

# Advancing the Circular Carbon Economy in Saudi Arabia

## About KAPSARC

KAPSARC is an advisory think tank within global energy economics and sustainability providing advisory services to entities and authorities in the Saudi energy sector to advance Saudi Arabia's energy sector and inform global policies through evidence-based advice and applied research.

*This publication is also available in Arabic.*

## Legal Notice

© Copyright 2023 King Abdullah Petroleum Studies and Research Center (“KAPSARC”). This Document (and any information, data or materials contained therein) (the “Document”) shall not be used without the proper attribution to KAPSARC. The Document shall not be reproduced, in whole or in part, without the written permission of KAPSARC. KAPSARC makes no warranty, representation or undertaking whether expressed or implied, nor does it assume any legal liability, whether direct or indirect, or responsibility for the accuracy, completeness, or usefulness of any information that is contained in the Document. Nothing in the Document constitutes or shall be implied to constitute advice, recommendation or option. The views and opinions expressed in this publication are those of the authors and do not necessarily reflect the official views or position of KAPSARC.

# Key Points

---

In May 2022, the King Abdullah Petroleum Studies and Research Center (KAPSARC) and King Abdullah University of Science and Technology (KAUST) co-organized an event titled “Advancing the Circular Carbon Economy in Saudi Arabia.” The one-day event, which comprised a high-level event and a workshop, took stock of progress in the circular carbon economy (CCE) in the Kingdom to date and implementation plans going forward. It also sought to draw attention to the role of research in supporting planning and implementation for the CCE across the public and private sectors.

This brief summarizes the proceedings of the workshop, which focused on three themes: quantifying and accounting for greenhouse gas (GHG) emissions and sinks; CCE metrics and standards; and CCE pathways to net-zero emissions. Highlights from each theme are presented below.

Regarding quantifying and accounting for GHG emissions and sinks, the participants highlighted the following:

Scientists are developing more detailed data on the Kingdom’s natural and technological emission sequestration capacity. Some estimates are already available. Accelerating the deployment of related solutions will require significant efforts, including further research and development (R&D), public-private partnerships, integrated policies and governance, and economic incentives, including those related to carbon markets.

Measuring and reporting on emissions is becoming increasingly important for corporations, particularly those that have set emission reduction targets and wish to participate in carbon markets to offset a share of their emissions. Some companies have already established elaborate organization-wide emission frameworks, which can provide valuable lessons for others. On an economy-wide scale, current challenges, including lack of reporting and underreporting by companies, can increasingly be overcome with the help of satellite monitoring.

Regarding CCE metrics and standards, the participants highlighted the following:

Metrics and standards are crucial enablers for both policy development and implementation. Different carbon circularity metrics, for example, enable data-driven discussions on country- or organization-specific ways to develop net-zero pathways and policies. Certification, international standards and a life-cycle approach to measuring emission intensities, in turn, will be crucial for accelerating the demand for clean hydrogen.

Clean hydrogen and carbon capture, utilization and storage (CCUS) are receiving increasing attention from policy makers in the Kingdom, as these factors are expected to play an important role in reaching the 2060 net-zero GHG emission target. CCUS hubs are currently seen as the ideal way to scale up capacity in a cost-efficient manner. Regulation and policies are considered the main enablers of CCUS, whereas for clean hydrogen, which will largely be exported, certification will be a fundamental factor for ensuring acceptability on the buyer side.

## Key Points

---

Regarding modeling CCE pathways to net-zero emissions, the participants highlighted the following:

In country contexts, net-zero scenarios that embrace the CCE, allowing for all technologies to be utilized, generally result in more affordable mitigation pathways. CCE net-zero scenarios are also often more equitable in terms of distributional impacts across countries. For Saudi Arabia specifically, preliminary simulation results suggest that a cost-effective net-zero energy transition for the Kingdom would involve high levels of electrification and large-scale deployment of renewable energy, CCUS, and clean hydrogen technologies.

In corporate contexts, companies should first map their activities to the CCE concept to understand how different circularity options apply to various parts of their operations. Then, they should prioritize their approach by using tools such as technology potential and cost estimates, equilibrium and process models, and marginal abatement cost curves. Reducing emissions and monitoring these reductions also require specific management processes and metrics, which should all be contained within a broader corporate management program, such as an environmental, social and governance (ESG) framework.

# Background of the Workshop

---

**S**audi Arabia has been at the forefront of promoting the CCE concept as a holistic framework for managing GHG emissions and Paris Agreement-aligned energy transitions. Today, the CCE concept frames the Kingdom's efforts to reach its medium- and long-term climate and energy targets, which include considerable GHG emission reductions, compared to business-as-usual scenarios, by 2030 and net-zero GHG emissions by 2060. Two leading national research institutions, KAPSARC and KAUST, have been supporting this effort through scientific innovation, economic modeling, policy advice, and technology demonstrations.

On May 31, 2022, KAUST and KAPSARC co-organized an event that took stock of progress on the CCE in Saudi Arabia to date and implementation plans going forward and drew attention to the role of research in supporting planning and implementation across the public and private sectors. The event, titled “Advancing the Circular Carbon Economy in Saudi Arabia,” which took place at KAPSARC in Riyadh, brought together approximately 75 CCE stakeholders

representing research and academia, government, businesses, and the not-for-profit sector.

The event had two parts: a high-level event in the morning convened a broad audience of stakeholders from Saudi Arabia's energy ecosystem and beyond to hear updates on cutting-edge CCE research and analysis conducted at KAPSARC and KAUST and on how CCE champions from various sectors see the road ahead in Saudi Arabia for advancing carbon circularity in the economy. A workshop held in the afternoon connected a group of CCE experts and stakeholders for a deeper dive into the topics discussed in the morning to identify concrete ways forward toward a CCE in the Kingdom.

