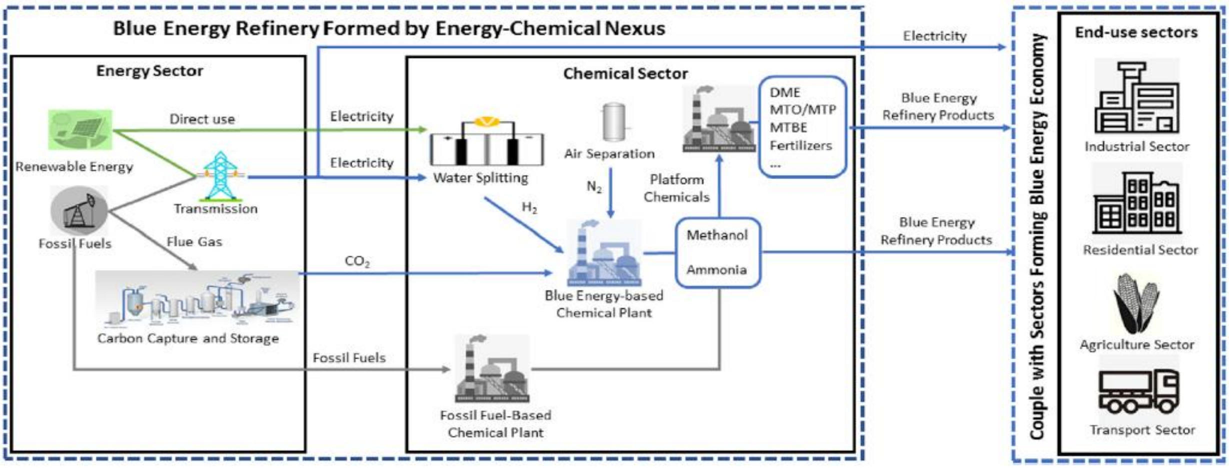


Fig. 2. Blue Energy economy and the refinery of blue energy's concepts. The nexus of energy to forms of chemical on the refinery of blue energy along with its end-use sectors integration, it also shapes the economy of blue energy. By way of nexus on energy to chemical, Ammonia & Methanol that act as energy carriers, are produced by using both green as well as grey energy, Li et. al. (2021).

## 3. Result

### *3.1. China's Carbon Neutral Energy Policy and Strategy*

The paper that examines China's long-term carbon neutral policy and strategy in 2060 using Ammonia & Methanol as energy carriers is entitled "*A quantitative roadmap for China towards carbon neutrality in 2060 using Ammonia & Methanol as energy carriers*" written by Li et al. (2021). This article was written by Yinan Li, Son Lan, Morten Ryberg, Javier Pèrez-Ramirez, in 2021 in the iScience Journal which examines optimism of the renewable energy and fossil fuels combination that forms "*blue energy economy"* as a promising and feasible form to be carbon neutral. There are several studies that support the evidence regarding the role of new energy in carbon neutrality that will assist the China's energy independence strategy (Caineng et al., 2021; Yongjun et al., 2021).

The background of hydrogen and Ammonia as research objects of Li et al. (2021) is because of Ammonia & Methanol manufacturing is Carbon dioxide emissions' largest contributor in China. Moreover, this study is a continuation of previous research which studied the nexus of chemical-energy for The Country's renewable Methanol manufacturing on sectoral development, environmental, geography, as well as the costs of economic's perspectives (Li et al., 2020). The used of methodologies and concepts in the previous research on the nexus of energy-chemical for China's Methanol manufacturing were as follows as shown in Figure 1.

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The method that is used in this research as a continuation of previous research is analytical research on the development of the economy of blue energy through the relationship between energy to chemical. The study of Li et al. (2021) uses a model of cooperation on regional which can optimize China's regional development of chemical and energy fields through the scenario of carbon neutral policy by 2060 with a minimal cost. The method that is used in this research as a continuation of previous research is analytical research on the development of the economy of blue energy through the connection of energy to chemical. The study of Li et al. (2021) uses the model of regional cooperation which can optimize China's energies and chemical sectors on its regional development through the scenario of carbon neutral policy by 2060 with a minimal cost.

The nexus of chemical and energy sectors have formed the refineries of blue energy by dividing the resources. It is shown in Figure 2, that the Carbon dioxide, fossil fuels and electricity are supplied simultaneously by the sector of energy to the chemical sector. Which then fuels on fossils-based along with chemical plants that based on the blue energy, creates Ammonia and Methanol with derivations of non-fossil and fossil energy. Beside of utilization as products of chemical, the importance of Ammonia & Methanol are also as raw materials for fertilizers on agricultural sectors, also various other products of chemical products and fuels, that will enlarge the blue energy refineries.

The formation on the economy of the blue energy will require other sectors to be merged with the blue refineries. Therefore, a carrier that fit in the blue energy is a key to all sectors' holistic transformation. Moreover, as Ammonia & Methanol are substance of liquids, that are suitable for keeping in a storage due to its stability at ambient conditions in transport, as well as circulation, thus, they are proposed as the carriers for the blue energy. In addition, a possibility to produce Ammonia & Methanol with derivations of non-fossil and fossil may in the future, offers an effective and a smooth transition of switching the economy of a conventional gray energy into a blue energy economy that is more sustainable.

In the study of Li et al. (2021) it conducted an analysis of a feasibility to establish a blue energy economy in China that are influenced by four factors, namely the first factor is an oversupply of electricity that is produced in a way of renewable energy with a large-scale deployment, regarding this matter the blue energy refineries biggest challenge is producing commercial hydrogen in a large-scale. However, hydrogen manufacturing method in electrolysis is promising, this can become a "0" emission based on which power source is being utilized.

With incentive policies stimulation, a significant progress has been made by China in the deployment of power plants based on renewable energies, that they have the biggest capacity of renewable energy plants being installed in the world. The three main renewable energy sources in China are namely: wind, hydro, and solar energy, furthermore their total capacity that has been installed in 2019 has gained 770 GW as we can see in Figure 3A. Biomass energy in China has also developed rapidly in comparison to those prime renewable energies, which in 2019 have improved by 26.6% and gained about 22.4 GW. Despite of the country's rapid development of installations, renewable energy's utilization is limited due to its intermittent as well as fluctuate nature.

