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# Briefed on the development and progress of CCUS projects in China, USA, Western Europe, Russia, Norway, India, and Indonesia: a journal review

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**Abstract**
The global commitment to manage climate change issues is getting stronger and stronger. Therefore this review is carried out with the objective to obtain recent progress of efforts on emission control and handling through CCUS by various countries around the world. This review is carried out to highlight the development of carbon capture utilization and/or storage (CCUS) in China, the USA, and India, as these countries are known to be the most energy consumption countries. Its campaign to reduce emissions will contribute significantly to the effort of managing the global warming issue. The method used in this study is a literature review on the policies, studies, and projects mainly in China, and several other countries for comparison. The review found that although China is relatively late in doing such activities on climate change, but the progress is significantly faster than the others. The numbers of studies and patents are much higher than other countries, and the central and local governments issued a number of policies to help encourages the industries. The USA is known as one of the leading countries implementing CCS/CCUS and still creating incentive policies. European, Russian, and Indian countries pay serious attention to this effort and implement it while Indonesia as a non-industrial country is catching up. From this literature research, it can be concluded that the technology for implementing CCUS is still at a high cost so policy and government funding support is needed as well as non-traditional sources of capital source such as green funding, carbon trading, etc.

**Keywords**: CCUS; climate change; global warming; net zero emissions; policies

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## 1. Introduction

According to the IPCC's sixth assessment report, between 1850 and 2020, the average global surface temperature rose by around 1.09°C, and nearly all parts of the world experienced surface warming (Li et al., 2022). Similar to the aforementioned IPCC report, The Sustainable Development Goals Report (SDGs United Nations, 2022) predicted that, compared to the pre-industrial age between 1850 and 1900, the world temperature climbed by 1,1°C in 2021 and will do so again in the following 1–5 years, reaching 1,5°C. According to the IPCC (2014) and Tarufelli et al. (2021), industrial processes, combustion, and anthropogenic gas emissions account for the majority of the rise in GHG emissions between 1979 and 2010. For at least the last 2000 years, human activity has been responsible for a significant increase in the global temperature. Additionally, every populated area on the planet is already experiencing the effects of climate change, with human activity responsible for a large number of documented changes in weather and climatic extremes (IPCC Working Group I, 2021). According to the International Energy

Agency (IEA), 2021 study A Roadmap for the Global Energy Sector, the goal of having net zero emissions by 2050 is necessary to keep global temperatures from rising by 1.5°C. The objective of this research is to understand how the world reacts to the climate change issues explained above and learn about studies and implementation of CCUS (Carbon Capture Utilization and Storage) that have been carried out and are in progress to help manage the increase of carbon emission in the atmosphere.

## 2. Methods

The journal titled Several Key Issues for CCUS Development in China Targeting Carbon Neutrality Jiutian et al., (2022) is selected by the authors as the main article reviewed to evaluate the development of CCUS (Carbon Capture and Storage) in China. The authors are interested in CCUS as this effort contributes 32% of emissions reduction by 2050 (Leonzio et al., 2020).

The authors will also review other journals and articles to enrich this review which includes study activities, pilot projects, government policies, and costs from various countries, such as the USA, Europe, Russia, India, and Indonesia. In addition, various forms of support from the government are also reviewed, starting from fiscal policy, carbon credit, government financial assistance, carbon trading mechanism, and environmental-based sources of funding.

## 3. Results & Discussion

### *3.1. CCUS in China*

The journal Several Key Issues for CCUS Development in China Targeting Carbon Neutrality written by Jiutian et al., (2022) opens with an overview of the general condition of $CO_2$, world organizations in the field of climate control, and examples of ongoing CCUS activities

In the introduction, it is written that carbon neutrality, also known as zero $CO_2$ emissions, can be attained by balancing the direct and indirect production of $CO_2$ from human activities with a continuous effort by CCUS. CCUS activities have been executed in the oil and gas field for a long period of time, one of which is a gas purification facility in Texas during early 1970s, which was sent to nearby oil fields to improve oil production. Up until the end of 2020, 65 CCUS activities have been executed across the globe, 26 of which have operated with a capacity of 40 million tons of $CO_2$ annually.

