Carbon Capture, Utilisation, and Storage (CCUS) in India

From a Cameo to Supporting Role in the Nation's Low-Carbon Story

Ankur Malyan and Vaibhav Chaturvedi

Issue Brief | August 2021

Abstract

The role of carbon capture, utilisation and storage (CCUS)[1] in climate change mitigation has been a topic of debate for over two decades. The Intergovernmental Panel on Climate Change's (IPCC) Special Report on Global Warming of 1.5°C and the recent series of announcements by nations on net-zero have enthused the proponents of this technology, given the potential role offsets are expected to play in a net-zero world. In India, stakeholders have largely remained sceptical of the CCS technology because of the negligible progress on the deployment of this technology in the last two decades, the perverse incentive it presents to postpone mitigation actions, and the potential increase in the cost of power generation if this technology is deployed. In contrast, CCS offers a lease of life to investors and corporations in fossil-energy-dependent businesses and could save them from massive disruptions required to achieve a low carbon future.

1. Carbon capture, utilisation and storage, or CCUS, is an important emissions reduction technology that can be applied across the energy system. CCUS technologies involve the capture of carbon dioxide (CO2) from fuel combustion or industrial processes, the transport of this CO2 via ship or pipeline, and either its use as a resource to create valuable products or services or its permanent storage deep underground in geological formations (IEA 2021).

In this brief, we present an assessment of relevant documents of the Government of India, critical global literature, and announcements by Indian industries to unravel the changing focus on CCS technology. Though CCS is far from becoming a mainstream technology, our assessment shows a bubbling interest in the uptake of this technology in India, both by the government and the private sector. They are now keen to understand the technical and financial aspects of this technology. How this will play out in the future is anyone's guess, but it can be safely concluded that the narrative around this technology is slowly changing in India.

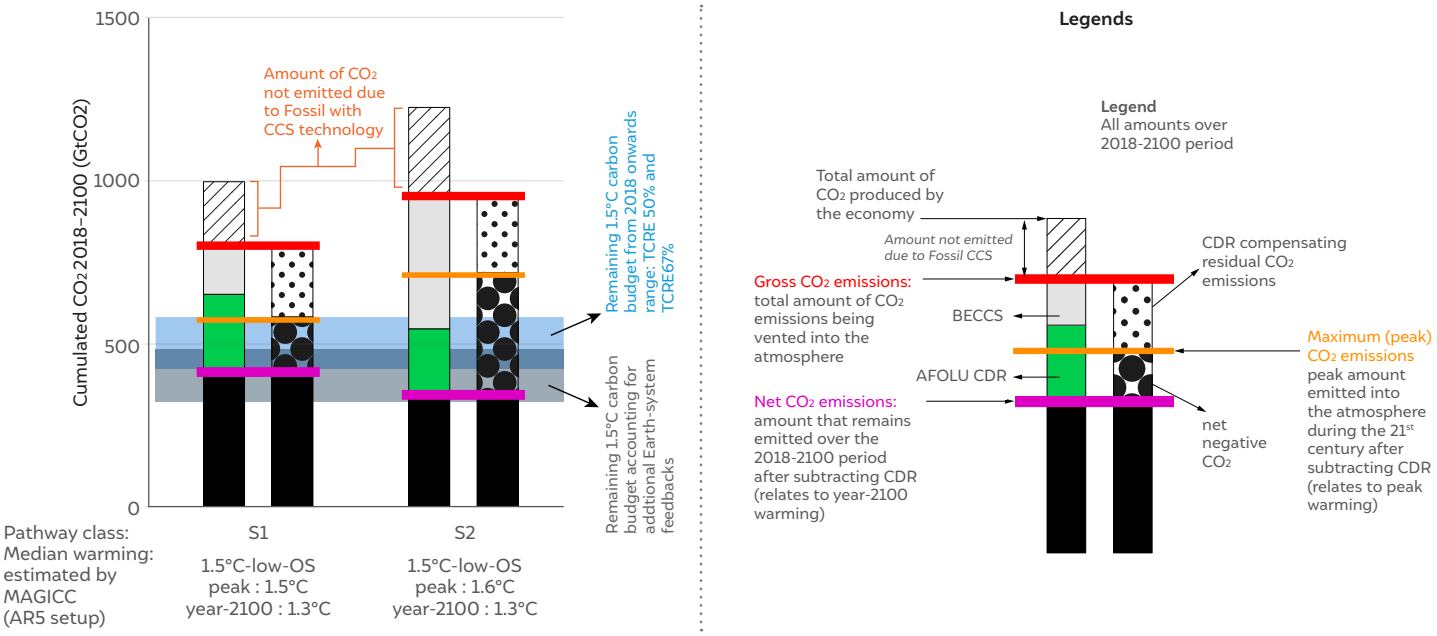
1. Introduction

For achieving ambitious long-term climate goals such as net-zero/carbon neutrality by restricting global temperature rise to under 1.5°C or 2.0°C, urgent actions are first needed to reduce anthropogenic emissions. Global emissions have to be cut by 45 per cent from the 2010 levels to keep temperature rise below 1.5°C so that net-zero can be realised by 2050 (IPCC 2018).

Achieving carbon neutrality would only be possible by retiring fossil-fuel-based power plants and electrifying industrial processes (IEA, 2020; Friedmann et al., 2020). However, the transition to a complete renewable-based power system or electrified industrial processes has a threshold that is limited by the current technological advances both in renewable energy and electrification (Bühler, Müller Holm, and Elmegaard 2019; Deason et al. 2018). In this context, the role of carbon capture, utilisation, and storage is being debated, yet considered crucial for sustainable development (IEA, 2021; Friedmann et al., 2020; IEA, 2018). Figure 1 describes the cumulative CO_2 emissions across two different pathways in a 1.5°C low overshoot scenario. As highlighted, CCS with the use of fossil fuel holds a great potential to mitigate the emissions from fossil fuel consumption between 2018 and 2100.

> **Carbon capture, utilisation and storage (CCUS) is essential for achieving climate ambitions such as net-zero.**

Figure 1 Cumulative carbon dioxide emissions in 1.5°C low overshoot scenarios



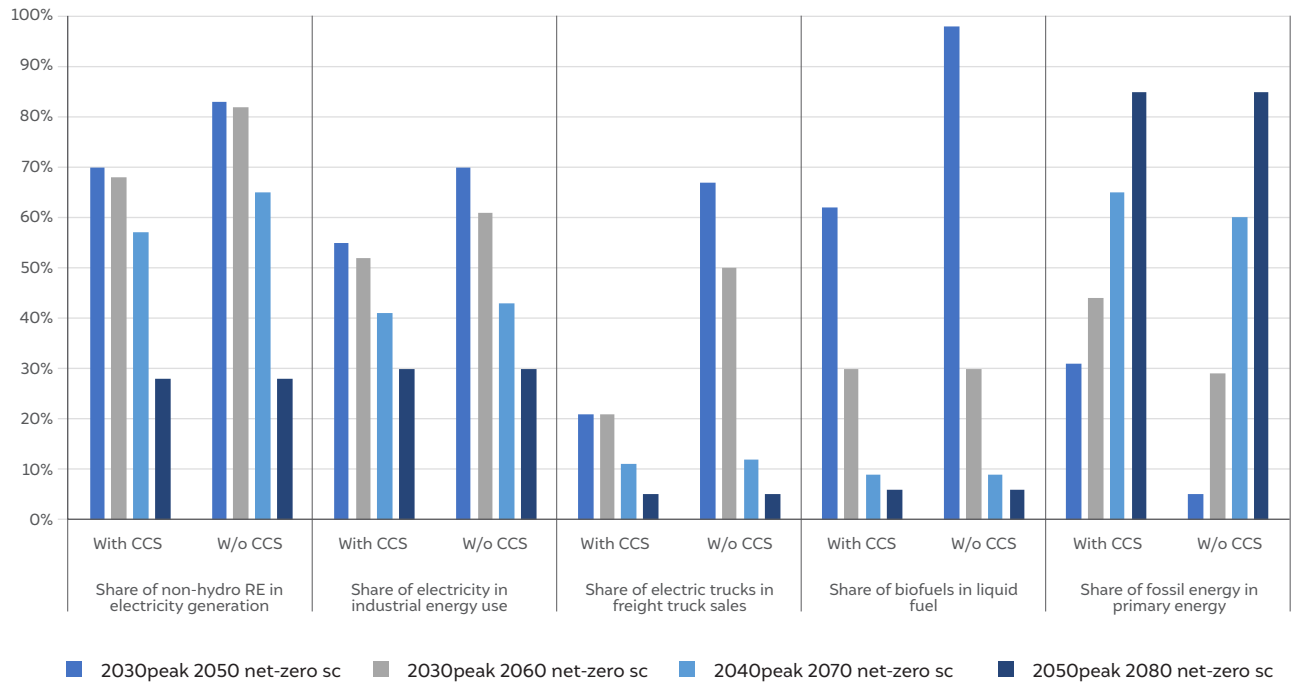
Source: IPCC. 2018. Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. New Delhi: Intergovernmental Panel on Climate Change. Note: The above schematic is edited by the authors to highlight the role of CCS with fossil fuels in scenarios

