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King Abdullah Petroleum Studies and Research Center

The Circular Carbon Economy

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April 19, 2024
Tokyo, Japan

The 9th IEEJ/APERC International Energy Symposium

Overview

KAPSARC is an advisory think tank focusing on global energy economics and sustainability and providing analysis and advice to policymakers in the Saudi energy sector

TO BE A LEADING ADVISORY THINK TANK IN ENERGY ECONOMICS AND SUSTA

VISION

To be a leading advisory think tank in energy economics and sustainability

MISSION

To advance Saudi Arabia's energy sector and inform global policies through evidence-based advice and applied research

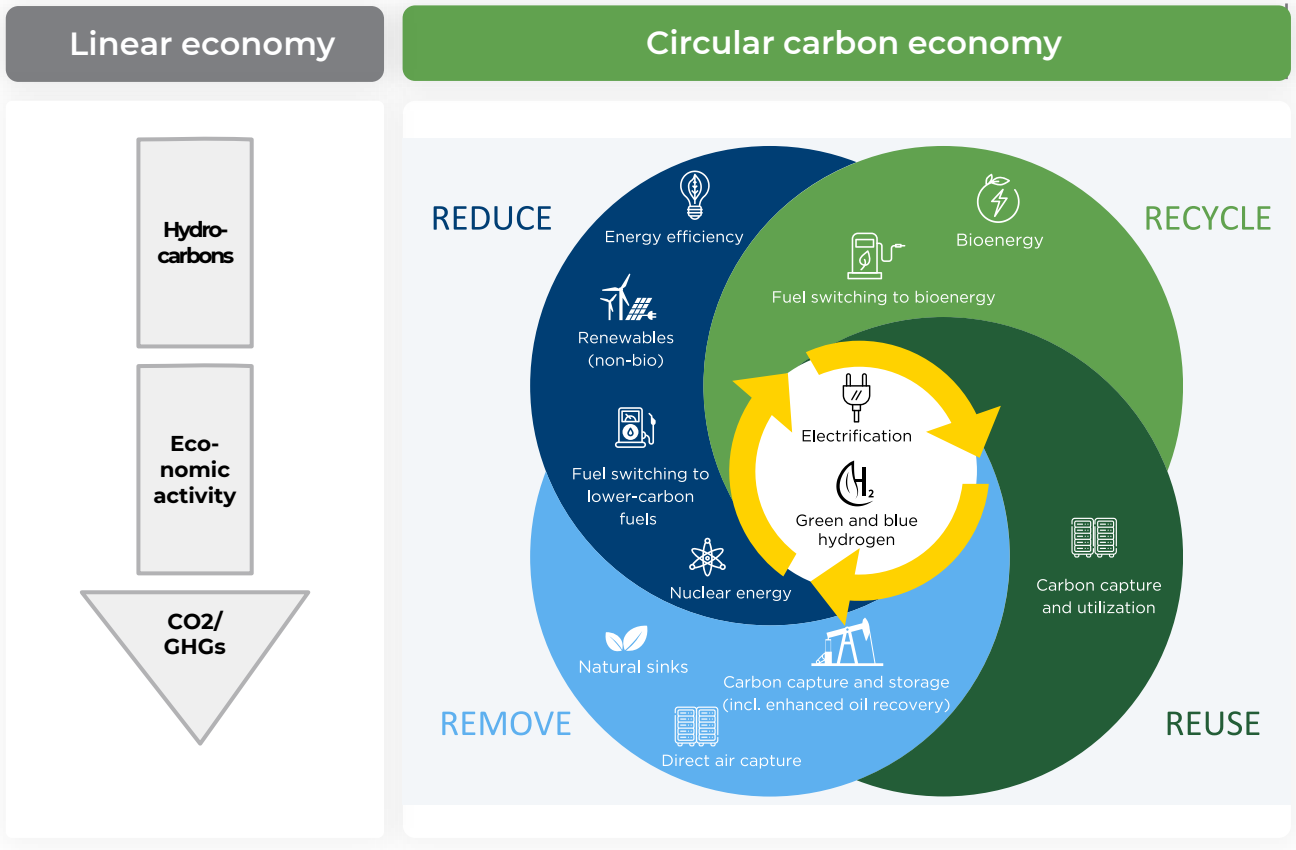
293
Employees

25
Nationalities

31%
Female

The circular carbon economy

- A framework to **support transitions to net-zero emissions** in line with the Paris Agreement's goals
- Focuses on **energy** and **emissions flows**
- 4 pillars: **reduce, recycle, reuse** and **remove**
- **Holistic**, technology-neutral approach that enables effective and efficient emissions reductions
- Aim: avoiding **atmospheric** emissions, reaching **net-zero emissions**, monetizing **carbon**
- Each country will have its **own pathway & technology mix**
- Endorsed by **G20 leaders** in 2020 as a holistic, integrated, pragmatic approach to managing emissions while promoting economic growth



Sources: Williams (ed.) 2020; Luomi, Yilmaz and Alshehri 2021

The Circular Carbon Economy:

The CCE Index

The CCE Index

A composite indicator that enables measuring country performance and potential to progress toward CCEs and net-zero emissions in diverse contexts.

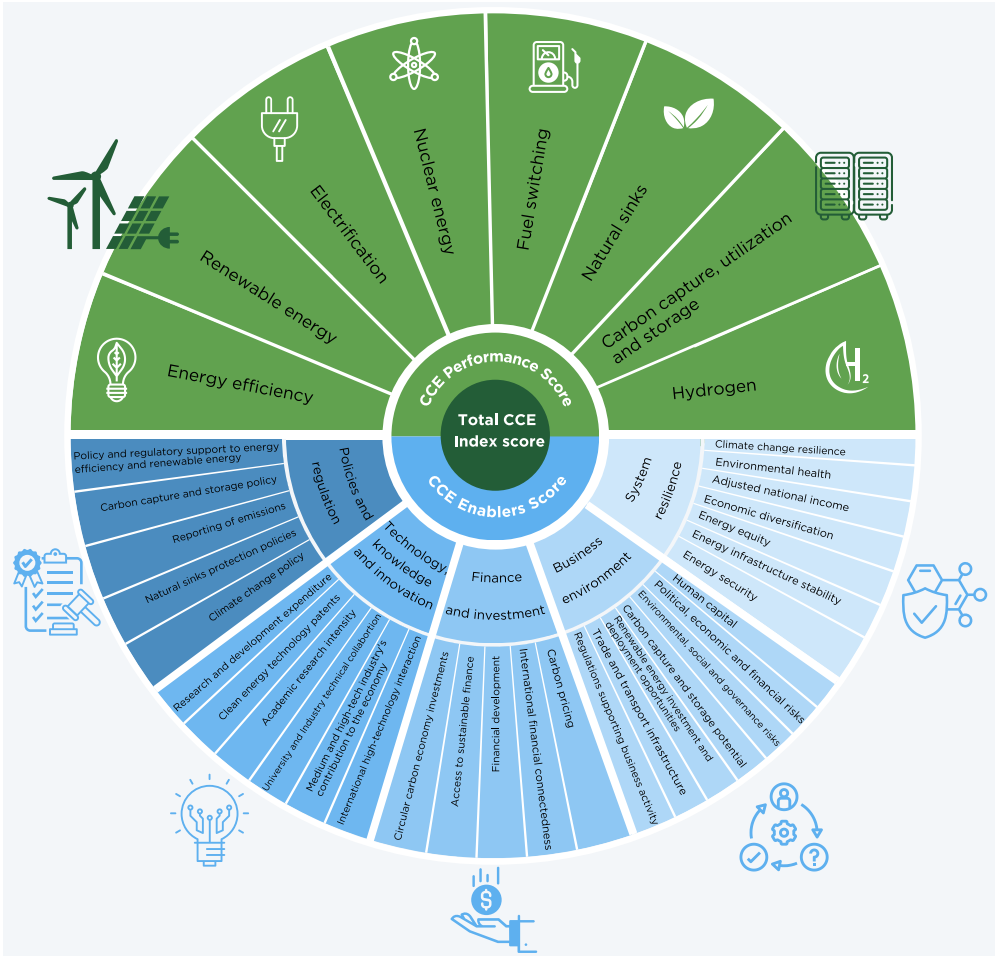
43 quantitative indicators, derived from harmonized international datasets, aggregated to form the CCE Index score. Two sub-indices answer the questions:

CCE Performance:

- How are countries engaging with diverse climate change mitigation options and technologies in terms of depth and diversity?