The first step in the fight against climate change was the establishment of the Intergovernmental Panel on Climate Change (IPCC) in 1988, thanks to the efforts of the World Meteorological Organization and the United Nations Environment Program. Several countries joined the UNFCCC (United Nations Framework Convention on Climate Change), an international framework for coordinated efforts to combat climate change by slowing the rate of global warming, in 1992. Paltsev et al. (2021) estimate that China contributed almost 84% of the world's industrial $CO_2$ emissions, which increased from 6.91 $GtCO_2$ in 1990 to 11.1 $GtCO_2$ in 2014.

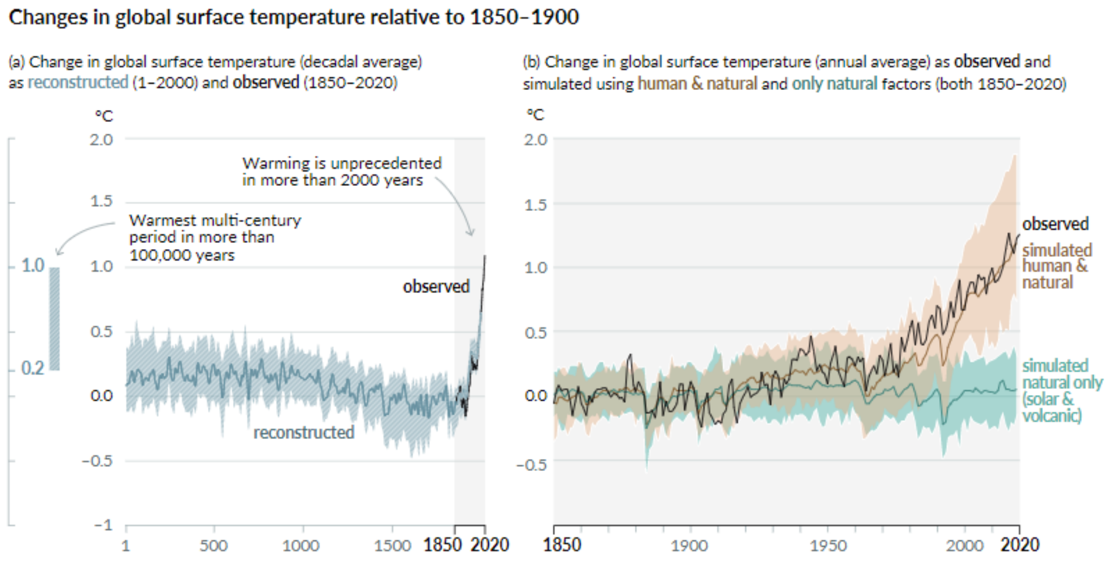


Figure 1. Global Surface Temperature
(Source: IPCC Working Group I Report, 2021)

This reviewed journal states that under the 2016 Paris Agreement, IPCC published the 2018 report that states that to reduce the global temperature by 1,5$^{0}$C, net zero emission must be achieved by 2050. In accordance with it, in the year 2020, the Chinese government proclaimed the Net Zero Emission by 2050 target (NZE-2050).

The CCUS program development in China is split into two phases; before and after the proclamation of the NZE-2050 target. Before the NZE-2050 era, the CCUS program is initially featured in the "Outline of the National Medium and Long Term Science and Technology Development" document published by the State Council in 2006. The policy is then followed up by the Ministry of Science & Tech, Ministry of Ecology & Environment, and the National Development and Reform Commission publishing a few derivative policies, among which are (1) "Technology Roadmap Study on CCUS in China", (2) "Technical Guideline on Environmental Risk Assessment for Carbon Dioxide Capture, Utilization & Storage", (3) "The 12$^{th}$ Five-year National Special Plan for the Development of CCUS Technology", (4) "The 13$^{th}$ Five-year Plan to Control GHG Emission", and (5) "Promoting CCUS Pilot Demonstration".

Some local governments in China also published policies in support of CCUS development. One of them is the Guangdong province government giving out incentives for CCUS projects in the power plant industry. Even though numerous projects run in the era, most of the policies centered around research and development. Economic incentives are still few and in-between, thus support for implementation projects is still insufficient.