India has held an ambiguous position regarding the use of CCUS in its long-term climate strategy (Global CCS Institute and TERI 2013). As the nation's energy demand has increased multifold in recent decades and is likely to propel India to becoming one of the largest energy markets in the future, the transition towards a green economy remains the government's priority (PIB 2019; Sokołowski 2019). Countrywide electrification across sectors and promoting renewable and alternate energy sources such as solar and hydrogen are gaining prominence in the energy economy. Despite these efforts, many long-term projections show that fossil fuels will still be part of India's energy economy, especially for meeting the demand of power systems and industries (IEA 2021; Chaturvedi, Nagar Koti, and Chordia 2021; Thambi, Bhatacharya and Fricko 2019; CEA 2018). Still, CCUS did not generate interest in the country's climate debate. The essential role of CCUS in India's low-carbon future revolves around three key areas: (i) research and development (R&D), (ii) finance, and (iii) policy. There have been limited efforts made historically to understand the potential of the CCUS technology and associated geological assessment (Gupta and Paul 2019). However, the high cost of capital and generation (nearly 63–75 per cent increase in the base cost of generation) (Rao and Kumar 2014) has been a significant barrier to adopting CCUS technology despite the technology enjoying nearly five decades of global development, since, USA's Carbon dioxide enhanced oil recovery (CO_2-EOR) project (Nuñez-López, et al. 2019). Apart from the technical aspects, politico-economic aspects also play crucial role in carving the path for CCUS adoption in low carbon transition (Romasheva and Ilinova 2019). Since India is a price-sensitive market, the additional cost to be borne due to CCUS could be detrimental in a more extensive policy context (Gupta and Paul 2019).

Besides the role CCS could play in climate change initiatives, its contribution in bringing about long-term deep decarbonisation is also a topic of extensive debate. Currently, the technology seems economically unviable, however, long-term analysis across scenarios stress the need for CCS in the energy system. Recent analysis by Chaturvedi (2021) highlights the magnitude of disruptive transformation required in the energy systems of India to achieve net-zero climate targets across different scenarios by 2050 (described in Figure 2), and the importance of CCS for the state of future energy systems.

Feasibility of CCUS could ease the pace and magnitude of energy system transformations significantly.

Figure 2 Implementation of CCS in the Indian economy across net-zero scenarios relaxes the pace of transition required across progress variables significantly



Source: Reproduced from Chaturvedi, Vaibhav. 2021. Peaking and Net-Zero for India's Energy Sector CO_2 Emissions: An Analytical Exposition. New Delhi: Council on Energy, Environment and Water

Research & Development, finance, governance and policy are the key pillars for CCUS future in India.

Figure 2 highlights that there could be a significant difference between the level of transformations required in the energy system with CCS and without CCS in the economy. In the scenario of reaching net-zero by 2050, the share of non-hydro RE, when the CCS is feasible with fossil-based electricity generation, could be 13 per cent lower than that without CCS. Additionally, the CCS technology would help in accommodating nearly 30 per cent of fossil fuel's share in the primary energy, which otherwise needs to be only 5 per cent without CCS availability. CCS being feasible in refineries would help in promoting biofuels and require much slower transformation in the electric freight truck sales (21 per cent), which without CCS would be 67 per cent by 2050 (Chaturvedi 2021). Additionally, studies suggest that in deep decarbonisation scenarios in India, CCS has a mitigation potential of 780 Mt [million tonnes]/year below 60 USD [US dollar]/t-CO_2 in a 2°C scenario and further 250 Mt/year up to 75 USD/t-CO_2 in a well below 2°C scenario (Vishwanathan et al. 2018; Garg et al. 2017). Hence, CCS could help in achieving net-zero target at the same time easing the pace of transition away from fossil energy, thus providing some relaxation in system transformation and the needed investments for this transformation. But it has to be noted that CCS feasibility is a big assumption in these cases and as discussed, the economic and policy feasibility of CCS has not gained sufficient traction in last decade in India. Nevertheless, in recent times, increasing efforts (induced by global ambitions) to push for CCUS in the Indian economy are directed at defining the techno-economics and policy for CCS, that is, R&D, finance, and policy context. In addition to these challenges, the risk associated with the storage of carbon also presents a challenge to the governance of CCS along with the above-mentioned challenges. People participation and awareness of the technology is very low, leading to a 'not in my back yard' (NIMBY) mind-set, elevating public concerns (Tcvetkov, Cherepovitsyn, and Fedoseev 2019). Additionally, there are questions around the liability, penalties, long-term management, and stewardship, which are also governance concerns linked to CCS and need to be focused upon if this technology penetrates the economy in a substantial manner (IRGC 2018).

In this brief, we present an assessment of the Government of India's documents relevant to CCS/CCUS debate such as national communications and Biennial Update Reports (BURs), key global literature focusing on changing role of this technology across regions, and major announcements by Indian industries to capture the changing narrative of CCUS in the Indian context. In the rest of this brief, we discuss the key insights from the assessment, conclusions, and way forward, highlighting the focus areas to maintain the momentum of the CCS/CCUS debate in India.