This brief provides a summary of the afternoon workshop discussions, which focused on three topics:

- Quantifying and accounting for GHG emissions and sinks
- CCE metrics and standards
- Modeling CCE pathways to net-zero emissions

# Quantifying and Accounting for GHG Emissions and Sinks

A fundamental first step toward achieving emissions circularity is developing a detailed understanding of the potential of each circularity solution, from reducing, through recycling and reuse, to removing carbon dioxide (CO<sub>2</sub>) and other GHG emissions. In the first workshop session, which focused on quantifying and accounting for GHG emissions and sinks, presenters discussed the quantification of Saudi Arabia's geological CO<sub>2</sub> storage potential and the CO<sub>2</sub> sequestration potential of its nature-based solutions. Participants also heard about how a megaproject in Saudi Arabia is accounting for and managing its GHG emissions to achieve carbon neutrality by 2030.

Regarding **quantifying technological CO<sub>2</sub> storage potential**, KAUST, in collaboration with Saudi Aramco, is developing an atlas that will map

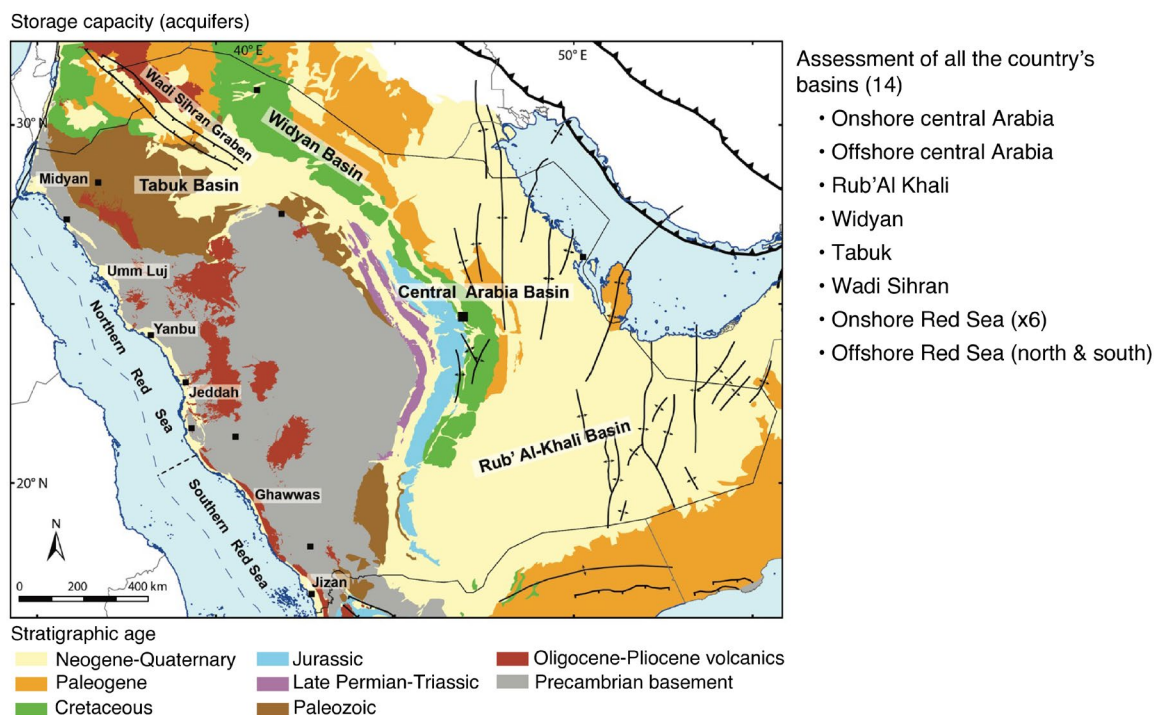
the Kingdom's geological CO<sub>2</sub> storage resources. The project comprises three steps:

Producing a localized CO<sub>2</sub> inventory containing information on major stationary sources of CO<sub>2</sub> in the Kingdom, including information on emissions by sector, location (province and city), and contributions by fuel type.

Studying the capacity and feasibility of geological storage sites, covering saline aquifers, CO<sub>2</sub> mineralization in basalt formations, and the use of CO<sub>2</sub> in enhanced oil recovery (EOR) and storage in depleted oil reservoirs (see Figure 1).

Estimating the cost and readiness of the available storage options, including CO<sub>2</sub> capture, transportation, and injection and "CCUS hubs."

**Figure 1.** Atlas for Geological CO<sub>2</sub> Storage in Saudi Arabia: Capacity mapping.



Source: KAUST 2022

Regarding **quantifying natural CO<sub>2</sub> sink storage potential**, KAUST has launched various projects to assess the contribution of nature-based solutions to the “removal” component of the CCE, namely, removing CO<sub>2</sub> from the atmosphere to achieve negative emissions. In addition to storing CO<sub>2</sub>, nature-based solutions provide various other cobenefits, as they support ecosystem conservation and strengthen resilience to negative climate change impacts. Under the Saudi Green Initiative, the government has set a goal of planting 10 billion trees across the kingdom. As part of this effort, it announced ambitious targets for 2030, which include planting 450 million trees and rehabilitating eight million hectares of degraded lands to reduce 200 million tons of CO<sub>2</sub> (MtCO<sub>2</sub>) emissions (Saudi Green Initiative 2021, 2022). The National Center for Vegetation Cover is leading the effort. The majority of these trees are expected to be planted in terrestrial ecosystems, but marine ecosystems could also contribute.