In the post-2020 era, after China established the NZE-2050 target, the Chinese government shows more tangible support for the policy. For the first time, the CCUS program is featured in the 5-Year work program "The 14$^{th}$ Five-year Plan for Economic and Social Development" in the year 2021, followed by a pair of general policies, (1) "Working Guidance for Carbon Dioxide Parking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy" a joint policy by the Communist Party of China Central Committee and the State of Council to push the research and development of technology, large scale experiments, and implementations, and (2) "Action Plan for Carbon Dioxide Peaking Before 2030", published by the State of Council as a comprehensive base for CCUS initiative, encompassing research and development of technology, large scale experiments, and international partnership.

The Ministry of Ecology & Environment published "Guidance on Promoting Investment and Financing in Response to Climate Change" in October 2020, instructing capital resources to be involved in the climate control endeavor. This publication marked the beginning of financial policy support's fulfillment. In 2021, the Ministry of Ecology and

Environment strengthened the idea of the funding and investment system in support of CCUS, and on November 2021, the People's Bank of China (PBOC) launched a new mechanism to push the funding of Low-Carbon, which focuses on some areas such as environmental protection programs, technology development for emission reduction, energy conservation, and clean energy. A minimum of 3000 billion yuan (USD 437 billion) was spent in advance of lowering carbon emissions.

China achieved second place in the world for publishing 984 analysis publications between 2000 and 2019. in 2016, China exceeded the USA by 170 published articles. China also booked 1067 patents in the period between 1967-2018, exceeding the USA in the year 2012 by 220 patents.

*3.2. Comparison with the USA*

To Compare the policies of CCUS China and the USA, the authors referenced to the journal titled "Comparison and Clarification of China and US CCUS Technology Development" (Li et al., 2022). According to this journal, $CO_2$ contributed 63% of the greenhouse emission that caused global warming, and CCUS contributed to the effort of reducing 15% of $CO_2$ emissions - a number that keeps growing in accordance with the growth of technology. CCUS aims to be able to contribute 9% of emission accumulation reduction by 2050 (International Energy Agency (IEA), 2019). IPCC's 5th comprehensive report said that carbon re-injection to the subsurface cannot be ignored in the effort to reach the target in economically viable terms. If carbon re-injection is ignored, the cost of emission reduction would increase by 138%. There are a few challenges that need to be faced in the execution of carbon re-injection, among which are the cost of capture, the energy consumption, and the amount of energy loss

The quantity and scale of China's CCUS project have not reached USA's, whether in terms of capture, transportation, storage, or utilization.

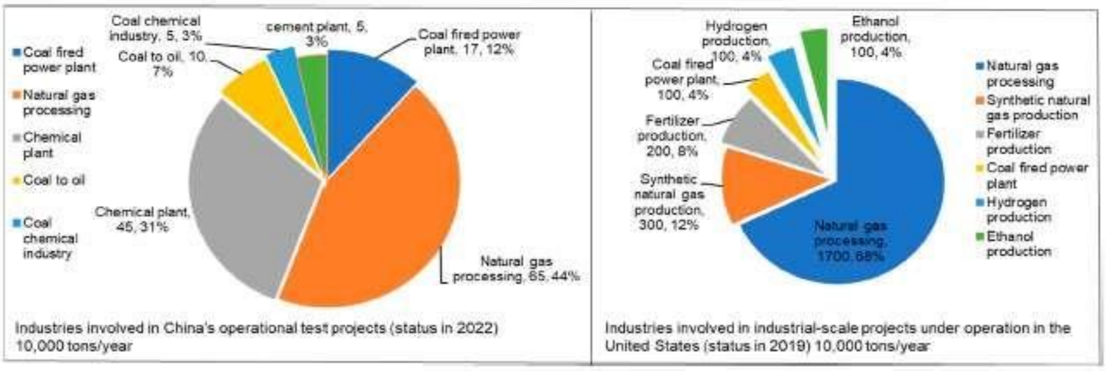


Figure 2. Development and application of CCUS in China and the USA
(Source: Li et al., 2022)

Three main factors that prevented the growth of CCUS in China compared to the USA are (1) The absence of regulations for the transportation, injection, and storage of carbon emissions, as well as for environmental protection, (2) the minimum number of operational incentive and tax credit policies that can persuade businesses to pursue low-carbon development, and (3) the uncertain carbon pricing mechanism.

The research and development of CCUS in China, while late compared to other nations, has been rapid in development. This is proven by the comparison of capture patent claims in China (4517) in comparison to USA's (4270) and storage and utilization patent claims (3371 in China vs 2349 in the US). The development of capture and utilization and storage patents can be seen in Figure 3.

