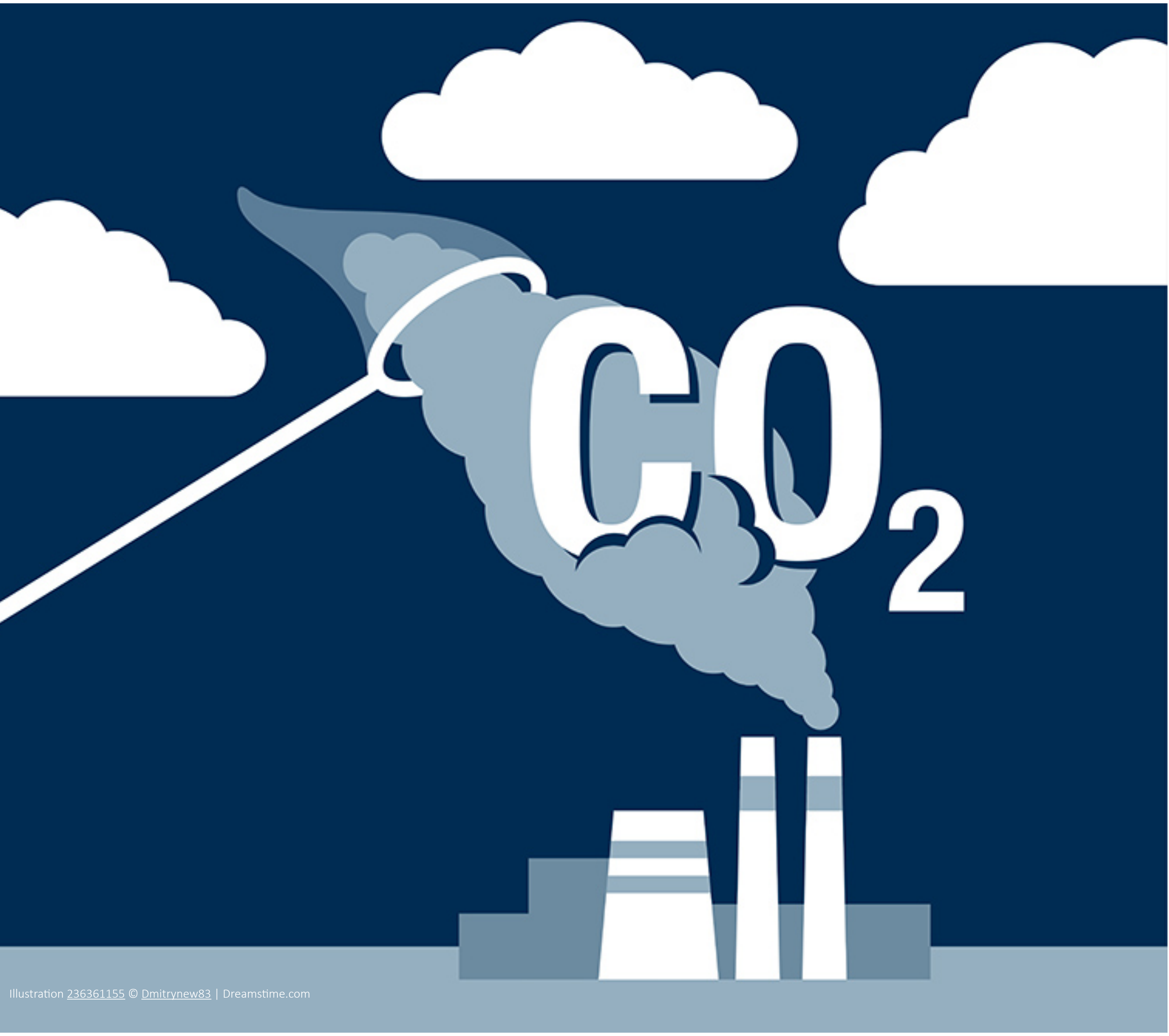
July 2023

REMENA Policy Paper Series No. 2

Regional Programme Energy Security and Climate Change
Middle East and North Africa

KONRAD ADENAUER STIFTUNG



AS ABOVE, SO BELOW: THE MENA REGION'S CCUS AMBITION TOWARDS CARBON NEUTRALITY

Author: Maryem El Farsaoui

Edited by: Robin Mills, CEO of Qamar Energy and author of
Capturing Carbon: The New Weapon in the War Against Climate Change

قمر
QAMAR ENERGY

What is Carbon capture, use and storage (CCUS)?

Several leading climate organisations refer to CCUS's role as a crucial decarbonisation technology in meeting global climate targets. CCUS constitutes a suite of technologies and methods to remove carbon dioxide (CO_2) emissions from large point sources including power plants, refineries, and industrial, fossil-fuel-based facilities, followed by recycling the CO_2 for utilisation and/or storing it in deep geological formations.

How does it work?

Currently, industrial facilities integrated with CCUS can capture around 90-95% of the CO_2 present in flue gas, with new developments promising a 99% capture efficiency. The main methods for carbon capture are post-combustion (separates CO_2 from the flue gas using a chemical solvent after the fuel is burnt), pre-combustion (converts the fuel into a gas mix consisting of hydrogen and CO_2 before it is burnt, and subsequently separates CO_2) and oxy-fuel combustion (burns a fuel with almost pure oxygen to produce CO_2 and steam, with the released CO_2 subsequently captured). Variants on these may be applied to industrial facilities which produce CO_2 from processes as well as combustion, such as cement manufacture and iron ore reduction. Post-combustion and oxy-fuel can be integrated with new plants or retrofitted to existing facilities built without it, while pre-combustion is more suitable for new plants since it requires larger modifications.

Once captured, the CO_2 is compressed into liquid state and transported for use in other industrial facilities or for storage into suitable depleted oil and gas reservoirs or saline aquifers.

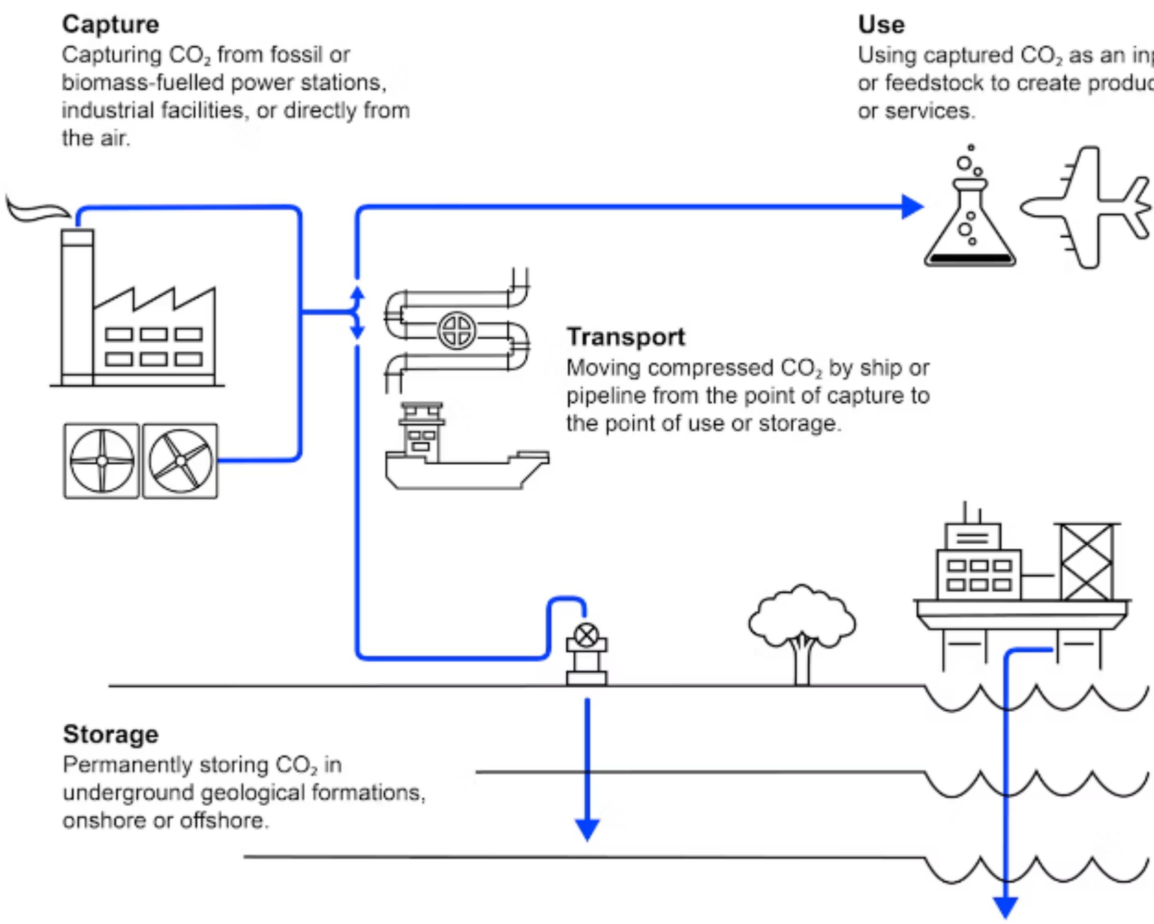


Figure 1 From capture and use to storage: a CCUS schematic (IEA)

