KAPSARC
مركز الملك عبدالله للدراسات والبحوث البترولية
King Abdullah Petroleum Studies and Research Center

Circular Carbon Economy

International CCUS and Hydrogen Symposium

Hosted by Ministry of Energy, Japan

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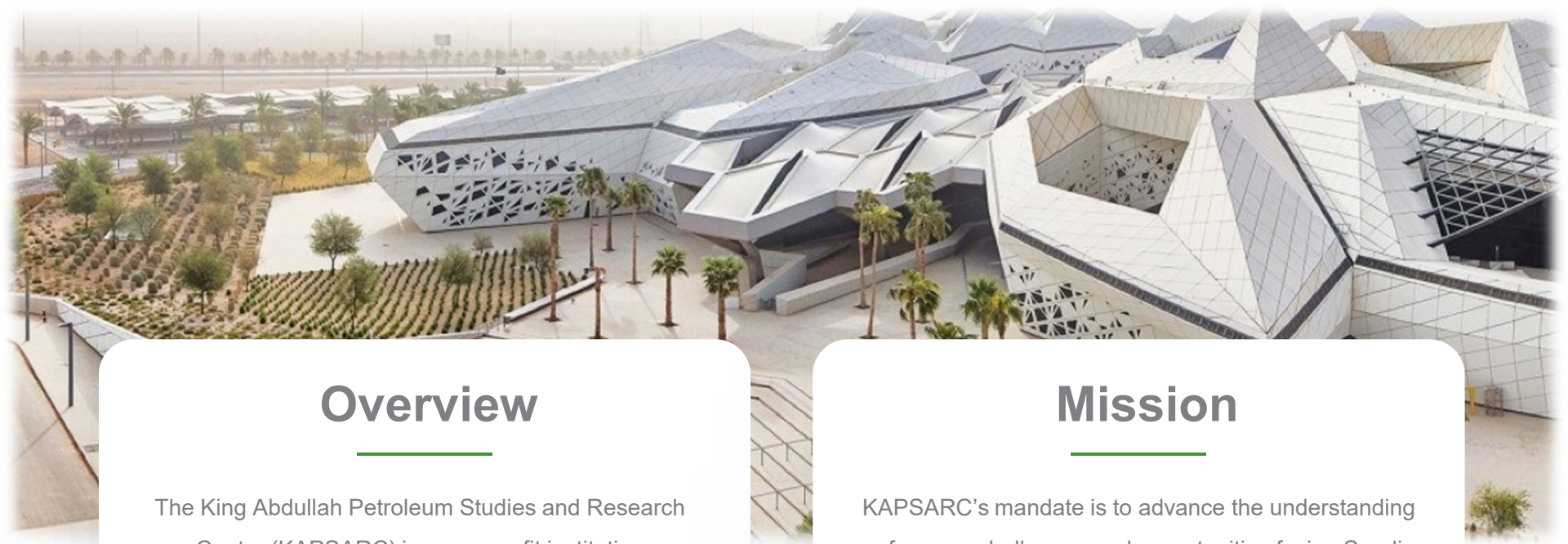


Overview

The King Abdullah Petroleum Studies and Research Center (KAPSARC) is a non-profit institution dedicated to independent research into energy, economics, policy, technology, and the environment

Mission

KAPSARC's mandate is to advance the understanding of energy challenges and opportunities facing Saudi Arabia and the world, through fact-based research that informs high-quality energy policy decision making


80
Researchers
45
Ongoing Projects
88+
Journal articles
155+
Online publications
1100+
Open data sets
140
Professional Staff
22
Nationalities
30%
Women
KAPSARC Today

Collaborations and partnerships

National partners and collaborators

International partners and collaborators

Circular Carbon Economy (CCE)