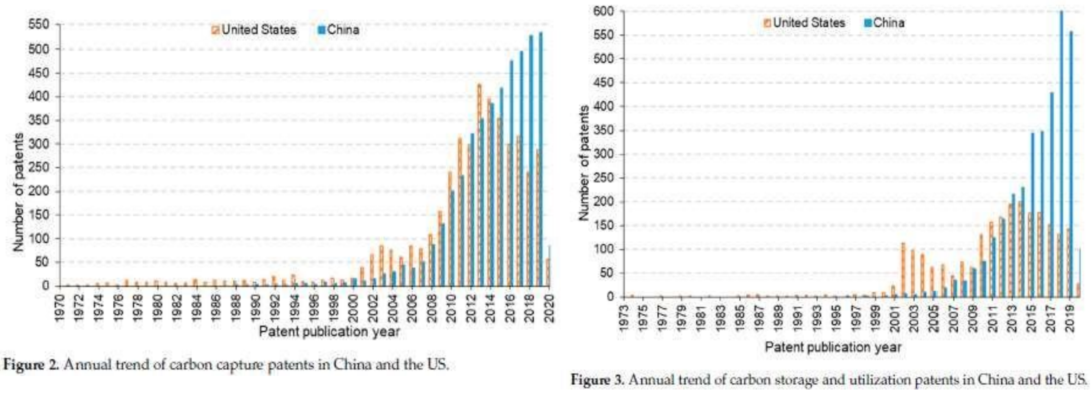


Figure 3. CCUS patent development in China and the US
(Source: Li et al., 2022)

The USA got an early lead in the development and patents of carbon capture technology in the 1970s, however, China which got its first patent in 2011 rapidly grew and overtook the USA in 2013.

USA got the advantage in the research step and early development to observe post-injection, risk warning, and control technology because they have applied $CO_2$ capture to increase oil production for more than 4 decades. The roadmap of USA's CCUS in 2019 emphasized energy safety and economic viability.

In the last 25 years, the roadmap of CCUS USA is composed of large-scale development, technical development requirement, and the passing of supporting laws. Fundamentally, the roadmap is divided into three periods. The first period is called Activation Period (5-7 years) with USD 50 per ton of $CO_2$ incentive, attaining 40 million tons/year capacity and cumulatively creating 10,000 per year jobs. The second period is called Expansion Period (15 years) with USD 50-90 per ton of $CO_2$ incentive, attaining 150 million tons/year capacity and cumulatively creating 40,000 jobs per year. The third period is called Scaling Period (25 years) ) with USD 90-100 per ton of $CO_2$ incentive, attaining a capacity of 50,000 tons/year and cumulatively creating 230,000 jobs per year.

In China, petrochemical and coal-based chemical businesses, as well as coal plants and gas processing plants, use technology to integrate and categorize emission reduction systems. In the US, mentioned technologies are used in coal power plants, fertilizer, synthetic gas generation, gas processing, hydrogen products, and ethanol goods. In contrast to China, which has only constructed 30.07 miles, the United States has established a $CO_2$ pipe network that is 5,000 miles long (equal to 85% of the world's $CO_2$ pipe networks) and will double in length by 2030.

For geological $CO_2$ sequestration needs, the USA will apply 3 plans; (1) sequestration tax reform, (2) laws that enable the use of government land for $CO_2$ sequestration, and (3) gradual expansion of $CO_2$ sequestration processing from land to coast. On the other hand, China plans to reach the breakthrough of reservoir storage in the estuary and brackish water. USA's method emphasized the future of thermochemistry, electrochemistry, biology, carbonization, and cement carbonization, meanwhile China emphasized chemical industry and the conversion of $CO_2$ to foods.

The US Congress established the 45Q tax credit in 2008 to assist the storage and/or utilization of carbon dioxide (CO2) that would otherwise be released from industrial or combustion sources. For the program's initial allocation, enhanced oil recovery (EOR) credit of USD 10 per tonne and long-term $CO_2$ storage credit of USD 20 per tonne were each given (Folger, 2017). Nevertheless, 45Q keeps a sunset clause, which states that tax credits for any given project expire 12 years after storage starts (Tarufelli et al., 2021).