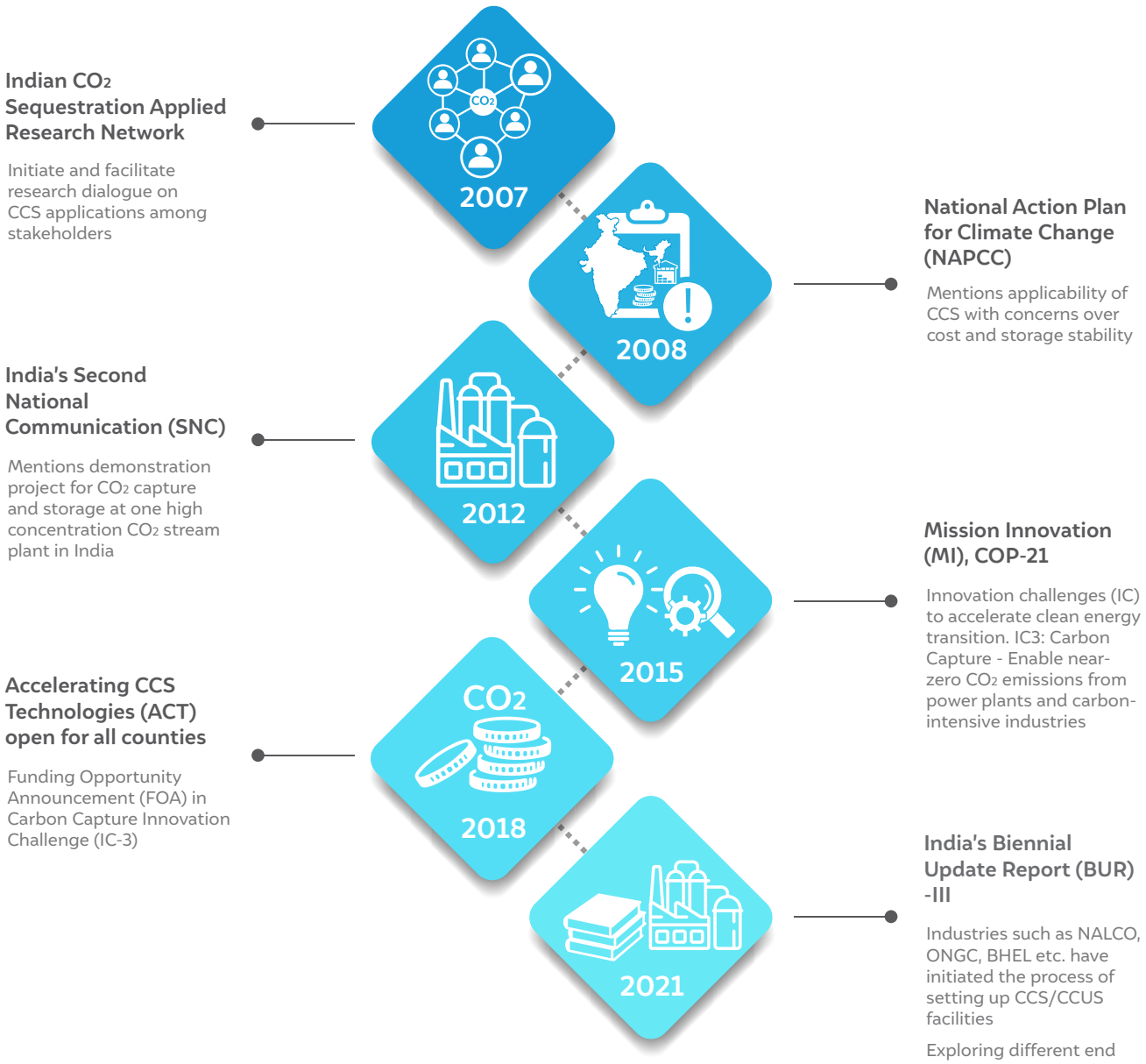
2. Assessment of progress on CCUS

2.1 A review of the Government of India's documents

The debate on CCUS in India has not been given a critical attention, but it is not new to the energy and climate policy space. Figure 3 describes the key milestones in the evolution of the CCS/CCUS debate in India. The establishment of the Indian CO_2 Sequestration Applied Research (ICOSAR) Network by the Department of Science and Technology (DST), Government of India, in 2007 was one of the key developments to initiate and facilitate research dialogue on CCS applications among stakeholders (Viebahn, Vallentin, and Höller 2014; Viebahn et al. 2011; Bumb and Rituraj n.d.). In 2008, the Government of India came up with the National Action Plan on Climate Change (NAPCC), which did mention the CCS in reference to reducing emissions from coal power plants while highlighting concerns regarding its high cost and (in)stability of CO_2 storage repositories (PMCCC 2008). In the Second National Communication (SNC) to the United Nations Framework Convention on Climate Change (UNFCCC) as well, India presented a demonstration project for carbon dioxide capture and storage (MoEF 2012) . Soon, the CCS conversation lost its momentum in India's growth story and climate debate. The subsequent BURs did not include the progress of CCS in the country. Both BUR-I and BUR-II did not mention much about India's carbon capture activities (MoEFCC 2015, 2018). However, in 2015, the Conference of Parties (COP)-21 launching Mission Innovation (MI) emerged as another milestone for R&D on CCS technology in India (MoEFCC 2018).

Discussion on CCUS in India has faced multiple crests and troughs.

Figure 3 Conversation around and finances for exploring CCUS in India has gained momentum after 2015 facilitated by Mission Innovation



Source: Authors' compilation based on multiple sources

Legends:

US DoE: United States Department of Energy;

DST: Department of Science and Technology, Government of India;

BHEL: Bharat Heavy Electricals Limited;

NALCO: National Aluminium Company;

ONGC: Oil and Natural Gas Corporation.

Mission Innovation under Paris Agreement has re-fuelled the CCUS debate in India.

As part of Mission Innovation (MI), India is collaborating with 24-member countries[2] and the European Union (EU) to deliver on eight innovation challenges.[3] The innovation challenge (IC)-3 focuses on 'Carbon capture—Enable near-zero CO2 emissions from power plants and carbon-intensive industries' (MoEFCC 2021). Since India does not have much experience in implementing CCUS at scale, the innovation plan focuses on building and speeding up the developments through peer learning among MI nations (DBT and DST 2018). The MI countries have also agreed to double the funding from the 2015 baseline to provide a financial boost to the R&D activities for the mentioned innovation challenges (GoI 2017). Additionally, the commencement of MI has had many positive effects on the adoption of CCUS technology in India. The Department of Biotechnology (DBT) and DST, along with Accelerating CCUS Technologies (ACT) initiative under MI, has played an essential role in bringing back focus on CCS/CCUS in the Indian context by peer technology exchange and allocating funds for R&D. In the latest call for financial support, 15 ACT member countries and organisations have decided to participate. However, the funds will be allocated from national and regional budgets that support research and development as well as pilot and demonstration projects. Some of the research priorities highlighted in the third call include: efficient absorbents for CO2 absorption, economics and industry evaluation of technology, sequestration by enhanced oil recovery etc. (DBT and DST 2018). CCUS has started gaining momentum across industrial sectors in India. Heavy industries such as National Aluminium Company (NALCO), Oil and Natural Gas Corporation (ONGC), and Bharat Heavy Electricals Limited (BHEL) are initiating the process of setting up the CCUS facilities. The leading companies from the most emission-intensive iron and steel and cement industries are following the path to exploring CCUS technologies with a vision stay carbon-neutral (MoEFCC 2021). Nonetheless, the dialogue between the United States Department of Energy (US-DoE) and the DST has led to India's participation in Accelerating CCUS Technologies (ACT), which has resulted in a US–India collaboration for CCUS development in the country (MoEFCC 2021). Also, the recently launched roadmap 2030 for India-UK future relations considers CCUS under clean energy and transport focus areas (MEA 2021). Thus, multiple initiatives highlight the resumption of the application of CCUS across industries in India. This regained thrust of the CCUS debate is likely to sustain with many nations and industries coming up with ambitious climate change mitigation targets.