CCE Enablers:

- How are countries positioned to accelerate progress toward circular carbon economies?



Source: Luomi, Yilmaz and Alshehri 2024.

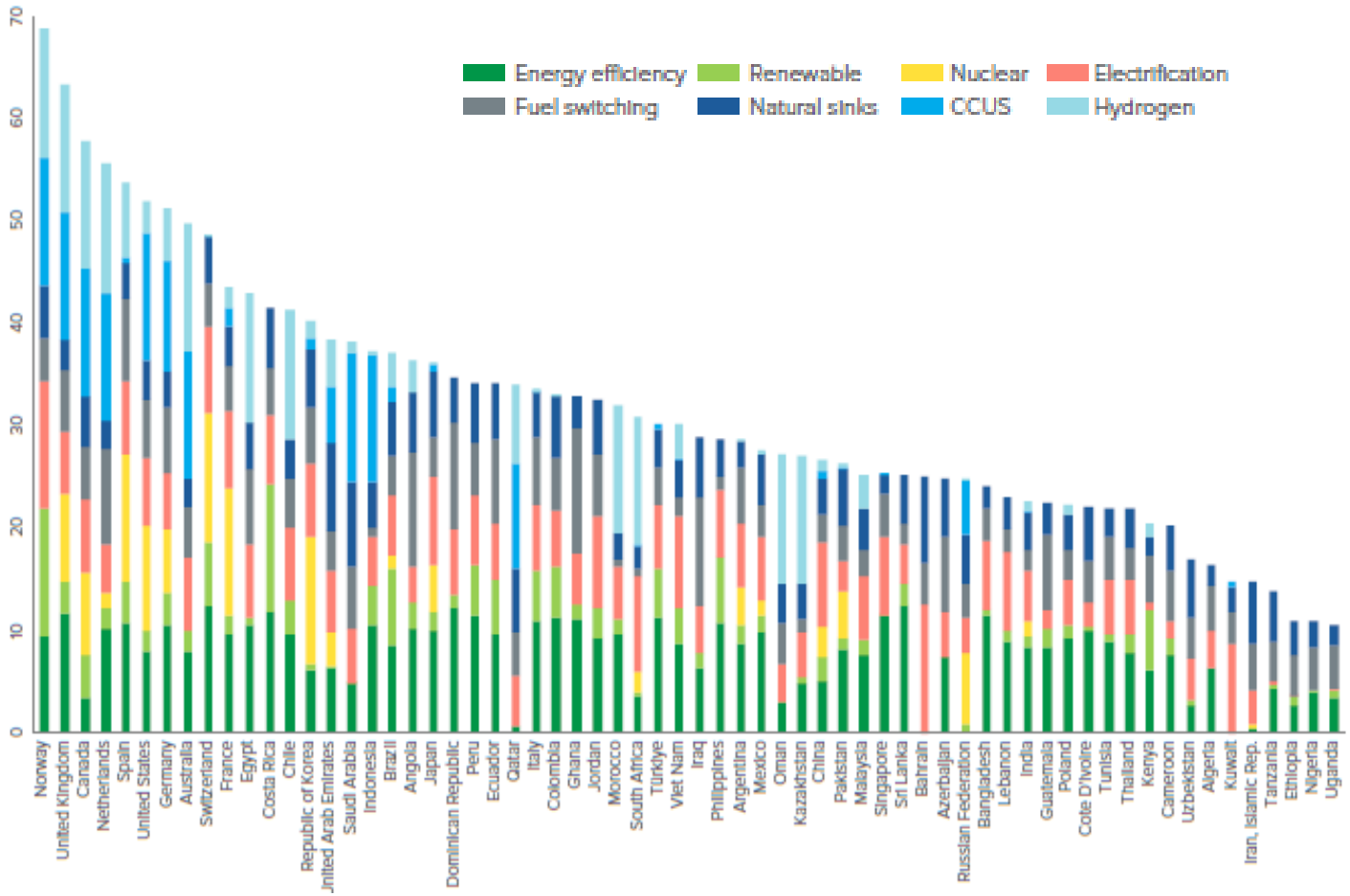
Country coverage

Inclusion criteria:

- At least 1 million population
- Largest economies from each World Bank region
- Top-30 oil and gas producers
- Arab League member countries
- 80% or more of indicators values available

Source: CCE Index web portal: https://cceindex.kapsarc.org/

2023 CCE Performance scores



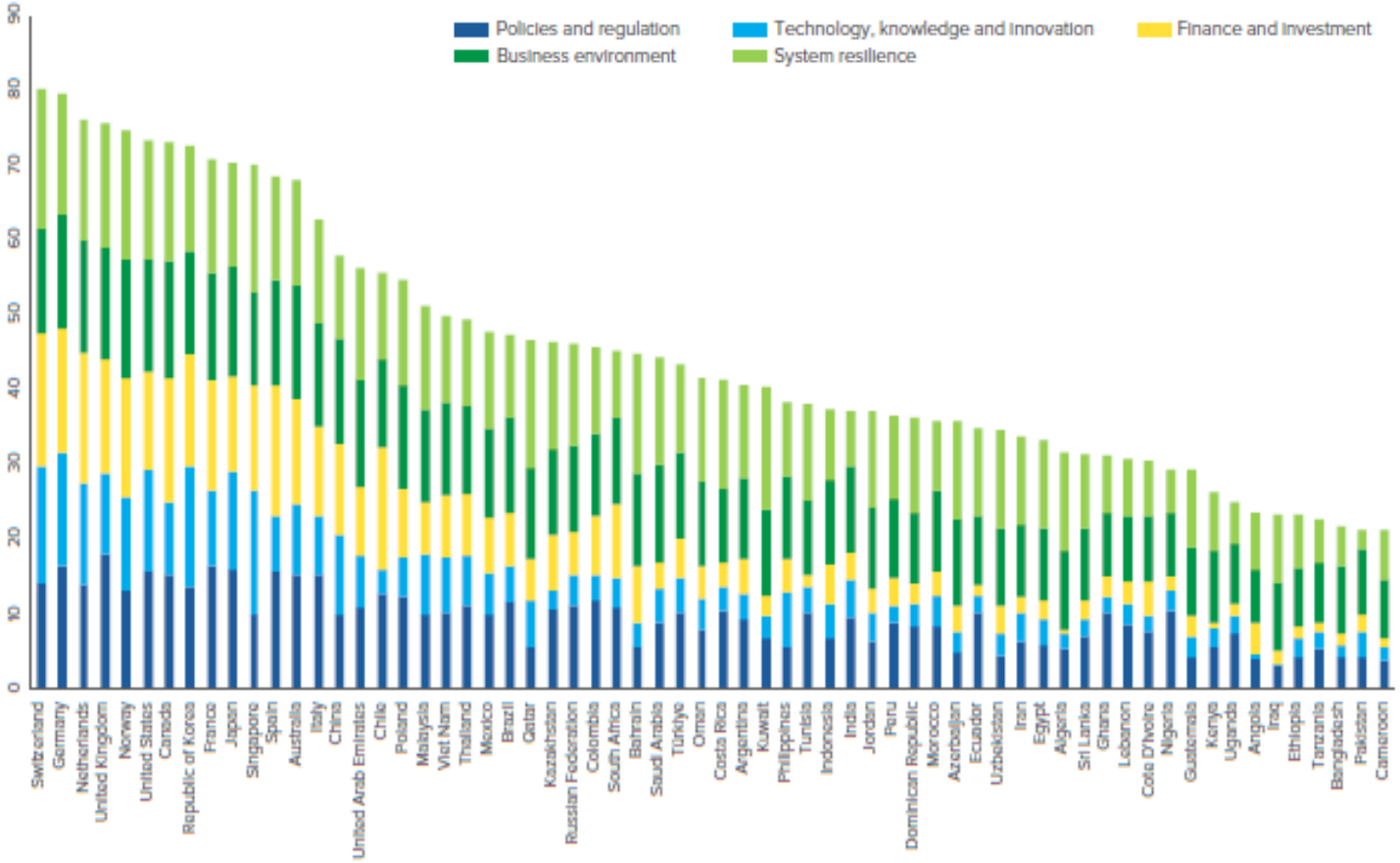
The CCE Performance score rewards countries that **engage with a range of CCE technologies and approaches and achieve high scores in these**.