Executive Summary

- As governments pursue carbon neutrality over the next thirty or so years, they cannot afford to dismiss CCUS and ignore its unique strengths in providing resiliency, diversity and flexibility.
- Renewables and green hydrogen alone are not enough to reach net-zero; CCUS is an essential technology to decarbonise hard-to-abate sectors and remove residual emissions via direct air capture (DAC).
- The MENA region is left with two options: decarbonise, or brace for impact. With CCUS, the MENA region should not have to compromise on its economic growth and energy security to meet its climate targets while it pursues economic and energy diversification plans.
- There is no silver bullet; net-zero in MENA will require extensive policy support, investment, R&D, and incentives for all of CCUS, renewables, low-carbon hydrogen, energy efficiency and carbon dioxide removal (CDR), and other approaches.
- Three of the Gulf Cooperation Council countries, the UAE, Saudi Arabia and Qatar, are set to emerge as CCUS champions, with a notable shift from CO_2-enhanced oil recovery (EOR) to more industrial decarbonisation-focussed projects, while other MENA countries demonstrate progress in carbon dioxide removal-focussed initiatives, namely Oman, Bahrain, and Morocco.
- CCUS-integrated hydrogen production will remain a competitive option in regions with low-cost fossil fuels and CO_2 storage resources. In Qatar and Saudi Arabia, where natural gas costs around US$ 3/MMBtu, 'blue' hydrogen could be produced for as low as US$ 1.5/kgH_2.
- A Gulf Emissions Trading System (GETS) could be linked to the EU's ETS and possibly other national schemes to incentivise CCUS uptake and at the same time cut carbon leakage, maintaining the local industrial competitiveness. This would reduce or eliminate the region's exposure to the EU's carbon border adjustment mechanism (CBAM).
- The EU & MENA could leverage their energy ties to create large-scale CCUS hubs linked to blue hydrogen 'valleys', mainly to reduce costs and risks for potential upcoming projects and enable capture from smaller-volume industrial facilities.
- EU-MENA CCUS clusters could establish a CCUS workforce as part of a knowledge- and expertise-sharing programme. The workforce would assess innovative CCUS technologies and applications and explore potential cost reductions and efficiency improvements.
- Regional policy cooperation should support the monitoring, reporting and verification (MRV) of captured CO_2, along with operational and safety regulations that allocate liabilities across the value chain. This should be extended to CCUS-integrated hydrogen production, which requires EU-compatible certification to ensure credibility and quality for potential off-takers.
- The MENA region can position itself as a CCUS leader and advocate as it is presented with a rare opportunity to host the UN Conference of the Parties (COP28) in the UAE in November this year. COP28 offers a platform for the region to advocate for the global deployment of CCUS through supportive policy, investment and technological advancement.

A wake-up call for the MENA region

"The Middle East is Becoming Literally Uninhabitable", "MENA Region Warming at nearly Twice the Global Average", "Extreme Hotspot", "Grave Threat to Life", "MENA States Most Vulnerable to Future Heat-related Deaths." These worrying headlines on the impact of global warming on the MENA region, supported by climate modelling, point to the same conclusion: even if global warming is limited to 1.5 or 2 ℃ as targeted by the Paris Agreement, the MENA region is set to experience temperatures well beyond this projection. Temperatures are set to rise in the region by at least 4 ℃ by 2050 if GHG emissions continue to increase at the current rate (Figure 1),[i] exceeding a threshold for human adaptability and leading to higher mortality rates. Even in moderate emissions scenario RCP 4.5 which limits global warming to 2-3℃ by 2100, mortality rates could surge more in MENA than any other region, according to the International Monetary Fund (IMF). This a wake-up call for the region to avert a climate catastrophe.

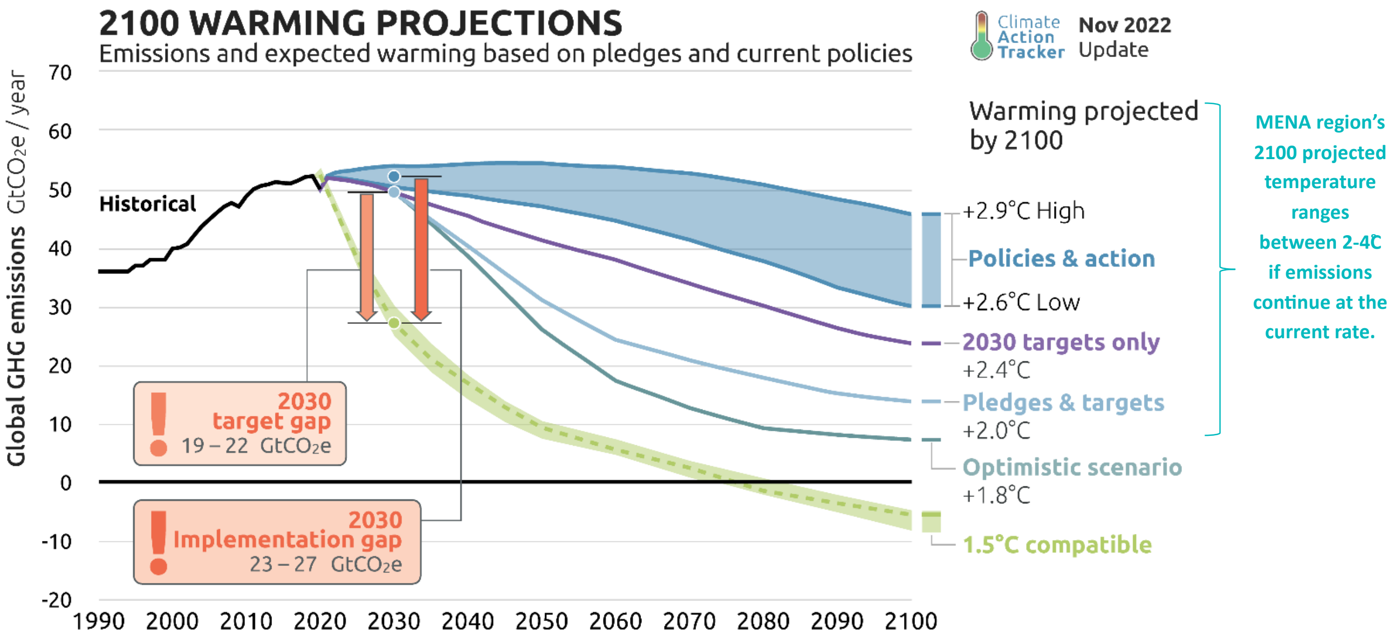


Figure 2 Emissions and expected warming based on current policies, actions and pledges by 2100[ii]

According to the IPCC's Sixth Assessment Report (AR6), there is a more than 50% chance that global temperature rise will reach or surpass 1.5 ℃ between 2021 and 2040, across different studied scenarios, and might hit this threshold even sooner between 2018 and 2037, under a high-emissions pathway. Changing course to limit global warming to 1.5 ℃ will require aggressive emissions reductions which, in modelled pathways, would necessitate moving from fossil fuels without CCS to very low- or zero-carbon energy sources, including renewables, fossil fuels with CCS, demand-side measures and improving efficiency, reducing non-CO_2 GHG emissions and carbon dioxide removal (CDR). Three of the four pathways depicted in AR6 on 1.5℃ involve major use of CCS, ranging from 350 to 1200 $GtCO_2$ to be captured and stored within this century.[1] The Global Carbon Budget, too, warns that "if emissions are not reduced through decarbonisation technologies such as CCUS, the world will have exhausted its 1.5℃ carbon budget in nine years." Around 380 Gt of CO_2 emissions are left in the 1.5℃ budget, and currently over 40 Gt of it is being used each year.[iii] Meanwhile, the IEA Sustainable Development Scenario expects CCUS to account for nearly 15% of the cumulative reduction in emissions. These, and other scenarios from leading climate action-based organisations stress the use of CCUS as an essential decarbonisation technology to keep the Paris Agreement's 1.5℃ global warming limit within reach.

[1] AR6 mentions CCS 11 times as a critical CO_2 mitigation option for the power sector, along with cement and chemical production, noting that its deployment in these industries is less mature compared to its application in the oil and gas industry. It also cites CDR 13 times as a necessary tool to achieve net-negative CO_2 emissions and to counterbalance hard-to-abate residual emissions, including unavoidable ones from agriculture, aviation, shipping, and industrial processes. Meanwhile, it only mentions Carbon Capture and Utilisation (CCU) once.