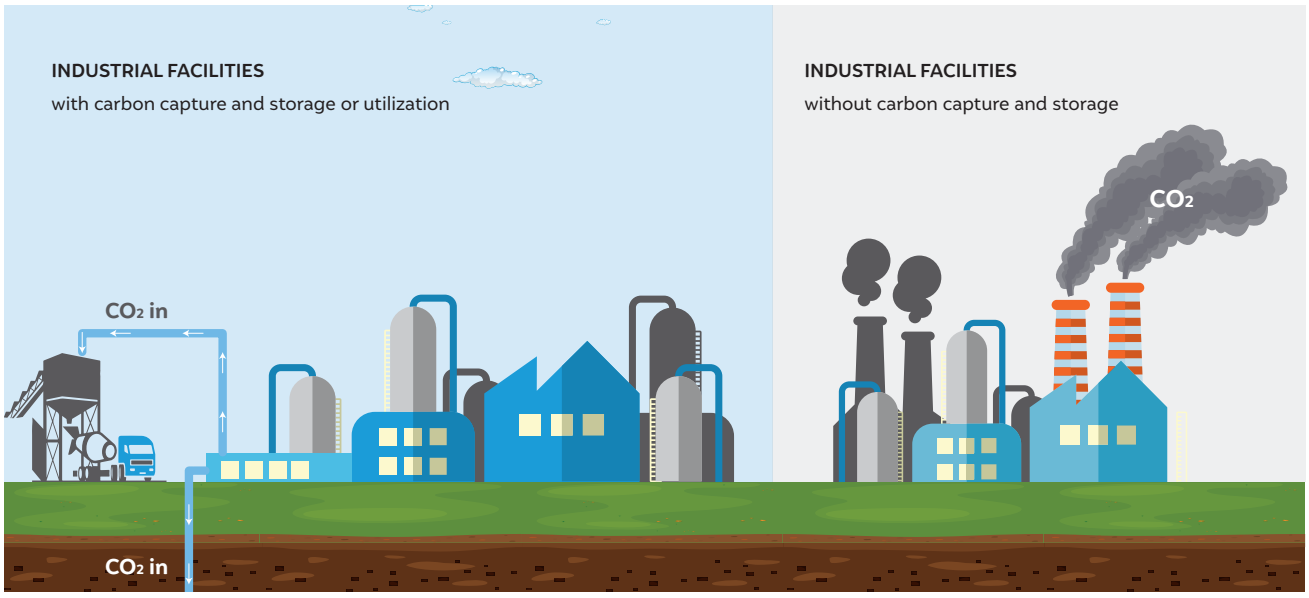
2.2 Review of global policy documents on CCS/CCUS

In 2015, the global efforts focusing at climate change mitigation led to nationally determined contributions (NDC) by respective countries pledging to reduce emissions under the aegis of the Paris Agreement. However, studies have already stated that NDCs are not enough to even achieve the reduction of global temperature below 2°C (R. Liu and Raftery 2021; Wang and Chen 2019). Since the mitigation targets were not ambitious enough, NDCs submitted to the United Nations Framework Convention on Climate Change (UNFCCC) by the parties include CCS only negligibly as a prospective technology in future. A review of NDCs highlights that out of 163 nations, only 13 countries and the EU (for its member countries) mentioned CCS in their declarations (Campbell et al. 2018). However, in case of mid-century strategies (MCS)[4], only three out of six nations quantified the possible reduction by implementing CCS in the economy (Campbell et al. 2018).

But increasing realisation of the adverse impacts of climate change has pushed nations towards stringent climate pledges such as net-zero. Larger economies like the EU (by 2050), Japan (by 2050), and China (by 2060) have already announced their net-zero targets (Murray 2020). With the change of leadership in the United States, pledging for net-zero by 2050 is also on the

13 countries (and the EU - for its member countries) out of 163 mentioned CCUS in their NDC declarations.

2. The member countries of Mission Innovation include the United States, UK, Australia, UAE, and Japan, among others. The complete list can be accessed from http://mission-innovation.net/our-members/
3. The eight innovation areas as smart grids, off-grid access to electricity, carbon capture, sustainable biofuels, converting sunlight, clean energy materials, affordable heating and cooling of buildings, and renewable and clean hydrogen.
4. Six nations which had proposed the MCS and considered by Campbell et al. (2018) are Canada, France, Germany, Mexico, the United States and Benin.



Upcoming net-zero strategies across countries hold a crucial space for CCUS.

priority list of the Biden administration (Mooney 2020). Simultaneously, the International Energy Agency's (IEA) analysis on the role of CCUS in clean energy transition clearly states that achieving carbon neutrality without CCUS technology is virtually impossible (IEA 2020). In a similar direction, projections for achieving net-zero in the major economies emphasise CCS playing a prominent role in tight carbon constraints scenarios. As estimated, Europe would need a large CCS facility for capturing nearly 230–430 MtCO2/yr in 2030 and increasing it to 930–1,200 MtCO2/yr by 2050 to reach net-zero by 2050 consistent with 1.5°C global temperature reduction target (Butnar, Cronin, and Pye 2020). Even an analysis of China's net-zero ambition shows that by 2060, 16 per cent of the energy demand will be dependent on fossil fuels and would necessarily need coupling with CCS technology to achieve the target (Nature 2020; Bloomberg 2020b).

Despite the significance of CCUS in achieving global temperature reduction targets and urgency with which climate change has to be addressed, the investment and development of the CCUS project pipeline are not as fast as it should be (IEA 2020; Global CCS Institute 2019). Historically, despite announcements, the investments for financing CCS in major economies did not pick up. Out of USD 31 billion announced in 2009 by the United States, Europe, Australia, Canada, and Great Britain, only USD 3 billion was actually invested, with cancelled CCS projects in Europe largely accounting for the gap (Romasheva and Ilinova 2019). After a steady decline in CCS capacity from 2010 to 2017, it has started climbing from 2017 to 2020. As CCS regains momentum globally, the current operational capacity stands four times compared to that in 2010 (Global CCS Institute 2020a). The increasing ambitions are driving national leaderships towards more push for the adoption of CCS technology. The growing climate change mitigation ambitions and the realisation of inevitability of CCS in the long term have started attracting investments across major nations. Table 1 describes the major announcements of financial support and investment initiatives from the governments of major economies for CCS facilities.

The dynamism of climate change mitigation pledges from the developed nation will impact India's perspective and decision making. The escalating global ambitions are likely to build diplomatic pressure on India to either go for net-zero or raise its mitigation targets significantly. India is nonetheless praised for demonstrating leadership in climate change mitigation initiatives. Also, India is only one of the G20 nations to be on track of reducing the temperature rise to 2°C.

Being a leader, India holds a significant position in global climate change politics. However, as more and more G20 nations[5] are coming up with carbon neutrality targets, India not planning for matching ambitious targets could result in the country losing its leadership position in international climate change politics.

There are multiple finance supports announced across by various nations to fuel the momentum gained by CCUS.

Table 1 Major announcements for financial support and incentives for CCS/CCUS adoption

Region	Initiative	Budget	Scope
UK	CCS Infrastructure Fund	USD 1.37 billion	The fund aims to develop four carbon capture and storage hubs and cluster projects across UK by end of decade with vision to reach net-zero by 2050. Additional USD 0.2 Billion has been announced for CCUS under UK 10-point plan.
Norway	CCS Infrastructure and Support Fund [Longship CCS project]	USD 1.83 billion	The fund aims to support CCS infrastructure and create a whole new value chain that is needed to deliver on the Paris Agreement.
European Commission	ETS Innovation Fund	Total fund: USD 11.9 billion (part of which will be allocated to CCUS)	The fund aims to support low-carbon technologies including CCUS, renewables, and energy storage to achieve carbon neutrality in Europe.
United States	Federal funding to support the development and advancement of carbon capture technologies	USD 72 million	The support aims to support research and development of coal and natural gas power plants' projects and remove CO_2 from the atmosphere. Out of the total federal funds pledged, USD 51 million has been awarded to nine projects in power plants and rest is for 'direct air capture'.
	Section 45Q Tax credit	---	Section 45Q tax credit is one of the most aggressive CCS-specific incentives providing break-even cost estimate ranges from 5 USD/t-CO_2 to 60 USD/t-CO_2
India	DBT-DST-ACT support for R&D in CCS	USD 1.19 million (INR 8 crore)	DST participated in multilateral ACT (Accelerating CCS Technologies) programme that is focused on accelerating CCUS technologies. Current plan is to support four projects, with each receiving around USD 0.3 million (~INR 2 crores).
Australia	Support fund for CCUS [part of larger new energy technology package (USD 1.5 billion)]	USD 39 million	The fund will provide targeted support to a wide array of carbon capture, use and storage opportunities, including carbon recycling, etc.
Canada	Tax incentives for CCUS adoption	---	As a part of green programs in the budget, 50 per cent reduction in income tax rates is announced for businesses that manufacture zero-emission technologies as well as tax incentives to adopt carbon capture, utilisation and storage (CCUS).