In 2023, the top performers were Norway, the UK and Canada.

There is a major **gap** between the top and bottom performers.

Source: Luomi, Yilmaz and Alshehri 2024.

2023 CCE Enablers scores



CCE Enablers are an aggregate measure of the five enabling areas gauged by the index: **policy, technology, finance, business environment, and overall system resilience.** These measure factors that countries will need to have in place to support their journey to net-zero emissions.

In 2023, Switzerland, Germany and the Netherlands rank the highest on CCE Enablers.

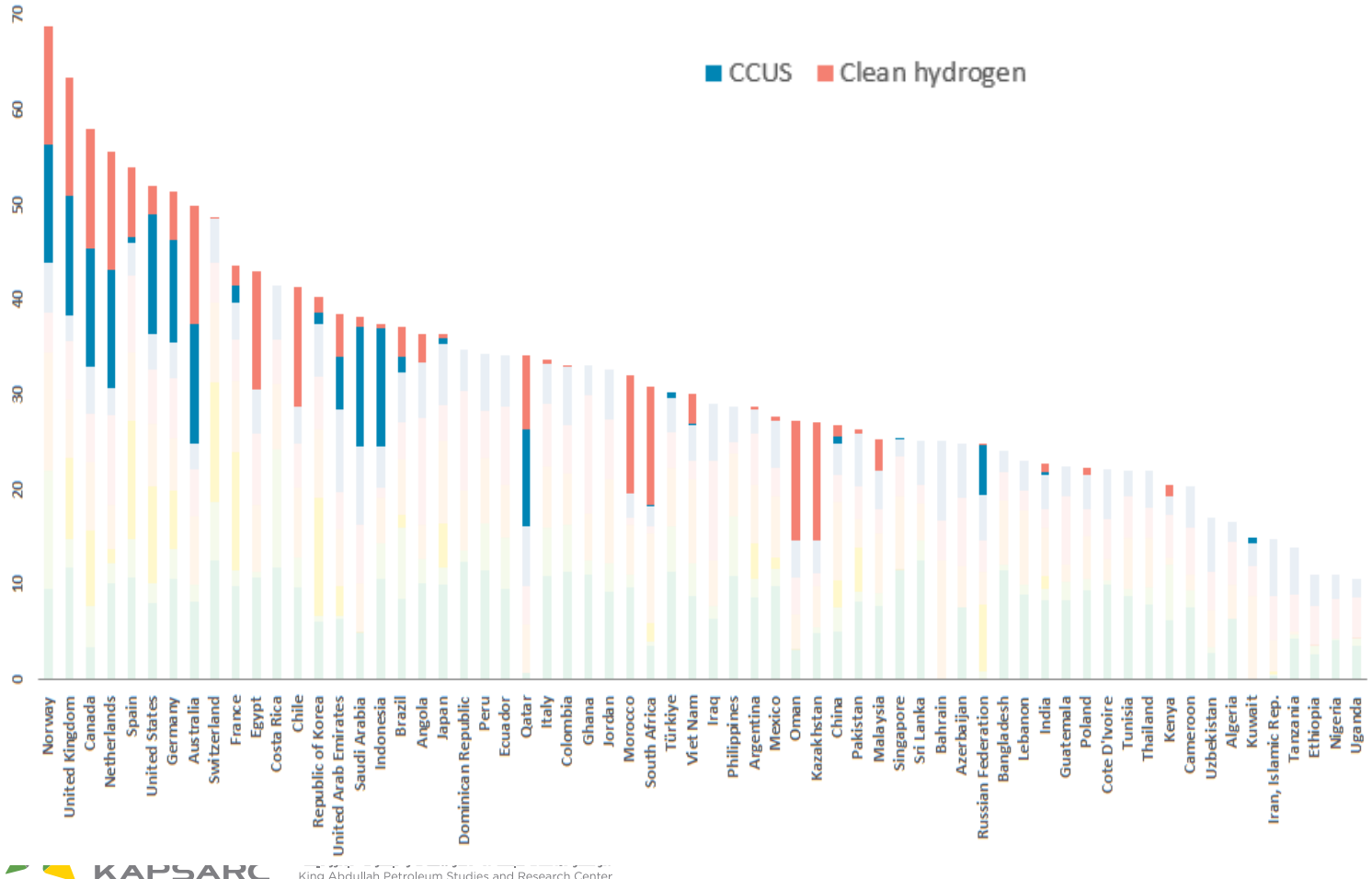
Gaps between the top and bottom performers are extremely wide in most of these areas.

Source: Luomi, Yilmaz and Alshehri 2024.

The Circular Carbon Economy:

Hard-to-Abate Sectors & Finance & Investments

2023 CCE Performance scores: hard-to-abate sector transition technologies

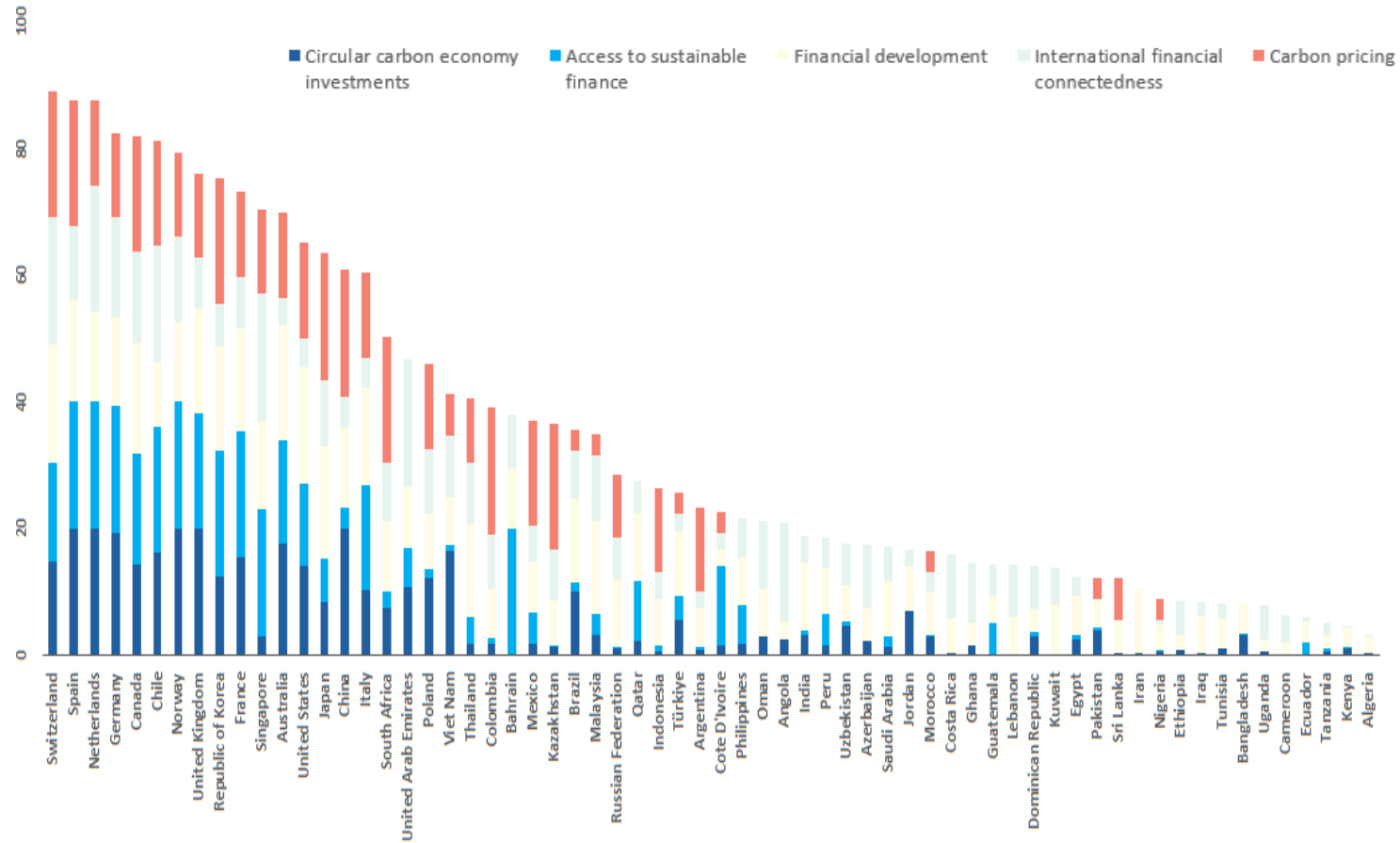


Source: Luomi, Yilmaz and Alshehri 2024.

The CCE Performance sub-index reveals **major gaps** in countries' ability to engage with technologies that are considered crucial for **enabling hard-to-abate sectors to transition to net-zero**, namely CCUS and clean hydrogen.

Over the three annual editions of the CCE Index, an **increase** in project pipelines is visible, but remains **highly concentrated** in a small number of countries.

2023 CCE Index finance and investment gaps



There is a highly unequal distribution among countries in what proportion of their GDP they spend in **CCE investments.**

There is a similar pattern in **ESG finance** (sustainable debt instruments, including bonds and loans).

Carbon pricing gives countries points depending on whether they have in place, or in the pipeline a carbon tax, ETS or crediting scheme. A total of 30 out of the 64 countries currently score a zero on this metric.

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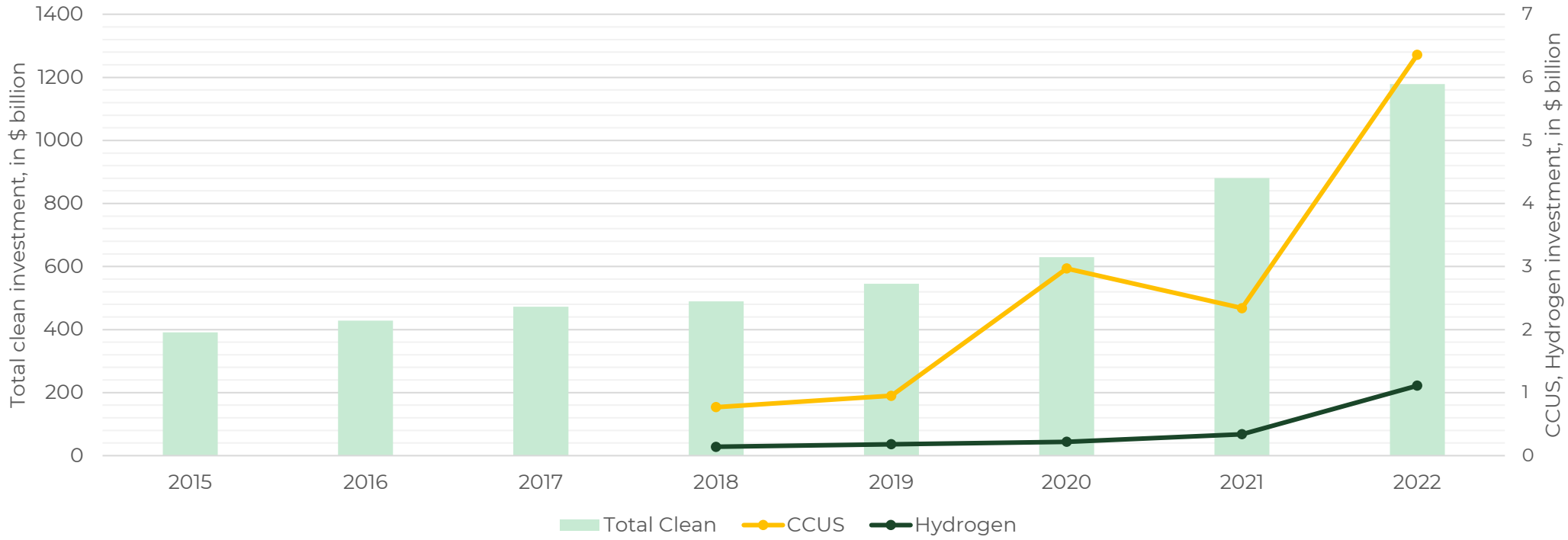
CCE INDEX Circular Carbon Economy Index مؤشر الاقتصاد الدائري للكربون

Source: Luomi, Yilmaz and Alshehri 2024.

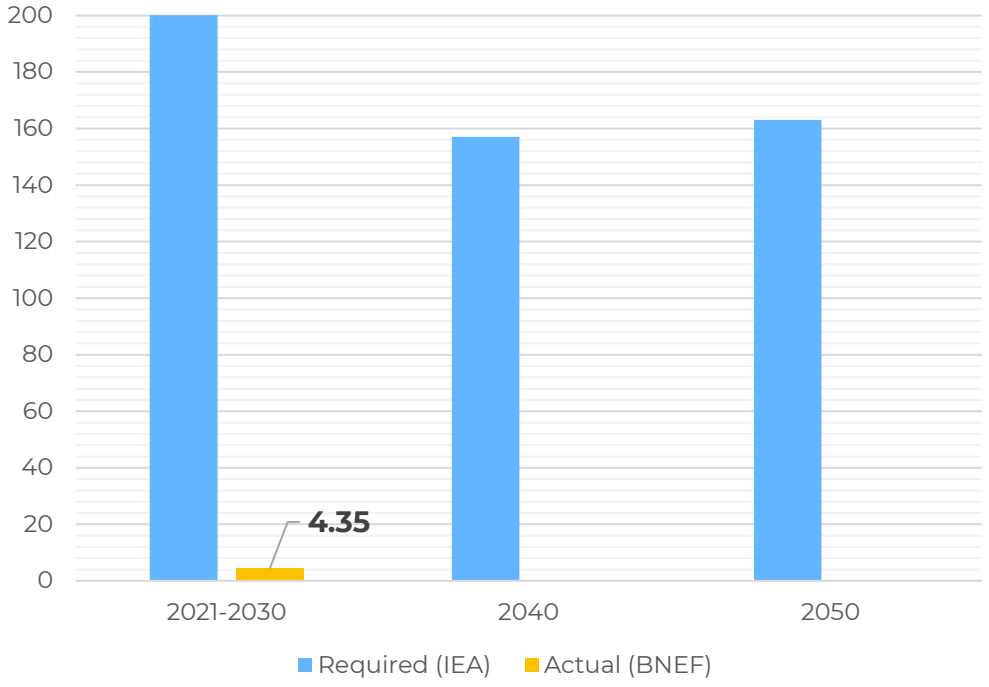
Investments in critical technologies for hard-to-abate sectors (CCUS and H_2) have been drastically low