The second influencing factor is $CO_2$ enermous amount as a result of Carbon Capture Storage's (CCS) development. Besides $H_2$, another paramount raw material on the manufacturing of Methanol in the chemical plants of blue energy is Carbon dioxide. $CO_2$ can be collected effectively from power plants of coal-fired thermal as well as another sources of emission with CCS itechnology. In China, deployment of the CCS is rapidly spread out by various policies in series that have been inniated by the authority. As described in Figure 3B, China in 15 provinces in 2018, already had 18 facilities of CCS, with involvement of industries regarding coal, oil and power. The maximum capacity of capturing Carbon dioxide in total are able to achieve for about 5.2 Mt annualy from the China's 18 CCS facilities.

In the future, the biggest segment for CCS Technology will be China (Wang et al., 2020). But, in that country there are many challenges faced by the large-scale deployment of CCS. The main barrier that hinders the CCS adoption to widespread is claimed to be namely the high costs, more specifically are the costs to guarantee the storage of geological security (Budinis et al., 2018). Even though the fastest solution for capturing CO2 is by having a storage of geological, utilizing Carbon dioxide as Methanol manufacturing's raw material will probably increase CCS economy significantly. As a consequence to improve the CCS promotions.

As a third factor, the readiness level on an advance technology for chemical synthesis of mediated Hydrogen. The level of proceeding as well as technological prepareness for mediated Hydrogen production of Ammonia & Methanol is seen in Figure 3C. The process of Haber-Bosch on transforming the Hydrogen along with Nitrogen to become Ammonia is a major industrial method to produce Ammonia in worldwide. Although the method of Haber-Bosch was invented in 1913 by Carl Bosch and Fritz Haber , and their technology is already as old as a century but it remains constantly producing Ammonia as of today for more than 90 percent globally (Wang et al., 2018a).

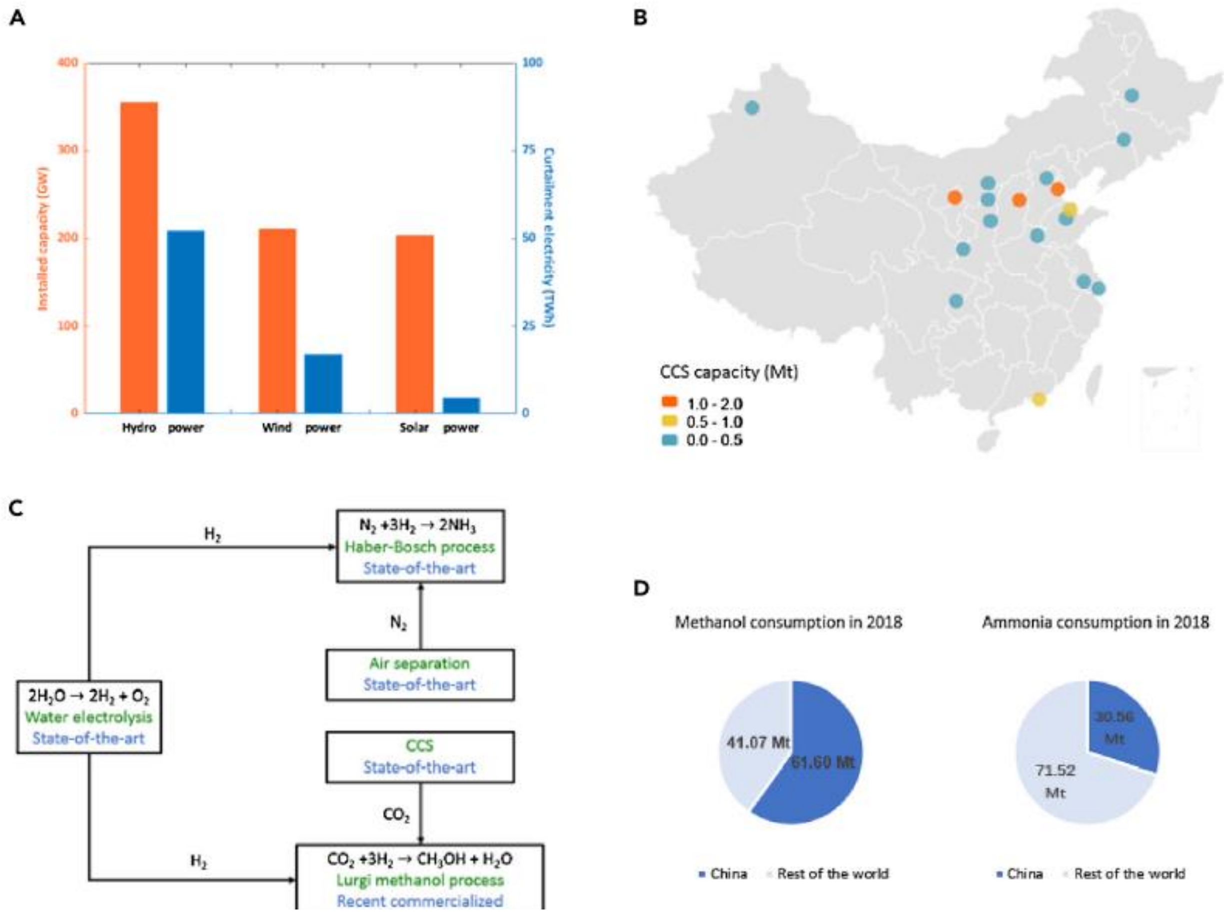


Fig. 3. China's feasibility studies on blue energy economy's forming. Li et al. (2021)
(A) Electricity comes from large-scale deployment of renewable energy is oversupplied.
(B) CCS facilities distribution.
(C) The readiness level of $H_2$-mediated chemical synthesis on high technology.
(D) Ammonia & methanol's largest market.

Nowadays, the world's Ammonia for about two thirds of it, is coming from natural gas. Meanwhile, because of the vast availability of coal as well as a limited reserves of natural gas, therefore around 97% of Ammonia is manufactured on coal-based, in China (Xiang and Zhou, 2018). The creation of Methanol from Hydrogen and Carbon dioxide is a relatively new applied science, in comparation to the immediate creation of Ammonia on Nitrogen and Hydrogen-based by the method belongs to Haber-Bosch.

A business firm in Iceland that is called Carbon Recycling International (CRI), has started the initial plant with a commercial-scale in the world for manufacturing Methanol that resulted from an immediate fusion of the Hydrogen and Carbon dioxide. The mill of CRI's has manufactured Methanol since 2014 for around 4000 t/annualy and is planning vigorously to enlarge its commercial scale of plant up to 50 Mt/annualy of Methanol that uses the Methanol of Lurgi process using Hydrogen and Carbon dioxide for its raw material (Graves et al., 2011).

