Chapter 1

Global State of Affairs for Carbon Capture, Utilisation, and Storage

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Chapter 1
Global State of Affairs for Carbon Capture, Utilisation, and Storage

1. Historical development

Carbon capture, utilisation, and storage (CCUS) has been adopted for almost half a century to address important economic and environmental issues. A classic type of CCUS can be found in enhanced oil recovery (EOR), which involves the capturing of carbon dioxide (CO_2) from fossil fuel production or industrial plants and injecting the captured CO_2 into oil wells. EOR leads to improved oil production and was favoured by oil companies that wanted to prolong the longevity of oil wells. It was adopted by many oil companies in the United States amidst the oil crises in the 1970s. EOR eventually spread to other oil-producing countries, such as China, Saudi Arabia, and Brazil, over the 2000s and 2010s. In China, in particular, the dependence on fossil fuels by the energy and petrochemical industries, as well as the resulting CO_2 emissions in these sectors, has prompted them to explore EOR. Climate change is another issue that has given renewed focus to CCUS. Pioneered by Norway since the 1990s, CCUS for the purpose of CO_2 sequestration is being considered, tested, and implemented by countries with high goals for climate mitigation and is especially active amongst European countries. Table 1.1 lists commercial CCUS projects by country.

Table 1.1. Commercial CCUS Projects by Country

	EOR	Onshore CCS	Offshore CCS
Australia		1	
Brazil	1		
Canada	3	1	
China	2		
Norway			2
Qatar	1		
Saudi Arabia	1		
United Arab Emirates	1		
United States	12	2	

CCUS = carbon capture, utilisation, and storage, EOR = enhanced oil recovery.
Note: The Boundary Dam project in Canada involves both EOR and CCS. The utilisation targeted in this classification is EOR.
Source: Created by Mitsubishi Research Institute based on GGCSI (2020b).

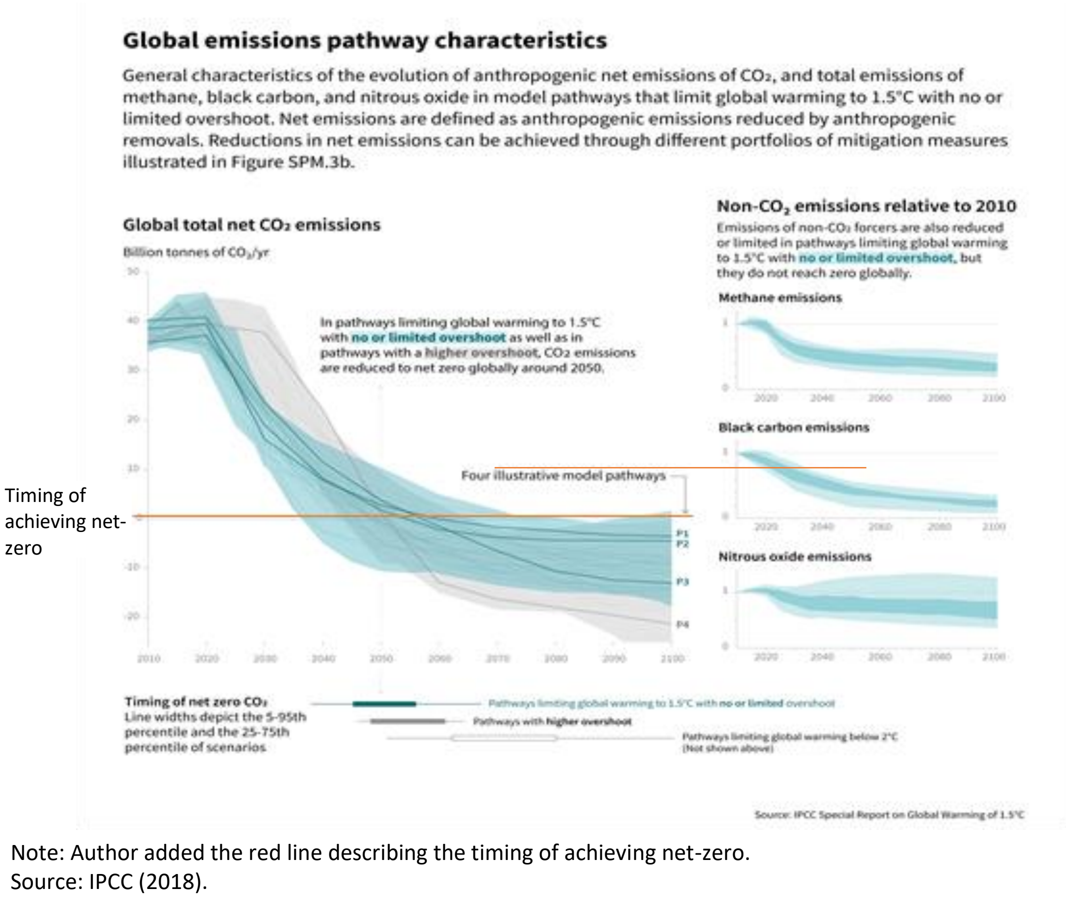
2. Global policy agenda

2.1. Paris Agreement

As previously stated, climate change issues have led to the renewed rise of CCUS in recent years. Global demand for the mitigation of climate change culminated in the Paris Agreement, which was agreed upon by participating parties to the United Nations Framework Convention on Climate Change (UNFCCC) in 2015. The Paris Agreement set the goal of limiting global warming to well below 2-degrees Celsius, and preferably below 1.5-degrees Celsius, compared to pre-industrial levels.