CCE importance to mitigate the climate challenge

CCE concept and CCE Guide

G20 endorsement

KSA progress in adopting the CCE framework

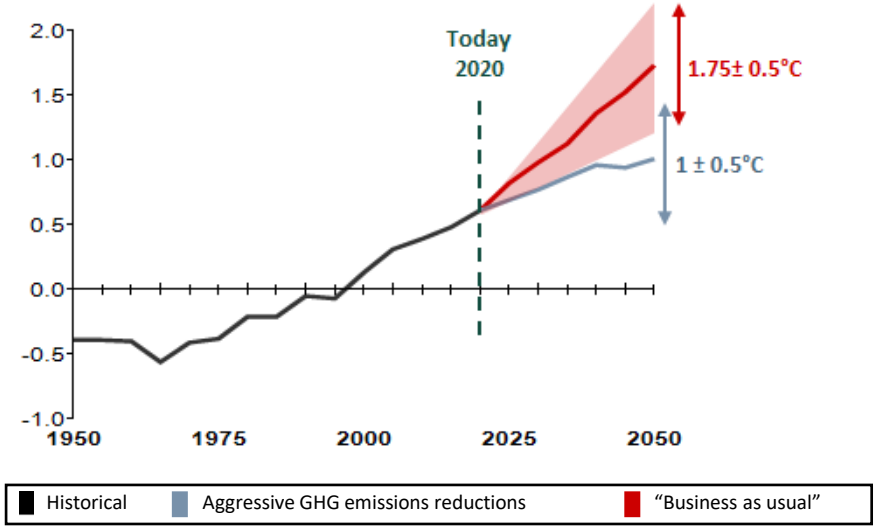
Climate change has become a key area of focus globally as a result of rising temperatures

Temperatures have risen ~1°C since mid-20th century

Scientific community has declared major problems if aggressive emission reductions are not taken

Global leaders have pledged to limit the global temperature rise this century to well below 2°C above pre-industrial levels

Global average surface temperature change (°C)[1]



As a result Saudi Arabia developed the Circular Carbon Economy Framework

Narrow focus on only reducing fossil fuels will result in significant socio-economic consequences

Inefficient utilization of existing infrastructure

- Inadequate utilization of **infrastructure investments already committed** e.g.:
  - Ports
  - Pipelines
  - Power plants
- Significant **cost and time in switching to new energy sources**
  - E.g. Fully renewable grid to cost United States $4.5 trillion over next 10 years

Reduced energy access and reliability

- **Increase in overall energy costs** since renewable energy and low carbon fuel sources are not always commercially viable
- **Deterioration of energy reliability** as a result of depending heavily on renewable sources
  - E.g. California blackouts (summer 2020)
- **Major impact on developing countries** that require affordable and reliable energy access

No practical solutions for hard to abate sectors

- Few cost efficient **emissions reduction solutions** for energy-intensive **hard to abate sectors** e.g.:
  - Aviation
  - Shipping
  - Cement
  - Aluminum

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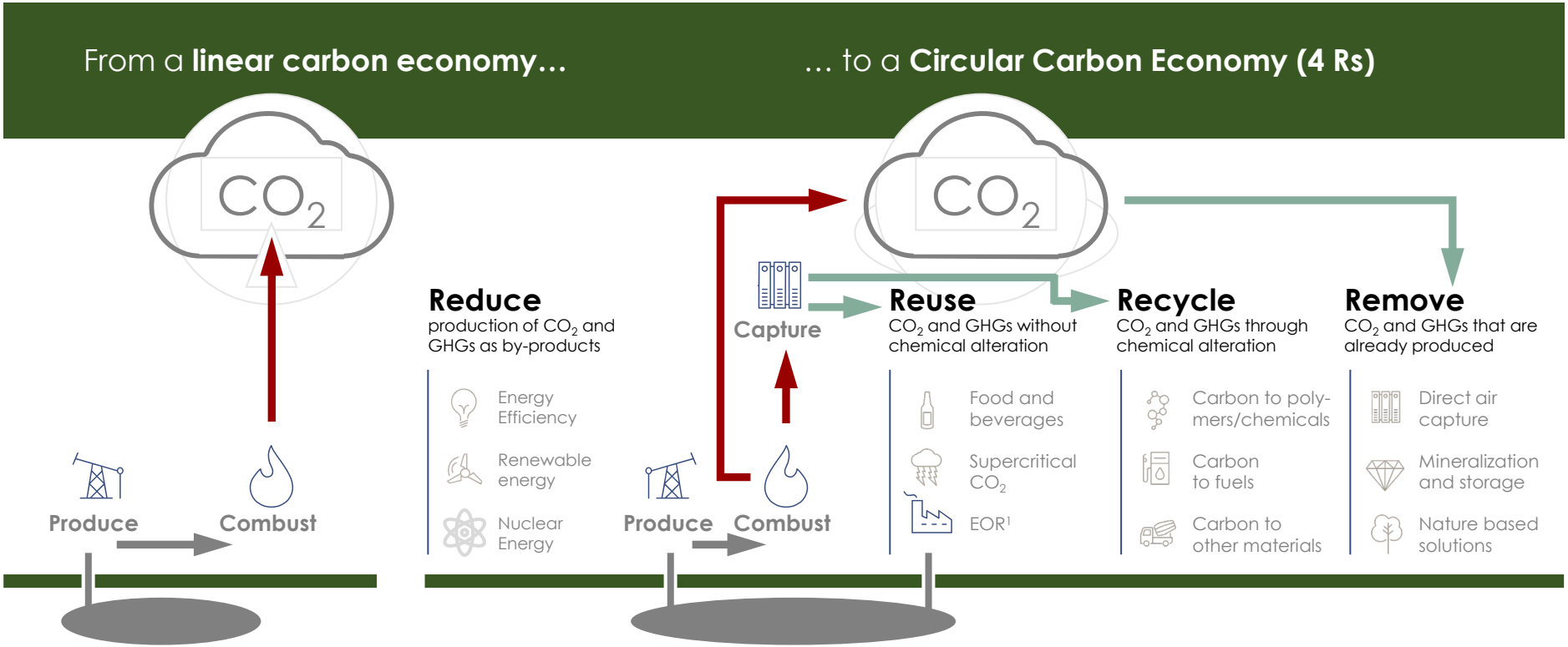
Circular Economy ⟶ Circular Carbon Economy