Blue carbon, namely, CO<sub>2</sub> sequestration by oceanic and coastal ecosystems, has significant potential for sequestering carbon. Some studies have estimated the total mitigation potential of mangroves worldwide as close to 800 MtCO<sub>2</sub>, while tidal marshes and seagrass together could mitigate well over an additional 400 MtCO<sub>2</sub> (Macreadie et al. 2021). The total approximately equals the collective estimated annual GHG emissions of all six Gulf Cooperation Council (GCC) countries (WRI et al. 2022). Blue carbon is also seen as a potential source of carbon credits for the rapidly growing carbon markets worldwide.

Studies have estimated that in Saudi Arabia, the annual blue carbon soil sequestration by seagrasses and mangroves is approximately 4,400–6,000 tonnes of CO<sub>2</sub> (tCO<sub>2</sub>) in the Red Sea and 66,000 tCO<sub>2</sub> in the Arabian Gulf (Almasheer et al. 2017; Serrano et al. 2018; Cusack et al. 2018). Mangroves

in particular have further sequestration potential. Over recent decades, KAUST estimated that mangroves in the Red Sea have increased by only 50 km<sup>2</sup>. This increase has been the result of one of the world’s largest mangrove restoration projects. Accelerating delivery of the existing potential will therefore require significant efforts, including further R&D, public-private partnerships and integrated policies and governance.

Regarding **corporate GHG accounting**, the NEOM megainitiative has set a target of reaching carbon neutrality by 2030. An organization-wide “carbon management framework” acts as a key enabler for achieving this ambitious target within less than a decade. The framework comprises six areas:

**Measuring:** NEOM emissions are measured, reported and verified (MRV’d) through a GHG inventory system that enables annual reporting of the company’s emissions.

**Reducing:** NEOM is working on emission reduction programs that consider various priorities, including technology availability, attractiveness to tenants, and measurability of reductions.

**Offset procurement:** To achieve carbon neutrality, NEOM will need to purchase carbon credits to compensate for the residual emissions that it will not be able to avoid when constructing the project. These will be procured from high-quality projects, with a preference for domestic and regional projects.

**Offset projects registration:** NEOM also plans to develop carbon offsetting projects that it would register under reputable, internationally recognized accreditation schemes.



## Quantifying and Accounting for GHG Emissions and Sinks

---

**Certification:** NEOM will use third-party verification to ensure the quality and credibility of its emission inventories and compensation and neutrality claims.

**Communication:** NEOM will also share the lessons learned from its journey to carbon neutrality.

NEOM has already developed two annual inventories (2020 and 2021), one of which, along with the inventory system itself, has achieved third-party verification. It is in the process of automating its emissions monitoring systems and developing emission reduction strategies for all sectors. The corporation also expects to need a significant quantity of carbon credits in the coming years and sees Saudi Arabia as an important market for domestic offset supply.

In the discussion, the participants also highlighted the following:

Regarding the potential of carbon capture and storage (CCS), capture costs remain high – varying from US\$15 to US\$150 – and are a barrier to unlocking this potential.

Regarding corporate GHG accounting, robust, globally recognized methodologies, such as the GHG Protocol and the ISO 14064 standard, exist for corporate accounting. However, many companies consider that disclosing detailed GHG inventories will reveal sensitive data that they do not wish to expose to their competitors. Current challenges, including lack of reporting and underreporting by companies can be increasingly overcome with the help of satellite monitoring.

Regarding the carbon credit market potential in Saudi Arabia, many companies seeking to buy carbon credits are likely to prefer domestically generated credits. However, this requires new offsetting projects, which have yet to take off. Currently, the Kingdom has no projects registered under globally recognized standards that could generate the needed credits. Establishing a domestic carbon market could incentivize project development and generate opportunities for the private sector. In the medium term, all types of credits will be in demand. As the world approaches net-zero emissions, demand will shift to the so-called removal credits, i.e., those that have resulted in negative emissions.



# CCE Metrics and Standards

**D**eveloping targets to reach CCEs and ensuring that circularity technologies are brought to market and implemented rapidly and at scale requires clear metrics and standards. In this session, speakers shared GCC-specific highlights from the KAPSARC CCE Index and updates on the CCE National Program work related to strategic planning, CCUS regulation, and clean hydrogen certification. Furthermore, speakers shared insights into clean hydrogen certification and clean ammonia life-cycle analysis.

**The CCE Index** was first launched at the UN Climate Change Conference in Glasgow in 2021 (COP 26). It is a composite index that uses 47 quantitative indicators to measure countries' CCE performance and their potential to transition to CCEs and net-zero emission economies. The index allows for comparisons across countries by proposing a common set of metrics. At a domestic level, the index can help unlock data-driven discussions on country-specific ways to develop net-zero pathways and policies. The CCE Index web portal (<https://cceindex.kapsarc.org/>) offers two simulation tools that allow users to change the weights of specific indicators (e.g., give more weight to a technology of their preference) and toggle countries' indicator values (e.g., to see how reaching a policy target would impact a country's score and rank).

