A Guide to the 
Circular Carbon Economy
Payne Institute
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circular carbon economy
A holistic approach to Carbon Management

The Circular Carbon Economy can guide international efforts toward a more inclusive, resilient, sustainable, and carbon neutral or net-zero energy system.

Read the guide
Experts largely agree that the challenge of achieving the Paris Agreement climate goals requires the pursuit of all options that can manage greenhouse gas (GHG) emissions. Carbon dioxide is one of those GHGs. The global energy mix needed for a carbon balance, or net-zero, or carbon neutrality includes all sources of energy (including hydrocarbons). The resulting carbon emissions from this energy mix must be managed. The Circular Carbon Economy is an extension of the idea of the Circular Economy. CCE is a useful framework for understanding how carbon can be managed and for visualizing how carbon mitigation options are interrelated.
## CCE Guide – Background

<table>
<thead>
<tr>
<th></th>
<th>Circular Economy</th>
<th>Circular Carbon Economy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What</strong></td>
<td>Reduce, Reuse, Recycle</td>
<td>Reduce, Reuse, Recycle, Remove</td>
</tr>
<tr>
<td><strong>Scope</strong></td>
<td>Framework for sustainable production and consumption</td>
<td>Framework for climate mitigation valuing all options</td>
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<tr>
<td><strong>Goal</strong></td>
<td>Minimize resource consumption / waste disposal</td>
<td>Manage GHG emissions (including CO2) toward balance</td>
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Circular Carbon Economy – Flows

Reduce

Reuse

Recycle

Remove

Circular Economy

Blue Hydrogen

Green Hydrogen

Hydrocarbons

Non-bio renewables

Nuclear

Bio-energy

Energy Efficiency

Biomass

Natural sinks

Photo-synthesis

DAC

Carbon capture

Geologic Storage

Carbon utilization
• The **Circular Carbon Economy** (CCE) is an integrated and inclusive approach to transitioning toward more comprehensive, resilient, sustainable, and climate-friendly energy systems that support and enable sustainable development.

• A pathway to the Paris Agreement’s climate goals should include all options: including non-biomass renewables, efficiency / demand reduction, nuclear energy, bioenergy, and CCUS.

• The energy mix for scenarios underpinning the IPCC 1.5 degree report that result in a less than 2 degree C increase:
  - All renewables including bioenergy: 34% to 98% share (64% average)
  - Energy efficiency / demand reduction: 21% to 35% share
  - Nuclear: 7% average share
  - CCS: 24% average share

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**Scenarios**

- Hydrocarbons w/o CCS
- Biomass w/o CCS
- Nuclear
- Hydrocarbons & Biomass w/ CCS
- Non-biomass renewables
• **Energy Efficiency** is the largest factor in global energy intensity improvement between 2018 and 2019

• IEA modelling shows the potential of existing technologies to deliver an annual energy intensity improvement rate of 3.6%, if fully deployed. This would provide around 40% of the GHG emissions abatement required by 2040 to be in line with the Paris Agreement

• In 8 of the last 9 years, however, global energy intensity has failed to reach the 3% improvement needed for sustainable development goals; recent years were well below this goal

• With ambitious policies and strong incentives, and by encouraging private-sector leadership, gov’ts can accelerate uptake of efficient technologies
• **Non-bio Renewables:** IRENA concludes that renewables plus energy efficiency can achieve over 90% of the energy-related carbon emission reductions needed to meet the Paris Agreement’s climate goals
• Solar PV and wind are increasingly the lowest-cost electricity generating options in many markets
• The variability of renewable energy generation can be addressed through several solutions, such as utility-scale batteries, heat pumps and smart grids
• IRENA envisions that 80% of the investment in the energy system through 2050 will be in renewables, energy efficiency, end-use electrification and power grids and flexibility
• IRENA sees ambitious targets as key to driving markets and innovation, complemented by support measures like pricing and competitive procurement, capital grants, tax exemptions, and investment subsidies
**Nuclear:** The Nuclear Energy Agency (NEA) states that by 2040, nuclear capacity is expected to increase by 35% from today’s levels; this translates to a doubling of the current annual rate of capacity additions.

- Reaching this increased deployment of nuclear power requires the “long-term operation (LTO) of existing nuclear power plants, new nuclear builds of large Gen-III reactors and... emerging technologies such as SMRs”

- The NEA states that on a megawatt (MW) to MW basis, nuclear power avoids twice as much carbon dioxide (CO2) as offshore wind and three times as much as solar PV.

- By 2050, the NEA states that nuclear power can avoid over 2 gigatonnes (Gt) of CO2 per year.

*Figure 19: CO2 emissions avoided by nuclear power in the IEA SDS scenario in 2040*
• **Carbon Reuse:** The International Energy Agency (IEA) states that new technologies that convert CO2 into fuels, chemicals and building materials are needed to expand CO2 use from today’s 230 MT/year

• Producing synthetic hydrocarbon fuels and chemical intermediates is energy-intensive and costly – currently between US$ 200- 650 per barrel

• Using CO2 in building materials is less energy intensive and provides a form of CO2 storage

• Verifying emission reductions will be central to carbon management

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**Figure 2.** Breakdown of global demand for CO2 (2015).