	Circular Economy	Circular Carbon Economy
	 Reduce  Reuse  Recycle	 Reduce  Reuse  Recycle  Remove
What	Framework for sustainable production and consumption	Framework for climate mitigation valuing all options
Scope	Resource and material flows	Energy and carbon flows
Goal	Minimize resource consumption / waste disposal	Manage GHG emissions (including CO2) toward balance

CCE is a holistic approach, that utilizes all available levers to address CO2 emissions while generating value



Note: [1] EOR: Enhanced Oil Recovery

Key elements of the CCE framework

- The Circular Carbon Economy (CCE) is a holistic approach to carbon management that can guide domestic and international efforts toward a more inclusive, resilient, sustainable and carbon-neutral / net-zero energy system

- CCE provides a useful way to understand a broad range of climate change mitigation options and how they interconnect; CCE reveals how choke points in any one of the Rs – reduce, reuse, recycle and remove – can make carbon flows in the system unmanageable if a key technology is under-represented or unavailable

- CCE shows that hydrocarbons can continue to play an important role even with a transition toward net zero as long as CCUS technologies are deployed, and recycle and reuse options are incentivized

Guide to the Circular Carbon Economy www.cceguide.org

- KAPSARC engaged **leading International Organizations** to write a series of reports on carbon management that form the CCE Guide
- The CCE Guide series provides **practical information for policymakers** to understand the **challenges and opportunities** presented by each element within the CCE
- The Guide illustrates the **degree to which each CCE element can contribute to climate goals** while also pursuing an improved quality of life

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Summit Leaders from the Group of 20 countries (G20) endorsed the "Circular Carbon Economy" 4 Rs platform to reduce carbon emissions

32. We endorse the Circular Carbon Economy (CCE) Platform, with its 4Rs framework (Reduce, Reuse, Recycle and Remove), recognizing the key importance and ambition of reducing emissions, taking into account system efficiency and national circumstances. The CCE is a voluntary, holistic, integrated, inclusive, pragmatic, and complementary approach to promote economic growth while enhancing environmental stewardship through managing emissions in all sectors including, but not limited to, energy, industry, mobility, and food. We acknowledge, in this context, the various voluntary opportunities and their acceleration highlighted by the CCE Guide. We acknowledge the Presidency Reports of the Climate Stewardship Working Group that can be utilized as a toolbox in addressing sustainability including climate change in the context of national circumstances. We also acknowledge the importance of fostering synergies between adaptation and mitigation, including through nature-based solutions and ecosystem-based approaches.