Whilst CCUS was rarely identified as a climate change mitigation measure in the nationally determined contributions (NDCs) submitted by the parties following the ratification of the Paris Agreement, the Intergovernmental Panel on Climate Change (IPCC) recognised the significant role of CCUS in achieving the 1.5-degree target in its ‘Special Report: Global Warming of 1.5℃’. The report, in developing the four pathways towards achieving the 1.5-degree target, includes CCUS technology in three out of the four pathways. As described in Figure 1.1, the amount of accumulative CO_2 removal by CCUS for Pathway 2, Pathway 3, Pathway 4 is 348 gigatonnes (Gt) of CO_2, 687 Gt of CO_2, and 1,218 Gt of CO_2, respectively. As demonstrated in Figure 1.2., analysis by the IPCC reveals that the sooner the expected achievement of net-zero, the greater the dependence on CO_2 removal by CCUS (IPCC, 2018).

Figure 1.1. Characteristics of Global Emissions Pathways



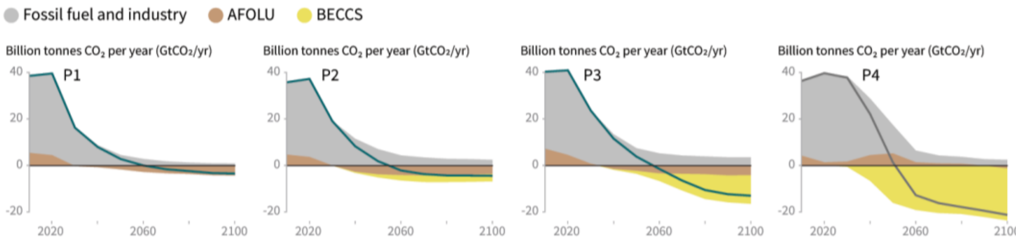
Note: Author added the red line describing the timing of achieving net-zero.
Source: IPCC (2018).

Figure 1.2. Four Illustrative Model Pathways and the Role of CCUS

Characteristics of four illustrative model pathways

Different mitigation strategies can achieve the net emissions reductions that would be required to follow a pathway that limits global warming to 1.5°C with no or limited overshoot. All pathways use Carbon Dioxide Removal (CDR), but the amount varies across pathways, as do the relative contributions of Bioenergy with Carbon Capture and Storage (BECCS) and removals in the Agriculture, Forestry and Other Land Use (AFOLU) sector. This has implications for emissions and several other pathway characteristics.

Breakdown of contributions to global net CO_2 emissions in four illustrative model pathways



P1: A scenario in which social, business and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A downsized energy system enables rapid decarbonization of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

P4: A resource- and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas-intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

Global indicators	P1	P2	P3	P4	**Interquartile range**
Pathway classification	No or limited overshoot	No or limited overshoot	No or limited overshoot	Higher overshoot	No or limited overshoot
CO_2 emission change in 2030 (% rel to 2010)	-58	-47	-41	4	(-58,-40)
↳ in 2050 (% rel to 2010)	-93	-95	-91	-97	(-107,-94)
Kyoto-GHG emissions in 2030 (% rel to 2010)*	-50	-49	-35	-2	(-51,-39)
↳ in 2050 (% rel to 2010)	-82	-89	-78	-80	(-93,-81)
*Final energy demand** in 2030 (% rel to 2010)*	-15	-5	17	39	(-12,7)
↳ in 2050 (% rel to 2010)	-32	2	21	44	(-11,22)
Renewable share in electricity in 2030 (%)	60	58	48	25	(47,65)
↳ in 2050 (%)	77	81	63	70	(69,86)
Primary energy from coal in 2030 (% rel to 2010)	-78	-61	-75	-59	(-78, -59)
↳ in 2050 (% rel to 2010)	-97	-77	-73	-97	(-95, -74)
from oil in 2030 (% rel to 2010)	-37	-13	-3	86	(-34,3)
↳ in 2050 (% rel to 2010)	-87	-50	-81	-32	(-78,-31)
from gas in 2030 (% rel to 2010)	-25	-20	33	37	(-26,21)
↳ in 2050 (% rel to 2010)	-74	-53	21	-48	(-56,6)
from nuclear in 2030 (% rel to 2010)	59	83	98	106	(44,102)
↳ in 2050 (% rel to 2010)	150	98	501	468	(91,190)
from biomass in 2030 (% rel to 2010)	-11	0	36	-1	(29,80)
↳ in 2050 (% rel to 2010)	-16	49	121	418	(123,261)
from non-biomass renewables in 2030 (% rel to 2010)	430	470	315	110	(245,436)
↳ in 2050 (% rel to 2010)	833	1327	878	1137	(576,1299)
Cumulative CCS until 2100 ($GtCO_2$)	0	348	687	1218	(550,1017)
↳ of which BECCS ($GtCO_2$)	0	151	414	1191	(364,662)
Land area of bioenergy crops in 2050 (million km²)	0.2	0.9	2.8	7.2	(1.5,3.2)
Agricultural CH_4 emissions in 2030 (% rel to 2010)	-24	-48	1	14	(-30,-11)
in 2050 (% rel to 2010)	-33	-69	-23	2	(-47,-24)
Agricultural N_2O emissions in 2030 (% rel to 2010)	5	-26	15	3	(-21,3)
in 2050 (% rel to 2010)	6	-26	0	39	(-26,1)