In terms of incentives, the USA has policies that apply a special tax credit for carbon that is still in internal discussion, suggested further revision for 45Q, increased tax credit for $CO_2$-EOR in chapter 43, and expanded chapter 48 of tax laws to include more scenarios and emission sources. Meanwhile, China applied policies on macro levels, therefore there are no measures regarding tax and investment.

However, China has several advantages in CCUS technology developments for many reasons. First, the fact that fossil-based energy will still dominate the energy structure in the foreseeable future. Coal still has a major contribution to the supply and consumption of Chinese energy in the future. Coal still contributes 57.7% of Chinese energy consumption in China in 2019. Primary energy production will reach 4.3MT coals and $CO_2$ emission will reach its peak in 2030, estimated at around 11.2 MT. After which there will be an emission reduction and China will reach carbon neutrality in 2060. Secondly, the top-down decision-making process in China includes government policies, market domination, corporate participation, and trial and error - up to research facilities related to research and development, becoming a powerful and efficient asset in the development of the CCUS industry. Thirdly numerous and widespread large-scale emission sources concentrated in the eastern and southern zone are economically developing. These sources range from electricity, cement, iron and steel, chemical, coal, and other large-scale industries. These industries and the geothermal industry will be the main subjects of future CCUS applications. There are 18 CCUS systems running in China as of 2019, and they have effectively removed 1.7 million tons of emissions from the cement, fertilizer, natural gas, methanol, and coal chemical industries. Additionally, due to favorable geological conditions for extensive $CO_2$ storage, China's $CO_2$ storage capacity is projected to be trillions of tons. Major contributors include the 95.6% seawater layer, which is sustained by the coal layer, oil and gas reservoirs, and other geographic reservoirs. In the period between 2011 and 2015, the early and biggest CCUS attempt at absorbing coal-based $CO_2$ and geological storage of brackish water successfully injected 300,000 tons of $CO_2$, signaling China's success in creating a breakthrough in storing carbon in brackish water and the land ecosystem. China has a number of $CO_2$ consumption strategies, including $CO_2$-EOR and $CO_2$-ECBM, among others. The commercial application stage of $CO_2$-EOR has been reached, and its potential application may help the CCUS technical industrial chain develop.

Despite those advantages, China has several disadvantages in the CCUS development caused by the cost of low-concentration $CO_2$ absorption could reach USD 43-130/ton, this amount is not economically competitive and if applied to other fields could boost the oil industry significantly. The absence of clear legislation and policies to develop CCUS, the spatial distribution pattern that faces problems with dislocation between eastern and western China, which increases testing and promotion of integrated CCUS, and the complex geological conditions and dense population distribution, which necessitate high technical requirements for large-scale absorption, are additional disadvantages.

This publication suggested the five measures listed below after taking the benefits, opportunities, and vulnerabilities of the Chinese government into account: (1) Increase funds for fundamental research and development and establish a separate funding source to support post-combustion technology research and development, which is important for future carbon emission reduction. Implementing and developing CCUS is necessary due to the emphasis on reducing energy consumption and absorption costs, the promotion of $CO_2$-EOR that could be used to increase oil production, decrease reliance on oil, secure the nation's energy supply, while also reducing emissions, and the push for new technology in the emission absorption field. (2) Conduct additional research and develop rules and incentives to support commercial CCUS usages, such as defining CCUS standards and norms, particularly for $CO_2$ pipe transportation standards, safeguarding injection sites, post-injection risk assessment, and safety management. (3) Develop a platform for the cooperation of government, business, academia, and research, and strengthen industrial chain research. Integrate resources in each department, business, and associated institution effectively, and foster productive cooperation among these stakeholders. (4) Proactively and consistently encourage first testing. The promotion system shall screen and assess the early demonstration projects, taking into account the use of the Bohai Gulf and the Ordos Loop as well as the coal sector and conventional chemical industry. (5) As a unified demonstration project will be needed, choose the observation law, industry standards, financial assistance, regulations, and government incentives for demonstration projects.