G20 SAUDI ARABIA 2020

Leaders' Declaration

G20 Riyadh Summit
November 21 - 22, 2020

7. We acknowledge the work led by the King Abdullah Petroleum Studies and Research Center and the valuable contributions from the various international organizations (International Energy Agency, the International Renewable Energy Agency, the Nuclear Energy Agency, the Organisation for Economic Co-operation and Development, and the Global CCS Institute), which spelled out the various opportunities offered by the CCE approach and its 4Rs as indicated in the "CCE Guide" that could be considered in accordance with national circumstances.

G20 SAUDI ARABIA 2020

G20 Energy Ministers Communique

September 27 - 28, 2020

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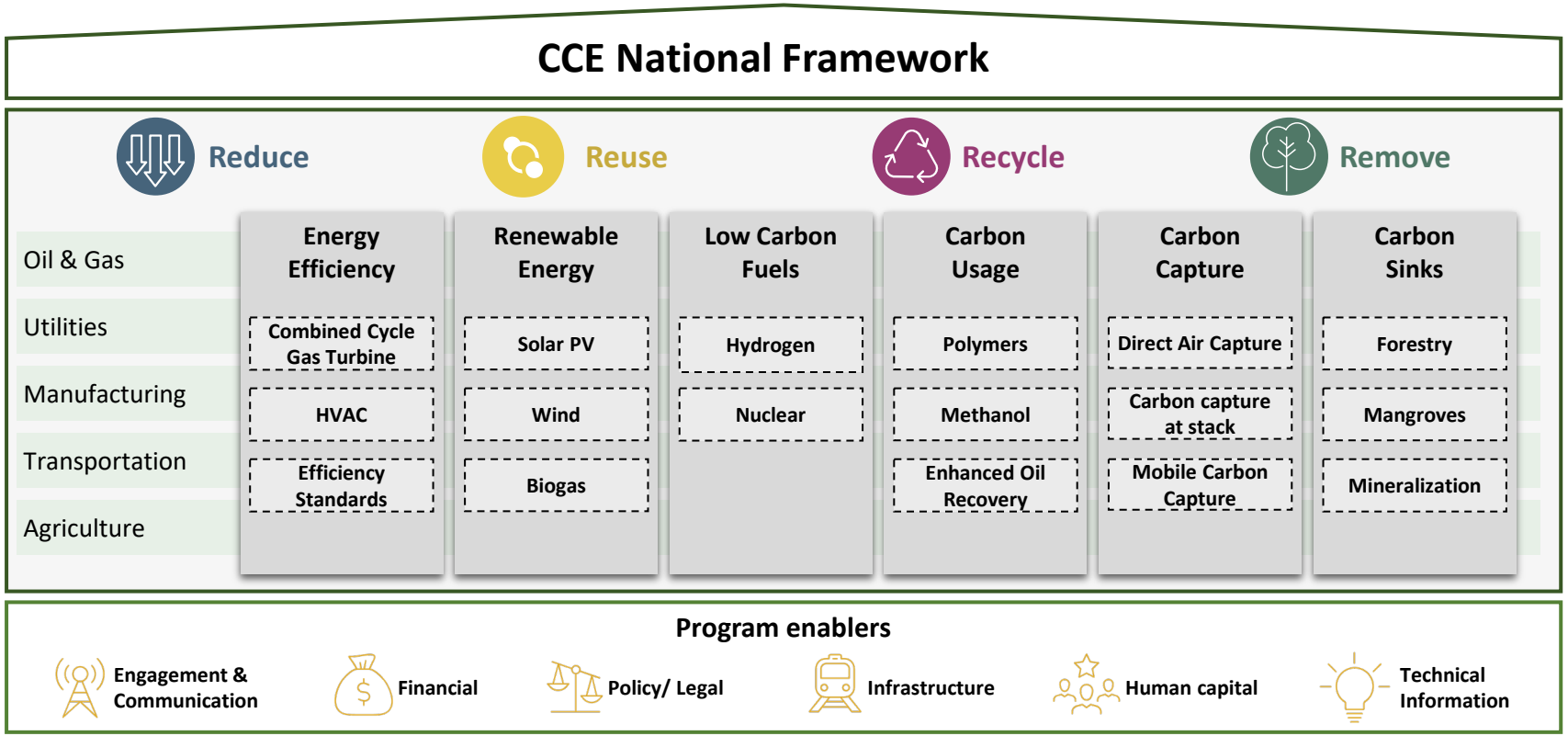
CCE framework can drive support and adoption domestically and globally