Note: The table is a compilation of information from various sources.

Sources: Global CCS Institute (2020b,c); Reuters (2020); USA DoE (2020); European Commission (2019); DST-ACT (2020); The Guardian (2020); UpStream (2020a); UpStream (2021); IHS Markit (2021)

5. G20 nations include Argentina, Australia, Brazil, Canada, China, Germany, France, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Turkey, the UK and the United States. Out of them, many nations such as Japan, France, China and South Korea have announced net-zero target.

Additionally, the EU is one of the early movers to go for the Carbon Border Adjustment Mechanism (CBAM) to avoid 'carbon leakage'. The CBAM could induce a jolt in the world trade and revise the terms of competitive advantages across nations (BCG 2020). On the one hand, India is moving closer to the free trade deal with the EU, which would make it easy for European players to enter the Indian market (Business Standard 2020). On the other, the EU envisages imposing a carbon tax on imports from high-emitting markets (Bloomberg 2020). The coexistence of these deals is likely to impact the competitiveness of Indian industries globally and locally. These concerns have induced the private sector in India to go beyond the usual trajectories and initiate pilots for CCS/CCUS facilities in industries.

2.3 Actions by Indian industries

Currently, achieving the deep decarbonisation potential in industries is more challenging compared to that in any other sector. The reasons are the limited possibility of switching, both because of existing investment in conventional processes and technology advancement limitations such as dependence on specific heat-based processes on fossils (Bühler, Müller Holm, and Elmegaard 2019; Deason et al. 2018). In this context, CCS/CCUS is widely discussed as a crucial mitigation technology to aid the industry significantly.

The industrial sector will continue to be crucial in terms of energy and emission in the Indian economy. The sector is expected to hold 58 per cent share in the total final energy consumption by 2050 (Chaturvedi, Nagar Koti, and Chordia 2021). Whereas its share in total economy-wide emissions will be around 31 per cent by mid-century (Chaturvedi, Nagar Koti, and Chordia 2021). Additionally, the industrial sector is expected to be dominated by fossil energy sources, which accounted for 66 per cent of the total industrial energy consumption in 2017 (IEA 2018) and likely to decline by only 2 per cent to 64 per cent by 2050 (Chaturvedi, Nagar Koti, and Chordia 2021). The expected long-term dependence on fossil fuels in India's industrial sector makes the role of CCUS technologies indispensable in deep decarbonisation scenarios in this sector. Despite the importance of CCUS technologies for the Indian industry, there is a lack of policy support in promoting these mitigation technologies in the industry. However, industry leaders being cognisant of the business risks in long-term sustainability (to remove the tag of being emission-intensive), have undertaken a few pilots for implementing CCS/CCUS in selected plants.

As mentioned in the earlier section, public sector undertakings such as NALCO, ONGC, and BHEL are taking up CCS pilots (MoEFCC 2021). NALCO has commissioned a pilot-cum-demonstration CO_2 sequestration plant (Gupta and Paul 2019). ONGC has signed a memorandum of understanding (MoU) with ILFS Energy and Tamil Nadu Power Company (ITPCL) in 2018 to inject CO_2 captured at the ITPCL plant into oil fields of ONGC Cauvery Asset (Cornot-Gandolphe 2019). Various reasons such as scalability of the technology, many successful demonstrations, ability to generate revenue while offsetting the high incurred cost of CCUS and being a precursor to pure sequestration projects makes EOR a preferred choice for CCUS projects. Since the oil discoveries are getting fewer, utilisation of CO_2 through processes like EOR showcase a great potential to rejuvenate mature oil fields (Mishra, et al. 2019). Hence, ONGC and Indian Oil Corporation Limited (IOCL) have signed an MoU for CO_2 based Enhanced Oil Recovery (EOR) by injecting CO_2 captured from IOCL's Koyali refinery. The effort aims to reduce India's carbon emission targets set forth in COP21 while enhancing production from domestic fields (ONGC 2019). According to the estimates, the ONGC's EOR project has the sequestration potential of around 5-8 MMT of CO_2 through structural, solubility and residual trapping mechanisms (Mishra, et al. 2019).

Additionally, private players such as Dalmia Cement, one of the leading cement manufacturers in the country, are exploring the adoption of CCS technology. The active participation of the private sector in the direction of deep decarbonisation of industries could be a game-changer for India's industrial sector. Hence, the case study of Dalmia Cement is highlighted in this brief.

> **Many Indian industries piloting CCUS projects have shown a clear signal of changing the CCUS narrative in the country.**

CASE STUDY **Dalmia Cement—Leading the cement industry towards CCS adoption**

Introduction

Dalmia Cement is one of the leading cement manufacturers in India with the current capacity of 26.5 million tonnes per annum and are operating 13 plants and grinding units across nine states (Dalmia Cement 2019). Additionally, it is largest producer of slag and speciality cement in India.

Sustainable vision

For their sustainability focus, Dalmia Cement has been certified to be ranked first in the global cement sector by Climate Disclosure Project (CDP) (Dalmia Cement 2019). Some of the key initiatives include usage of 100 per cent power from renewable energy sources by 2030, doubling energy productivity by 2030, increasing the usage of alternative fuels by 2035, and adoption of carbon capture and utilisation for process emissions by 2040 (Dalmia Cement and TERI 2020). These initiatives are planned towards achieving a larger vision: 'to be carbon negative by 2040'.

Dalmia-determined contributions (DDCs) and the role of CCUS

As of 2020, the carbon footprint of Dalmia Cement stands at 546 $kgCO_2$/ton of cementitious material, which is much lower than the global average of 900 $kgCO_2$/ton (Dalmia Cement and TERI 2020). However, the company plans to reach the level of –30 $kgCO_2$/ton by 2040, described as Dalmia-determined contributions (DDCs). To achieve this ambitious target, Dalmia Cement has announced the installation of a large-scale CCUS facility of capacity 0.5 $MtCO_2$ per annum at one of its plants in Tamil Nadu, India (Plaza, Martínez and Rubiera 2020). For the implementation of this facility, Dalmia Cement and Carbon Clean Solutions, UK, have come together to adopt the latter's patented technology, CDRMax (Global CCS Insitute 2019).

> **Indian industries are leading some of the largest projects exploring CCUS technology.**

It is evident from the case of Dalmia Cement that achieving ambitious targets such as net-zero for hard to abate sectors that have to deal with process emissions essentially has to include CCUS technology as part of the strategy, even if such industries are one of the most efficient ones across the globe. Similarly, Tata Steel's latest technology, 'HISARNA', is being planned to be implemented with the CCS technology. However, HISARNA technology with CCS is still under development and timeline of implementation is also unclear (TNO 2020).

Nevertheless, with global level changes in mitigation strategies such as Carbon Border Adjustment Tax in the EU to avoid 'carbon leakage', industries need to transition beyond the 'business as usual' to the lesser carbon-intensive state to stay competitive in the European markets. Nonetheless, considering the urgency with regard to climate change mitigation actions and ambitious climate pledges announced by several nations, more initiatives on the lines of EU's Carbon Border Adjustment Tax can be anticipated. Thus, the role of CCUS is being recognised by the industries, but more stakeholders are needed for the transition to promote the adoption of CCS/CCUS technology in India.