Table 1 CCUS in Net Zero Pathways, different Scenarios[iv]

Scenario	Annual CCUS in 2050 ($GtCO_2$)
IEA's Sustainable Development Scenario	6.6
BP Accelerated & Net Zero	4-6
BP New Momentum	1
DNV	2.2
IPCC (AR6)	4-15

CCS's advantages

The MENA is considered one of the most carbon-intensive regions; while it is not a large emitter in absolute terms, countries such as Qatar, Kuwait, The UAE, Bahrain and Saudi Arabia are among the world's top 10 per capita carbon dioxide emitters. The region holds a major stock of the world's oil and gas reserves, with the GCC[2] alone accounting for a tenth of world gas production and almost a quarter of world oil production. Strong global action on climate change, the growing policy pressure to reduce emissions, and the rapid improvement in non-fossil fuel technologies will contribute to a flattening of oil demand by the early 2030s and a sharp drop by 2050. This leaves the MENA region with two options: (i) stick to its legacy business and risk stranded fossil fuel assets, severe economic damage and climate-related disasters, or (ii) decarbonise fossil fuels with the integration of CCS, invest in clean technologies and secure a dominant position in emerging low-carbon markets (e.g., hydrogen) and avert a climate crisis. Thanks to decarbonisation technologies such as CCS, the MENA region, particularly fossil fuel-dependent economies do not have to compromise on their economic growth and energy security to meet their climate targets, while they pursue economic and energy diversification plans. CCUS, along with other low-carbon technologies, would allow the region to achieve deep decarbonisation in hard-to-abate sectors, enable the production of low-carbon hydrogen at scale, provide low-carbon dispatchable power, and deliver negative emissions, among other opportunities:

Opportunity	Application
Industrial decarbonisation – filling the gap	While renewable energy can replace fossil fuels in sectors including power generation, transport, residential and to a certain extent industrial heating, it cannot currently drive industrial processes that require very high temperatures, including steel manufacturing, cement and petrochemicals. Process (non-combustion) emissions are also not addressed by using low-carbon electricity or heat. CCS allows for the removal of 90-99%[v] of CO_2 emissions from an industrial plant, including both energy-related and process emissions. This constitutes an opportunity for the MENA region to reduce its energy and industrial emissions, which account for 60% of the region's total emissions.[vi]
Energy security, affordability, and climate change mitigation	CCS offers an opportunity to balance between energy security, price affordability and climate change mitigation. Instead of discarding the current energy system, it adapts it. It has become increasingly apparent that replacing a bicentennial fossil-fuelled economy with solar, wind and batteries is not possible at the required pace, whether logistically, economically, socially or politically. In addition, monoenergetic plans are rather unreliable and unaffordable, i.e., an energy system founded almost exclusively on one of fossil fuel, nuclear power, or renewable energy is subject to commodity and equipment supply shocks and technical, natural and political breakdowns, among other challenges. Therefore, it would be beneficial for the region to explore existing synergies between CCS and cleaner energy sources to maximise climate change mitigation efforts.
Circular carbon economy (CCE)	CCU can enable a circular carbon economy (CCE) using the captured CO_2 for conversion into other materials or products with higher economic value like plastics, concrete and synthetic fuels, avoiding combustion or lowering the volumes of CO_2 emissions. Today, around 230 $MtCO_2$ are recycled globally, mainly in direct use pathways in the fertiliser industry (to make urea from ammonia), at a capacity of around 130 Mt. The emissions reductions attributable to CCU depend on the source of CO_2 (fossil, biogenic, natural or air-captured), the product or service the CO_2-based product is displacing, the carbon intensity of the conversion process and how long the CO_2 is retained in the product.
Blue hydrogen	CCS creates a bridge between dirty grey and renewables-based ("green") hydrogen. Currently, the cost of CCS-integrated hydrogen production is lower than renewables-based hydrogen. US-based 8 Rivers announced $8RH_2$'s CO_2 Convective Reformer, which Cam Hosie, the company's CEO, says provides a low-cost carbon capture technology with 99% capture efficiency and maximum H_2 recovery (none burned).[vii] Blue hydrogen will remain a competitive option in regions with low-cost fossil fuels and CO_2 storage resources. The Middle East has a potential competitive advantage in blue hydrogen production. In Saudi Arabia and Qatar where natural gas costs around US$ 3/MMBtu, blue hydrogen could be produced for as low as US$ 1.50/kgH_2. This can build scale and infrastructure for the region to become one of the future market leaders in both blue and green hydrogen production.

[2] Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the UAE

CO2-enhanced oil recovery (EOR)	Globally, EOR projects use about 80 million tonnes of CO_2 per year, almost all of which becomes permanently trapped in oil reservoirs.[3] Of this number, about 20 Mtpa are captured from a variety of processes such as natural gas processing, ethanol and fertilizer production, and – notably – power generation and steelmaking. About 0.3 tonnes of CO_2 are stored to recover one barrel of oil, which produces 0.3-0.4 tonnes of CO_2 when combusted, making this a near-net zero process. CO_2-EOR can be optimised to raise the level of permanent CO_2 storage. CO_2 injection, whether for EOR or for pure storage, will have to be subject to rigorous site characterisation, management, verification and post-closure monitoring. Experience elsewhere suggests that leakage risks are low and can be minimised by good practices. The MENA region's well-understood, laterally-continuous geological reservoirs and seals, and the lack of major faulting and active tectonics in many areas, facilitates secure storage. Fields and saline aquifers are typically in sparsely-populated deserts or offshore, where any leaks would present little threat to people. However, depleted fields contain numerous old wells presenting possible leakage points, which may favour the use of saline aquifers. Further emissions reduction could be achieved in a more "upgraded" concept of CCUS involving four innovative elements of techno-ecological synergy, including (i) CO_2 geological storage, (ii) geothermal energy recovery during CO_2 geological storage, (iii) using CO_2 for EOR, (iv) solar and wind energy recovery – with geothermal, solar and wind power to cover the project's energy needs. This might also enable "gold" hydrogen extraction from depleted and abandoned oil and gas reservoirs by injecting bacteria that converts residual hydrocarbons into CO_2 and H_2. While hydrogen is extracted, the CO_2 is sequestered, making gold hydrogen a zero- to negative- emission process. If it proves commercially viable, the MENA region would have a competitive advantage in gold hydrogen production.
CCUS hubs	Clusters of high CO_2 purity, low-cost capture industries[4] coupled with nearby geological storage allow for the development of CCUS hubs (sometimes called clusters or 'valleys') which offer several distinct advantages for network participants, compared with traditional "point-to-point" projects. These shift away from small-scale <1 Mtpa projects to the cluster model of over 10-20 Mtpa combined projects.[5] CCUS clusters can reduce costs and risks for potential upcoming projects and enable capture from smaller-volume industrial facilities. Jubail in eastern Saudi Arabia, Ras Laffan in the north of Qatar, and Ruwais and KIZAD in Abu Dhabi would make excellent locations for CCUS hubs. Often these hubs can be combined with "hydrogen valleys" to produce blue hydrogen which would be used as a feedstock for industries such as fertilisers, synthetic fuels, steel and refineries. These clusters, however, may be subject to intersecting cross-border legal and administrative regimes, which would require coordination and alignment on regulations and approval processes, and determine which jurisdiction(s) can claim the emissions reductions.
Cross-border storage cooperation	The MENA region is endowed with significant geological storage potential in both depleted oil and gas reserves and saline aquifers, with 11 identified sedimentary sequences, along with Oman's ophiolite. Estimated storage volume in saline aquifers and ophiolite amounts to 127.5 $GtCO_2$, and a further 41.5 $GtCO_2$ in depleted gas fields.[viii] This presents the region with the opportunity to store imported CO_2 from countries with limited CO_2 storage capabilities, like Japan and South Korea. This is already in the works as Saudi Aramco and South Korea's Hyundai Oil Bank Co.'s agreed to ship liquefied petroleum gas cargoes from Saudi Aramco and convert them into hydrogen, with the CO_2 emitted in the hydrogen-making process to be transported back to Aramco for use in its oil production facilities.

A shift in perception can go a long way

While the different scenarios emphasise the role of CCS in limiting global warming, they also tell us that we are way off track. The first ever carbon capture plant was proposed in 1938, and the first large-scale project to inject CO_2 into the ground started in 1972 in the Sharon Ridge oilfield in Texas.[ix] 24 years later, Norway launched Sleipner in the North Sea, the world's first pure CO_2 storage project. Today, the world captures just about 43 Mt of carbon dioxide – around 0.1% of global emissions (Figure 3). Even if all the announced projects become commercially operational, 279 $MtCO_2$ would be captured annually by 2030, eliminating up 0.6% of today's emissions.[x] This means the world has 27 years to go from 43 Mt to about 6,000 Mt of capture per year (140x scale-up), about the same time as it had from 0.9 Mt at the launch of Sleipner till today's 43 Mt (~50x scale-up).

[3] The amount of CO_2 that can be stored via 'advanced' CO_2-EOR practices is determined by reservoir characteristics, wells and infrastructure design and operating choices and by economic variables.
[4] Petrochemicals, fertilisers, methanol, natural gas processing, hydrogen production at oil refining, steel facilities and GTL plants
[5] A number of projects have shifted to the cluster model, including (i) UK-based Drax BECCS which will anchor the East Coast Cluster made up of the Zero Carbon Humber and Net Zero Teesside projects, (ii) and PORTHOS in the Netherlands, among others.