The first Methanol manufacturing plant in China utilizing hydrogenation on $CO_2$ is being built in Anyang, Henan Province, which started in July 2020, the establishment of the plant is by bringing in the $CO_2$ hydrogenation to the technology of Methanol from the CRI (CRI, 2019). Along with the capacity of Methanol manufacturing that will reach about 110,000 t/annualy in the future, the Carbon dioxide hydrogenating Methanol manufacturing plant in Country will become the largest plant in the world (CRI, 2019).

The last factors are the implications of policy and the biggest consumer segments. The world's biggest producer and consumer of Ammonia & Methanol is China. The Nation's Ammonia & Methanol request has accounted for respectively 60% and 30% of global Ammonia & Methanol consumption, according to data in 2019, as can be seen in Figure 3D (Statista, 2020; USGS, 2020). The fossil resource structure of China is distinguished by ''abundant in coal, a little of oil, with a bit of gas''. Additionally, it has the proven reserves of 0.6% natural gas, 5% of crude oil, and 94% of coal (Han et al., 2018).

With a purpose to lessen its vulnerability on imports of gas and oil as well as to enhance its security in national energy, the Government of China is promoting the Ammonia & Methanol utilization as an alternative instead of importing natural gas and oil. As an example, to partially subtitute fossil-based gasoline, the Methanol-fueled vehicles are being introduced (Nami, 2015) as well as for heating purpose, the Ammonia & Methanol are also used to substitute the natural gas. The growth rate of the request in China is estimated to remain at 7% and request of Ammonia is steadily stable.

The current Ammonia & Methanol production methods mostly based on coal, in the country. This is due to the energy structure as mentioned above. The domination in producing top levels emmisions of Carbon dioxide, are the Chemical plants which are coal-based, combine with the increasing request of chemical products, this situation will probably hamper the target of neutrality in carbon by 2060. Thus, the perforation of chemical plants that are blue energy-based is very crucial for the development of the Methanol & Ammonia industry in China that is sustainable.

In addition, the majority of the plants of Ammonia in China are located as well as consolidated along with the plants of Methanol in sequent in the purpose to make a possible significant resilience because its proceeding is possible for a separation of a making process on Ammonia & Methanol that depends on the demand of the market (Xu et al., 2017). With a consolidated plant of chemical, not just allowing it to make an easier consolidation of adjustments to the demands of the market, also it will lead to reducing the production cost and investment capital which eventually provide a more significant possibility on consolidation of China's economy of the blue energy.

To conduct a research of nexus on energy-chemical in Li et.al's research, 2021, electricity was chosen as an example of a product related to the energy sectors that is possible to be produced with namely ten types of various technologies such as: solar, natural gas, coal, hydro, biomass and wind, including Carbon Capture Storage (CCS) also natural gas CCS, biomass CCS and coal CCS. Ammonia & Methanol can also be an alternative for the chemical sector, moreover these products can be made with a conventional materials such as coal, coke oven gas and natural gas, particularly, Ammonia & Methanol can also be made from Carbon dioxide and Nitrogen, each substance, processes by water electrolysis and supplied with H2 is referred to Methanol-based & Ammonia-based on Carbon dioxide and Nitrogen.

On researching the China's nowadays energy structure transition towards an economy of ''blue energy'' in the future in order to gain the goal of neutrality in carbon of 2060, it needs an optimization model to minimize current net costs over a period of more than 40 years from 2018 to 2060. Annually, it is required to use all available technologies that meet the product's demand (whether it is energy or chemical) while the amount of production does not exceed an already available capacity or a utilization of the potency.

Annual total emissions of GHG have to remain on the achievement plan that have been made by the authority throughout its period of the plan. As a record, political scheme in China is based on a structure of top to down. Therefore, local regulations are not acknowledged as a standalone regulation of their centralized system. When the government in the central published the strategy of nation on encouraging the economy of blue energy, then a firm inter-provincial cooperation is conducted by trading as well as distributing the resources.