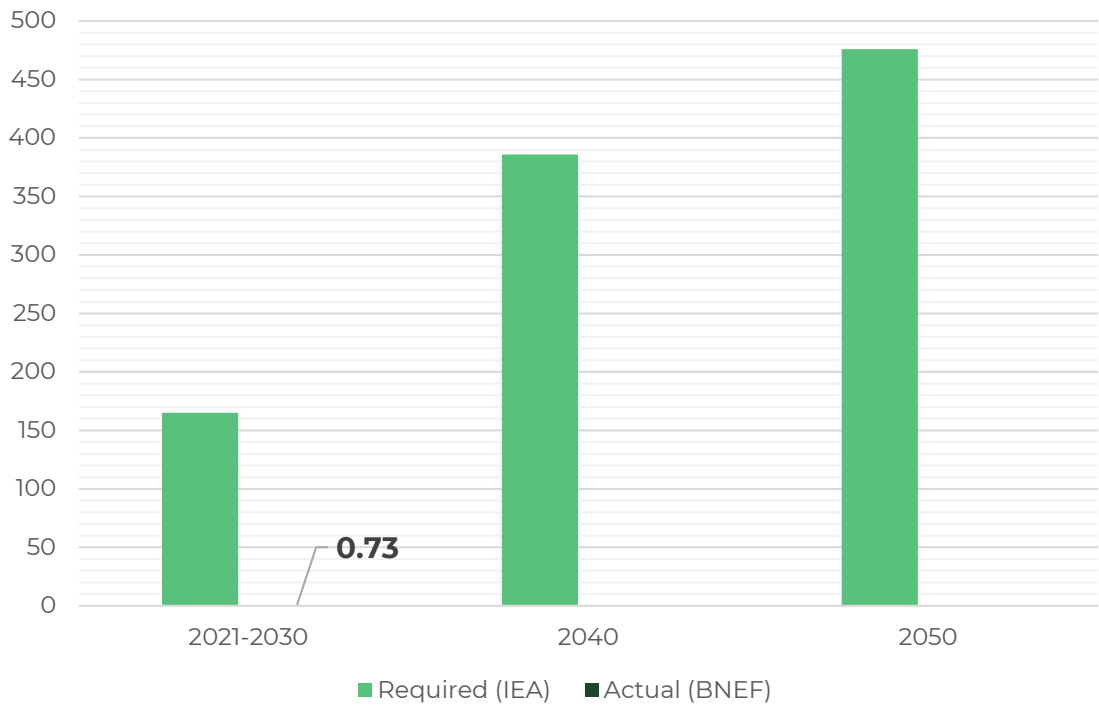
Note: The figure includes all clean energy transition investments.
Source: Author's construction from Bloomberg NEF.

The investment gaps for hard-to-abate sector transition technologies (e.g., CCUS and Clean H_2)

CCUS, $ billion annually



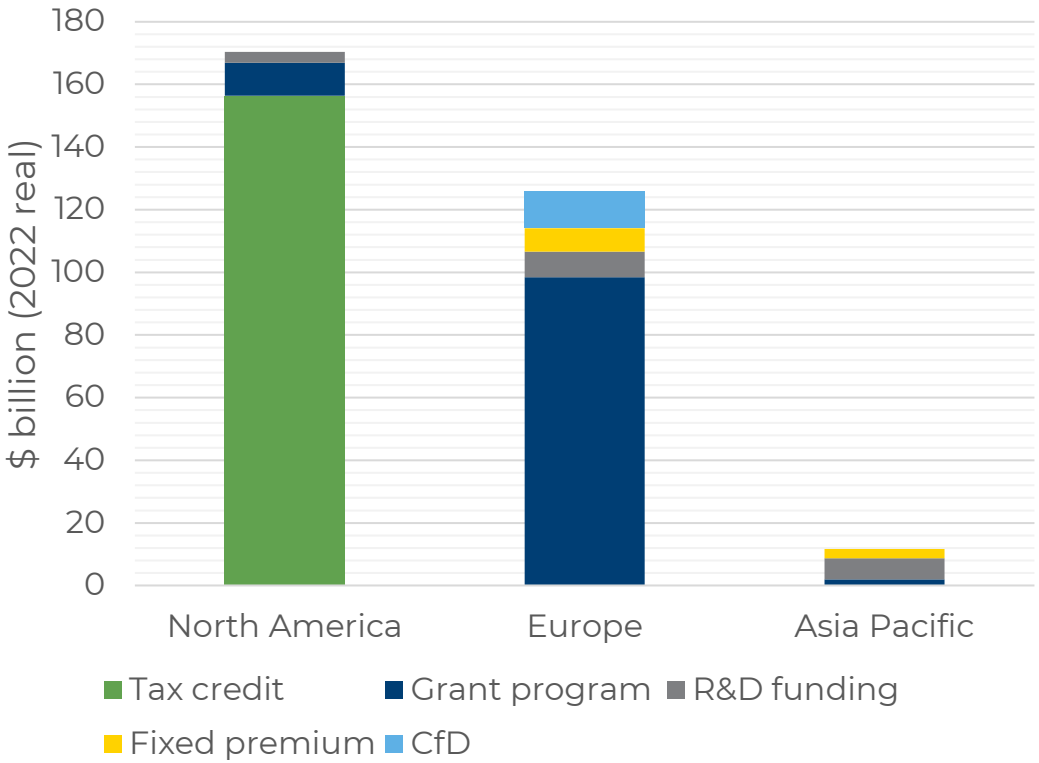
Hydrogen, $ billion annually



Source: Author's construction from Bloomberg NEF and IEA Net-Zero Scenario (2020).
Notes: Actual is the average of investment flows in 2021, 2022 and 2023.