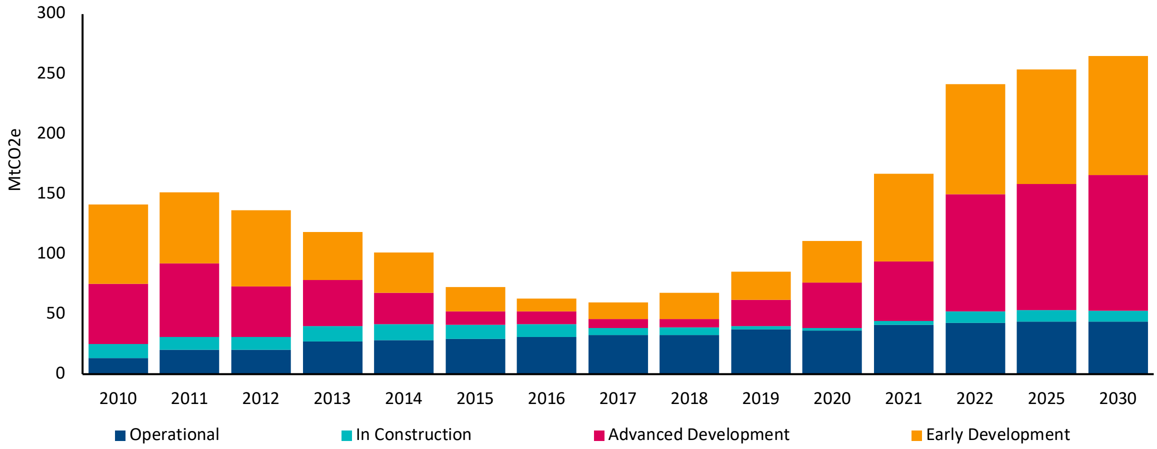


Figure 3 Pipeline of commercial facilities by capture capacity[xi]

So, what has held CCS back from reaching the required scale to achieve considerable emissions reductions?

- For one, **public acceptance**; CCS is often perceived as a "distraction"[xii] and an "false solution" to keep oil and gas companies in business.[xiii] The technology is also dismissed as unnecessary, unproven or risky[xiv], with particular resistance to onshore storage, notably in Europe.[xv]

- **The lack of supportive policy and regulatory frameworks**; policy support is slowly transitioning from restrictive and secondary references to CCS towards leading and more open formulations where policymakers acknowledge the role of CCS more clearly.

- **CCS's high cost** has been one of the main challenges to its uptake; CCS costs varies greatly by source: between US$ 13-25/tCO_2 for industrial processes producing "pure" CO_2 to US$ 40-120/tCO_2 for processes with "dilute" gas streams, such as cement production and power generation. Some CO_2 capture technologies are commercially operational, while others are still under development – this contributes to the large range in costs. At US$ 50/tonne of CO_2 emissions avoided, various chemical processes, bio-ethanol fermentation, and possibly iron, steel and hydrogen, would be economically feasible. Cement and power generation, which produce more dilute streams, have higher costs, but most of coal and gas generation could be viable with a carbon price of less than US$ 100/tonne. DAC, the most dilute source of all, has by far the highest costs (Figure 4).

- Most global jurisdictions do not have **carbon pricing**; even in the EU, the ETS was launched in 2005 but the price only consistently exceeded US$ 50 per tonne from mid-2021 onwards. The US introduced the 45Q tax credit in 2008 but only increased it to levels high enough to encourage CCUS in 2018. The details of Article 6.2 of the Paris Agreement, allowing international carbon trading, are still in negotiation. So there has been almost no direct economic incentive for CO_2 storage, and there still is not to this day in most parts of the world, including the MENA region.

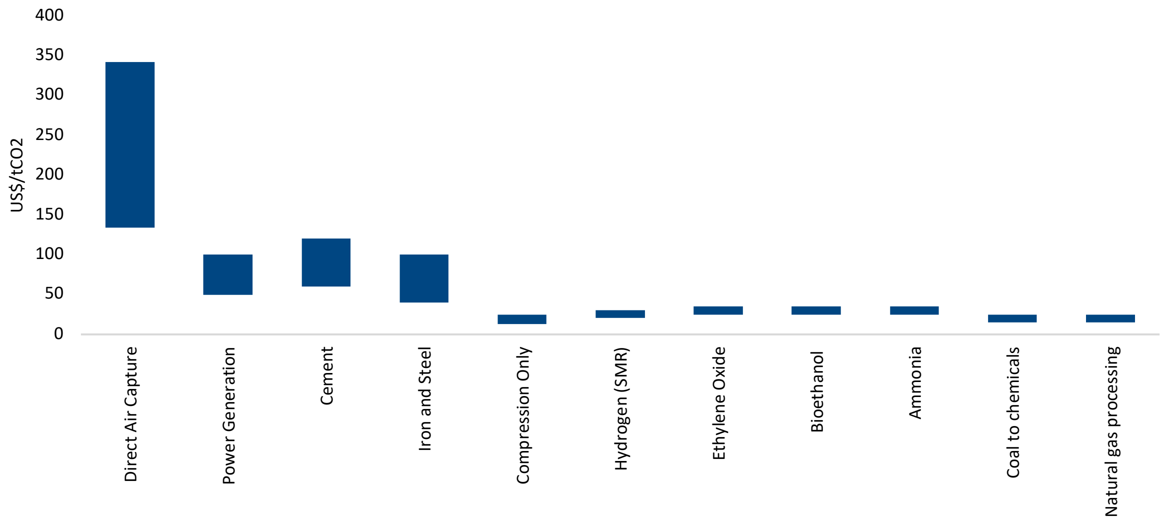


Figure 4 Levelised Cost of CO_2 Capture by Sector and Initial CO_2 Concentration (US$/tonnes), 2019 [xvi]

CCS might appear more costly on a simplistic head-to-head comparison with solar or wind; however, dismissing the technology on cost grounds would be to ignore its unique strengths in adding predictability, diversity and flexibility, making the energy complex cheaper and more resilient. As noted, it is essential to eliminate process emissions from certain industries, and in decarbonising high-temperature heat, where renewables are not applicable or feasible. In the meantime, new CO_2 capture technologies are in development that promise cost reductions.[6]

Other obstacles include chequered understanding of the technology itself, lack of incentives, and a lack of well-established revenue streams, making business cases challenging. In the MENA region, despite the various opportunities CCS could offer, there remain major challenges for its uptake, particularly the absence of a regulatory framework for project development at the investment level and promotion of competitiveness. The region's CCS investments are mostly state-led initiatives. Current regulation is more technical in nature and easy to tailor for injection purposes, but almost non-existent for storage. This could weaken the region's credibility for CCS, potentially driving away foreign investors who typically prefer structured and well-managed tender processes. This could also be an issue for companies interested in carbon credits from CCUS to achieve decarbonisation targets, since it would require a mandatory tie-in with a state-led oil company.

Although a carbon pricing scheme in select MENA countries or in the region as a whole could support CCS's deployment, there are concerns that it may undermine the region's industrial competitiveness if not carefully implemented. The greatest benefit of a carbon pricing mechanism in the MENA region would be the creation of a clear price signal that would facilitate emissions cuts across the entire economy, and would be more efficient than mandates, subsidies, direct spending or regulatory sectoral actions. It would also raise revenue that would finance the region's climate goals and net-zero targets. For example, under a US$ 40/tCO_2 scenario, the UAE's carbon price revenues would be almost US$ 10.5 bn. Revenues from a carbon pricing program could reach up to US$ 21 billion at a price of US$ 100/tCO_2 in the UAE. These revenues could be at least partly recycled to maintain competitiveness. Trade-exposed sectors could receive free allowances during a transitional period, 'grandfathered' at historic levels, or linked to meeting performance standards. US$ 40/t may be enough to encourage some low-cost CCUS (e.g. from gas processing, ethylene oxide or ammonia), or to support CCUS on projects that already have an economic rationale (e.g. blue hydrogen).

From enhanced oil recovery to carbon neutrality, is it possible?

The MENA region, specifically Saudi Arabia, Qatar and the UAE, accounts for almost 10% of the global CCUS capacity,[xvii] which is expected to reach 60 MtCO_2 by 2035, in line with their climate obligations and, in some countries, net zero targets. The GCC emerges as a CCS champion with a combined capacity of 4.7 Mtpa. Most of the projects are developed by national oil

[6] These include chemical looping processes, new adsorption processes, and new physical and chemical solvents for use in absorption processes along with new membranes for the separation of CO_2 from other gases.

companies, mostly for EOR purposes (by volume). The region is one of the world's most promising regions for large-scale CO_2 storage due to:

- favourable geography (flat land, low-lying terrains)
- favourable geology (extensive, thick, well-characterised reservoirs with high injectivity, large, simple structures with limited faulting or active present-day tectonics[7], and laterally-extensive, high-quality evaporite and shale seals)
- and a number of depleted or near-depleted oil and gas reservoirs.