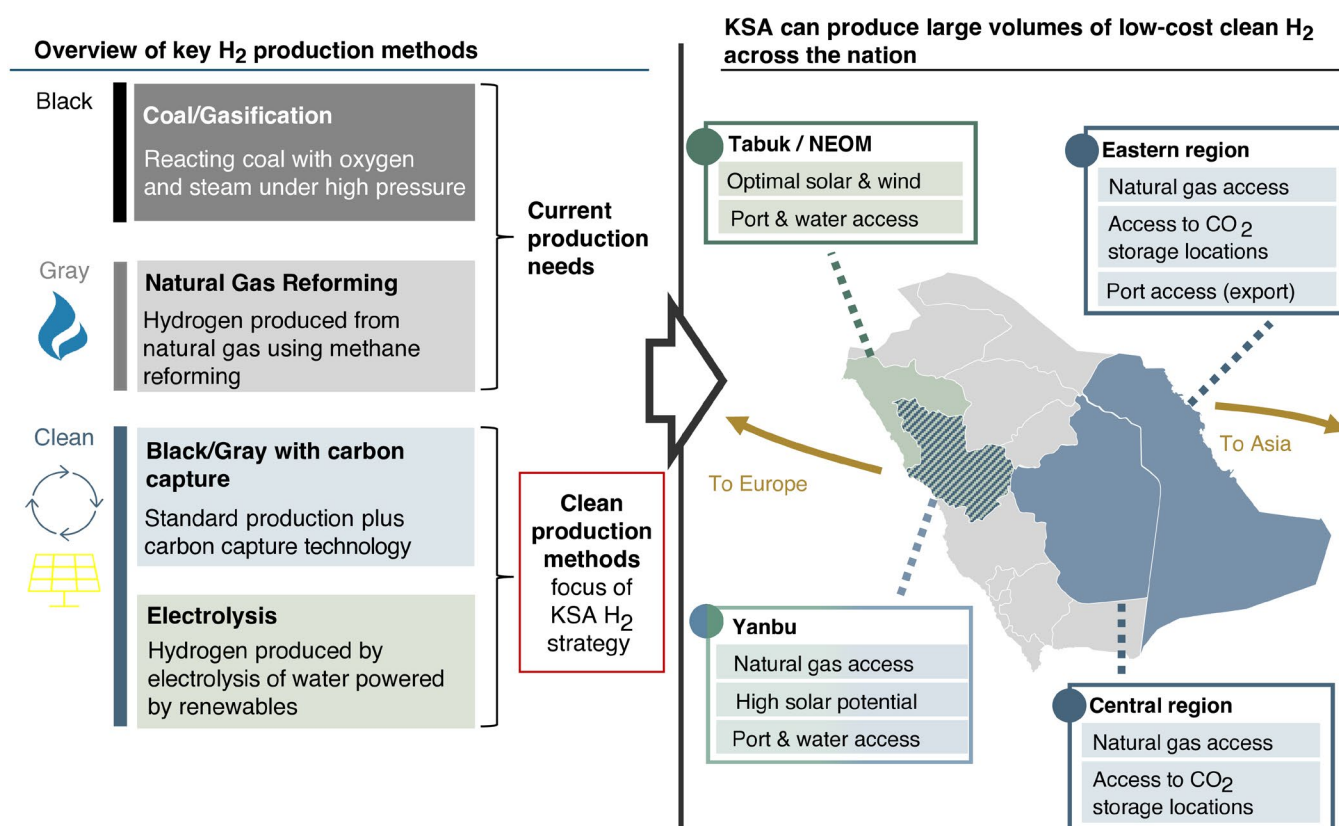
A recent study from KAPSARC focused on the GCC countries included in the first, 2021 edition of the index, which covered a total of 30 major economies and oil producers. Regarding current CCE performance, Saudi Arabia ranked the highest among the GCC countries, followed by the UAE and Qatar. Regarding CCE transition potential, measured through the "CCE enablers score," the UAE and Qatar received the highest scores. In the 30-country group, GCC countries are ranked mainly in the second and third tertiles on these two

subindices (performance and enablers). When the 19 major oil-producing countries included in the index are compared, Saudi Arabia ranks the highest among the GCC countries and sixth overall due to the low carbon intensity and fugitive emissions associated with its hydrocarbon production.

**The CCE National Program** is spearheading the Ministry of Energy's efforts to contribute to reaching Saudi Arabia's target of net-zero GHG emissions by 2060 through the adoption of the CCE framework. The CCE approach seeks to address the three pillars of the Kingdom's energy sector, namely, energy security, economic growth, and climate change. The ministry's new Integrated Energy Strategy framework includes hydrogen and CCUS as key pillars alongside four already existing pillars, namely, oil; natural gas; refining and petrochemicals; and power, renewables, and nuclear energy. The framework also spells out six strategic objectives, including emissions management and local content, along with the required key enablers that are being developed through collaboration among public and private sector entities participating in the Kingdom's "Energy Ecosystem." The ministry has identified CCUS and clean hydrogen as playing important roles in achieving the 2060 target. Medium-term targets in these areas are developing a "CCUS hub" with a CCUS capacity of 44 MtCO<sub>2</sub> per year by 2035 and producing 4 Mt of clean hydrogen per year by 2030 (CDM-DNA 2021). In the longer term, CCUS, direct air capture (DAC), and hydrogen are expected to contribute approximately one-third of the emission reductions needed by 2060.

**CCUS** hubs are currently seen as the ideal way to scale up capacity in a cost-efficient manner. The ministry has assessed optimal locations for CCUS hubs in the Kingdom and has identified specific facilities with low-cost opportunities for starting implementation. The hubs themselves would be

**Figure 2.** The “color-blind view” of hydrogen, and clean hydrogen potential in the Kingdom.



Source: CCE National Program, Ministry of Energy 2022

deployed in the form of companies. The ministry is currently conducting feasibility studies for joint venture models in this space.

Regulations and policies are considered the main enablers for CCUS, whereas for clean hydrogen, which will largely be exported, certification will be a fundamental factor to ensure acceptability on the buyer side. Regulations for CCUS will be needed in the following areas: government MRV<sup>ing</sup> of captured CO<sub>2</sub> quantities; ensuring operational safety and creating regulations that allocate responsibilities and liabilities across the value chain; and financial incentives and sustainability frameworks.

**Regarding clean hydrogen certification**, the ministry prefers a “color-blind view,” namely, focusing more on the carbon content of the hydrogen than on the energy source used to produce it – be it natural gas or renewable energy, for example (see Figure 2). To support the development and adoption of certification for clean hydrogen, the ministry has established a task force that focuses on certification, including whether to adopt international certification standards or develop a new domestic standard.