Current financing practice for technologies such as hydrogen depends heavily on government subsidies

H_2 Funding by incentive mechanisms



Key takeaways

- Most of the current CCUS and hydrogen projects are financed via government subsidies (e.g., IRA – 45Q and 45V – in the United States)
- Developing countries are significantly lagging despite the high needs
- Not sustainable in the long run given the drastic investment needs of approximately $ 5.25 trillion for CCUS and $10 trillion for H_2 by 2050 according to the IEA

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Source: BNEF, KAPSARC

The Circular Carbon Economy:

Oil Producing Nations & Methane Emission

The 2023 CCE Index

2023 CCE Index (OPL) indicator framework

CCE Performance:

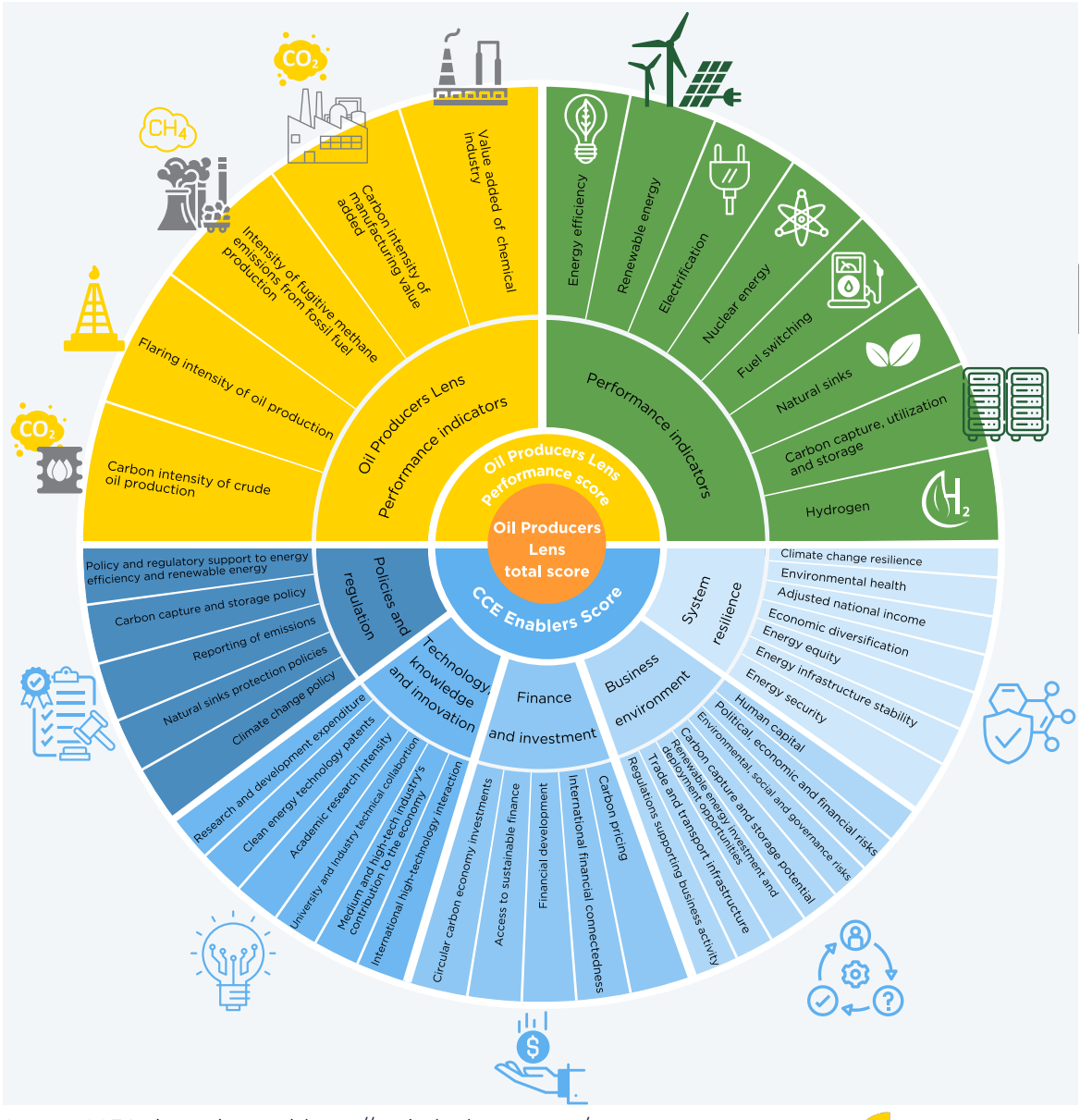
- How are countries engaging with diverse climate change mitigation options and technologies in terms of depth and diversity?

CCE Enablers:

- How are countries positioned to accelerate progress toward circular carbon economies?

Oil Producers Lens:

- How is major oil and gas producers' industrial performance (& business environments) aligning with the CCE?



Source: CCE Index web portal: https://cceindex.kapsarc.org/

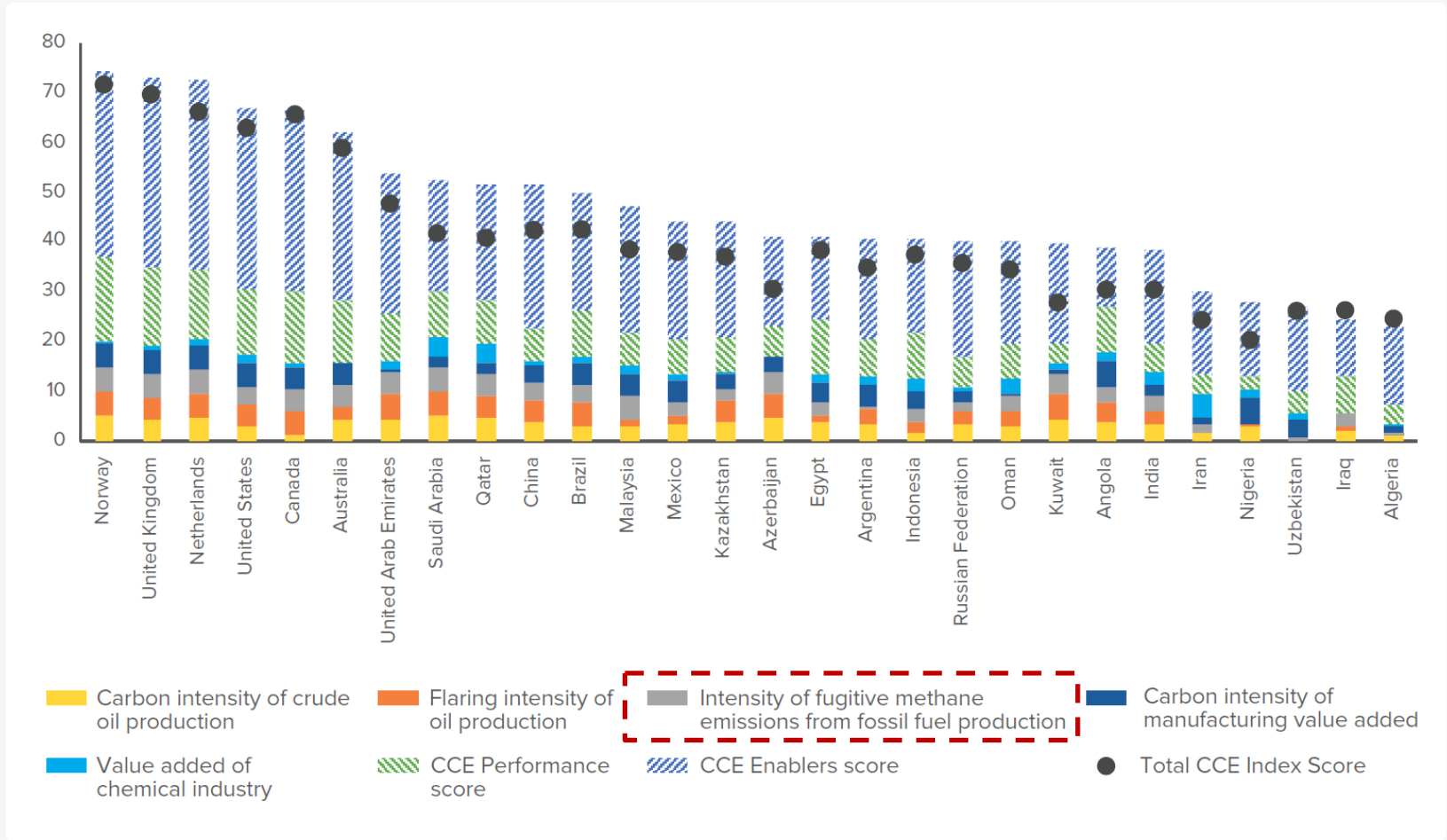
2023 Oil Producers Lens (total)