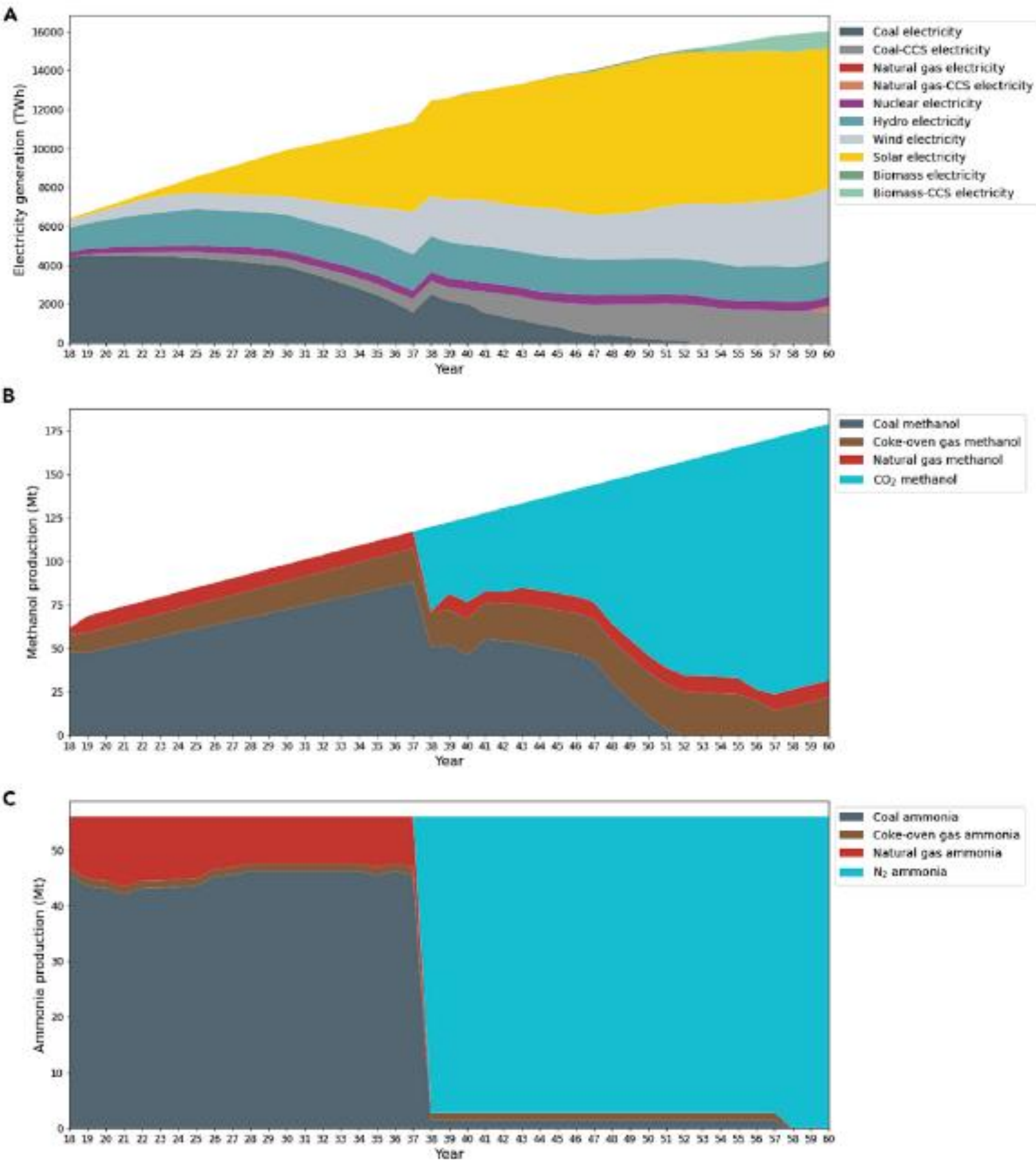


Fig. 4. Technology adoption: (A) Electricity; (B) Methanol; (C) Ammonia. Li et. al. (2021)

The mechanism of cooperation of interprovincial is able to make use the regional profits and find out about the most effective cost as pathways to achieve the economy of blue energy (Galán-Martin et al., 2018). To (IEA, 2019) recommend that limiting availability of $CO_2$ storage will increase energy transition costs. The Clean Technology Scenario (CTS) emission reduction pathway presumes the depository of Carbon dioxide is abundantly available to fulfill the agreed targets on the world's climate. These actions need an investment for an added amount of USD 9.7 trillion, in aspects of energy, fuel as well as industrial sectors transformations, relatively for a framework which comprehent solely on the recent devotion in national level.

Curbing the depository of Carbon dioxide will result a 40 percent acceleration in the added investment, for about USD 13.7 trillion, depending on emerged technologies as well as high-priced. To achieve net-zero emissions in an industry that is difficult to reduce like this may not be possible and at its best, it is more extravagant if not using the CCS. As it is one of the most develop as well as efficient alternatives in cost.

The results of Li et al. (2021) research are as follows:

*a. Technology assessment as well as its development in sectors.*

Along with the 2018 to 2060's planning period, various kinds of applied sciences were acquired in different annual periods, exhibiting an obvious trend of transition from a recent structure of the ''gray (conventional) energy'' onto the economy of ''blue energy''' future of as it shown in Figure 4. Regarding the types of power, with energies that are renewable gradually (i.e., water, solar, biomass, as well as wind) are number one sources of generation to make power, while the coal CCS plants will partially replace the coal-based facilities that are on process of being phased out. After 2050, biomass CCS will be adapted for driving more of GHG emissions to zero by 2060, this will work as a technology for a negative emission. In the chemical sectors, to anticipate an increasing demand of Methanol in the future. Regarding that issue, an observation of an early improvement in the making of fossil-based Methanol can be done; although, the process of making the Carbon dioxide-based will appear approximately at 2040 and by the end of the day will dominate a mixture technology of the finishing period of the plan. In the future, Ammonia request is hoped to be stable; furthermore, after 2040, an observation of a phase transition from fossil-based production of Nitrogen-based will be conducted when the majority of the already available plants will finish their lifespan.

In the energy sector, the renewable energy's share will significantly improve, giving around 70% of China's electricity generation in total by 2060 as can be seen in Figure 4A. Large-scale national energy production bases will be established in Xinjiang and Inner Mongolia. Eventhough the mainstream power plants of natural gas-fired as well as coal-fired will be entirely replaced, but for its substitutes: the biomass CCS, coal CCS, and biomass, will be widely spread out across the country, to make accertain of continuity on the entire system of power.

Each renewable *energy's share, namely* resources of wind for 90%, resources of solar for 80%, and China's resources of hydro for 80% are deployed in the north, southwest, and northwest regions (Huang, 2020). But, the main consumption of electricity is in the region of eastern. Thus, ultra-high voltage power for thousands of kilometers of transmission cables are required to meet with the China's methods *of* dealing with the imbalance geography. The blue energy refineries convert the renewable energies into *Eco* friendly chemicals.

With this method, renewable energies are not just being transported via the power grid but also transmitted out of the grid using ecofriendly Methanol and ecofriendly Ammonia as the vectors of the energies. It can be seen in Figure 4B, the extension of power grid is done by transporting the ecofriendly substances mentioned earlier.

In the sector of the chemical, a dominance of a conventional manufacturing ways of fossil fuel-based Ammonia & Methanol will disappear, and the main approach will be the manufacturing ways of blue energy-based chemical, namely Methanol and Carbon dioxide-based Ammonia manufacturing that uses $H_2$ provided by the water electrolysis. Even though gas-based Methanol production as well as coke oven natural gas will still be implemented in some areas of the provinces as their dominant method in 2060, with their total manufacturing output alone has accounted for about 30% of the total national Methanol manufacturing.

The plants of fossil fuel-based Ammonia will be entirely substituted by plants of the blue energy which made of Ammonia ($NH_3$) around 2060. Namely the provinces of Inner Mongolia, Qinghai, and Xinjiang will serve as the country's production bases for Ammonia & Methanol. The northwestern province, that is now quite least developed in comparison to the rest of the nation, will serve as the center of energies and chemical manufacturing in the country. These transformations will fully introduce an adoption of the Belt and Road Initiative as well as China's Western Development Program and China's Road (*China's Western Development Program and BRI*).

*b. The assessment of energy security*

A rapid growth of the demand as well as a declining reserves of oil has led to the country's dependence on imports of oil, that had surpassed 70% in last 2019 (IEA, 2020), a serious threat to China's resilience on energy sectors. The economy of "blue energy" will give China options to products of petroleum-based which also play a crucial measure in guaranteeing its security of energy. The country has acknowledged that Methanol is not just as a regular substance of chemical but also as an option for fuel on transportation means.

The People's Republic of China was the first nation to begin the implementation of a pure Methanol (M100) on modes of transportation, namely both for cars with passenger as well as trucks (Li et al., 2019). At 2019, the country's vehicles that used $CH_3OH$ in total have reached around 10,000 (Zhao, 2019). While cars with electric mode have outnumbered cars that used Methanol, which dominate alternative car fuel segments. Moreover, upgraded Methanol engines offer a more promising new direction. Therefore, based on this background, the substitution of gasoline that is supported by an existence of surplus in Methanol manufacturing is studied further in this part.