The CCE Program has three broad goals

Climate protection

- **Cost-efficiently abating CO_2 emissions** as a result of deploying CCE applications
- Ensure **all possible levers available for CO_2 abatement are utilized**

Socio-economic impact

- **Capture value from waste CO_2** released in the atmosphere
- **Promote new industries** based on CCE technology that will **contribute to GDP upliftment and employment generation**

Global leadership

- **Accelerate global adoption of the CCE program** via intl. advocacy and communication
- **Reinforce KSA "soft power" and leadership** on climate change globally

Evaluation of possible enabling mechanisms for CCE investments

Decision criteria	Investment category	Typical use case
Encourage large scale deployment	Industry commercial investment	Investments with commercial returns
Incentivize innovation	Emissions regulation with carbon trading	Technology agnostic national emissions reduction
Minimize government investment	Incentives	Deployment of strategic technologies
Increase industry competitiveness	Public private partnership	Applicable for CO2 infrastructure with business case
Minimize system wide abatement cost	Government investment	Deployment of infrastructure with limited business case

Hybrid options could combine multiple enabling mechanisms

Strategic priorities for the CCE national program going forward

Technology deployment

Pilot and deploy prioritized CCE initiatives (e.g. CCUS, Hydrogen, CO_2 reuse/ recycle)

Policies and funding

Design regulatory framework for emissions management and activate policy/ incentives for specific use cases

Research & Development (R&D)

Align R&D priorities to identified strategic CCE technologies and coordinate implementation between domestic stakeholders

International engagement

Setup intl. engagement initiatives (e.g. G20 and COP26, CCE event, website) including partnerships for scale-up/ R&D tech.,

Several ongoing and planned initiatives in the Kingdom across all 4R levers: Reduce, Reuse, Recycle, Remove

Reduce

- Hydrogen production and e-fuels
- NEOM Innovation & Commercialization Hub
- Liquid fuel displacement

Reuse

- Enhanced oil recovery
- CO_2 to cement products
- Composting Facilities

Recycle

- CO_2 to feedstock (urea and methanol)
- CO_2 to Olefins
- Converge Polypropylene Carbonates

Remove

- Cost effective carbon capture
- Tree plantation drive
- Mobile Carbon Capture

Carbon capture is a critical technology to enable reaching the climate goals

Carbon capture is recognized as a critical technology to address the climate change

"2 degrees, let alone 1.5 degrees, **cannot be met without carbon capture** and the best climate science available was continuing to support that fact"

ipcc
INTERGOVERNMENTAL PANEL ON climate change

"Reaching net zero will be virtually impossible without CCUS"

iea

"[…], **without CCUS** technologies the cost of **meeting** ambitious **climate change targets** will **increase by ~140%** worldwide"

UNITED NATIONS

Key benefits

- Reduces **process emissions** not **addressable** by other measures (e.g., energy efficiency and renewables)
- Reduces emissions from **hard to abate sectors** (e.g., cement); for some sources, carbon capture is the only technological option to tackle emissions
- **Enables sustainable economic development** by ensuring **continued use of low cost energy sources** without adversely impacting the environment

KSA has significant potential storage capacity across the country

KSA geological storage suitability

Highly suitable, sedimentary basins or continental margins

Suitable, sedimentary basins or continental margins

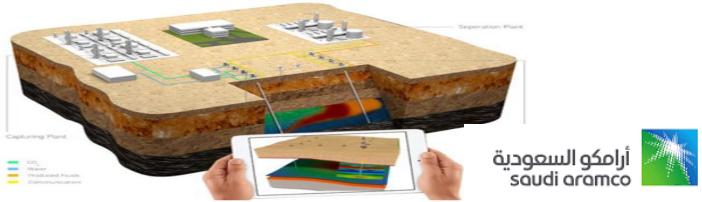
Key insights

According to geological surveys, large areas in KSA are highly suitable for CO_2 storage

Experts estimate that KSA has about 90% of the deep saline formations in the Middle East

KSA has the potential to take a broad, large-scale CCS deployment approach as an option to address CO_2 emissions