Uthmaniyah in **Saudi Arabia** and Rumaitha in the **UAE** are the two operational CO_2-EOR projects in MENA, with a combined capacity of 1.6 $MtCO_2$/y. This is set to increase to 10.6 $MtCO_2$/y as newly awarded Saudi CO_2-EOR projects at its gas processing plants come online. Although the GCC dominates the CO_2-EOR scene in the region, it was **Algeria** that launched the MENA region's first CO_2-EOR project at its gas processing facility at In Salah gas field, with 3.8 $MtCO_2$ to have been sequestered in the Krechba Foundation during the project's lifetime. Injection started in 2004 and was suspended seven years later due to concerns about the integrity of the seal, but no CO_2 leakage was reported during the project lifetime. The project provided valuable insight into how CO_2 can be stored in analogous Carboniferous sandstone reservoirs, common in the US, Northwest Europe and China.[xviii]

The MENA CCS landscape is witnessing a steady but notable shift from EOR to more decarbonisation-focussed projects which include CCUS in conversion processes, steel manufacturing, aluminium, hydrogen and ammonia production, alongside non-industrial CCS projects, targeting the removal of CO_2 from the atmosphere.

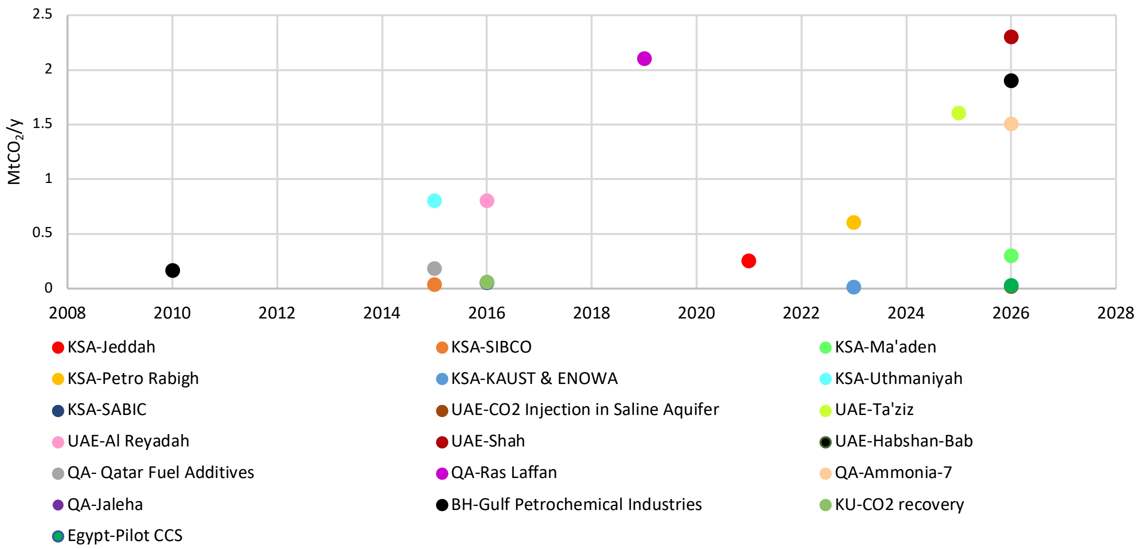


Figure 5 CCUS projects in the MENA Region, by capacity[xix]

Currently, just over 20 countries, of which 9 are in MENA, have mentioned CCS in their NDCs.[xx]

Table 2: CCS in Nationally Determined Contributions of MENA countries

Country	Net-Zero Target	CCS in NDC	Emissions reduction target
UAE	Yes, by 2050	Yes	31% reduction compared to a business as usual (BAU) scenario[8] by 2030
Saudi Arabia	Yes, by 2060	Yes	Reduce, avoid and remove GHG emissions of 278 MtCO2e annually by 2030
Qatar	No	Yes	Reduce 25% of GHG emissions by 2030

[7] In most areas; Iran and parts of Iraq are exceptions.
[8] A BAU scenario is the level of emissions that would result if future development trends follow those of the past and no changes in policies take place, according to the IPCC.

Oman	Yes, by 2050	No	Reduce GHG emissions by 7% relative to a BAU by 2030
Kuwait	Yes, by 2060	Yes	N/A
Bahrain	Yes, by 2060	Yes	N/A
Iraq	No	Yes	15% reduction compared to BAU by 2030
Iran	No	Yes	12% reduction compared to BAU by 2030
Egypt	No	Yes	33% reduction in power generation and transmission and distribution sectors / 70 $MtCO_2$ reduction compared to BAU by 2030
Algeria	No	No	7-22% reduction by 2030 against a 2013 baseline
Libya	No	No	N/A
Morocco	No	No	Reduce emissions by 45% below BAU by 2030
Tunisia	No	Yes	45% reduction compared to its 2010 baseline by 2030

Among them is Saudi Arabia, which is going big on carbon capture projects

"Don't be very surprised if we achieve this net-zero before then," said Saudi Energy Minister Prince Abdulaziz bin Salman at the COP27 climate summit in Sharm el-Sheikh, rather ambitiously. The OPEC de-facto leader had at this occasion announced plans for a circular carbon economy in line with the country's net zero target by 2060, which was announced in 2021, with no mention of reducing oil and gas exploration and production. The plan involves extracting and storing 44 Mtpa of carbon dioxide by 2035. This also entails the country's goal of becoming the world's biggest hydrogen supplier, targeting 4 Mtpa of "clean hydrogen" by 2030. Zeid Al Ghareeb, Director of the Circular Carbon Economy National Programme, mentioned that the Kingdom does not differentiate between blue and green hydrogen as the focus is on lower emissions. In the longer term, CCUS, DAC and hydrogen are expected to contribute about one-third of the emission reductions needed by 2060.

The Kingdom plans to advance the uptake of CCUS technologies and scale up its deployment with the aim to transform its industrial cities, Jubail and Yanbu, into global CCUS hubs. Saudi Aramco has already awarded Houston-based SLB, formerly Schlumberger, and Germany's Linde a contract to capture and store 9 $MtCO_2$ at Wasit, Fadhili and Khursaniyah gas plants. Although the project specifics were not disclosed, the EPC packages for phase 1 of the development, dubbed the Accelerated Carbon Capture and Storage (ACCS) project, are estimated around US$ 700-800 M. The captured CO_2 will be used for EOR at fields adjacent to Jubail, in line with the Kingdom's other ambition to raise crude production to 13 Mb/d by 2027. Saudi Aramco already captures 0.8 Mtpa from its Hawiyah gas processing plant before injecting it at the Ghawar field's Uthmaniyah section 85 km away.

Initially focussed on EOR, Saudi CCUS projects are increasingly targeting industry decarbonisation

The shift from CO_2-EOR is slowly picking up pace, as the company plans to use captured CO_2 for conversion into other materials or products. Back in 2016, Aramco acquired Converge, a petrochemical operation capable of turning captured CO_2 into industrial grade polyols. These chemical compounds can be used to make coatings for household appliances, packaging as well as consumer and industrial adhesives. They could also be utilised in the automotive and medical industries. Saudi Aramco owns 70% interest in Sabic, which built a 500 ktpa CCUS facility at its petrochemical facility in Jubail. Gas manufacturer Gulf Cryo has been capturing CO_2 from the boilers of Saudi drinks company, Sibco, in Jeddah. The resulting beverage-grade CO_2 is then used to carbonate Sibco's drinks, reducing its carbon footprint at the same time, with as much as 35 kt of CO_2 recycled every year. This trend is likely to pick up momentum as it provides a monetisation opportunity for CCU.