Top-3 countries:

Norway, United Kingdom, Netherlands

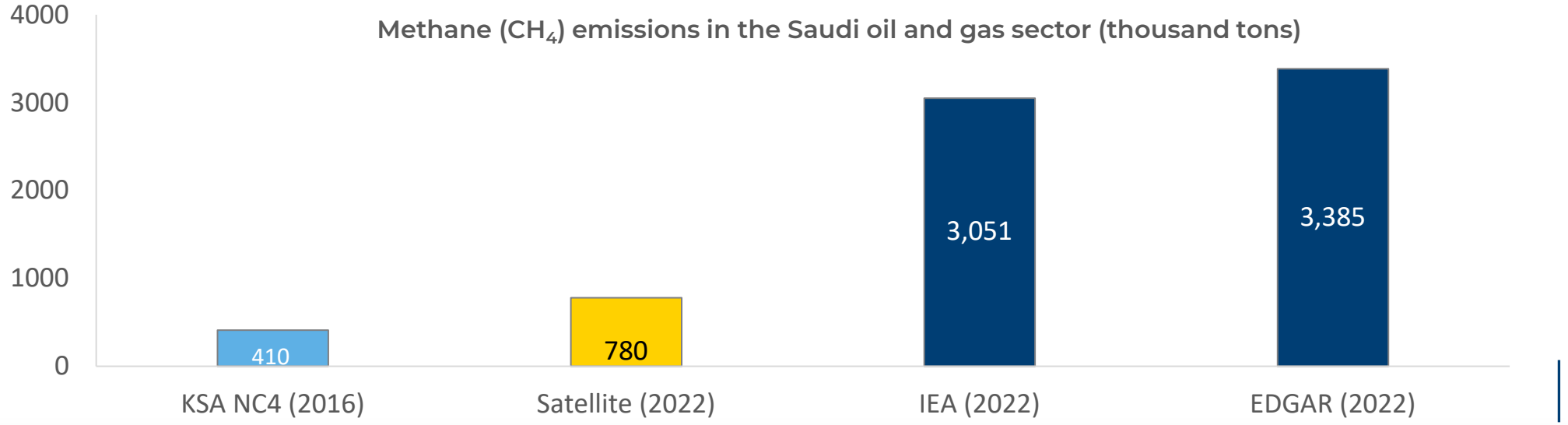
Bottom-3 countries:

Uzbekistan, Iraq, Algeria



Source: Luomi, Yilmaz and Alshehri 2023.

Satellite technology can answer important questions about large discrepancies in emission estimates



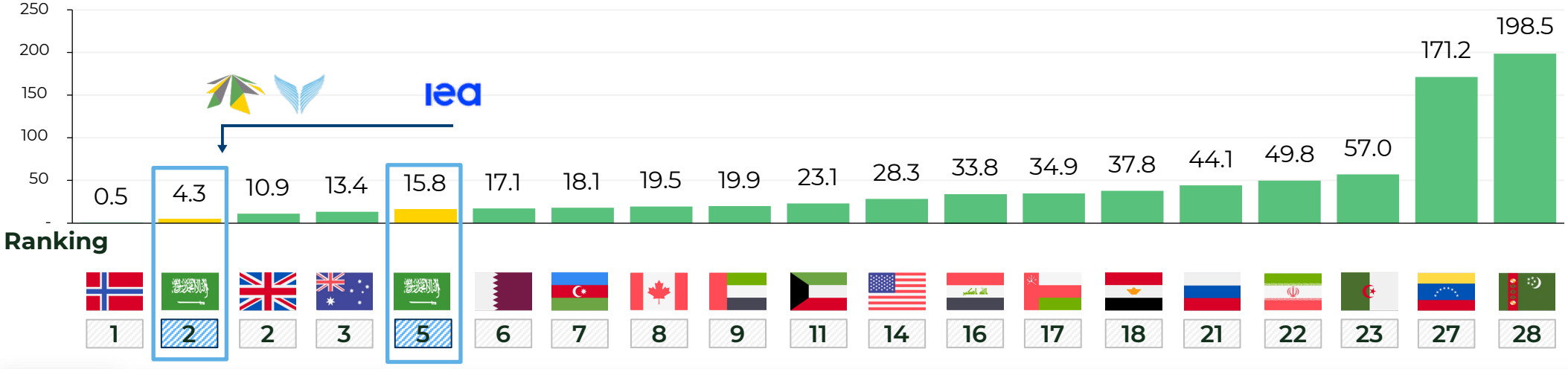
- Using satellites, we estimated methane emissions to be 780 thousand tons in 2022 in the oil and gas sector. Only the KSA NC4 estimate falls within our satellite estimate's uncertainty range
- We are currently expanding our satellite estimation of methane emissions to the UAE, Kuwait, Iraq, and Oman[1], and later will be expanded to the broader MENA region

Source: Gasim et al., 2023. Using Satellite Technology to Measure Greenhouse Gas Emissions in Saudi Arabia. KAPSARC Discussion Paper. Link

[1] We also explored the possibility of expanding our estimation to Qatar and Bahrain, but the very high share of offshore oil and gas fields in those countries makes it very challenging for satellites to detect methane.

Using our satellite estimates, Saudi Arabia improves its standing to the oil-producing country with the second lowest methane intensity

Selected countries ranking by methane intensity* (kg of CO2 equivalent / barrel of oil equivalent)



Satellite estimates yield a 73% decrease in methane intensity versus the intensity value reported by the IEA

KSA improves its ranking to the country with the 2nd lowest methane intensity after Norway

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*Countries included with a total oil and gas production above 1 million boepd; Intensities were calculated using IEA's 2022 methane emissions data and 2022 production data from Rystad

There remain challenges in accurately measuring emissions, with important policy implications

Satellites can help resolve some of these challenges

- We used satellites to measure methane, CO_2, and nitrous oxide emissions in multiple sectors in Saudi Arabia and to monitor “super-emitting events”
- Different measurement methods have different strengths and weaknesses. For example, one key strength of satellite technology is its transparency and timeliness
- Given the trade-offs, our work shows that countries may achieve a much better understanding of GHG emissions by striving to combine bottom-up and top-down methods