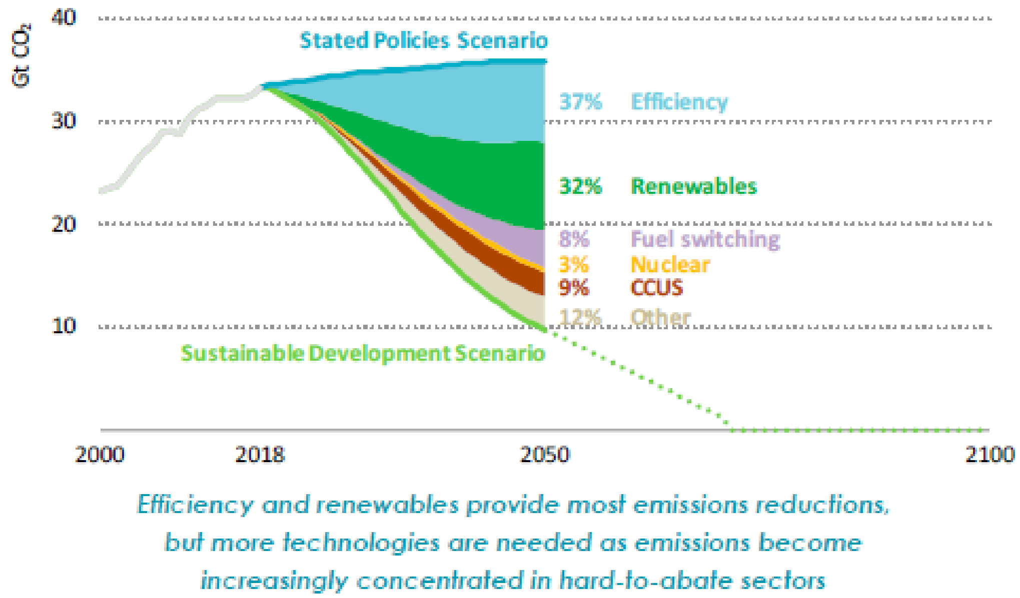
NOTE: Indicators have been selected to show global trends identified by the Chapter 2 assessment. National and sectoral characteristics can differ substantially from the global trends shown above.

** Kyoto-gas emissions are based on IPCC Second Assessment Report GWP-100*
*** Changes in energy demand are associated with improvements in energy efficiency and behaviour change*

CCS = carbon capture and storage, CO_2 = carbon dioxide, GHG = greenhouse gas, Gt = gigatonne.
Note: The author added the red box describing the emissions removal contribution by CCS.
Source: IPCC (2018).

The International Energy Agency (IEA) estimated that in order to deliver its Sustainable Development Scenario (SDS), which is in line with Paris Agreement's goals and expects to achieve net-zero by 2070, 9% of its cumulative energy-related emissions reduction is to be provided by CCUS as described in Figure 1.3. The mass of CO_2 captured annually in energy-related emissions using CCUS is expected to go up from 38 megatonnes (Mt) of CO_2 in 2018 to about 763 Mt in 2030 and 2,776 Mt in 2050 (IEA, 2019).

Figure 1.3. CCUS in Energy-related Emissions Reduction in the International Energy Agency's Sustainable Development Scenario