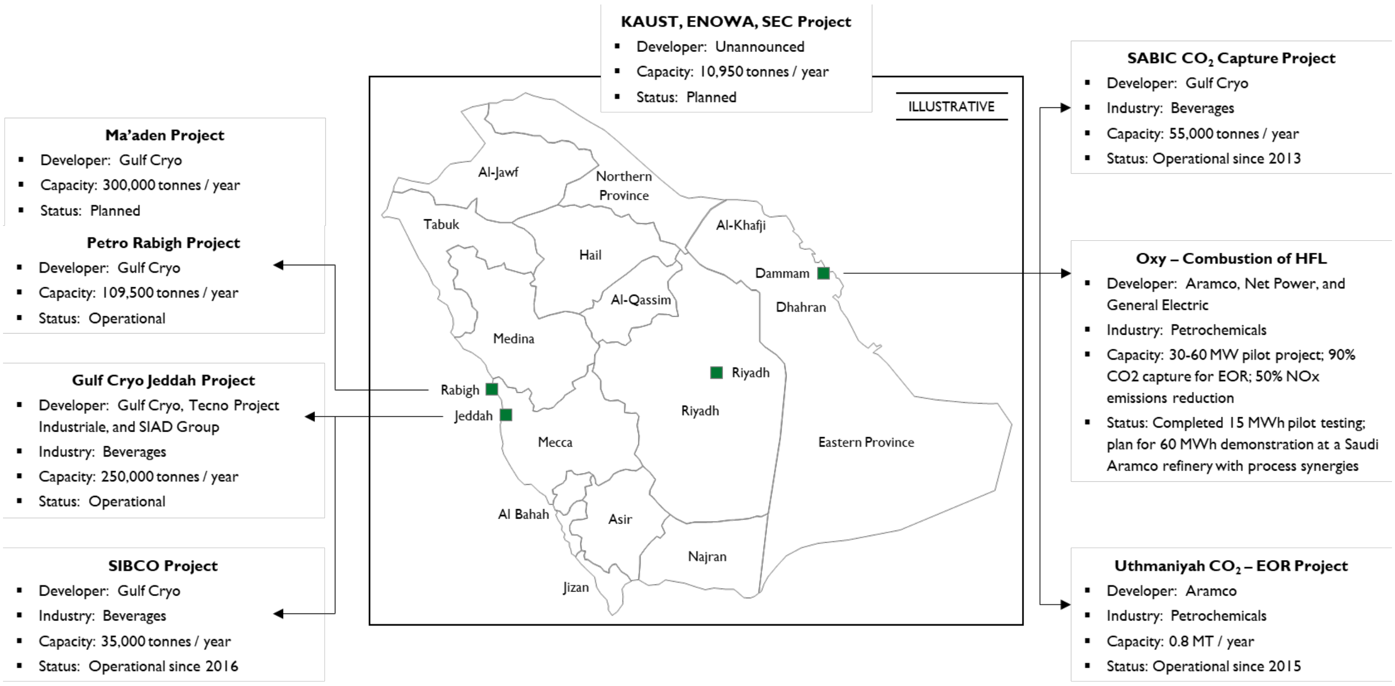


Figure 6 CCUS projects in Saudi Arabia, operational and planned[xxi]

CCUS will play a major role in advancing the Kingdom's hydrogen and climate goals

Aramco has been active in the hydrogen space since 2020, as it sent the region's first blue ammonia shipment to Japan through a pilot project developed by SABIC to demonstrate its export potential. Earlier in 2022, Saudi Aramco and China's Sinopec signed a deal to collaborate on CCUS and hydrogen development. Aramco and fertiliser producer SABIC AgriNutrients received the world's first independent certificate of accreditation for blue hydrogen and ammonia production from Germany's TÜV Rheinland. The latter also granted Saudi state-owned mining company Ma'aden certification to export 138 ktpa of blue ammonia, one of the largest certified volumes globally. The first shipment of 50 ktpa has been shipped in November to South Korea. Ma'aden also signed a 20-year agreement with Gulf Cryo to build and operate a CO_2 plant in its phosphate complex in Ras Al Khair, with a capture capacity of 300 ktpa from its three ammonia plants (Figure 6).

Saudi Arabia is considering using approaches to capture and/or remove carbon from the atmosphere including the use of nature-based (e.g., mangroves) and technological solutions, such as DAC. Saudi authorities launched a number of afforestation initiatives, including the Saudi Green and the Middle East Green Initiatives, aiming to plant 50 billion trees in the Kingdom and the broader Middle East region. It recently announced its first DAC plant to capture unavoidable CO_2 emissions from the atmosphere. The project is in its design phase, with details on capacity and development timeframe yet to be disclosed. The Kingdom also announced a US$ 1.5 bn fund to invest in and improve "CCS, energy efficiency, nature-based climate solutions, digital sustainability, hydrogen, ammonia and synthetic fuels."[xxii] However, if Saudi Arabia is to meet its climate goals and net-zero target by 2060, the country needs to invest in significantly more CCUS policy support to make it economically viable, backed by low-carbon hydrogen, increased renewables deployment and energy efficiency measures.

The CCUS picture is not so different in the UAE

"As long as the world needs oil and gas, we're going to give it to them," said UAE's Minister for Climate Change and Environment Mariam Almheiri on the side-lines of German Chancellor Olaf Scholz's visit to the UAE in September 2022. ADNOC announced that it will bring forward its 2030 target of 5 Mb/d of oil production capacity to 2027 to meet rising global energy demand, with plans for US$ 150 bn of capital expenditure in the next five years. At the same time, the UAE is pursuing an ambitious net-zero target by 2050, planning an aggressive mid-century decarbonisation pathway that includes interim emissions reduction targets for 2030 (-18%), 2040 (-60%), and 2050 (-100%), approved by a UAE Cabinet Resolution in October 2022 (. The UAE outlines the role of CCUS in decarbonising its power generation and heavy industry and in becoming among the top ten global producers of low-carbon hydrogen by 2031. The UAE's second NDC breaks down the GHG emission reduction target by sector, with the electricity sector projected to be the highest contributor to the target at 66.4%, followed by the industrial sector at 16.6%, transport at 9.7%, CCUS at 5.3% and waste at 2.1%. The share of CCUS in the emissions reduction pathway is set to increase in the upcoming third NDC, targeting EOR, blue hydrogen (Figure 7) and industrial decarbonisation.

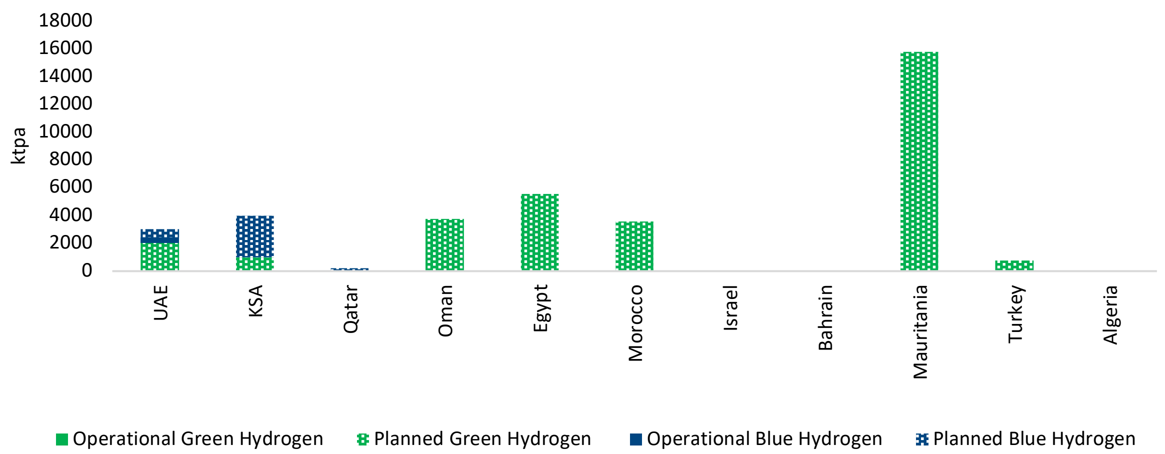


Figure 7 MENA H_2 project pipeline, 2038

Through ADNOC and Emirates Steel, the UAE already has sophisticated, mature CCUS capabilities responsible for capture, compression, and transportation of 0.8 Mtpa CO_2 for injection into ADNOC's onshore oilfields for EOR. The firm is planning to expand its CCUS capacity to 5 Mtpa by 2030 and considers it an integral aspect of its 2050 net-zero target. This will take place at the country's Shah and Habshan/Bab fields, which will have a combined CCS capacity of 4.2 $MtCO_2$.

While CO_2-EOR will make up a significant share of the country's CCUS capacity, the UAE is increasingly targeting new CCUS applications. CCS is already employed as a key facilitator of the transition to a low-carbon future in the UAE. In fact, the UAE has advocated for CCS since early days. In 2011, Dr Sultan Al Jaber, then Assistant Minister of Foreign Affairs and Special Envoy for Energy and Climate Change, attended, alongside delegates from 33 countries, a UNFCCC-led workshop titled "Technical Workshop on Modalities and Procedures for CCS in Geological Formations as CDM Project Activities." The now Minister of Industry and Advanced Technology, Group CEO of ADNOC and the COP28 President said during the workshop: "CCS is not the whole solution to climate change, but it has an important role to play as part of a balanced and diversified portfolio. The CDM can be one effective way of pushing this forward."[xxiii] This helped include CCS as an "emissions reduction" technology under the Kyoto Protocol and the associated CDM, which was later replaced by the Paris Agreement's Article 6.[xxiv] The UAE is also home to the Global CCS Institute (GCCSI), a global think tank with a mission to scale-up CCS technology to support climate neutrality. Led by Dr Mohammad Abu Zahra, the GCC's GCCSI has based its Middle East headquarters in Masdar City, joining a number of other climate-focussed institutions including IRENA.

The country has begun work on the world's first venture of capturing CO_2 in an underground saline reservoir composed of carbonates — rocks such as limestones — rather than the sandstones used elsewhere. It announced a pilot project in partnership with the Fujairah Natural Resources Corp. (FNRC) and 44.01[9] to inject carbon dioxide into peridotite rocks found in Fujairah (also widespread in neighbouring Oman), bearing the mineral olivine, which reacts with the gas to form solid minerals, guaranteeing permanent storage. Olivine could also be ground up and used as a soil additive or in marine areas to speed up its reaction with CO_2[xxv].