Based on the estimation of the Country's dependence on its imports of oil (Wang et al., 2018b), the oil expenditure in the Nation continues to increase as well as reach its point for around 1027 million tons, on the dependency of its oil import ratio surpassing 80% by 2030.. In general, presumes that $CH_3OH$ is eligible as an option to substitute petrol as well as to improve its reliability in energy sectors.

Methanol blazes more coherent compare to gasoline for the engines, Despite of its enthalpy is just half that of gasoline. In addition, Methanol for about 1.4 t is able to substitute for gasoline as much as 1 t (Yang and Jackson, 2012). Thus, a total amount of substituted gasoline that able to be transformed into crude oil based on the exact coefficient of oil standard for crude oil per kg is 0.83 kg gasoline (Zhili et al., 2019).

### *3.2. Indonesia's Carbon Neutral Energy Policy*

Indonesia's oil imports have increased rapidly in recent years. This resource-rich country is the fourth biggest coal manufacturer in the global rank as well as the biggest provider of natural gas for the region of Southeast Asia. Furthermore, this country is the third largest biofuel manufacturer in the world, after Brazil and the US, while doing on improvement efforts to exploit the potential of renewable energy (British Petroleum, 2020).

In Indonesia, all Ammonia plants based on local natural gas are located in Aceh, South Sumatra, West Java, East Java, East Borneo and Central Sulawesi with a total capacity of 8.59 Mtpa, 80% of the total production is used to produce nitrogen fertilizers (urea and its derivatives) and the remaining is used for raw materials of ammonium nitrate, industrial chemicals, and export commodities (*Pupuk Indonesia,* 2020; Ministry of Industry, 2021; BPS, 2020). Recently, Ammonia exports to Japan and other countries have increased. Japan is one of the countries that uses Ammonia as a green fuel. However, Indonesia has no plans yet to develop Ammonia as an alternative fuel.

Indonesia only has one local natural gas-based Methanol producer company that is located in East Borneo with a production capacity of 660 x $10^3$ tpa, however 50% of the total production has been committed to be exported to Japan as the investor. The remaining is consumed domestically for biodiesel and other chemical industries. Since 2015, the Government has required biodiesel B15 (85% diesel, 15% biodiesel) and applied B30 from 2016-2025 through the Regulation of Minister of Energy and Mineral Resources Number 12 of 2015 on The Third Amendment of the Regulation of the Minister of Energy and Mineral Resources Number 32 of 2008 on Provision, Utilization and Trading of Biofuels as Other Fuels (Ministry of Energy and Mineral Resources, 2015). Imports of Methanol have increased every year, especially in 2016 when the application of B30 has begun. For the production of 1 million liters of B30, 1,122 x $10^6$ tpa of Methanol is required (KMI, 2019).

In the long-term mitigation scenario (Indonesia LTS-LCCR 2050), the current policy scenario assumes measures as well as mitigation in NDC are prolonged to 2050 by mixing of Refuse-Derived Fuel (RDF) raw materials in the cement industry and escalating the efficiency of Ammonia plants with advanced technology.

Indonesia LTS-LCCR 2050 stated that in accordance with the target that has been set by the Indonesian Government in a purpose on maintaining a sufficient and secure food sector, The manufacturing of NH3 is predicted to accelerate at a growing rate of one percent annual, and reach 10.3 million tons by 2050. With an integrated urea manufacturing to an Ammonia production plant that captures $CO_2$ from $NH_3$ plants to be used in the raw materials of manufacturing urea. Therefore, urea manufacture has escalated from 6,6 million tons (2010) to 9,0 million tons (2020) with a growing rate of 3.2% annualy. In the event of COVID-19 pandemic, the manufacturing capability is at 9 million tons, this remains a high number (2020), also it is expected to increase by 2.4% annually on a period of 2020-2050 to gain 14.7 Mton in 2050.

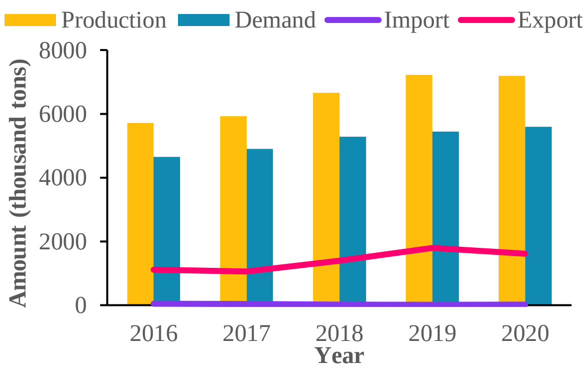


Fig. 5. Indonesia supply demand of Ammonia. (Pupuk Indonesia, 2020; MoI, 2021; BPS, 2020)

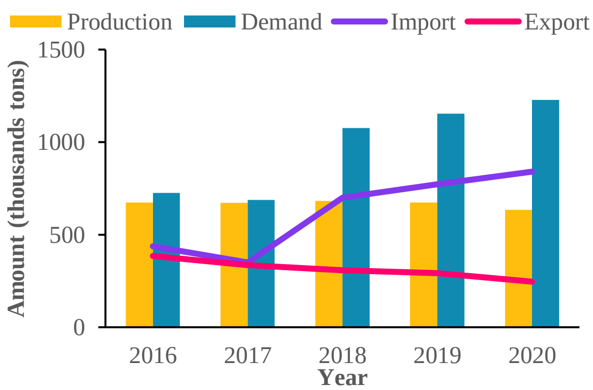


Fig. 6. Indonesia supply demand of Methanol. (MoI, 2021; BPS, 2020; KMI, 2020)