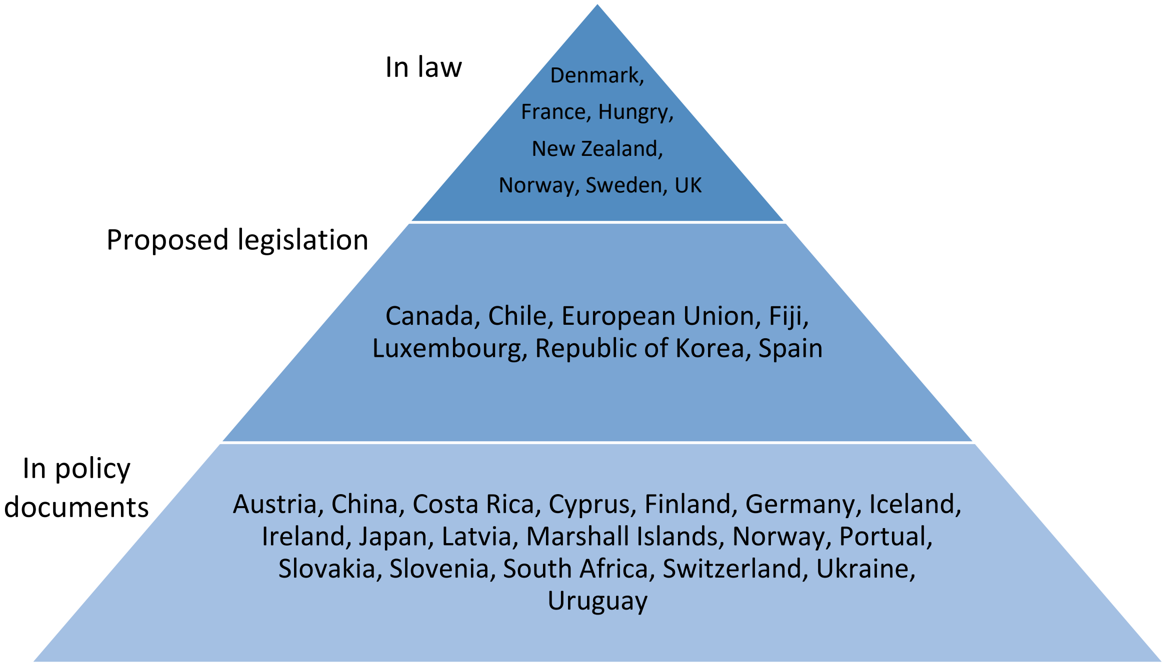
CCUS = carbon capture, utilisation, and storage, CO_2 = carbon dioxide, Gt = gigatonne.
Source: IEA (2019).

With the onset of many governments and multinational companies announcing net-zero goals by 2050, in 2020, the IEA developed a new 'net-zero scenario' (NZE2050), in which the IEA emphasises that CCUS needs to be deployed more and faster, including equipping CCUS with existing facilities, whilst estimating the shift from net-zero achievement year from 2070 to 2050 means approximately 50% more CCUS deployment (IEA, 2020a). The IEA states that CCUS will be used to capture emissions from around 270 million tonnes of oil equivalent (Mtoe), or 3.5 % of the total fossil fuel consumption in NEZ2050 in 2030. This translates into 1.15 billion tonnes of energy and industrial sector CO_2 emissions being captured (IEA, 2020b).

2.2. 'Net-zero' goals by governments and corporations

As indicated as a background to developing the IEA's NZE2050, there has been a recent surge in the announcement of 'net-zero' ambitions by governments, notably by industrial countries in Asia. China announced its 2060 net-zero goal in September 2020, whilst Japan and the Republic of Korea (henceforth, Korea) both made their 2050 net-zero announcements in December 2020. Figure 1.4 shows the countries with net-zero announcements in accordance with the level of policy enforcement. These announcements by governments are accompanied by plans to vigorously support the introduction of measures through CCUS.

Figure 1.4. Net-zero Commitments by Legal Status



UK = United Kingdom.
Note: Japan is reported to be in the process of drafting new legislation for its net-zero target as discussed at the Ministry of Environment working group on an institutional framework to promote global warming countermeasures, held on 21 December 2020 (MOE, 2020).
Source: Created by project members based on IEA (2020b) and Energy and Climate Intelligence Unit (2020). When the two sources conflicted, the author prioritised the latter due to its more recent publication.

Preceding many governments' announcements were pledges of net-zero by corporations around the world. The UNFCCC reported in September 2020 that the commitments of non-state actors (such as regional and local governments, private corporations, and citizens' groups) to net-zero doubled in less than a year. 1,101 businesses participate in the United Nations' Race to Zero campaign, most of whom pledge net-zero by 2050. Some ASEAN companies are also participants in this campaign as follows (UNFCCC, 2020):

- C.P. Group, Thailand
- Charoen Pokphand Group Co., Ltd., Thailand
- City Developments Limited (CDL), Singapore
- Sarawak Energy Berhad, Malaysia
- The Lux Collective Ltd, Singapore
- Tai Wah Garment Industry Sdn. Bhd., Malaysia

In addition, Petronas became the first oil and gas company in Asia to declare its ambition to reach net-zero by 2050. As described, there is a clear momentum of increased ambition both on the government and corporate sides that would give a strong foundation for policies and promotion measures specified for CCUS as a climate change mitigation measure.

2.3. CCUS in COVID-19 related economic recovery plans

The year 2020 saw a big boost to budgetary commitments to CCUS by some governments around the world. This movement was spurred by the need for package programmes to stimulate economies ailing from the effects of pandemic and the implications CCUS has on industrial development, which in turn lead to growth in income and employment. Figure 1.5 shows examples of governments' strong intentions to increase their support for CCUS with not only the aim of achieving the climate goals but also to impact economic growth through technology development and create new industrial activities coupled with employment, such as the hydrogen economy in conjunction with CCUS and CO_2 storage service. Although most of these announcements have been made by developed nations, they have repercussions on the developing countries in ASEAN as technology deployment is likely to go beyond borders.