Recently, the Abu Dhabi Waste Management Company (TADWEER) and LanzaTech NZ, a "Carbon Capture and Transformation company," joined forces to develop a large-scale conversion plant to transform waste carbon into sustainable aviation fuels. The UAE's Emirates Global Aluminium already sells carbon dust, a by-product of aluminium smelting, as an alternative fuel for the UAE cement industry. This has reduced UAE cement companies' requirements for other fuels, including in some cases coal imported from as far as South Africa.

[9] Named after CO_2's molecular weight, the firm's Earthshot prize-winning Carbon Capture and Mineralisation (CCM) technology promises to remove CO_2 from the atmosphere

For blue hydrogen, the country has already announced a 1 Mtpa blue ammonia project at its Ta'ziz chemical complex in Ruwais. Next to it, ADNOC and Switzerland-based methanol producer Proman will build the UAE's first CCUS-integrated methanol facility at Ta'ziz, producing 1.8 Mtpa of blue methanol (from 225 ktpa of blue hydrogen). Ruwais houses key hydrocarbon-related infrastructure, including natural gas production, pipeline transport, storage, LNG export and import terminals; gas-fired power plants; hydrogen-producing and -using facilities (ammonia plants, refineries, petrochemical plants, DRI), and CO_2 storage sites. The UAE has entered into agreements with several Japanese companies[10] to develop CCUS-integrated hydrogen projects to support Japan's energy transition goals.

Qatar is catching up with its Gulf peers

Since hosting COP18 in 2012 and the Carbon and Energy Forum in 2013, Qatar has somewhat lagged behind its other GCC counterparts like the UAE (and to a certain degree Saudi Arabia) in establishing concrete energy transition strategies with feasible clean and/or low-carbon energy targets, drawing criticism from international peers. However, recent announcements show that the country is catching up. In May 2023, the country hosted the first MENA CCUS Forum, focussed on fostering international collaboration and accelerating CCUS deployment. QatarEnergy is already investing in "technologies that will result in a 25% reduction in GHG emissions" from its North Field expansion project compared to similar facilities. It intends to reach a methane intensity of 0.2% by 2025, zero regular natural gas flaring and a portfolio with >90% gas by 2030, and has set a target of reducing carbon intensity, including direct and indirect emissions, by 15% from upstream facilities and 25% from LNG facilities by 2030 compared with 2013 levels. The country aims to be able to store as much as 11 $MtCO_2e$/y by 2035 (with the LNG industry capturing and sequestering >5 $MtCO_2e$ by 2025), becoming a leading global provider of low-carbon LNG.

Qatar Energy Renewable Solutions and QAFCO[11] will build the "world's largest blue ammonia facility," expected to come online by Q1 2026 and produce 1.2 Mtpa (from ~212 ktpa of blue hydrogen), according to Saad al-Kaabi, Qatar's Minister of Energy and CEO of QatarEnergy. The Ammonia-7 project, awarded to ThyssenKrupp and Consolidated Contractors Co., will capture 1.5 Mtpa of CO_2 from Mesaieed Industrial City (MIC), with an estimated cost of around US$ 1.06 B. It will also supply >35 MW of renewable power to the Ammonia-7 facility from its solar PV Plant in MIC, currently under construction, likely for running part of the plant's electrical needs. The project will be Qatar's first blue hydrogen production facility, with more to follow as the country aims to capture 11 $MtCO_2$ by 2030.

Qatar's abundance of low-cost natural gas reserves places the country in a very favourable position to become a leading blue hydrogen producer and exporter. The country has a large-scale CCUS facility from gas processing with a capacity of 2.1 $MtCO_2$ at Ras Laffan, sequestered into the Arab Formation, a saline aquifer. QatarEnergy has recently signed a number of deals with Shell, H_2Korea and Germany's Ministry of Economic Affairs and Climate Action to develop CCUS along with blue and green hydrogen projects. The country remains the GCC region's largest hydrogen consumer, housing the Pearl Gas-to-Liquids (GTL) plant, largest plant of its kind in the world, and the Oryx GTL plant, taking the country's hydrogen consumption to nearly 6 Mtpa (hydrogen forms part of syngas, an intermediate step in the GTL process). The GTL process also produces a CO_2 stream that could be captured.

More climate-focussed CCS: Lessons from other MENA countries

In **Bahrain**, a feasibility study is underway to develop one of the world's largest CCS projects, based on depleted onshore gas reservoirs. Proposals include a facility with a planned capacity of 10-12 $MtCO_2$, in line with the country's net zero target by 2060. Bahrain is seeking to develop economies of scale, instead of painstakingly developing individual projects of less than 1 $MtCO_2$/y. The country is also planning to decarbonise its aluminium industry as it partnered with Mitsubishi Heavy Industries to integrate its Alba Aluminium facility with CCS technology at a capacity of 0.5 $ktCO_2$/y.

In **Oman**, state-owned Petroleum Development Oman (PDO) is partnering with British major Shell to study CCUS opportunities in the Sultanate. The two firms signed an MoU to conduct a technical, commercial, regulatory and fiscal feasibility study focussed on reinjecting and storing CO_2 in the country. Shell is also seeking to increase its low-carbon hydrogen projects in the Sultanate. So far, Oman has been mainly focussed on green hydrogen projects, until Shell announced plans to produce blue ammonia from the Mabrouk gas field and state energy investment company OQ announced its plans to produce blue ammonia in the Sur Governorate to supply the local operations of Oman-India Fertiliser Co. (OMIFCO). More

[10] Including Mitsui, INPEX, ENEOS, and Itochu
[11] Qatar Fertiliser Company

recently, 44.01 and Oman's Ministry of Energy and Minerals (MEM) agreed on a concession for the world's first commercial-scale peridotite mineralisation project, which will begin in 2024 in the Hajar mountains.

Egypt is working on its first pilot carbon capture project with Italy's Eni to capture and store 25-30 ktCO_2/y at the firm's Meleiha Concession in the Western Desert. But Eni is not the only international firm eyeing CCUS in Egypt. The Oil Ministry signed 11 MoUs with international firms on CCUS at the Egypt Petroleum Show.[xxvi] CCUS opportunities are being discussed with a number of companies including US-based Honeywell, Germany's Wintershall Dea, and Japanese Toyota Tshusho and Mitsubishi Heavy Industries.

Morocco is also hopping on the CCS train as it announced a CO_2 sequestration plant to be developed by UK-based Brilliant Planet. The country's desert has been hosting pilot projects that use seawater to breed algae as a proven natural route to sequester CO_2 since 2013. According to Brilliant Planet, the marine plants "do not only clean up to 30 times more carbon dioxide per year than rainforests, but they also remove acid from coastal seawater to pre-industrialisation levels."[xxvii] The firm seeks to unlock the power of algae as an affordable method of permanently and quantifiably sequestering CO_2 at the gigatonne scale and to get the price of a ton of CO_2 removed from the atmosphere to a sub- US$ 50 price point. The nature-based carbon dioxide removal company will cover 30 hectares in Akhfennir. The plant, which will be powered by solar energy, will be the largest algae production facility in the world (by volume) and will be commissioned in 2024.[xxviii]

Increased EU-MENA CCUS cooperation is promising for both sides

While EU-MENA cooperation is essential, collaboration between MENA countries to develop CCUS capabilities, interconnections and hubs would prove beneficial in advancing the technology's deployment, hence, the region's decarbonisation efforts. The EU and MENA regions could expand this collaboration through policy and investment support and technology enablers. In the pursuit of carbon neutrality, an EU-MENA CCUS Alliance could advance CCUS deployment through four main areas:

- **Policy:** The nascent CCUS regulatory landscape creates an opportunity for companies and governments to pioneer cross-border CCUS policy cooperation, including establishing carbon pricing and/or trading schemes, carbon credits for CO_2 sequestration, and other incentives. This could be enabled through a cap-and-trade system implemented among the GCC countries to create a Gulf Emissions Trading System (GETS) linked to the EU's ETS and possibly other national schemes, to further cut carbon leakage, hence, maintain the local industrial competitiveness. This would reduce or eliminate the region's exposure to the EU's carbon border adjustment mechanism (CBAM), some form of which may also be adopted by other countries such as the US and Japan. The Gulf governments could either retain the revenues, or they could use them to fund mechanisms that enable exporting industries to cut emissions. Other CCUS regulations required to scale up its deployment that could be supported through regional cooperation are: (i) the monitoring, reporting and verification (MRV) of captured CO_2, (ii) operational and safety regulations that allocate liabilities across the value chain, (iii) and financial incentives and sustainability frameworks. For CCUS-integrated hydrogen production, the EU could facilitate the certification of blue hydrogen and ammonia projects to ensure credibility and quality to potential off-takers.