*3.3. CCUS Policy and Implementation Outside China and USA*

Several Western European countries have carried out CCUS activities such as Italy, France, Spain, Poland, and Germany. Research on carbon supply chains in Italy by Leonzio & Zondervan (2020) was conducted on 10 ten regions that have higher emission levels between 16.9-68.64 Mton$CO_2$/year with storage locations in the Adriatic Sea and utilization for methane production in Verbania for use in industry, residential cooks and heaters, as well as transportation. The Italian government has set an emission reduction target of 77 Mton/year (Leonzio et al., 2020). Research by Wesche et al. (2022) on policy frameworks, stakeholder perceptions, and costs of CCUS activities in France, Spain, and Poland shows some similarities and differences. The CCUS policy in Spain is contained in the Long-Term Strategy document (2050), France has included policies for climate change since 2009, while in Poland there is no reference to CCUS in the 2040 energy policy plan. From a perception standpoint, the French public supports the opinion that CCUS is part of the solution to solving the emissions problem, the Polish public has a divided opinion about whether CCUS is a potential solution, while the Spanish public is more concerned about whether $CO_2$ storage is safer than its use. In terms of costs, these three countries indicate that CCUS requires high costs with low economics. The low carbon economy policy is also implemented in the UK to achieve the 2030 emission target with cooperation between the government and the technology sector to develop frameworks for the development of CCUS (Leonzio et al., 2020). A study carried out by Ku et al., (2020) shows that implementing CCUS is an affordable intermediate solution for energy transformation in the UK and China. Meanwhile in Germany, the utilization of $CO_2$ is more in the form of converting it into methanol using hydrogen fuel from the water electrolysis process at a cost of EUR 207 billion/year to produce methanol of 203 Mtons/year (Leonzio et al., 2019). Leonzio et al. (2020) presented that the cost of implementing CCUS in Italy is around EUR 77.3 billion/year with an average cost of EUR 1,004/ton$CO_2$ captured. In Germany, the average cost is EUR 613/ton$CO_2$ captured, so the annual output is EUR 98 billion. The UK is one of those that can reduce costs on average by only EUR 164/ton $CO_2$ captured, with a total annual expenditure of EUR 1.05 billion.

CCUS activities are also carried out in Eastern Europe and Scandinavian. Russia has injected more than 1 million tons of $CO_2$ per year which is used to enhance oil recovery in 30 fields in Western Siberia. Nevertheless, Russia faces a dilemma to make the CCUS program economical, because it requires a significant increase in carbon tax which can spur inflation due to an increase in the cost of consumer goods of more than 300% (Bazhenov et al., 2022). Norway has begun its CCS with the Sleipner project in 1996 then followed by the Snohvit project in 2008. It was reported by Ringrose (2018) that these offshore projects have stored 17 and 5 Mt$CO_2$ respectively so the total $CO_2$ that has been stored is 22 Mt$CO_2$. Monitoring of $CO_2$ storage conditions is carried out periodically through seismic surveys to monitor dynamic conditions in the storage reservoir while monitoring the remaining capacity. The Norwegian government has made plans to establish a $CO_2$ capture, transportation, and injection project to deal with emissions from industrial activities onshore.

In general, the development of CCUS has been slower than the needs due to the enormous technical and economic risks, so an appropriate and fast policy-making process is needed to be able to encourage its implementation (Tapia et al., 2018).

Thus, to encourage and to help the economics of CCUS, in many developed countries, carbon tax and carbon trading mechanisms have been implemented, as shown in Table 1.

Table 1. Pricing and scale of existing carbon taxes and Emissions Trading Systems markets as of August 2017 (Ku et al., 2020) (Haites et al., 2018)