Figure 1.5. Examples of Government Announcements for Increased Funding for CCUS Activities

European Union	United Kingdom
■ €1 billion addition to Horizon 2020 for the research and development of CCUS. ■ Horizon Europe (€84.9 billion) to succeed Horizon 2020.	■ US$1.3 billion (£1 billion) as part of the "10 point plan" announced in November 2020. ■ Capture 10 megatonnes of carbon dioxide by 2030. ■ Establish two CCUS clusters in the 2020s and four by 2030. ■Create 50,000 jobs by 2030.
United States	**Asia**
■ President Joe Biden pledges to "double down on federal investments" as part of the Green New Deal. ■ Department of Energy announces series of grants for CCUS in 2020, totaling more than US$300 million.	■ Japan announced in December 2020 the establishment of US$19 billion (¥2 trillion) fund for technologies required to reach carbon neutrality by 2050, including CCUS, as part of the economic stimulus package. ■ Republic of Korea announced to spend US$7.1 billion (W8 trillion) on the Green New Deal.

CCUS = carbon capture, utilisation, and storage.
Sources: European Union: European Commission (2020a), European Commission (2020b); United Kingdom; Prime Minister's Office (2020); United States: Department of Energy (2020); Japan: Cabinet Office (2020); Republic of Korea: Korean JongAn Daily (2020).

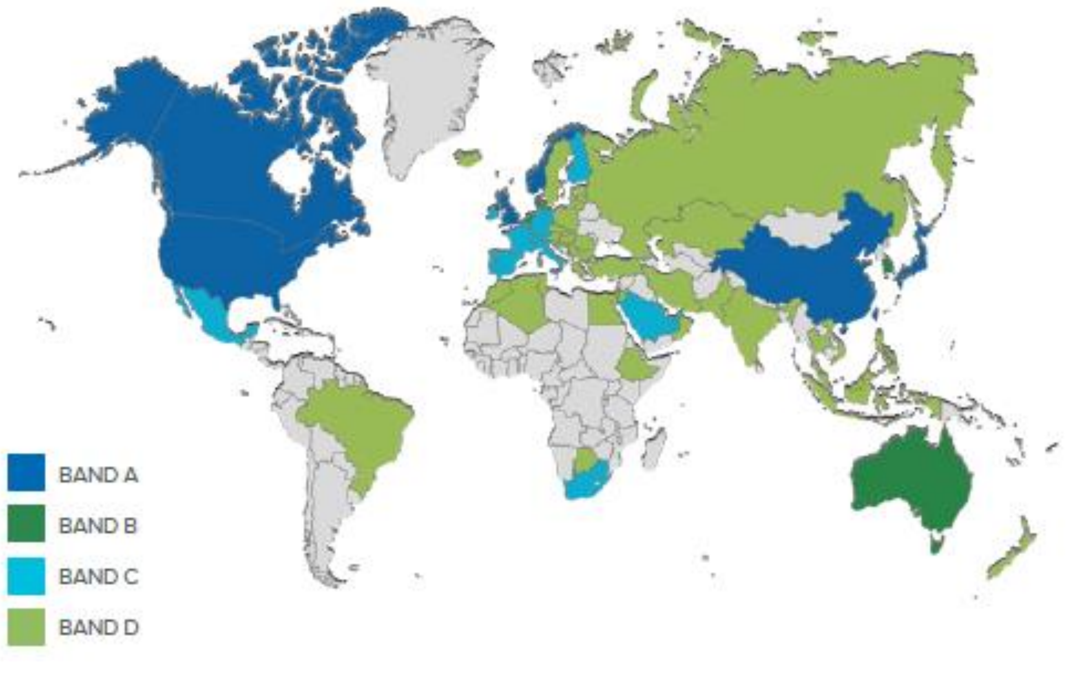
3. Policy and legal framework development

3.1. Global status of legal framework development

Even with strong commitments from governments backed by budgetary measures and the ambitions of the private sector, CCUS will not fully be realised in a commercial sense without a robust legal framework, which is essential in mitigating risks and securing finance.

The Global CCS Institute (GCCSI) studies the state of legal framework development around the world and provides a ranking of countries through its 'CCS Policy Indicator'. In the 2018 report, 68 countries were ranked based on government commitments to and interest in CCS, the provision of public assistance and incentives, capabilities, information sharing and collaboration with other countries, international assistance, market mechanisms, and organisational capacity, etc. as well as the development of policies and regulations by their respective governments. Figure 1.6 describes the classification of the countries into four bands, with Band A signifying most advanced favourable legal systems (GCCSI, 2018). Table 1.2 shows the global top three countries plus Asian countries in the top 10 in the 2018 Global CCS Institute Policy Report.

Figure 1.6. Global CCS Institute Global Legislation Rankings



Note: Band A = Score ≥ 27/100 ('clear leaders'), Band B = Score 23/100 to 26/100 ('sound foundation for policy development'), Band C = Score 11/100 to 22/100 ('very immersion'), Band D = Score ≤ 10/100 ('very immersion').
Source: GCCSI (2018).