3. Key insights and conclusions

The changing narratives towards the prospects of implementing CCS/CCUS technology across the globe, including India are evident, primarily driven by climate change mitigation ambitions. Our assessment highlights the following points:

- The narrative around CCS/CCUS technology has been regaining momentum in the Indian and global contexts in accordance with the countries ambitiously pledging for carbon neutrality.
- In India however, this technology is far from becoming mainstream, but the Government of

India and the Indian industry are trying to better understand the techno-economic feasibility and scalability of this technology.

- Indian industries and public sector undertakings (PSUs) are leading the way towards the promotion of CCS facilities while recognising the need to stay carbon-neutral in the broader context of sustainability and competitiveness.

After lying dormant for a decade, the CCUS debate has been reignited in India's climate change mitigation conversations. The discussions were first initiated in 2007, but they lost momentum over time. With India joining Mission Innovation in 2015 and with several nations making ambitious mitigation pledges such as carbon neutrality in recognition of an urgent need to address climate change, CCUS is regaining its momentum as an essential technology in the presence of fossil-based industries across nations, including India. Though CCUS could play a significant role in the power and industrial sectors, the power sector relies heavily on renewables in India at present. However, in long-term deep decarbonisation scenarios, CCUS could play an important role to achieve net-zero emissions in energy systems. Simultaneously, the industrial sector continues to face multiple challenges hindering its transformation. Consequently, with the growing acceptance of challenges and the need to mitigate the industrial sector emissions, CCUS is being adopted as a pilot by many Indian industries.

To address the challenges CCUS faces in India, there is a need to develop and evolve an ecosystem supporting CCUS facilities in the Indian market. Success of CCUS is not only impeded by technology which will be advancing in coming years but also by the lack of a policy ecosystem. The ecosystem should be built and strengthened around the essential pillars, namely, R&D, policy, finance, and governance. Except for MI-DBT-DST projects, no focused research is being facilitated for CCUS. However, an India-specific comprehensive analysis needs to be undertaken to understand the challenges and the local solutions that are possible. Besides this, research and communication are also required on the policy front to understand the changing requirements and implications of policies on the role of CCUS, especially in the industrial sector. There is a need

> **An ecosystem supporting R&D, finance, policy and governance is a must to grow and sustain CCUS technology in India.**

> **Enabling finance is a must to make CCUS is techno-economically feasible solution.**

for demonstration projects to increase the confidence of stakeholders with the technology and better understand the uncertainties associated with it. Additionally, market-based mitigation mechanisms could play a key role in promoting CCUS facilities among industries and the inclusion of CCUS as a crucial ecosystem enabler. The cost of CCUS is very high despite decades of research highlighting the requirement of alternative finance mechanisms and support to help consumers adopt this expensive yet relevant technology . As the uncertainty and risks of CCUS are well known, the long-term sustainability and associated trade-offs of CCUS penetration in the ecosystem should be focused upon. Nonetheless, the CCUS technology is relatively new to India compared to the developed nations and hence it requires more comprehensive research, actions, and discussions to keep the debate going while discussing India's low-carbon story.

References

R. Liu, Peiran, and Adrian E. Raftery. 2021. "Country-based rate of emissions reductions should increase by 80% beyond nationally determined contributions to meet the 2°C target." *Communications Earth & Environment 2* (29). doi:10.1038/s43247-021-00097-8.

BCG. 2020. *An EU Carbon Border Tax Could Be the Next Disruptive Force in Global Trade*. 30 June. Accessed February 22, 2021. https://www.prnewswire.com/news-releases/an-eu-carbon-border-tax-could-be-the-next-disruptive-force-in-global-trade-301085435.html.

Bloomberg (b). 2020. *China's Top Climate Scientists Plan Road Map to 2060 Goal*. 28 September. Accessed April 11, 2021. https://www.bloomberg.com/news/articles/2020-09-28/china-s-top-climate-scientists-lay-out-road-map-to-hit-2060-goal.

Bloomberg. 2020. *Carbon Border Tax Emerges in EU as Weapon to Protect Green Deal*. 29 September. Accessed February 22, 2021. https://www.bloombergquint.com/onweb/carbon-border-tax-emerges-in-eu-as-weapon-to-protect-green-deal.

Bühler, Fabian, Fridolin Müller Holm, and Brian Elmegaard. 2019. "Potentials for the electrification of industrial processes in Denmark." *Proceedings of ECOS 2019: 32nd International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems*. https://backend.orbit.dtu.dk/ws/portalfiles/portal/189357718/ECOS2019_B_hler_Fabian_Article_for_proceedings_PDF.pdf.

Bumb, Prateek, and Rituraj. n.d. *Carbon dioxide capture and storage (CCS) in geological formations as clean development mechanism (CDM) projects activities (SBSTA)*. UNFCCC - CDM.

Business Standard. 2020. *India set to resume talks on free trade agreements with EU, US*. 21 November. Accessed February 22, 2021. https://www.business-standard.com/article/economy-policy/india-set-to-resume-talks-on-free-trade-agreements-with-eu-us-120112100594_1.html.

Butnar, Isabela , Jennifer Cronin, and Steve Pye. 2020. *Review of Carbon Capture Utilisation and Carbon Capture and Storage in future EU decarbonisation scenarios*. The Carbon Capture and Storage Association and Energy Institute, University College London (UCL).

Campbell, Lisa , Lee Solsbery, Vicky Hudson, and Max Crawford. 2018. *Role of CCS in the Energy Transition*. BP, Chevron, BR Petrobras, ERM and CCP.

CEA. 2018. *Report of committee on optimal energy mix in power generation mix on medium and long term basis*. Central Electricity Authority, Ministry of Power, Government of India.

Chaturvedi, Vaibhav. 2021. *Peaking and Net-Zero for India's Energy Sector CO2 Emissions: An Analytical Exposition*. Delhi: Council on Energy, Environment and Water.

Chaturvedi, Vaibhav, Poonam Nagar Koti, and Anjali Ramakrishnan Chordia. 2021. "Pathways towards India's nationally determined contribution and mid-century strategy." *Energy and Climate Change* 2. doi:10.1016/j.egycc.2021.100031.

Cornot-Gandolphe, Sylvie. 2019. *Carbon Captre, storage and utilisation to the rescue of coal? Global perspective and focus on China and the United States*. Institut français des relations internationales (IFRI).

Dalmia Cement. 2019. *About Dalmia Cement*. Accessed March 16, 2021. https://www.dalmiacement.com/about-dalmia-cement.html#:~:text=The%20company%20operates%20a%20manufacturing,units%2C%20spread%20across%20nine%20states.&text=The%20largest%20producer%20of%20slag,specialty%20cement%20in%20the%20country.

Dalmia Cement and TERI. 2020. *Building a future ready business enterprise: To become the most respected and responsible global corporate citizen*. Dalmia Cement. https://www.teriin.org/sites/default/files/files/dalmia-bharat-climate-actions.pdf.

DBT and DST. 2018. *Funding Opportunity Announcement (FOA) in Carbon Capture Innovation Challenge (IC#3) jointly by Department of Biotechnology & Department of Science and Technology*. Department of Science and Technology (DST), Government of India. http://dst.gov.in/sites/default/files/FOA-IC3.pdf.

Deason, Jeff, Max Wei, Greg Leventis, Sarah Smith, and Lisa Schwartz. 2018. *Electrification of build-*

ings and industry in the United States. Berkeley CA: Ernest Orlando Lawrence Berkeley National Laboratory. https://ipu.msu.edu/wp-content/uploads/2018/04/LBNL-Electrification-of-Buildings-2018.pdf.