| Carbon taxes | | | | | Emission-trading systems | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Jurisdiction | Launch year | Tax* (USD/t$CO_2$) | Share of emissions (%) | Emissions covered ($MtCO_{2,eq}$) | Jurisdiction | Launch year | Price (USD/t$CO_2$) | Share of emissions (%) | Emissions covered ($MtCO_{2,eq}$/) |
| Finland | 1990 | 69–73 | 36 | 21 | EU | 2005 | 6 | 45 | 1963 |
| Poland | 1990 | <1 | 4 | 16 | Alberta | 2007 | 24 | 45 | 118 |
| Norway | 1991 | 4–56 | 60 | 32 | New Zealand | 2008 | 13 | 51 | 40 |
| Sweden | 1991 | 140 | 42 | 22 | Switzerland | 2008 | 7 | 35 | 17 |
| Denmark | 1992 | 27 | 45 | 23 | RGGI (USA) | 2009 | 4 | 20 | 86 |
| Slovenia | 1996 | 20 | 24 | 4 | Saitama | 2011 | 14 | 35 | 7 |
| Estonia | 2000 | 2 | 3 | 1 | California | 2013 | 15 | 20 | 365 |
| Latvia | 2004 | 5 | 15 | 2 | Tokyo | 2010 | 14 | 18 | 10 |
| British Columbia | 2008 | 24 | 70 | 42 | Quebec | 2013 | 15 | 85 | 66 |
| Liechtenstein | 2008 | 87 | 26 | 0 | Beijing (CN) | 2013 | 8 | 40 | 5 |
| Switzerland | 2008 | 87 | 35 | 17 | Guangdong (CN) | 2013 | 2 | 60 | 388 |
| Ireland | 2010 | 24 | 33 | 20 | Shanghai (CN) | 2013 | 5 | 57 | 170 |
| Iceland | 2010 | 12 | 55 | 3 | Shenzhen (CN) | 2013 | 6 | 40 | 30 |
| Japan | 2012 | 3 | 70 | 913 | Tianjin (CN) | 2013 | 1 | 55 | 100 |
| UK | 2013 | 24 | 25 | 122 | Chongqing (CN) | 2013 | <1 | 40 | 126 |
| France | 2014 | 26 | 40 | 186 | Hubei (CN) | 2013 | 2 | 35 | 324 |
| Mexico | 2014 | 1–3 | 46 | 332 | South Korea | 2014 | 18 | 68 | 470 |
| Portugal | 2015 | 8 | 26 | 18 | | | | | |
| Average | | **USD 13.04** | **46.69%** | | Average | | **USD 7.79** | **48.01%** | |
| Range | | <1 to 140 USD | 3 to 70% | **Total 1774** | Range | | <1 to 24 USD | 18 to 85% | **Total 4286** |

Apart from European countries, India, as the third largest country after China and the USA in terms of emission production, has committed to reducing emissions by 50% in 2050 and achieving net zero emissions in 2070 (Mukherjee & Chatterjee, 2022). CCUS is an important factor in efforts to reduce carbon emissions in the industrial and power sectors where currently 70% of India's electricity source comes from coal-fired power plants. Even though India is currently building a lot of environmentally friendly power plants, this increase can only offset the additional needs due to economic growth, and cannot replace the current base load. India has started implementing Direct Air Capture technology, but the cost is still quite expensive, around USD 400-800/ton$CO_2$ captured. To initiate the CCUS project in India, an initial investment of around USD 100-150 billion is required to capture, utilize, and store $CO_2$ emissions of 750 mtpa. If this investment is made, it is hoped that it will be the start of building a market of $CO_2$ and will increase GDP by around USD 100-150 billion for the next 30 years. In addition, there are other economic opportunities from CCUS-enabled coal gasification projects in the form of petrochemical products which can reduce imports by up to USD 13 billion per year. CCUS also creates new jobs, starting from its development project until the time of its operation, including a domino effect on economic growth in the surrounding area.

### *3.4. Development of CCUS in Indonesia*

In Indonesia, CCUS is considered a new technology and is not yet widely implemented, with the exception of a few oil and gas fields utilizing pressure maintenance to improve the production of oil and gas. However, the country is now beginning to launch a campaign for the implementation of CCS/CCUS to contribute to the nation's commitment when ratifying the Paris Agreement, followed by releasing an NDC (Nationally Determined Contribution Document) in 2016 and an Updated NDC in 2021 (Government of Indonesia, 2021), and later Enhanced NDC in 2022 (Government of Indonesia, 2022).

During the UN Climate Change Conference (COP26) in 2021, Indonesia announced its commitment to reach net zero emissions by 2060. This announcement has then been followed up by the Ministry of Energy and Mineral Resources (MEMR) of Indonesia and the International Energy Agency (IEA), working collaboratively on a detailed scenario and policy analysis of what this target means for Indonesia's energy sector (International Energy Agency (IEA), 2022).