Table 1.2. Top Three Countries Plus Asian Countries in Top 10 in the 2018 Global CCS Institute Policy Report

Ranking	Country	Overall Score (value out of 100)	Change from 2015 Reports	Notable Points
1	Norway	56 (Band A)	▲	• Norway's score increased in 2018 because the government decided to support Front End Engineering and Design (FEED) costs for two large CCS facilities (the previous score in 2015 was 40).
2	United Kingdom	46 (Band A)	▼	• The Government of the United Kingdom expressed its long-term commitment to CCS in its 'Clean Growth Strategy' published in 2017. • GCCSI took the establishment of the 'CCUS Cost Challenge Taskforce' positively.
3	United States	41 (Band A)	▼	• The United States' score dropped significantly after announcing its withdrawal from the Paris Agreement. • The Global CCS Institute took the expansion of the CCUS/CCS eligible for the 45Q tax credit positively.
5	China	40 (Band A)	▲	• The Chinese government continues to provide various support for CCUS/CCS projects. • China's state-owned oil company had its first large-scale CCS project in 2018, and two other state-owned companies plan to begin construction of large-scale CCS facilities.
6	Japan	39 (Band A)	▲	• Since the Japanese government is providing support for the demonstration project, the score increased from the previous time.

CCS = carbon capture and storage, CCUS = carbon capture, utilisation, and storage.
Source: Created by project members based on METI (2020) and GCCSI (2018).

3.2. Implications for ASEAN and East Asia

The GCCSI observes that there are mainly two types of legal framework development in some early mover countries. One type is the CCUS-specific model of legislation to regulate the entire process of CCUS. A typical case of this type is the European Union's (EU) CCS Directive. The other type is utilising existing regulations on oil and gas activities or environmental regulations. An example of this second type is the United States, where Underground Injection Control regulations established for the purpose of safeguarding drinking water are used to govern CCUS activities. Table 1.3 summarises the key issues in establishing CCUS-related legal frameworks identified through MRI's previous research based on interviews with government and industry stakeholders in key countries.

Table 1.3. Key Issues in Establishing CCUS/CCS Laws and Regulations

Importance	Number	Items	Points of Contention
Medium	1	Comprehensive regulations on CCUS/CCS	・Control CCUS/CCS within the framework of existing oil and gas industry and environmental laws and regulations ・Introduction of new regulations specific to CCUS/CCS
High	2	Classification of CO_2	・Pollutants, waste (whether injection into geological formations is considered an act of disposal), etc. ・Commodities (CO_2 trading)
High	3	Land use, ownership, and permits	・Ownership and use rights of land and underground (including the pore space) under existing domestic laws
Medium	4	London Convention, London Protocol (sub-seabed injection)	・Response to treatment under the London Protocol to the London Convention (limited to projects involving transport by vessels and sub-seabed injection)
High	5	Legal liability and how to handle damages	・Rules for the allocation of liabilities after the closure of the CCS-EOR site, the applicable period, the liability transfer, etc.
High	6	Financial security	・Conditions for obtaining permission related to CCUS/CCS include the existence and severity of financial security requirements
High	7	Monitoring technique	・Existence of explicit monitoring methods
Medium	8	Handling of CO_2 transboundary movement	・Presence of laws and regulations on transboundary movements of CO_2 (only sites where transboundary CO_2 migration may occur)
Low	9	Site selection method and exploration method	・Requirement of specific technologies to be applied to site selection and exploration methods

CCS = carbon capture and storage, CCUS = carbon capture, utilisation, and storage, CO_2 = carbon dioxide, EOR = enhanced oil recovery.
Note: 'High' means important items. 'Medium' means important items but limited to related projects. 'Low' indicates items that are often referred to as laws and regulations but are low in priority from the viewpoint of the development of laws and regulations as they can be integrated into guidelines, etc.
Source: Created by project members based on METI (2020).

As ASEAN countries embark on developing legal frameworks for CCUS, the GCCSI indicates that the following are important points of consideration (GCCSI, 2020a):

- Whether to develop CCUS-specific legislation and the time needed to develop such legislation;
- Whether to regulate across the full chain of storage aspects or focus on discrete aspects;
- Addressing novel aspects and risks unique to CCUS, such as the classification of CO_2 for the purpose of permanent storage, temporal aspects of technology deployment, and arrangements for the long-term management of CO_2 storage and the related liability; and
- Administrative implications and arrangements for the regulatory framework to be considered.

Box 1. Examples of Different Types of Legal Framework

Case 1: Comprehensive CCS regulation in the European Union (EU CCS Directive)

- Regulates site selection and exploration, storage permits, carbon dioxide (CO_2) stream composition, monitoring and reporting, closure and post-closure obligations, transfer of responsibility, financial security, and financial contributions.
- Incentives are provided through various funding schemes and the EU emissions trading scheme.

Case 2: Utilisation of existing legal framework in the United States (Underground Injection Control Program)

- Regulation was originally developed to control underground activities for the safeguarding of drinking water.
- Regulated depending on Class II (CCS-EOR) and Class IV (Storage).
- Incentive is provided by Section 45Q of the Internal Revenue Code that stipulates CO_2 pricing to rise to US$50 for storage projects and US$26 for CCS-EOR projects.
- The guidance on 45Q also clarifies some of the liability issues, such as the recapture requirement of CO_2 in the event of leakage (GCCSI, 2020c).