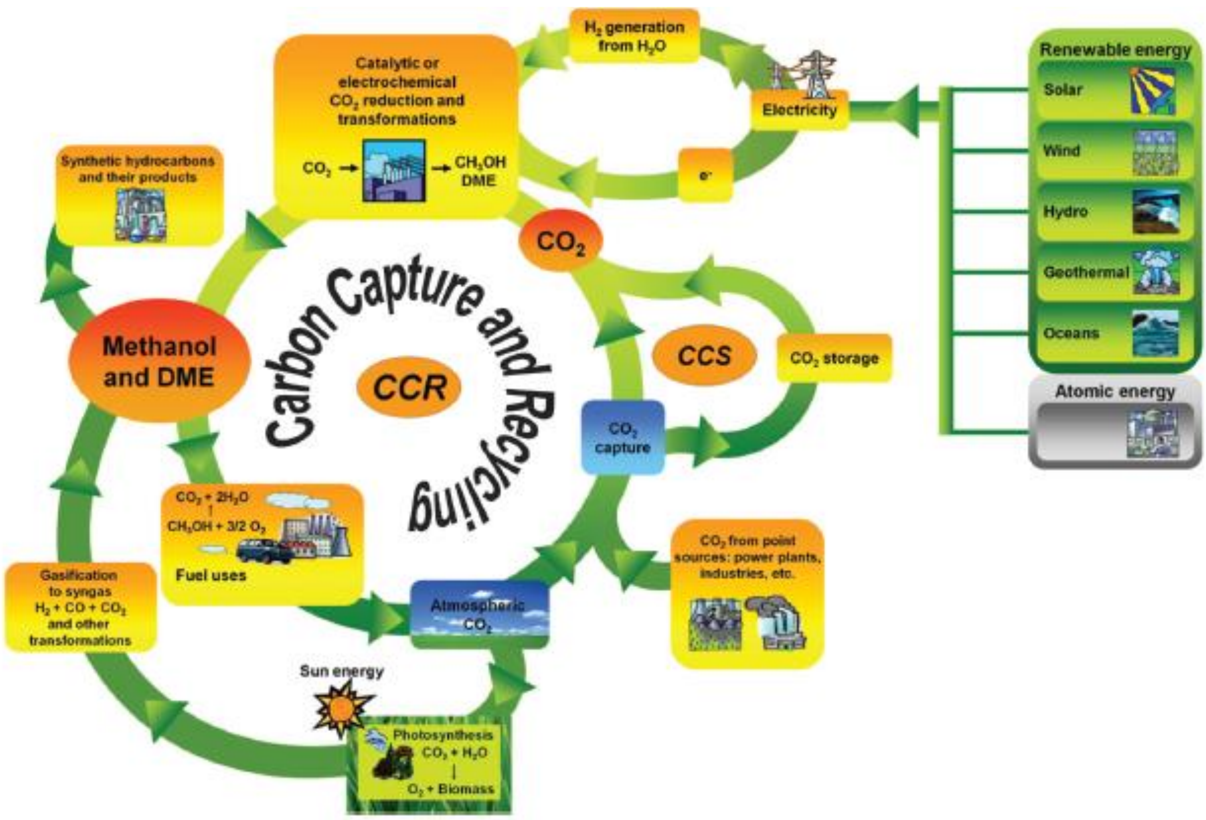


Fig. 7. Antropogenic carbon cycle within the Methanol economy. Goeppert et al. (2014)

The Ammonia reformer technology was upgraded from 45 gigajoules/ton $NH_3$ to 40 gigajoules/ton $NH_3$ on consumption of natural gas. The improved technology could be in the form of a coherent $NH_3$ reformer and/or a coherent urea in capturing $CO_2$. By 2050, it is presumed that 38% of a dominant $NH_3$ production consumes natural gas at a level of 40 gigajoules pertonnage $NH_3$. With the transition scenario, mitigation is increased by applying better technology in order to make most of the Ammonia production that consumes a level of 40 gigajoules/ton natural gas of $NH_3$ by 2050. In the framework of low in carbon which in line with the PAg purpose, the utilization of natural gas in major power plants shall consume natural gas for at a minimum level of 36.6 gigajoules of natural gas pertonnage $NH_3$ or as in The Best Practice Technology (BPT)of 2050.

The technology of $NH_3$ plants was upgraded from 45 gigajoules pertonnage $NH_3$ to 40 gigajoules per tonnage $NH_3$ on consumption of natural gas. The improved technology could be in the form of a coherent $NH_3$ plant and/or a coherent urea in capturing $CO_2$. By 2050, it is presumed that 38% of the dominant $NH_3$ production consume natural gas at a level of 40 gigajoules pertonnage $NH_3$. With the transition scenario, mitigation is increased by applying better technology in order to make most of the Ammonia production that consumes natural gas with a level of 40 gigajoules per tonnage $NH_3$ by 2050. The low in carbon framework in line with the PAg purpose, the utilization of natural gas in predominant power plants shall at least consume natural gas on the level of 36.6 gigajoules of natural gas per tonnage $NH_3$ or in line with BPT at 2050.

For the record, the world's BPT currently has consumption of natural gas with a level of 32 gigajoules pertonnage $NH_3$, whlist the Best Available Techniques (BAT) in Europe has reached 31.8 gigajoules/ton $NH_3$, the global BAT has reached 28 gigajoules pertonnage $NH_3$, and several factories Ammonia in Indonesia have 33-35 gigajoules pertonnage $NH_3$ (Indonesia LTS-LCCR 2050). Indonesia has not yet published a scenario for Ammonia as a green fuel or developed it to produce Ammonia from renewable materials.

Indonesia is a country of a large oil and gas manufacturer, meanwhile in order to sustain as well as improve its manufacturing, the Government will need to access more on gas fields of high Carbon dioxide. The said purpose also needs a strategic planning as well as consideration for Carbon dioxides reduction, to gurantee the maintenance as well as viability on commercial projects of a low in carbon hereafter. Numerous funded researches as well as project of

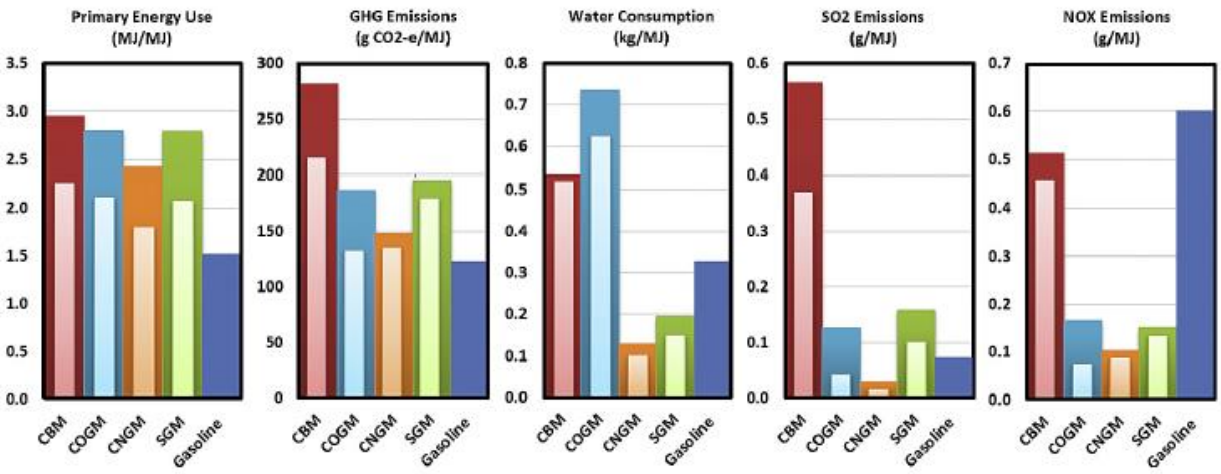


Fig. 8. The Methanol ($CH_3OH$) that is made of regular petroleoum as well as four types of raw material, creates life-cycle burdens of environment (*Coal based Methanol (CBM), Coke Oven-Gas based Methanol (COGM), Conventional Natural Gas-based Methanol (CNGM), Shale Gas-based Methanol (SGM)*). *Yao et. al. (2018)*