DST-ACT. 2020. *Call for shortlisted 5 pre-proposals received against the ACT Call 3 to submit full proposal*. Accessed April 11, 2021. https://dst.gov.in/sites/default/files/ACT%20Call%203%20Stage%202%20Call%20for%20shortlisted%20preproposals%20to%20submit%20full%20proposals%20-%20Last%20date%20-%2015.03.2021%20_0.pdf.

European Commission. 2019. *Towards a climate-neutral Europe: EU invests over €10bn in innovative clean technologies* . 26 February. Accessed April 11, 2021. https://ec.europa.eu/commission/presscorner/detail/en/IP_19_1381.

Friedmann, S. Julio, Alex Zapantis, Brad Page, Chris Consoli, Zhiyuan Fan, Ian Havercroft, Harry Liu, et al. 2020. *Net-zero and Geospheric Return: Actions today for 2030 and beyond*. Columbia School of International and Public Affairs (SIPA) Center on Global Energy Policy and Global CCS Institute. https://www.globalccsinstitute.com/wp-content/uploads/2020/09/Netzero-and-Geospheric-Return-2.pdf.

Garg, Amit , P.R. Shukla, Shrutika Parihar, Udayan Singh, and Bhushan Kankal. 2017. "Cost-effective architecture of carbon capture and storage (CCS) grid in India." *International Journal of Greenhouse Gas Control* 66: 129-146. doi:10.1016/j.ijggc.2017.09.012.

Global CCS Insitute. 2019. *Dalmia Cement (Bharat) Limited and Carbon Clean Solutions team up to build cement industry's largest Carbon Capture plant*. 20 September. Accessed March 16, 2021. https://www.globalccsinstitute.com/news-media/latest-news/dalmia-cement-bharat-limited-and-carbon-clean-solutions-team-up-to-build-cement-industrys-largest-carbon-capture-plant/.

Global CCS Institute (b). 2020. *UK Government Set to Fund Four CCS Hubs and Clusters*. 18 November. Accessed April 09, 2021. https://www.globalccsinstitute.com/news-media/press-room/media-releases/uk-government-set-to-fund-four-ccs-hubs-and-clusters/.

Global CCS Institute (c). 2020. *The US Section 45Q Tax Credit for Carbon Oxide Sequestration: An Update*. Global CCS Institute. https://www.globalccsinstitute.com/wp-content/uploads/2020/04/45Q_Brief_in_template_LLB.pdf.

Global CCS Institute and TERI. 2013. "India CCS Scoping Study: Final Report." https://www.globalccsinstitute.com/archive/hub/publications/88981/india-ccs-scoping-study-final-report.pdf.

Global CCS Institute. 2020. *Global Status of CCS 2020*. Global CCS Institute. https://www.globalccsinstitute.com/wp-content/uploads/2020/12/Global-Status-of-CCS-Report-2020_FINAL_December11.pdf.

GoI. 2017. *Mission Innovation: Accelerating the Clean Energy Revolution*. Government of India. http://mission-innovation-india.net/wp-content/uploads/2018/04/mission-innovation-india-report-2017.pdf.

Gupta, Abhishek, and Askhoy Paul. 2019. "Carbon capture and sequestration potential in India: A comprehensive review." *Energy Procedia: 2nd International Conference on Energy and Power, ICEP2018, 13-15 December 2018, Sydney, Australia* 160: 848-855. doi:10.1016/j.egypro.2019.02.148.

IEA. 2021. *Carbon capture, utilisation and storage*. 14 April. Accessed May 11, 2021. https://www.iea.org/fuels-and-technologies/carbon-capture-utilisation-and-storage.

IEA. 2020. *Energy Transition Perspectives 2020*. Paris: International Energy Agency (IEA).

IEA. 2021. *India Energy Outlook 2021*. Paris: International Energy Agency.

IEA. 2020. *The role of CCUS in low-carbon power systems*. France: International Energy Agency (IEA). https://iea.blob.core.windows.net/assets/ccdcb6b3-f6dd-4f9a-98c3-8366f4671427/The_role_of_CCUS_in_low-carbon_power_systems.pdf.

IEA. 2018. *World Energy Outlook 2018*. Paris: International Energy Agency.

IHS Markit. 2021. *Canada's FY2021/22 budget includes big green investments, indication of additional GHG emissions cuts*. 20 April. Accessed June 01, 2021. https://ihsmarkit.com/research-analysis/canadas-fy202122-budget-includes-big-green-investments-indicat.html.

IPCC. 2018. *Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission*

pathways. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf.

IRGC. 2018. *Regulation of Carbon Capture and Storage*. Polcy Brief, International Risk Governance Council.

MEA. 2021. *Roadmap 2030 for India-UK future relations launched during India-UK Virtual Summit (4 May, 2021)*. 04 May. Accessed June 01, 2021. https://mea.gov.in/bilateral-documents.htm?dtl/33838/Roadmap+2030+for+IndiaUK+future+relations+launched+during+IndiaUK+Virtual+Summit+4+May+2021.

Mishra, Gaurav Kumar , Rakesh Kumar Meena, Sujit Mitra, Kunal Saha, Vilas Pandurangji Dhakate, Om Prakash, and Raman Kumar Singh. 2019. "Planning India's First CO2-EOR Project as Carbon Capture Utilization & Storage: A Step Towards Sustainable Growth." *Society of Petroleum Engineers*.

MoEF. 2012. *India: Second National Communication to the United Nations Framework Convention on Climate Change*. Ministry of Environment and Forest, Government of India. https://unfccc.int/resource/docs/natc/indnc2.pdf.

MoEFCC. 2015. *India: First Biennial Update Report to the United Nations Framework Convention on Climate Change*. Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India. https://unfccc.int/sites/default/files/resource/INDBUR1.pdf.

MoEFCC. 2018. *India: Second Biennial Update Report to the United Nations Framework Convention on Climate Change*. Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India. https://unfccc.int/sites/default/files/resource/INDIA%20SECOND%20BUR%20High%20Res.pdf.

MoEFCC. 2021. *India: Third Biennial Update Report to the United Nations Framework Convention on Climate Change*. Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India. https://unfccc.int/sites/default/files/resource/INDIA_%20BUR-3_20.02.2021_High.pdf.

Mooney, Chris. 2020. *Biden wants the U.S. to stop contributing to climate change by 2050. Here's what that would actually take*. 16 December. Accessed March 04, 2021. https://www.washingtonpost.com/climate-environment/2020/12/15/biden-wants-halt-all-us-climate-emissions-by-2050-heres-what-that-would-actually-take/.

Murray, James. 2020. *Which countries have legally-binding net-zero emissions targets?*. 05 November. Accessed March 04, 2021. https://www.nsenergybusiness.com/news/countries-net-zero-emissions/.

Nature. 2020. *How China could be carbon neutral by mid-century*. 19 October. Accessed April 11, 2021. https://www.nature.com/articles/d41586-020-02927-9.

Nuñez-López, Vanessa , Ramon Gil-Egu, Pooneh Hosseininoosheri, Susan D. Hovorka, and Larry W. Lake. 2019. *Carbon Life Cycle Analysis of CO2-EOR for Net Carbon Negative Oil (NCNO) Classification*. United States of America (USA): Bureau of Economic Geology, The University of Texas at Austin.

ONGC. 2019. *ONGC join hands with Indian Oil to reduce carbon emission, enhance oil recovery*. 01 July. Accessed June 01, 2021. https://www.ongcindia.com/wps/wcm/connect/en/media/press-release/ongc-join-hands-oil-recovery.