As an effort to solidify the effort to reach the goal, the Indonesian government through the National Development Planning Agency (Bappenas) released National Midterm Plan RPJMN 2020-2024 (Presidential Decree No.18 Tentang Rencana Pembangunan Jangka Menengah 2020-2024, 2020). In this document, the reduction of emission is placed as part of the 6th national priority, "pembangunan lingkungan hidup, peningkatan ketahanan bencana dan perubahan iklim". According to the (Roadmap Nationally Determined Contribution (NDC) Adaptasi Perubahan Iklim, 2020), climate change has the potential of causing an economic loss of 0.66-3.45% of Indonesia's GDP in 2030, according to OJK estimate, in 2030, Indonesia's GDP would reach 24,000 trillion Rupiahs (Supangkat, 2022), therefore the loss due to climate change is estimated around 158-858 trillion Rupiahs.

Nawawi (2022) said, to reach the Updated NDC 2021 emission reduction target, the estimated required funding is 266.3 trillion Rupiah per year until 2030, even so, the average APBN funding in the 2020-2022 period is only 37.9 trillion Rupiah. The realization of the funding only reached 17% of it or 6.4 trillion Rupiah, of which 82% is utilized for adaptation and 18% for mitigation. He also expressed that the government will prepare various activities to reach the emission reduction target, consisting of the development of a fiscal framework for mitigation and adaptation of climate change, Government spending through K/L for climate change (climate change tagging), Taxing and taxing facilities, for example, the stimulus for private companies for environmentally friendly product development like electric vehicles and renewable energy. The Government of Indonesia will also deliver policies regarding decentralized funding distribution, for food fields, medical water supply, forest, and living environment, waste management, and utilization of low-emission alternative energy, reparation, and preservation of the living environment. In the financing area, some tools will be provided, including a funding framework through obligation/green *sukuk*, formation of disaster fund pooling, continuous funding platforms, like Financial Body to Manage Environmental Fund - *BLU Badan Pengelola Dana Lingkungan Hidup* (BPDLH), and also a mechanism for carbon taxation.

The various funding schemes for climate change countermeasures are of utmost importance to the Indonesian government. This could be achieved through public funding, both domestic and international, and non-public funding.

## 4. Conclusions

The progress of CCUS activities in China is rapidly improving since the design of net zero target emission in 2020 research and development activities and the produced patent has surpassed the US. The ministry's accommodation for the living environment sector through the collaboration with the government bank to prepare 437 billion USD shows the government's determination to push the emission reduction efforts. These impressive numbers of research and patents as well as the amount of funds facilitated by the Chinese government and country experts are very aggressive compared to the USA.

USA started CCUS activities years ago to improve oil and gas production and continues to do to this day. Even though there has been many established pipe networks, $CO_2$ injection facilities, and carbon trading mechanisms, the US government still provide progressive tax incentive until 2050. The tax credit program for $CO_2$ injection issued by the US government, instead of facilitating the provision of funds, is significantly distinctive compared to government programs in China and other countries in the world.

Many CCUS activities have also been carried out in Russia, Norway, India, and Western European countries such as Italy, Germany, the UK, Spain, and Poland. Even though there are differences in terms of emission patterns, storage availability, carbon utilization options, and stakeholder perceptions, there are similarities between experiences in these countries regarding costs and technical challenges, where with the current technology the CCUS project is still expensive and not economical. Even though the carbon trading mechanism can help the project's economics, for CCUS to run as needed it still requires support from the government.

The Indonesian government has executed emission reduction programs by law no. 12 released in 2016 regarding Paris Agreement ratification. The implementation of the Paris Agreement commitment is written on the Nationally Determined Contributions document (NDC). The journal reviewed by the authors only referenced to 2021's Updated NDC (Government of Indonesia, 2021), meanwhile, the Indonesian Government has released the 2022 Enhanced NDC (Pemerintah Indonesia, 2022), in which the emission reduction target has been increased to 31.89% for the independent scheme and 43.20% for the scheme with international aid. However, in the implementation, there is a big gap between the required 266.3 trillion rupiahs per year emissions reduction program with the National Annual Budget (*APBN*) allocation of 37.9 trillion rupiahs. Moreover, the absorbed realization is only 17% of the allocated *APBN* budget, indicating the lack of government support. In terms of policies, the government has published various policies required to facilitate the NDC target in 2030, but to this day the main policies regarding carbon tax and fiscal incentives to help upstream oil and gas have yet to be published. Thus, when compared to India and the industrialized countries reviewed in this research, the realization of the Indonesian government's support seems not as high as the realization of commitments from those countries.

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