pioneers have been held and authorities of the Indonesian oil and gas sectors are under discussion of Enhanced Oil or Recovery $CO_2$-EOR and Enhanced Gas Recovery or $CO_2$-EGR.

Japan continues as a strong supporter and promoter of the region's Carbon Capture, Utilization and Storage (CCUS) as well as developing the technology of CCS for domestic and export necessities. In that purpose, Japan, through a Joint Crediting Mechanism (JCM), has shown support for the CCS project in Indonesia.

The selected well as a candidate to be converted The selected well as a candidate to be converted into Carbon dioxide injector well is Jepon-1 (JPN-1) well in Gundih Field, Indonesia, that is used to be an exploration well of gas. This research discusses about assessment of the JPN-1 Well integrity, with main focuses on namely 1) The analysis on corrosion as well as selection on tubing materials, 2) The assessment on the well for any leaks , 3) The cement's assessments that cover in behind an available casing as well as liner, 4) The assessments of repairment on cementing, and 5 ) The future rework design plans (Marbun et al., 2019).

In 2020, September, there was an announcement by the government of Japan on stating they would support the pilot project at Central Java, in the Gundih Gas field. This project was established by JANUS as well as J-Power with collaboration to PT Pertamina along with other related local stakeholders. The consortium will draft a detail plans for a demonstration project of the CCS that will distribute $CO_2$ gained from the proceeding of natural gas via a pipeline for four kilometer to a close by well for EGR along with its injection. The consortium was inspecting a probability on implementing JCM for the said project. (Kadir, 2020).

In addition, one of the Ammonia producers that located in Central Sulawesi supported by Mitsubishi Corporation, Japan Oil, Gas, and Metals National Corporation (JOGMEC) that has signed a Memorandum of Understanding (MoU) with the Bandung Institute of Technology (ITB) in April 2021, to develop a study regarding CCS and CCUS to absorb $CO_2$ emissions from Ammonia plants because the factory has not been integrated with the urea plant (ITB, 2021). By 2050, the power generation fusion will be: 43 percent renewable energy, 38 percent coal, 10 percent natural gas, and bioenergy with 8 percent CCS/BECCS. It is estimated that by 2050, about 76 percent of coal-fired power plants will be equipped with the CCS to reach the zero emissions target in coal-fired power plants (Indonesia LTS-LCCR 2050).

## 4. Discussion

It began with the coal, and then proceeded with petroleum as well as natural gas, the use of fossil as conventional fuels has made it possible for a rapid and unprecedented development of human society. However, the burning of this resource at an ever-increasing rate is resulting a large amounts of anthropogenic $CO_2$ emissions, which have exceeded a natural carbon cycle, that cause adverse global environmental changes, the full extent of which remains unclear. Even though fossil fuels are now still abundant, they are in limited amount and eventually will run out of time.

The Carbon dioxides recycling on chemical into materials and fuels that are renewable, particularly Methanol($CH_3OH$) provides a strong options to address these problems, namely changes in global climate and depletion of a fossil-based conventional fuels. Furthermore, the energy that is required to reduce $CO_2$, is possible to be derived from various renewable sources of energy such as wind and solar. In addition, the $CH_3OH$, is the simplest liquid of C1 product that can be taken out of any sources of carbon, which include Carbon dioxides and biomass, that had been introduced to be the key component of the anthropogenic carbon cycle within the scenario of the ''Economy-based on Methanol''.

Methanol is an excellent fuel also for fuel cells, stoves, internal combustion engines, etc. Its dimethyl ether, the dehydration product, that is used as a substitute for liquefied petroleum gas (LPG) as well as a diesel fuel. For other usages, $CH_3OH$ is able to be converted into ethylene, propylene, and some other products of petrochemical that are made of fossil fuels at this moment (Goeppert et al., 2014).

With the reputation as the largest Methanol manufacturer in the globe, PRC is always a way ahead of establishing Economic-based on $CH_3OH$ compare to other countries, aided with supports of the Government. The PRC government in 2009, has promoted the Methanol-petroleum (M85) fuel fusion, with a national standard for eighty five percent, thereby boosting the vehicles with Methanol-powered to spread out. However, the country does not produce $CH_3OH$ as a purpose for establishing the Economic-based on $CH_3OH$, which was bio-Methanol manufacture, in contrary, it was made of three raw materials of fossil: natural gas., coke oven gas (COG), and coal. The investigation of the impact on environment due to the utilization of CH3OH that is made of various kinds of raw materials as propellent has been conducted. The results are illustrated in Figure 8.

The environmental burden has been mirrored with a higher level of energy as well as consumption of water which also released the gases of greenhouse along with the sulfur dioxide. The technology of gas coke oven-based that is carried out by the government of PRC is environmentally friendly even more, compare to the coal-based, on the other hand it is also less profitable compare to the petroleum (Yao et al., 2018).

Methanol is a versatile chemical raw material, including for fuel. In addition to fossil sources, various raw materials may involve in the production of Methanol, from: biomass through municipal solid waste to $CO_2$ from exhaust gas. The Life Cycle Assessment (LCA) has obviously emphasized on the profits for environment on utilizing $CH_3OH$ that is made of renewable energy used as a raw material for propellant. We can say that the technology to manufacture $CH_3OH$ uses Hydrogen for raw material as an alternative to $CO_2$ requires electricity content with a significant amount, which then made the contribution of $CH_3OH$ for maintenance is in accordance with the usage of the energy sources.

In terms of Circular Economy (CE) and its sustainability, the utilization of sources on renewable energy is profitable for all aspects. Methanol economy contributes to CE's goals by, among other things, converting exhaust gases from recovery energy into a secondary level of the raw materials. A transformation into CE is reachable by using methods and technologies that are new and innovative, together along with an effective action in political aspects (Magda et al., 2019).