Another workshop held in May 2022 at KAPSARC focused on ways to accelerate the demand for clean hydrogen. The participants identified three main components:

**Policy and regulatory frameworks** that facilitate technology adoption, including decarbonization and hydrogen targets, a strong innovation framework, and setting a value for carbon.

**Sound business models** in which risk is shared, as hydrogen projects are costly and therefore require long-term contracts.

**Certification and international standards.**

Regarding certification and international standards, the lack of an internationally agreed-upon definition for clean hydrogen is hindering market development. A range of standards have emerged, each with different criteria, such as for calculating green electricity, project boundaries or acceptable sources of hydrogen. Convergence appears extremely challenging, and this problem could lead to market fragmentation and a market that is less liquid and sees lower levels of production. Many believe that instead of focusing on agreed-upon standards, reaching a universal definition for calculating carbon intensities of different stages of hydrogen production could be a way forward.

**Life-cycle assessment for hydrogen** allows the effects of hydrogen on the environment over its entire life (from production to consumption) to be quantified. When it is applied to the production of hydrogen from different sources, the actual environmental impact and “global warming potential” of the entire production (and transportation) system on, for example, a technology or project basis can be estimated. For example, one kilogram (kg) of green ammonia (produced from hydrogen) emits 0.6 kg of CO<sub>2</sub>e. Emissions arise from the manufacturing of the solar panels or wind generators used to produce the hydrogen. One kg of blue ammonia (produced from hydrocarbons with the CO<sub>2</sub> captured and stored) in turn emits 2.9 kg of CO<sub>2</sub>e. The carbon intensity of hydrogen or ammonia would both impact the price and have implications for whether it could be sold in certain markets.

Overall, hydrogen should be seen as an important part of net-zero pathways for energy sectors. The world currently consumes 600 exajoules of energy per year, and by 2040, some projections indicate that this amount could rise to 800 exajoules per year. Higher penetration rates of renewable energy will take time, potentially decades, which means renewable energy should be used wisely in the production of hydrogen. One such way could be to use some renewable energy as part of blue hydrogen production to achieve lower emissions. The energy required to power the process for generating blue ammonia accounts for more than 2 kg of the 2.9 kg emitted, but capturing the emitted CO<sub>2</sub> is easier. This could help expand the market not only for blue ammonia but also for clean ammonia more broadly by leveraging the energy accumulated within hydrocarbons.

In the discussions, the participants highlighted the following additional points:

Regarding **energy and climate policy considerations relating to hydrogen**, clean hydrogen production will, on the one hand, require large amounts of additional energy – be it from the grid or from natural gas, for example. This additional energy needs to be accounted for in energy planning. Additionally, when exported, the benefits of clean hydrogen will accrue to the consumer, which means that exports will not contribute to Saudi Arabia’s net-zero efforts because in national-level inventories, GHG emissions are accounted for where they are generated.

Regarding **certification**, the simpler the clean hydrogen standard, the more likely that it will be adopted and used, as long as it maintains high levels of quality and integrity. Furthermore, standards should be developed for carbon-based products, such as polymers or concrete, even if applications remain limited.

# Modeling CCE Pathways to Net-zero Emissions

**T**he use of analytical modeling capabilities is a critical element in devising climate change mitigation plans for achieving net-zero emissions. Among other things, models enable the production of detailed quantitative estimates of economically cost-effective pathways. They also allow for examining the inevitable tradeoffs that arise when pursuing one policy goal.

The CCE concept offers a comprehensive modeling framework for understanding the role of the different technologies under the four “Rs,” namely, reduce, recycle, reuse and remove. It also considers each country’s specific national circumstances. The third workshop session shared insights from modeling work on pathways to achieve net-zero emissions through the lens of the CCE framework at the global, national, and corporate levels.

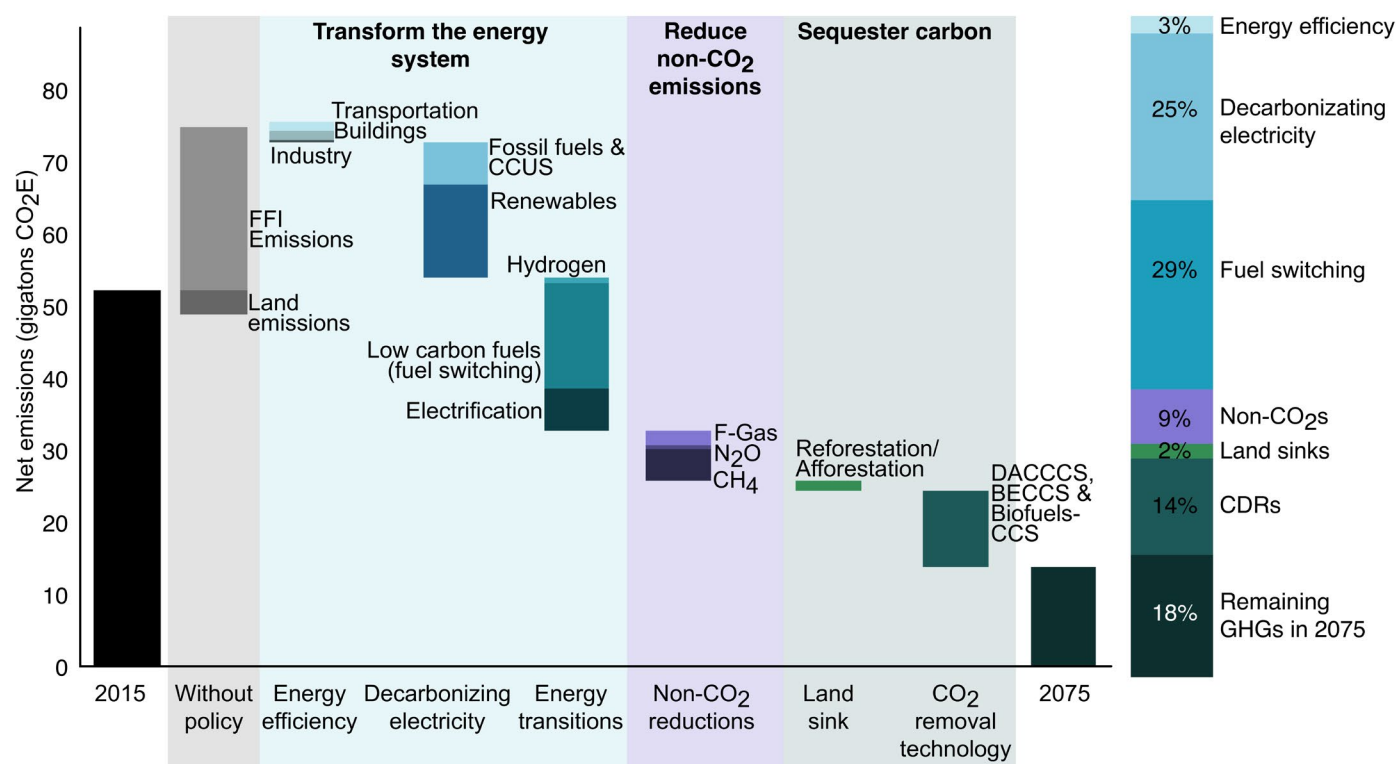
Regarding **global net-zero pathways**, KAPSARC has conducted modeling work using the CCE approach. Clearly defining the boundaries of the system that is being examined is a fundamental first step when initiating a modeling exercise: the modelers need to decide which components and processes of the human and natural systems they will track. When using a CCE approach, taking a