4. Potential for developing CCUS projects

4.1. CO_2 storage demand and storage potential

As stated in Section 2, the amount of CO_2 to be stored globally is expected to reach around 5.6 Gt of CO_2 in 2050. On the question of whether this is enough storage capacity to accommodate the demand, GCCSI estimates there is plenty. According to GCCSI findings, the total amount of CO_2 storage resources in major oil and gas fields in selected countries alone amounts to approximately 310 Gt. In addition to these sites, the amount of CO_2 storage availability in saline formations is estimated to be 10 times that of oil and gas fields.

4.2. Assessment of storage capacity in key ASEAN countries

Although a global-scale study on CO_2 storage capacity has been conducted by international organisations, such as GCCSI, there is limited information on the storage capacity in individual ASEAN countries. METI conducted a study on storage potential and assessed the potential for its utilisation in Indonesia, Thailand, and Viet Nam based on existing information from GCCSI and other international and national sources in 2019–2020 (METI, 2020). Table 1.4 demonstrates the findings from the storage potential assessment for these three countries. Figures 1.7-1.9 show maps of the identified storage potential.

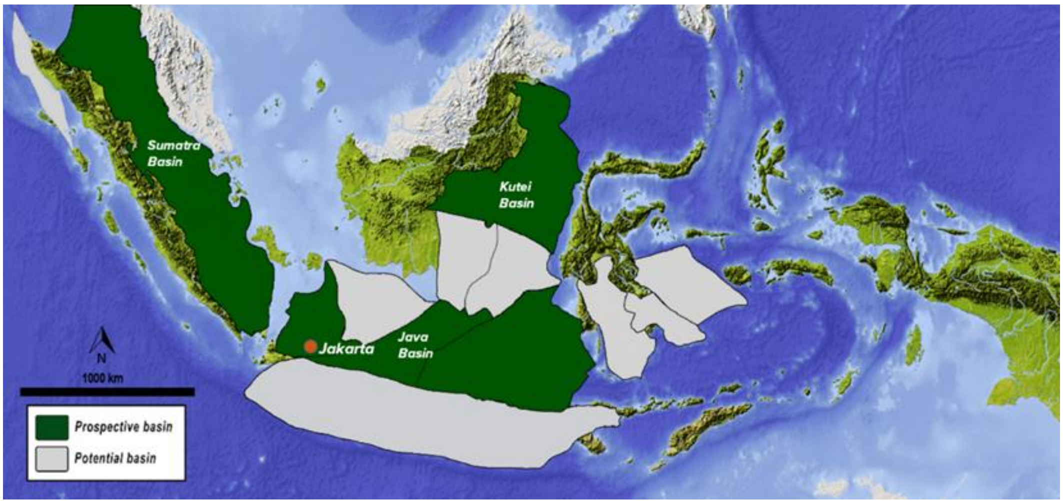
Table 1.4. Summary of CO_2 Storage Assessment in Indonesia, Thailand, and Viet Nam

Country	Identified Potential CO_2 Sources	Development Potential
Indonesia	● South Sumatra Basin: 7.65 $GtCO_2$ (Hedriana et al.) ● Java Basin (deep saline layers): 386 $MtCO_2$ (World Bank) ● Tarakan Basin: 130 MtCO2 (CCOP) ● Central Sumatra Basin: 229 $MtCO_2$ (CCOP)	Relatively high for enhanced oil recovery (EOR)-type projects. Reservoirs are located near developed or already depleted gas and oil fields. Access to mining plants and oil refineries, which are major sources of emissions in the country, would be a key factor.
Thailand	● Saline formation in the Greater Thai Basin and Pattani Basin: 8.9 $GtCO_2$ (ADB) ● Gas and oil fields: 1.4 $GtCO_2$ (ADB)	Demand for EOR is expected to be high as both Thailand's gas and oil fields are on the verge of exhaustion.
Viet Nam	● Deep saline reservoirs: 10.4 $GtCO_2$ ● Depleted oil and gas fields: 1.4 $GtCO_2$	Limited information.

$GtCO_2$ = gigatonnes of carbon dioxide, $MtCO_2$ = megatonnes of carbon dioxide.