Saudi Arabia has two operational carbon capture projects

	Hawiyah carbon capture project	Carbon capture and purification project
		
Overview	• Pilot program at **Hawiyah NGL capturing and injecting CO_2** at Uthmaniyah (EOR)	• World largest **CO_2 capture and purification facility**, capturing CO_2 from the production of ethylene glycol that would otherwise be emitted into the atmosphere
CO_2 captured	• **0.8M metric tons p.a. of CO_2**	• **0.5M metric tons p.a. of CO_2**
CO_2 utilization	• **Captured CO_2 is piped** 85km to the Uthmaniyah oil field **and injected into the oil reservoir**	• Supplying CO_2 for conversion into valuable chemicals (urea, methanol) and applications in the F&B industries

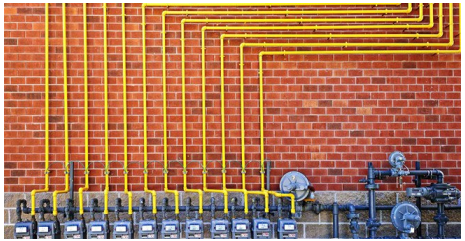
Hydrogen can play a major role in energy transition given the wide range of potential applications

Feedstock/Industrials

- H2 is primarily used as a feedstock for Agri-Nutrients (e.g. ammonia) and chemicals (e.g. methanol) production and in refineries to process crude oil into refined fuels
- There are smaller scale applications of H2 in other industrial fields (metalworking, electronics), and pilot projects to use H2 in DRI steel production

2020 demand, mt

Power and Heat



- H2 can be stored for extended periods of time, and then used to balance supply/demand fluctuations of other energy sources and as reliable back-up power
- H2 can replace natural gas used as a heat source (in commercial/residential uses, and high-temperature industrial processes)

2020 demand, mt

Transport

- H2 is used in fuel cells to produce electric power – currently small scale only, future applications most likely for high-density mobility (HDVs, bus, rail)
- There is also long-term potential for hydrogen to be used in synthetic fuel production (for use in traditional ICEs)

2020 demand, mt

Note: DRI = Direct reduced iron, HDV = heavy-duty vehicles (i.e. shipping trucks, construction machinery), ICE = internal combustion engine, Source: IRENA

One of the world's largest green hydrogen projects being developed at NEOM

- **Partners:** Air Products & Chemicals and ACWA Power ($5bn partnership, equally owned)
- **Input:** 100% renewable energy
  - **4 GW of electricity** from wind and solar projects
- **Output:**
  - **230k ton/ year of hydrogen**
  - Equal to **1.2M ton/ year of green ammonia**
    - > Alkaline technology
    - > Air Products will be the exclusive off-taker of ammonia
    - > It intends to transport it around the world to produce green hydrogen for the transportation market
  - Production used to power NEOM and to be sent abroad
- **Timeline:** operational in 2025

Major milestone in demonstrating the KSA commitment in CCE

Is the world's first shipment of 40T of blue ammonia

Overview

MoEnergy signed **a memorandum of cooperation with the Japanese Ministry of Economy, Trade and Industry in Sep. 2016 to export Hydrogen to Japan**

Saudi Aramco, the Institute of Economics of Japan (IEEJ) and **SABIC** partnered to study the **possibility of producing blue ammonia**

The **Hydrogen exported will be used for power generation** in Japan, that will be emissions free

These efforts led to the **production and export of 40T of blue ammonia** from KSA to Japan in **Sep. 2020**