more holistic approach by capturing how natural processes and human activities evolve and interact and their associated natural and human-made emissions and sinks is important.

Characteristically, scenarios that embrace the CCE, allowing for all technologies to be utilized, generally result in more affordable mitigation pathways. This finding corroborates those of the Intergovernmental Panel on Climate Change (Kriegler et al. 2013; Bauer et al. 2018). A second characteristic of CCE net-zero scenarios is that they are often more equitable in terms of distributional impacts across countries. The reason is that the CCE approach allows each country to maximize its own mitigation potential and choose the least-cost options, which in turn reduces the gap between “winners” and “losers” in the transition.

Many global models still do not include a number of removal technologies, such as afforestation or DAC. Bioenergy with CCS is the most commonly included technology. When not included in models, technologies become excluded from the “solution space.” The spirit of the CCE is to include all technologies and approaches to mitigation. This is the third characteristic of CCE-based scenarios, as shown in Figure 3.

**Figure 3.** Global CCE net-zero CO<sub>2</sub> emissions scenarios. This waterfall plot shows the difference between a counterfactual “without policy” scenario and a net-zero CO<sub>2</sub> emission scenario with regard to emission reductions by various mitigation measures. Note that while energy efficiency is a key mitigation strategy of any global net-zero emission scenario, the low contribution shown is simply because energy efficacy is accounted for in both scenarios.



Source: Hejazi 2022.

Regarding **net-zero scenarios for Saudi Arabia**, KAPSARC is also working on quantifying economically efficient 2060 net-zero GHG emission scenarios for the Kingdom, using a general equilibrium model that focuses on the interplay between the supply and demand of various products, including energy and nonenergy commodities. The model will estimate the differential between the cost of reaching net-zero emissions and a business-as-usual scenario. Additional costs associated with net-zero pathways may include, for example, more expensive technologies or decreasing oil revenues as Saudi Arabia's oil export destination countries move toward net-zero. On the other hand, cost increases may be mitigated by factors such as energy price reforms that improve energy use

allocation, energy-efficiency improvements, or revenues from clean hydrogen exports.

The modelers make a number of assumptions relating to macroeconomics (e.g., demographics and employment and productivity growth dynamics), energy technologies and resources (e.g., costs and efficiency), energy and climate change policies (e.g., domestic energy pricing, clean energy targets and use of carbon offsetting), and the international context (e.g., hydrocarbon prices and global climate change policies). They then generate a reference, or business-as-usual, scenario, which assumes, among other things, that energy transition policies are limited to liquid replacement in the power sector, domestic energy prices remain at current levels,



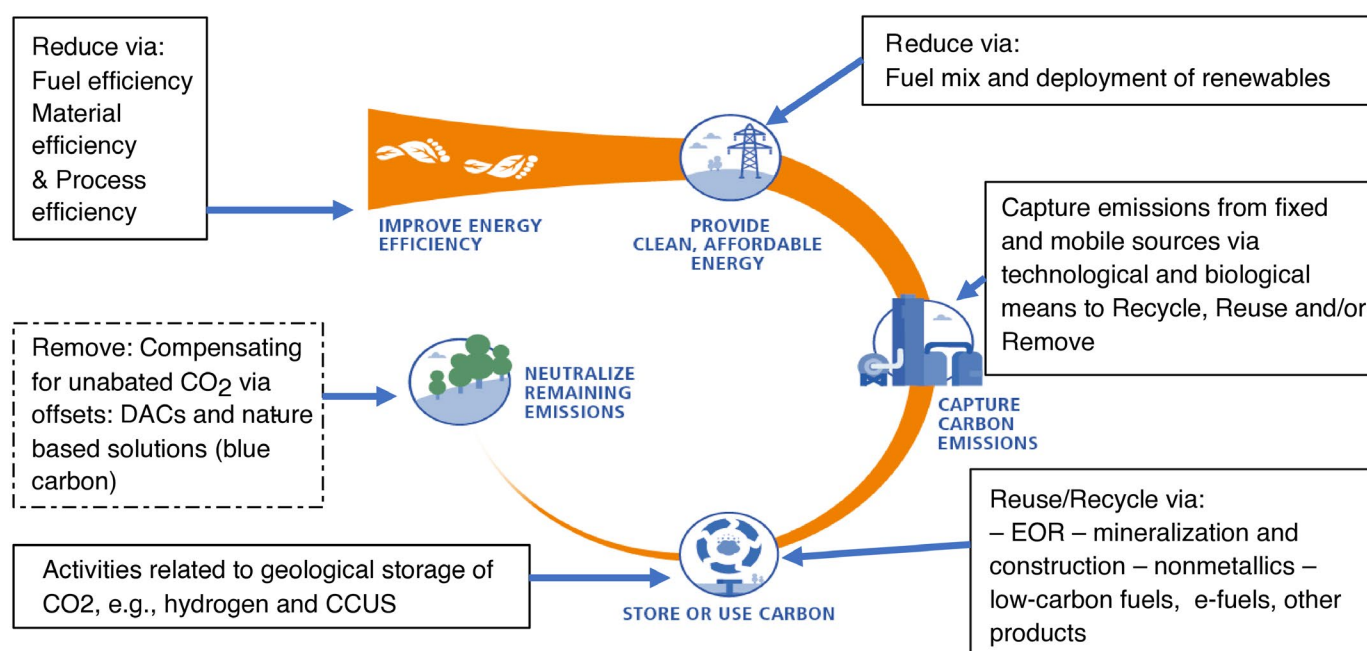
## Modeling CCE Pathways to Net-zero Emissions