PIB. 2019. *Year Ender 2019 Ministry of Heavy Industry*. 20 December. Accessed February 22, 2021. https://pib.gov.in/PressReleseDetailm.aspx?PRID=1597099#:~:text=Total%20turnover%20of%20the%20Indian,million%20direct%20and%20indirect%20jobs.

Plaza, Marta G. , Sergio Martínez, and Fernando Rubiera. 2020. "CO2 Capture, Use, and Storage in the Cement Industry: State of the Art and Expectations." *Energies, MDPI* 13 (21): 5692. doi:https://doi.org/10.3390/en13215692.

PMCCC. 2008. *National Action Plan on Climate Change*. New Delhi: Prime Minister's Council on Climate Change, Government of India. https://archivepmo.nic.in/drmanmohansingh/climate_change_english.pdf.

Rao, Anand B. , and Piyush Kumar. 2014. "Cost Implications of Carbon Capture and Storage for the Coal Power Plants in India." *Energy Procedia: 4th International Conference on Advances in Energy Research 2013, ICAER 2013* 54: 431-438. doi:10.1016/j.egypro.2014.07.285.

Reuters. 2020. *Norway preps project Longship for second attempt at carbon 'moon landing'*. 21 September. Accessed April 09, 2021. https://www.reuters.com/article/norway-ccs-idUSKCN26C1CK.

Romasheva, Natalia , and Alina Ilinova. 2019. "CCS Projects: How Regulatory Framework Influences Their Deployment." *Resources (MDPI)* 8 (181). doi:10.3390/resources8040181.

Sokołowski, Maciej M. . 2019. "When black meets green: A review of the four pillars of India's energy policy." *Energy Policy* 60-68.

Tcvetkov, Pavel , Alexey Cherepovitsyn, and Sergey Fedoseev. 2019. "Public perception of carbon capture and storage: A state-of-the-art overview." *Heliyon* 5. doi:10.1016/j.heliyon.2019.e02845.

Thambi, Simi , Anindya Bhatacharya, and Oliver Fricko. 2019. *India's Energy and Emissions Outlook: Results from India Energy Model*. Working Paper, New Delhi: NITI Aayog.

The Guardian. 2020. *Boris Johnson announces 10-point green plan with 250,000 jobs*. 17 Nov. Accessed June 01, 2021. https://www.theguardian.com/environment/2020/nov/17/boris-johnson-announces-10-point-green-plan-with-250000-jobs#:~:text=The%2010%2Dpoint%20plan%20comprises,to%20power%20every%20UK%20home.

TNO. 2020. *Technology Factsheet: HISARNA with CCS*. TNO. https://energy.nl/wp-content/uploads/2020/09/HIsarna-CCS-Technology-Factsheet_080920.pdf.

UpStream. 2021. *Australian government looks to spur investment in carbon capture and storage projects*. 02 March. Accessed June 01, 2021. https://www.upstreamonline.com/energy-transition/australian-government-looks-to-spur-investment-in-carbon-capture-and-storage-projects/2-1-972268.

UpStream. 2020a. *Norway takes aim at CCS with huge government investment*. 21 Sept. Accessed June 01, 2021. https://www.upstreamonline.com/energy-transition/norway-takes-aim-at-ccs-with-huge-government-investment/2-1-878651.

USA DoE. 2020. *Department of Energy Invests $72 Million in Carbon Capture Technologies*. 01 September. Accessed April 11, 2021. https://www.energy.gov/articles/department-energy-invests-72-million-carbon-capture-technologies.

Viebahn, Peter , Daniel Vallentin, and Samuel Höller. 2014. "Prospects of carbon capture and storage (CCS) in India's powersector – An integrated assessment." *Applied Energy* 117: 62-75. doi:10.1016/j.apenergy.2013.11.054.

Viebahn, Peter , Samuel Höller, Daniel Vallentin, Holger Liptow, and Andreas Villar. 2011. "Future CCS implementation in India: a systemic and long-term analysis." *Energy Procedia* 4: 2708–2715. doi:10.1016/j.egypro.2011.02.172.

Vishwanathan, Saritha S., Amit Garg, Vineet Tiwari, and P.R. Shukla. 2018. "India in 2°C and well below 2°C worlds: Opportunities and challenges." *Carbon Management* 9 (5): 459-479.

Wang, Huan, and Wengying Chen. 2019. "Gaps between pre-2020 climate policies with NDC goals and longterm mitigation targets: analyses on major regions." *Energy Procedia* 159: 3664-3669. doi:10.1016/j.egypro.2019.01.894.

Ankur Malyan
ankur.malyan@ceew.in | @ankur_malyan

Ankur is a Programme Associate at CEEW in the Low-Carbon Pathways team. He is engaged in the analysis of the long-term aspects of decarbonisation pathways for India. Additionally, he analyses the state-level energy and climate policy using the integrated assessment modelling framework. Ankur is an alumnus of TERI School of Advanced Studies, Delhi. He also holds a post-graduate diploma from National Law University, Delhi and WWF-India.

Dr Vaibhav Chaturvedi
vaibhav.chaturvedi@ceew.in

Dr Chaturvedi, a Fellow at CEEW, leads the Low- Carbon Pathways focus area. His research on energy and climate change policy is positioned within the integrated assessment modelling framework of the Global Change Assessment Model. Dr Chaturvedi is an alumnus of the Indian Institute of Management Ahmedabad and Indian Institute of Forest Management, Bhopal.

Suggested citation: Malyan, Ankur, and Vaibhav Chaturvedi. 2021. *Carbon Capture, Utilisation and Storage (CCUS) in India: From a Cameo to Supporting Role in the Nation's Low-Carbon Story.* New Delhi: Council on Energy, Environment and Water.

Disclaimer: The views expressed in this study is that of the authors. They do not necessarily reflect the views and policies of the Council on Energy, Environment and Water.

Peer reviewers: Dr Saritha Sudharmma Vishwanathan, Post-Doctoral Fellow, Social Systems Division, National Institute of Environmental Studies, Japan; Gaurav Kumar Mishra, Executive Engineer, Oil and Natural Gas Corporation (ONGC), India; and Tirtha Biswas, Programme Lead, Council on Energy, Environment and Water (CEEW).

Acknowledgments: We would like to thank Dr Saritha Sudharmma Vishwanathan, Post-Doctoral Fellow, Social Systems Division, National Institute of Environmental Studies, Japan, Gaurav Kumar Mishra, Executive Engineer, Oil and Natural Gas Corporation (ONGC), India and Tirtha Biswas, Programme Lead, Council on Energy, Environment and Water (CEEW), India for being the reviewers of the study and providing their details comments and suggestions for improvement. Their valuable inputs have shaped the research piece significantly. The authors' take full responsibilities for any errors in the document.

Organisation: The Council on Energy, Environment and Water (CEEW) is one of Asia's leading not-for-profit policy research institutions. The Council uses data, integrated analysis, and strategic outreach to explain – and change – the use, reuse, and misuse of resources. It prides itself on the independence of its high-quality research, develops partnerships with public and private institutions, and engages with wider public. In 2021, CEEW once again featured extensively across ten categories in the *2020 Global Go To Think Tank Index Report.* The Council has also been consistently ranked among the world's top climate change think tanks. CEEW is certified as a Great Place To Work®. Follow us on Twitter @CEEWIndia for the latest updates.

For queries contact

COUNCIL ON ENERGY, ENVIRONMENT AND WATER (CEEW)

Sanskrit Bhawan, A-10, Qutab Institutional Area
Aruna Asaf Ali Marg, New Delhi - 110067, India
T: +91 (0) 11 4073 3300

info@ceew.in | ceew.in | @CEEWIndia | ceewindia