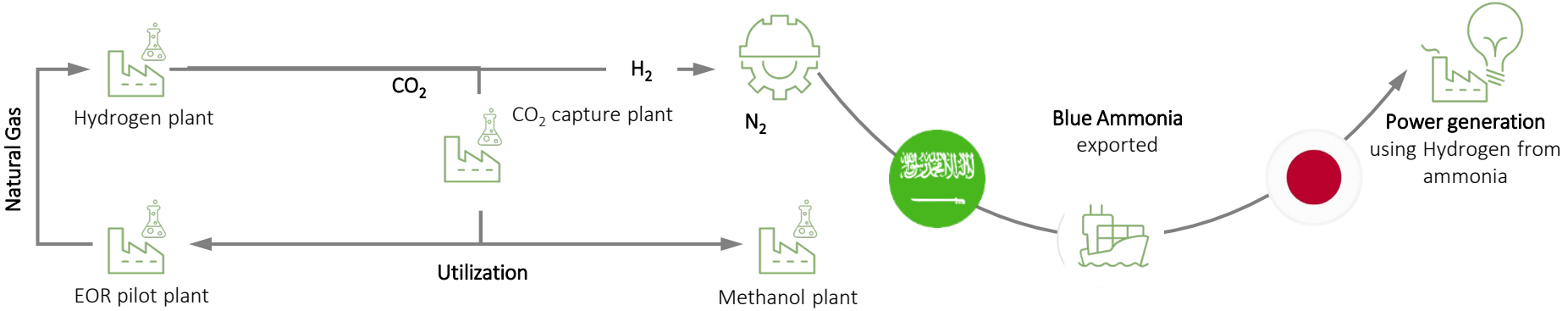
Stakeholders

Gov. entities	Research Institutes	Industry leaders
وزارة الطاقة MINISTRY OF ENERGY	IEE JAPAN	أرامكو السعودية saudi aramco
METI Ministry of Economy, Trade and Industry		سابك sabic

A significant step towards a sustainable hydrogen usage demonstrating the circular carbon economy

The first blue ammonia cargo of 40 mt has been shipped from Saudi Arabia to Japan to be used for power generation, with **30 mt of the CO_2 captured during the process designated for use in methanol production at SABIC's Ibn-Sina facility**, and another **20 mt of captured CO_2 in the process being used for Enhanced Oil Recovery at Aramco's Uthmaniyah field**.

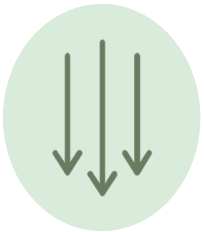
Supply Network Overview



Under Review:
Stationary CCS has a strong rationale for implementation in KSA

Meet global GHG reduction ambition

Meet **global emissions abatement ambitions** set during **Paris agreement**



Decarbonize hard to abate sectors

Stationary CC remains **the only technology** that can deliver **deep emissions reductions in hard-to-abate industrial sectors** such as steel, fertilizer and cement

Support KSA vision 2030

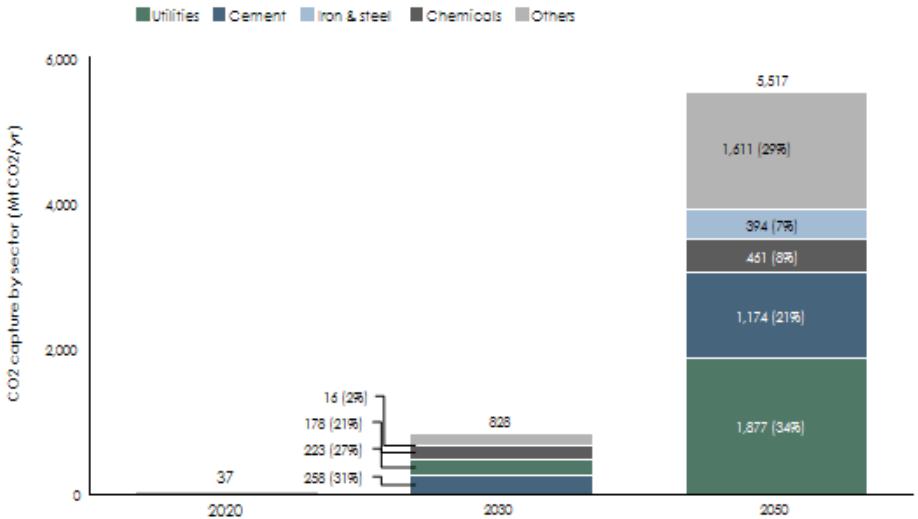
Enable new industries thus supporting vision 2030 objective of **diversifying the economy and creating jobs**

CC know how and storage capacity

KSA has **local expertise in carbon capture technologies** (2 operational projects) and **cost advantage** implementing CC vs other countries

KSA has **locations applicable for CO_2 storage**

Stationary carbon capture has significant abatement potential of ~0.8 Gt by 2030 and 5.5 GT by 2050