- **Investment:** An EU-MENA Climate Neutrality Fund could mobilise public and private finance for CCUS projects. Currently, the MENA region receives the smallest amount of climate finance of any region in the world, around US$ 16 bn a year, according to the Climate Policy Initiative, making up only 8% of the region's financing needs which are estimated at around US$ 186 bn in NDCs submitted by countries committing to climate action, leaving lower-income MENA countries behind. The Fund should cover all available decarbonisation technologies including renewables, low-carbon hydrogen, nuclear, CCUS, carbon removal and energy efficiency, prioritising high-impact mitigation projects in countries where viable financing models are otherwise not readily available, and aiming to unlock and leverage private capital and other financing sources wherever possible.

- **CCUS hubs & blue hydrogen valleys:** Both regions could leverage public and private energy ties to create large-scale CCUS and blue hydrogen hubs. Multiple industries would feed into common CO_2 transport and storage systems. Industries like petrochemicals, cement or steel would be encouraged to capture their emissions in the presence of a capable operator to manage their CO_2 emissions' transport and storage for a suitable fee. Smaller emitters unable to carry through a viable project on their own can make use of the shared infrastructure. These hubs could be designed to handle both CO_2 and H_2, potentially combining the two to form useful chemicals. They could also allow CO_2 import opportunities, mainly from countries unable to store it due to geological limitations, including South Korea and Japan.

- **Technology:** As Europe and the MENA region plan to employ CCUS to meet their net-zero targets, they could benefit from regional cooperation to improve CCUS technology's economics and efficiency. The relative lack of progress in deploying CCUS implies that many technologies and applications are at an early stage of commercialisation. This presents ample potential for cost reductions, which will require significant CCUS policy support, incentives, R&D, and investments. EU-MENA CCUS clusters could establish a CCUS workforce as part of a knowledge- and expertise-sharing programme. The workforce would assess innovative CCUS technologies and applications and explore potential cost reductions and efficiency improvements.

What's the next step for MENA?

"We need to make 2023 the year of CCUS and enhance collaboration to improve the investment in and usage of this technology," says Joseph McMonigle, Secretary General of the International Energy Forum (IEF). The MENA region can position itself as a CCUS leader and advocate as it is presented with a rare opportunity to host the UN Conference of the Parties (COP28) in the UAE in November this year. COP28 offers a platform for the region to advocate for the global deployment of CCUS through supportive policy, investment and technological advancement.

Pointers for COP28:

- There is no silver bullet; countries need to employ all possible options in their journey towards net zero, including CCUS, renewables, low-carbon hydrogen, energy efficiency measures[xxix], and carbon removal.

- CCUS has a prominent role in most leading studies of Paris Agreement-compatible pathways, particularly in "hard-to-abate" sectors. The focus should therefore be on the proven and demonstrated qualities and capabilities of CCUS as an emissions reduction method, and learning from previous challenges with CCUS technologies rather than using them to argue against the technology as a whole, or arguing that its link to fossil fuels somehow discredits its viability.

- Credible climate organisations should bring forward objective research on the role of CCUS in the pursuit of carbon neutrality and address misinformation campaigns aimed at discrediting it. Emphasis should be placed on improving the understanding of the technology's efficiency, costs, usage and appropriate supportive policies, regulations and business models.

- Governments are encouraged to develop, with the help of global think tanks like GCCSI, capacity building programmes for public and private stakeholders to advise on CCUS strategies, technologies, uses, and costs. This will help address the limited technical knowledge and expertise in CCUS.

- The role of CCUS, via DAC and other carbon removal methods, to address residual and historic emissions, should also be strengthened given the urgency of scaling up from very small levels today. The deployment of some form of carbon pricing would be very helpful in supporting the business case for CCUS, as for other low-emitting technologies. COP28 can help promote early and gradual regional adoption to deliver a non-volatile, resilient and successful transition.

- Regulations to report, monitor and verify captured emissions and allocate responsibilities and liabilities along with economic incentives will kick off the carbon market in the region.

- Connected CCUS hubs of the scale of 10s of $MtCO_2$/year each, rather than small individual projects, are essential to deliver rapid, wide-scope decarbonisation and create economies of scale.

- Regional cooperation on cross-border projects is helpful, but not crucial in most cases, as the larger MENA countries each have critical mass for their own hub(s).

- A joint regional workforce to share knowledge and expertise is essential to unlock cost reductions and improve technological efficiency across the value chain as well as explore new CO_2 removal innovations that could be scaled up in regions with limited geological storage.

- A MENA-EU Carbon Neutrality Fund designed to mobilise public and private investments into decarbonisation technologies could support projects in finance-constrained MENA countries.

---

[i] https://carnegieendowment.org/2022/02/24/cascading-climate-effects-in-middle-east-and-north-africa-adapting-through-inclusive-governance-pub-86510
[ii] https://climateactiontracker.org/global/temperatures/
[iii] https://www.aster.com/carbon-capture-as-a-service-scaling-a-new-ccus-business-model/
[iv] https://www.iea.org/reports/ccus-in-clean-energy-transitions/ccus-in-the-transition-to-net-zero-emissions ; https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2022.pdf ; https://eto.dnv.com/technology-progress-report-2021/energy-use-conversion/carbon-capture-storage-2-0 ; https://report.ipcc.ch/ar6syr/pdf/IPCC_AR6_SYR_LongerReport.pdf
[v] Paltsev, Sergey, Morris, Jennifer, Kheshgi, Haroon, Herzog, Howard, "Hard-to-Abate Sectors: The role of industrial carbon capture and storage (CCS) in emission mitigation," *Applied Energy*, Volume 300, 2021, https://www.sciencedirect.com/science/article/pii/S0306261921007327
[vi] https://www.consultancy-me.com/news/5323/middle-east-must-slash-co2-emissions-by-42-to-meet-2030-target
[vii] https://www.linkedin.com/feed/update/urn:li:activity:7074813354271244288/
[viii] https://www.ogci.com/wp-content/uploads/2023/04/Gulf-CCUS-challenges-and-opportunities-Mar-2022_compressed.pdf
[ix] You Asked: Does Carbon Capture Technology Actually Work? - You Asked (columbia.edu)
[x] https://about.bnef.com/blog/global-carbon-capture-capacity-due-to-rise-sixfold-by-2030/
[xi] Qamar Energy Research, with data from GCCSI, "Global Status of CCS 2022", https://www.globalccsinstitute.com/resources/global-status-of-ccs-2022/ and IEA, "Capacity of large-scale CO_2 capture projects, current and planned vs. the Net Zero Scenario, 2020-2030", October 2022, https://www.iea.org/data-and-statistics/charts/capacity-of-large-scale-co2-capture-projects-current-and-planned-vs-the-net-zero-scenario-2020-2030
[xii] https://climateactiontracker.org/publications/countdown-to-COP28/
[xiii] https://www.rifs-potsdam.de/en/blog/2023/04/hydrogen-vs-carbon-capture-why-europe-needs-both-net-zero
[xiv] https://www.thenationalnews.com/business/comment/2022/09/26/why-carbon-capture-is-crucial/
[xv] https://www.iea.org/reports/ccus-in-clean-energy-transitions/a-new-era-for-ccus
[xvi] Qamar Energy Research & https://www.iea.org/data-and-statistics/charts/levelised-cost-of-co2-capture-by-sector-and-initial-co2-concentration-2019
[xvii] https://cms-lawnow.com/en/ealerts/2023/04/the-future-of-blue-hydrogen-in-the-middle-east
[xviii] https://sequestration.mit.edu/tools/projects/in_salah.html
[xix] Qamar Energy CCUS Database (internal database)
[xx] GCCSI; https://status22.globalccsinstitute.com/wp-content/uploads/2022/12/Global-Status-of-CCS-2022_Download_1222.pdf
[xxi] Qamar Energy Research (internal database)
[xxii] https://www.offshore-energy.biz/saudi-giant-unveils-1-5-bln-fund-to-support-stable-and-inclusive-energy-transition/
[xxiii] https://www.eco-business.com/news/abu-dhabi-workshop-makes-major-progress-towards-international-support-for-ccs/
[xxiv] https://www.globalccsinstitute.com/wp-content/uploads/2020/04/Article-6-and-CCS-GCCSI-April-2020-1.pdf
[xxv] https://www.vesta.earth/
[xxvi] https://enterprise.press/stories/2022/05/08/oil-ministry-announces-launch-of-egypts-first-pilot-carbon-capture-project-with-eni-raft-of-other-green-energy-initiatives-70415/
[xxvii] https://www.atalayar.com/en/articulo/new-technologies-innovation/worlds-largest-co2-capture-farm-will-be-morocco/20220429145922156231.html
[xxviii] https://carbonherald.com/brilliant-planet-to-work-with-mott-macdonald-on-algae-carbon-removal-facility-in-morocco/

Konrad-Adenauer-Stiftung e. V.

Veronika Ertl
Director
Regional Programme Energy Security and Climate Change
Middle East and North Africa
veronika.ertl@kas.de
www.kas.de/remena