The transition of the world's economy to neutral in carbon energy will require abundant investments for the development of infrastructures, deployment, as well as technologies. The scale in the economies of the production and utilization of renewable Methanol will eventually take in to a competitive propellent prices for various fields. As the substance of a liquid with the highest ratio of hydrogen in to the carbon from all non-solid fuels (especially liquid), $CH_3OH$ may become the major carrier for energy.

Because of $CH_3OH$ is able to be utilized in the available combustion engines, along with rail power as well as chemicals from more sophisticated proceeding of a creation of the regular gray as well as blue $CH_3OH$ that are able to be used as of today, but overtime there will be a tremendous transition to the green $CH_3OH$. Thus, $CH_3OH$ as a renewable energy has a unique position to become the fuel of the future (IRENA, 2020).

Another undeniable challenge is the PRC's establishment of new coal plants continuously, as well as its support for expansion in other countries. Despite of a decreasing benefit of coal-fired power plants, in 2020, just in the first 6 months of the year, the Country has established more coal-based power plants than half of new coal-based power plants in the whole world. Furthermore, the PRC is right now also has an on going plan for 249.6 gigawatts of coal power capability, this is larger than the available capability in the United States of America as well as India, respectively 246 gigawatts and 229 gigawatts of coal power plants capability that are already available on those countries (Myllyvirta et al., 2020).

With an accounting for more than three-quarters of global net growth, China is by far the single biggest driver of primary energy growth. The next biggest contributors are India and Indonesia, while the US and Germany recorded the biggest declines in terms of energy. In 2019, Indonesia exported 16.5 x $10^9$ $m^3$ of LNG and of which 6.2 x $10^9$ $m^3$ to China. In addition, at the same year Indonesia also exported 9.18 exajoules of coal (3.13 x $10^8$ TCE (tons of coal equivalent)), of which 2,19 exajoules (7.5 x $10^7$ TCE) was exported to China (British Petroleum, 2020).

Regarding renewable energy, Indonesia leads in terms of biofuel production in the Asia Pacific Region at 123 x $10^6$ tons in 2019, while China is only 50 x $10^6$ tons. Proven coal reserves at the end of 2019 were 39.89 x $10^9$ tons (British Petroleum, 2020). These data show that Indonesia has the potential to utilize domestic coal for Methanol production to support biodiesel and DME production as a substitute for LPG. At the end of 2020, Indonesia imported 76% of the total demand, or 6.1 million tons of LPG (CNBC Indonesia, 2020).

The policy for developing Methanol from natural gas as well as Methanol and DME from coal has been designated as a National Strategic Project through Presidential Regulation Number 109 of 2020 on the

Third Amendment to Presidential Regulation Number 3 of 2016 on Acceleration of Implementation of National Strategic Projects (PSN) covering the Bintuni Bay Industrial Estate, West Papua Province, Tanjung Enim Coal Gasification, South Sumatra Province and Construction of Coal to Methanol Facilities in East Kutai, East Borneo Province.

Moreover, in this regulation, Indonesia has also set PSN for the development of green fuels (*Merah Putih* Catalyst of *Pupuk Kujang* Cikampek, Hydrogenation of CPO PT Pusri Palembang, RU III Plaju Green Refinery, and Green Diesel Bio Revamping RU IV Cilacap) in Central Java Province, South Sumatra, and West Java Province.

Indonesia's initial plan to build CCS on oil, gas and coal sources, which is targeted to reach 76% by 2050, needs to be reviewed to set a more aggressive target because on that year, based on the research's results by Li et al. (2021), is a preparation for take-off moment towards carbon neutrality in 2060.

In addition, Indonesia's geological vulnerability, which is an area with a prone of earthquakes due to its path of meeting for the 3 tectonic plates, which are: the Eurasian Plate, the Indo-Australian Plate, and the Pacific Plate, will give its own constraint and will require a carefully planning in terms of CCS security against earthquake disaster.

This situation is giving its own obstacles to the development of CCS and a follow up $CO_2$ utilization. In designing earthquake-resistant infrastructure, the magnitude of the earthquake burden is determined based on the Indonesia Earthquake Hazard Map which is very specific accustom to Indonesian situation of earthquakes. Recent national sources of earthquake and hazard maps describe at least there are active faults of 295 along with megathrust earthquakes of 16, in segments (Irsyam et al., 2020).

The policy of energy-chemical nexus in forming the blue energy economy that was offered by Li et al. (2021) covers Ammonia and Methanol, can be considered by Indonesia to prioritize national energy resilience and giving more attention to research and investment in transportation systems, downstream industries and electricity as well as other sectors. Ammonia derivative industries that are able to absorb $CO_2$ other than urea, is including soda ash that made of Ammonia, salt and $CO_2$ which are indispensable to support the glass, ceramics, detergent industries need to be prioritized for import substitution and provide added value domestically rather than being exported. However, even until now, Indonesia does not have any soda ash factories.

Indonesia is a destination country for China's BRI investment, that includes the industrial sectors connected to mining activities, smelting, cement and power generation, which are growing in all over Indonesia; therefore, this may become an important dynamic to monitor. As an example: the plant may use a less sophisticated technology due to budgetary constraints, but also because of various technological flexibility issues, such as: in a remote area, it may have smaller infrastructure capacity, that probably can only accommodate subcritical power plants. Eventually, it will bring to an adverse social impacts as well as the environment (Tritto, 2021).

A loose requirements as well as a weak enforcement of technology standards in Indonesia, become the reasons of variation in technologies between the Chinese and Japanese companies. Therefore, initiating funding support the way that has been done by Japan in the CCS program, is also necessary to be done by China for its industry in Indonesia. In another critical condition, Indonesia is an archipelago country, while China is a mainland country; therefore, Indonesia has a higher risk of vulnerability to the impacts of climate change.

## 5. Conclusion

The energy-chemical nexus that focuses on Ammonia and Methanol for the China's blue energy economy as one of its strategies towards carbon neutral 2060, provides economic and energy resilience to face the 2030 energy transition. By optimizing its coal energy resources consistently from conventional technology and gradually shifting it to environmentally friendly technologies, China is placed as the biggest manufacturer of Ammonia, Methanol, DME and car Methanol in the whole world.

Based on empirical evidence it is thought that it is important for the Indonesian policy makers to explore thoroughly the planning and strategy of carbon neutral 2060 by basing on the potential of primary energy and integrating it with the chemical sector to create energy-chemical linkages. This is a way to achieve sustainable development goals in mitigating and adapting to climate change.

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