oil prices remain high through midcentury, and an international market for hydrogen is in place by 2030. A net-zero by 2060 scenario then builds on this model by changing a number of assumptions, including a linear reduction in emissions from 2025 through 2060, deregulated domestic energy prices, and an international context in which mitigation action in other countries reduces global oil prices. The preliminary simulation results suggest that a cost-effective net-zero energy transition for Saudi Arabia involves high levels of electrification and large-scale deployment of renewable energy, CCUS, and clean hydrogen technologies.

Regarding **CCE-based modeling for net-zero emissions in corporate contexts**, an initial step is to frame and map a company's activities in relation to the CCE concept to understand how different circularity options apply to various parts of the company's operations (see Figure 4).

Next, businesses should prioritize and optimize their approach by using tools such as technology potential and cost estimates, equilibrium and process models, and marginal abatement cost curves (MACCs). MACCs, for example, identify a company's mitigation potential and rank all available technologies/options based on their costs for the company. Having this information allows companies to decide where and how they wish to reduce emissions. The next step is reducing emissions, which requires its own management processes. Companies also need to monitor their performance over time, which involves setting metrics, KPIs, GHG emissions and/or other CCE-related targets; MRV'ing, disclosing and communicating the corporate carbon/GHG footprint; and tracking progress toward the set targets and compared to peers. Finally, everything mentioned above should be contained in a corporate management program, such as an ESG framework.

**Figure 4.** Framing and mapping corporate activities to the CCE.



Source: Babiker 2022, based on OGCI 2018.

In discussions, the participants drew attention to the following:

**Lower emissions and reaching net zero can be seen as a competitive advantage**, and quantifying such benefits could also be beneficial, for example, in relation to carbon border adjustment taxes.

**Negative impacts of climate change** that are already happening and are expected to happen – namely, the costs of inaction – should be quantified when assessing the costs of climate change policies and the energy transition, as the faster emissions are reduced, the less these impacts will be.

**Carbon prices**, based on many other countries' experiences, need to be a part of the conversation about assessing cost-effective ways to reduce emissions. Many economic models already implicitly set a price on carbon when imposing a level on emissions, which results in an increase in the deployment of more costly mitigation technologies in these models over time.

**Distributional impacts of the use of economic instruments**, such as energy price reforms or carbon pricing, should be studied further to guide policy choices and improve the understanding of both mechanisms and policies (such as the Saudi Citizen Account Program) that can be implemented to alleviate these impacts.



# References

---

Almasheer Hanan, Oscar Serrano, Carlos M. Duarte, Ariane Arias-Ortiz, Pere Masque, and Xabier Irigoien. 2017. “Low Carbon Sink Capacity of Red Sea Mangroves.” *Scientific Reports*, 7, 9700 (2017). <https://doi.org/10.1038/s41598-017-10424-9>

Bauer, N. et al. 2018. “Global energy sector emission reductions and bioenergy use: overview of the bioenergy demand phase of the EMF-33 model comparison.” *Climatic Change*, 1–16, doi:10.1007/s10584-018-2226-y

Cusack M. et al. 2018. “Organic Carbon Sequestration and Storage in Vegetated Coastal Habitats along the Western Coast of the Arabian Gulf.” *Environmental Research Letters*, 13, 074007. <https://iopscience.iop.org/article/10.1088/1748-9326/aac899>

Clean Development Mechanism Designated National Authority of Saudi Arabia (CDM-DNA). 2021. ‘The Kingdom of Saudi Arabia reiterated the importance of renewing efforts...’ November 23, 2021. <https://www.cdmdna.gov.sa/events/47/hrh-minister-of-energy-meets-with-president-designate-of-cop26-to-unfccc>

Kriegler, E., O. Edenhofer, L. Reuster, G. Luderer, and D. Klein. 2013. “Is atmospheric carbon dioxide removal a game changer for climate change mitigation?” *Climatic Change*, 118(1), 45–57, doi:10.1007/s10584-012-0681-4

Macreadie, Peter I., Micheli D. P. Costa, Trisha B. Atwood, Daniel A. Friess, Jeffrey J. Kelleway, Hilary Kennedy, Catherine E. Lovelock, Oscar Serrano, and Carlos M. Duarte. 2021. “Blue Carbon as a Natural Climate Solution.” *Nature* 2, pp. 826–839. <https://www.nature.com/articles/s43017-021-00224-1>