→

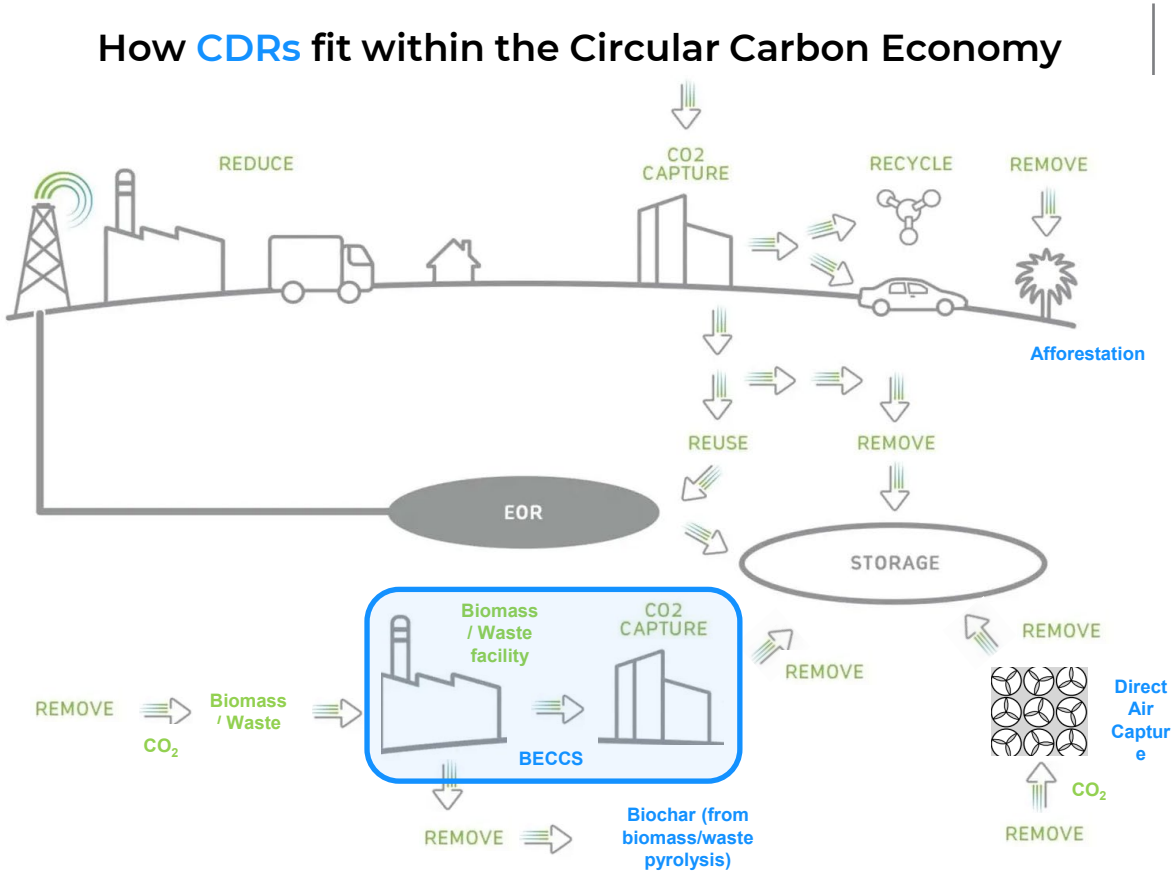
- Better emission measurement
- More effective climate actions
- Successfully achieving climate goals

The Circular Carbon Economy:

Carbon Dioxide Removal (CDR) Technologies & the Case of the Kingdom

CDRs are embedded within the CCE framework

- **Reuse:** capture and utilization of CO_2 (**CCU**) whether for EOR or in manufacturing sustainable products.
- **Remove:** capture and permanent storage of carbon in geological formations (**CCS**).
- **CDR** refers to CCS or CCU applications when the CO_2 is removed *from the atmosphere* (whether *directly* as in afforestation or DAC, or *indirectly* as in BECCS or biochar).
- **IEA NZ scenarios**: 1 Gt CO_2/y of **CCS** are needed by 2030 (including 75 Mt/y DAC and 190 Mt/y of BECCS are needed by 2030) and 6 GT CO_2/y by 2050.
- Current deployment rates significantly fall short of achieving this target due to **significant barriers**



CDRs deployment faces significant barriers

Engineered CDR solutions have significant potential but technical challenges and high costs

Barriers for engineered solutions

Barrier	Details
Technical	❖ The capture and removal of CO_2 requires significant amounts of energy ❖ Complex CO_2 transport and storage infrastructure is needed ❖ New measurement and monitoring procedures are needed
Economic	❖ Very high capital and operating costs and difficulty of obtaining finance ❖ Lack of predictable long-term demand and stable revenue streams ❖ Immature carbon removal markets
Environmental	❖ DAC and BECCS use chemical solvents which, while removing CO_2, could lead to unintended environmental impacts
Policy	❖ Policy to incentivize CDR deployment through financial investment ❖ Regulation to address CO2 transport and storage issues (liability, monitoring, long-term responsibility, ownership, rights of access) ❖ Absence of widely-recognized MRV and CDR certification systems
Non-financial constraints	❖ Availability of equipment and skills in a highly competitive market for such technologies

CDRs in Saudi Arabia – Current Status

- Currently there is no legally binding or separate target for CDR in KSA, but the government is developing a CDR strategy
- Saudi Arabia is a founding member of **Mission Innovation on Carbon Dioxide Removal** launched in 2021
- KSA with Australia are leading the 2023-2026 **Work Plan on Enhanced Mineralization Technical Track** launched at COP28
- The **Greenhouse Gas Crediting & Offsetting Mechanism (GCOM)** launched in 2023 allows offsetting through CDRs
- **CCS is an enabler** for engineered CDRs (9 Mt CO_2/y of CCS by 2027 and 44 Mt CO_2/y by 2035)
- Recent work by KAUST evaluated & characterized **CO_2 storage opportunities**
- Work underway by KAPSARC and KAUST for developing a comprehensive understanding of **CCS clusters** and **CO_2 storage hubs**

Examples of CDR projects in KSA

- Demonstrating onshore enhanced mineralization project in Jizan,
- The Climatree technology (a DAC carbon capture microalgae photobioreactor integrated with a CO_2 scrubber by Aramco)
- A DAC test unit in Dhahran (by Aramco in collaboration with Siemens)
- Mangrove initiatives along the Arabian Gulf coastline
- Saudi Green Initiative commits to planting 10 billion trees and rehabilitating 40 million hectares of land by 2060.
- Development of a DAC Atlas for Saudi Arabia
- Work underway by KAPSARC on assessing feasibility of DAC and energy-from-waste BECCS

Is CCS-EOR a climate change mitigation technology?

- **The status of CCS-EOR as a climate change mitigation technology is often contested** on the grounds that the resulting increase in oil production undermines its environmental benefits
- Through economic analysis, we show that CCS-EOR **is** a climate-change mitigation technology
- We **compare** the size of the **subsidy** in the revised Section 45Q of the 2022 US **IRA** to **our results**
- The paper is open access on the website of The Energy Journal

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Mitigating Climate Change While Producing More Oil: Economic Analysis of Government Support for CCS-EOR

Hossa Almutairi[a] and Axel Pierru[b]

ABSTRACT

By storing CO_2 captured from the atmosphere or point sources into oil fields, carbon capture and storage with enhanced oil recovery (CCS-EOR) increases the fields' output by raising reservoir pressures. Since CO_2-EOR has been experimented with for decades and the revenues from the additional oil production improve projects' economics, CCS-EOR is the most readily deployable CCS technology. However, government support for CCS-EOR projects is sometimes contested on the grounds that the resulting increase in oil production undermines their environmental benefits. Addressing this concern requires determining the effects of implementing CCS-EOR on global CO_2 emissions. This paper presents a simple approach based on a marginal reasoning consistent with economic decision-making. It produces analytical formulas that account for the effects on the global oil market of incentivizing CCS-EOR. In addition, we quantify the volume of oil that can be decarbonized by storing a ton of captured CO_2 through EOR from different perspectives. We produce numerical results based on a first-cut calibration. They suggest that, from an economic perspective that mitigates global emissions. However, after accou bonize the EOR oil, the reduction in emissions is signi quantity of CO_2. If fully allocated to oil production, of capturing a ton of CO_2 and storing it through conv oil producer to decarbonize 3.4 barrels on a well-to-w when offsetting its oil-upstream emissions only. Fisca ernments to support CCS-EOR as a climate-change m be sized accordingly. We compare our findings to th revised Section 45Q of the 2022 United States Inflatio

Keywords: CCS, EOR, CO_2, Displacement, IRA, mar Scope 3

https://doi.o

1. INTRODUCTION

Carbon dioxide enhanced oil recovery (CO_2-EOR) i mature oil reservoirs to make the oil flow more easily to the wel

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