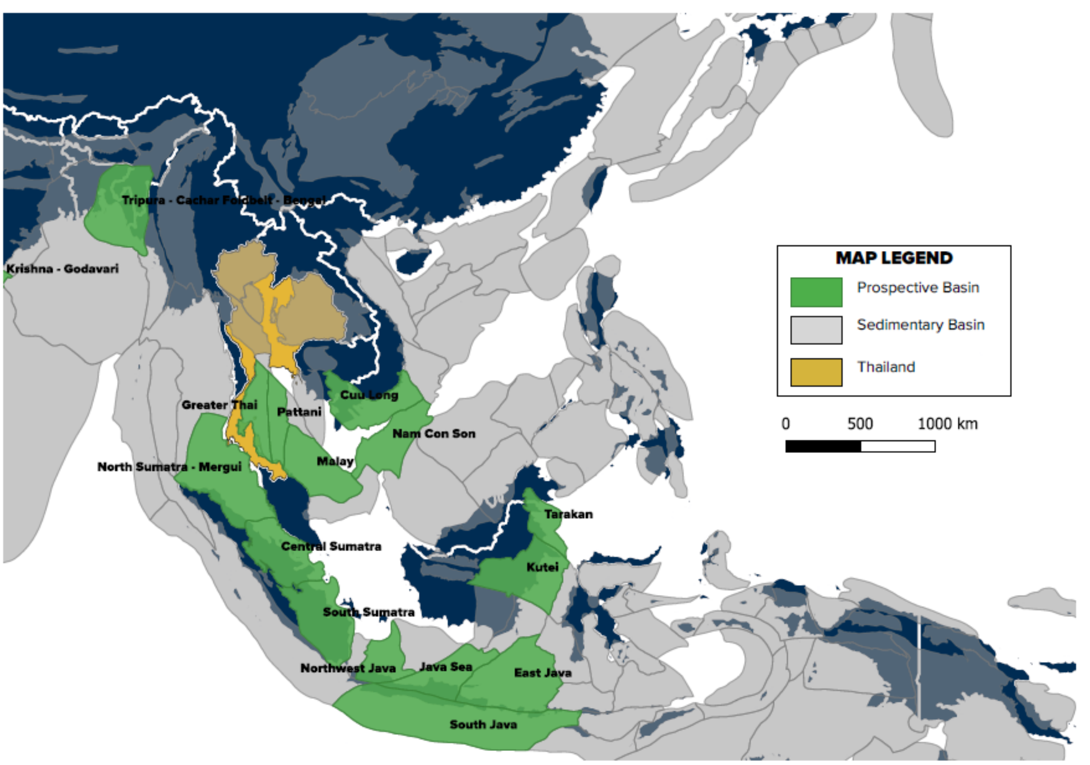
Source: Created by project members based on METI (2020).

Figure 1.7. Underground Deep Strata with Potential for CO_2 Storage Around Indonesia



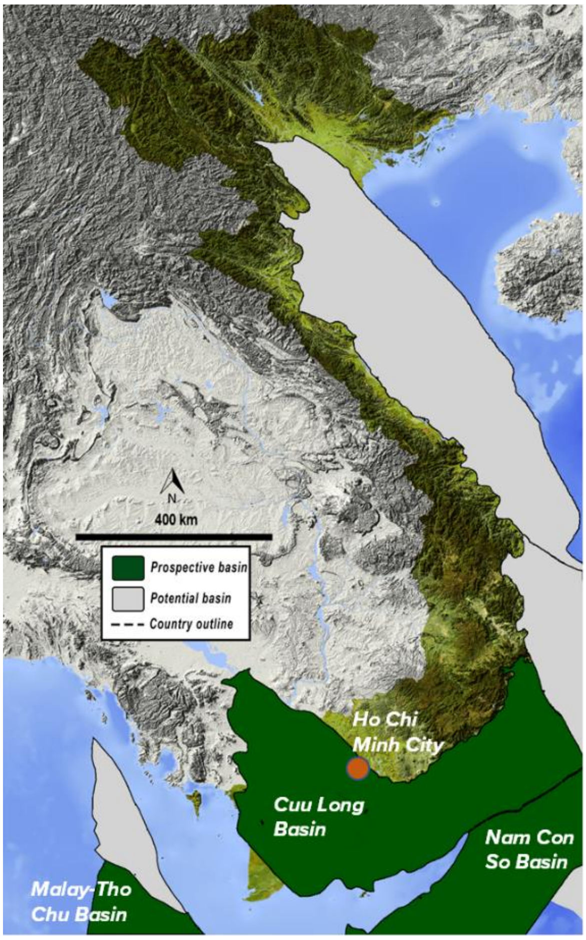
Note: Deep underground strata with particularly high storage potential (green); deep underground strata with some storage potential (grey).
Source: METI (2020), prepared by GCCSI.

Figure 1.8. Underground Deep Stata with Possibility of CO_2 Storage Around Thailand



Note: Deep underground strata with particularly high storage potential (green); deep underground strata with some storage potential (grey).
Source: METI (2020), prepared by GCCSI.

Figure 1.9. Underground Deep Strata with Possibility of CO_2 Storage Around Viet Nam



Note: Deep underground strata with particularly high storage potential (green); deep underground strata with some storage potential (grey).
Source: METI (2020), prepared by GCCSI.

It should be noted that apart from oil and natural gas reservoirs in the South Sumatra Region of Indonesia, no deep underground geological survey has been conducted. There is room for further surveys to conduct a more accurate analysis of the storage potential, which would be a big push for project development to achieve deep decarbonisation in the region.

4.3. Summary

As stated, the needs and potential of CCUS globally are evident. In order to translate this into reality and deploy CCUS in ASEAN and East Asia, more awareness-raising is required both at the policy and commercial levels. Governments need to make a stronger commitment to decarbonisation with CCUS as a technology option, and there needs to be an environment to attract private sector involvement. The following chapters elaborate on the technological and commercial considerations and the ramifications on ASEAN and East Asia.