Key insights

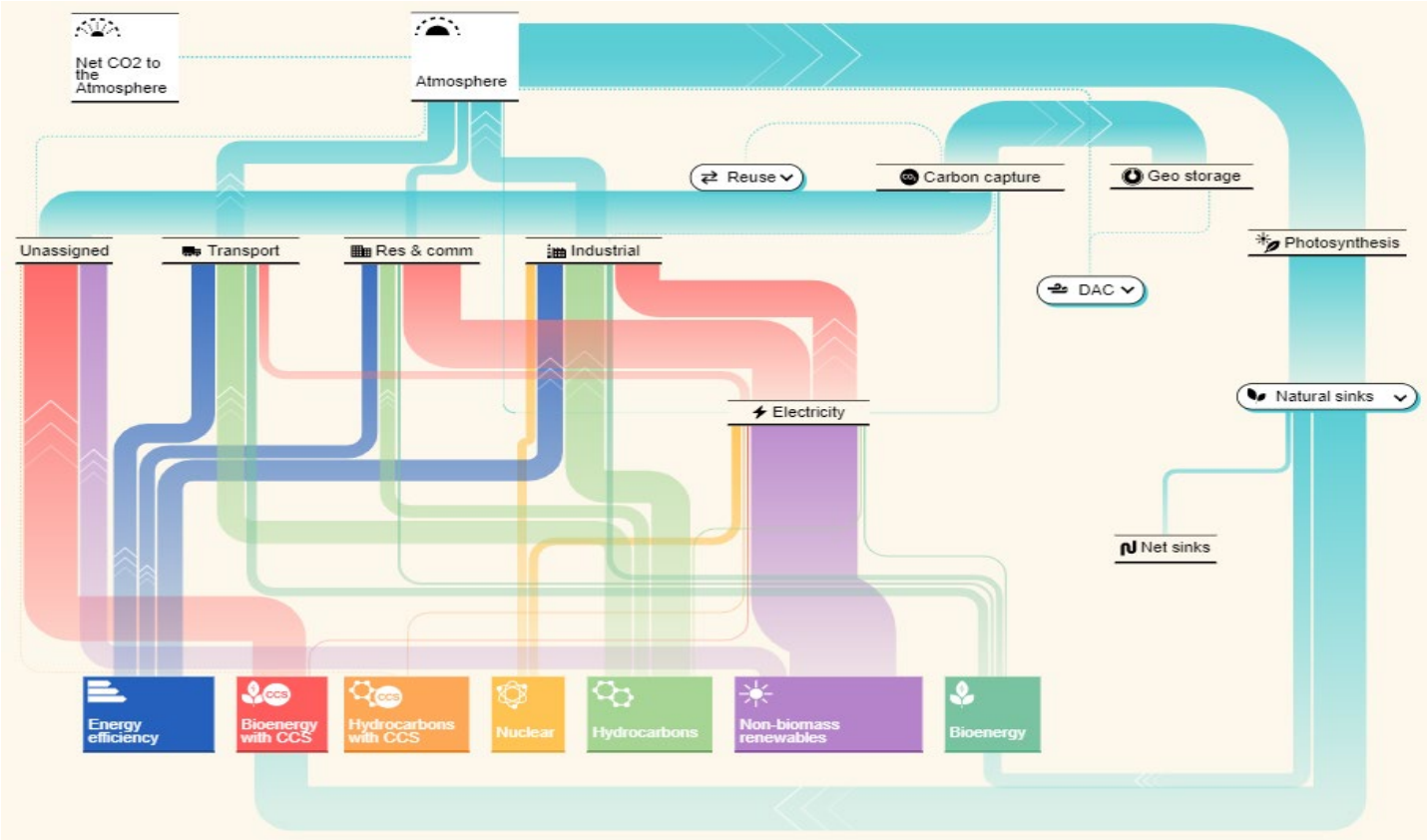
In 2050 in the Sustainable Development Scenario, 5.5 $GtCO_2$ is captured and stored/ used

The power sector accounts for around ~35% of the captured CO_2 in 2050

Around one-third of the CO_2 captured is in heavy industries, where emissions are hard to abate in other ways

Note: Others=fuel transformation sector to produce hydrogen and ammonia from fossil fuels as well as CO2 captured from biofuel plants, used to make synthetic fuels or stored for carbon removal; Source: Sustainable Development Scenario (SDS), IEA;

Thank You



CCE Visualizer
www.cceguide.org