Saudi Green Initiative. 2021. “His Royal Highness the Crown Prince announces the Kingdom of Saudi Arabia’s Aims to Achieve Net Zero Emissions by 2060.” Press release, October 23, 2021. [https://www.saudigreeninitiative.org/pr/SGL\\_Forum\\_Press\\_Release-EN.pdf](https://www.saudigreeninitiative.org/pr/SGL_Forum_Press_Release-EN.pdf)

———. 2022. “Greening Saudi.” Website. Accessed June 18, 2022. <https://www.saudigreeninitiative.org/targets/greening-saudi/>

Serrano, Oscar, Carlos Duarte, David John Gregory, Dorte Krause-Jensen, and Eugenia Apostolaki. 2018. “Seagrass, Protector of Shipwrecks and Buried Treasure.” *The Conversation*. <https://theconversation.com/seagrass-protector-of-shipwrecks-and-buried-treasure-103364>

# About the Workshop

**K**AUST and KAPSARC co-organized a workshop titled “Advancing the Circular Carbon Economy in Saudi Arabia” on May 31, 2022, at KAPSARC, Riyadh. A total of 37 participants attended, representing various entities from Saudi Arabia’s “Energy Ecosystem” and beyond, including research and academia, government, and the corporate sector. The purpose of the workshop was to share updates on the latest research and policy developments in the Kingdom relating to the CCE and to strengthen the science-policy interface by enhancing dialogue among these different stakeholder groups.

## Speakers

**Fahad Al-Meer** – Senior Specialist, Circular Carbon Economy National Program, Ministry of Energy

**Thamir Al Shehri, KAPSARC** – Research Lead, Climate and Sustainability Program, King Abdullah Petroleum Studies and Research Center (KAPSARC)

**Mustafa Babiker** – Senior Analyst and Planning Consultant, Saudi Aramco

**Thomas Bosse** – Manager, Certificates, ENOWA

**Carlos Duarte** – Distinguished Professor and Tarek Ahmed Juffali Research Chair in Red Sea Ecology, Red Sea Research Center, King Abdullah University of Science and Technology (KAUST)

**Olivier Durand-Lasserve** – Fellow II, Energy Micro and Macroeconomics Program, KAPSARC

**Frank Felder** – Director, Utilities and Renewables Program, KAPSARC

**Jorge Gascón** – Professor of Chemical Engineering, Circular Carbon Initiative Lead, and Director of KAUST Catalysis Center, KAUST

**Mohamad Hejazi** – Acting Director and Fellow III, Climate and Sustainability Program, KAPSARC

**Hussein Hoteit** – Associate Professor and Chair, Energy Resources and Petroleum Engineering Program, KAUST

**Noura Mansouri** – Fellow I, Climate and Sustainability Program, KAPSARC

**Carlos Santamarina** – Professor, Energy Resources and Petroleum Engineering, and Associate Director, Ali I. Al-Naimi Petroleum Engineering Research Center, KAUST

**Rami Shabaneh, KAPSARC** – Fellow I, Oil and Gas Program, KAPSARC

**Manus Ward** – Director, Research Planning and Partnerships, KAUST

**Fatih Yilmaz** – Fellow I, Climate and Sustainability Program, KAPSARC



# Notes

---

## About the Core Organizing Teams

**The KAPSARC Circular Carbon Economy (CCE) Index project** seeks to expand and add rigor to the conceptual basis of the concept of CCE, as well as its practical operationalization, by developing a robust quantitative framework to measure countries' performance and their progress toward it. The resulting CCE Index is a composite indicator that measures various dimensions of the CCE in a national context across countries. Its main foci are current performance and enabling factors for future progress.

The first edition of the CCE Index, published in November 2021, covers 30 major economies and oil-producing countries. It is being disseminated through various research outputs, including a KAPSARC Discussion Paper presenting the 2021 CCE Index results, a KAPSARC Methodology Paper laying out the 2021 CCE Index methodology and an online platform, located at <https://cceindex.kapsarc.org>. Further research and analysis that use the CCE Index results to analyze countries in more detail are also available. The 2022 edition will be launched in November 2022.

The CCE Index project members are Mari Luomi, Fatih Yilmaz, and Thamir Al Shehri.

**The KAPSARC Climate Adaptation and Mitigation Partnership (CAMP) project** is timely and of dire importance to Saudi Arabia given the mounting risks associated with climate change impacts, the urgency of driving toward a low-carbon future while maintaining national economic growth, and the potential economic ramifications of global mitigation efforts for the Saudi energy sector and economy.

Against this backdrop, the CAMP project will investigate (1) the climate conditions over Saudi Arabia, (2) the sectoral impacts and the role of adaptation measures, and (3) the pathways of the Saudi economy to achieve a low-carbon future or climate neutrality by midcentury. (4) The study will also adopt the CCE concept in characterizing the Saudi government's efforts to decarbonize its own economy while meeting its growth aspirations.

The CAMP project is led by Mohamad Hejazi.

**The KAUST Circular Carbon Initiative (CCI):** Since the inception of KAUST in 2009, research into circular carbon economy (CCE) technology solutions has been an integral part of its portfolio, including CO<sub>2</sub> capture, nature-based solutions, renewable energy and CO<sub>2</sub> utilization. With the launch of the KAUST CCI, the university aims to more deeply connect the different strands of its CCE research, to create a strong and well-informed network of researchers at different career stages, to identify and seek to engage missing expertise and, last but not least, to proactively contribute to the ongoing efforts of the Kingdom of Saudi Arabia to implement a CCE National Program.

The KAUST CCI has been defined with the objective of filling this innovation gap through multidisciplinary work and in turn supporting the Kingdom of Saudi Arabia in championing its CCE program. The initiative is led by Professor Jorge Gascón.



[www.kapsarc.org](http://www.kapsarc.org)