• **Bioenergy:** According to IRENA, in 2017, bioenergy represented 70% of the global renewable energy supply and 10% of the total primary energy supply.
• Modern bioenergy could supply 23% of primary energy in 2050 under the climate-friendly transforming energy scenario
• Bioenergy can be used in various ways within the circular carbon economy, including as a fuel and as a feedstock that can replace fossil fuels in end-use
• Bioenergy can also be used to generate electricity and can contribute to balancing an electricity grid with a significant share of variable renewables
• Bioenergy in combination with CCS offers a prospect of negative emissions
• IRENA concludes that bioenergy can avoid about 2.6 GtCO2 per year by 2050
• **CCS:** The Global Carbon Capture and Storage Institute (GCCSI) reports that 19 commercial CCS facilities are currently operating, three are under construction, and 36 are in development.

• Each of these facilities will store between hundreds of thousands and millions of tonnes of CO2 per year.

• To date, 260 mega tonnes of CO2 (MtCO2) have been stored permanently in geological formations.

• Continued improvements in CCS technology halved capture costs for power stations over the past decade, with the next generation of technologies promising even lower costs.

• The lowest-cost opportunities for CCS can deliver multi-million tonne CO2 abatement at a single facility, at a cost of less than US$ 20 per tonne.

• IPCC estimates of a cumulative geologic storage potential of over 1,200 GtCO2 this century.
• **Hydrogen:** According to the IEA, 75 Mt of pure hydrogen is produced globally, with another 45 Mt of hydrogen mixed with other gases. This releases more than 800 MtCO2 to the atmosphere. For hydrocarbon-derived hydrogen to be a key part of the CCE, the CO2 must be captured and stored.

• “Green hydrogen” can be produced via electrolysis powered by renewables.

• IEA says hydrogen is versatile. It can be used to produce a variety of synthetic fuels, many of which are compatible with existing energy infrastructure.

• End-use applications: heavy-duty vehicles and freight, maritime shipping, and aviation, hard-to-abate industrial applications, heat, power generation (for temporary energy storage and load balancing).

• IEA says hydrogen used in place of natural gas in electricity peaking could reduce global emissions by 220MtCO2 per year.
• **Enabling Policies:** The OECD points out the need for more specific policies for reuse and remove that provide for a ‘robust revenue stream’ along the value chain of capture, transport and use/storage of carbon

• Financing costs are a barrier. Governments can help reduce finance costs “through short-term guarantees during the construction phase, through public-private partnerships or blended finance, and through international collaboration and sharing of experience in financing and creating markets for CCUS”

• Technology innovation is crucial

• Governments can help drive R&D through leveraging public partnerships between universities and private sector research efforts
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.

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

The CCE Guide report 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 may be able to contribute to climate goals while also pursuing an improved quality of life.
from
Circular Carbon Economy Guide
to
CCE National Program
KAPSARC survey to gather ongoing and planned CCE initiatives in Saudi Arabia

<table>
<thead>
<tr>
<th>Stakeholders</th>
<th>Initiatives</th>
<th>Ready to implement</th>
<th>Research-based</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>190</td>
<td>39</td>
<td>43</td>
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**Government entities / ministries**

**Research institutes and Giga cities**

**Companies**
<table>
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<tr>
<th>Initiative</th>
<th>Description</th>
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<tr>
<td>CO2 to Olefins</td>
<td>Using CO2 as feedstock to produce ethylene and propylene through dry Reforming, Single-Step DME and XTO processes.</td>
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<tr>
<td>CO2 to feedstock (urea and methanol)</td>
<td>SABIC captured and utilized 2,200 KTA of CO2 as feedstock for urea and methanol production.</td>
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<td>Tree plantation drive (~49M trees planted)</td>
<td>MEWA-led Kingdom wide tree plantation drive in partnership with major public sector entities.</td>
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<td>Enhanced oil recovery</td>
<td>Captured CO2 in Hawiyah NGL plant used for EOR in Uthmaniyah oil field.</td>
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<tr>
<td>Composting Facilities</td>
<td>Transform ~1.2 MT of organic waste material into compost structural material.</td>
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<td>Saudi CAFE Standard</td>
<td>Set the fuel economy performance requirements for all light-duty vehicles.</td>
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<td>Smart meters program</td>
<td>Installation of 10M smart meters in Kingdom that will be key in improving energy efficiency in homes.</td>
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<tr>
<td>Hydrogen and e-fuels production</td>
<td>Green hydrogen production plants and e-fuels hub at NEOM by 2022.</td>
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<tr>
<td>Cost effective carbon capture</td>
<td>Metal organic framework (MOF) largest surface area of any molecule (~11K m²/gm) and can be used to store CO2.</td>
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## Initiatives underway or ready to go (2/2)

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<tr>
<th>Wave I</th>
<th>Reduce</th>
<th>Reuse</th>
<th>Remove</th>
<th>Recycle</th>
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<tr>
<td><strong>Hydrogen and e-fuels</strong></td>
<td>Transition the Kingdom to become a leading producer, consumer and exporter of synthetic fuels (e-fuels).</td>
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<td><strong>Renewable plus storage</strong></td>
<td>Technology configuration that allows the use of Flow battery coupled with renewable energy source to generate electricity</td>
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<td><strong>Liquid fuel displacement</strong></td>
<td>Convert Yanbu 3 From Liquid fuel oil to natural gas, thereby reducing CO2 emissions by 25%</td>
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<td><strong>SWCC Energy Efficiency</strong></td>
<td>SWCC aims to improve the efficiency of assets used by SWCC; and Increased environmental commitment</td>
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<td><strong>Polypropylene Carbonates</strong></td>
<td>A technology that allows for co-polymerization of CO2 and proplyene to produce high-grade polyols</td>
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<td><strong>Energy efficiency enhancement</strong></td>
<td>Undertaking set of energy efficiency enhancement projects that resulted in GHG reduction</td>
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<td><strong>Mobile Carbon Capture (MCC)</strong></td>
<td>MCC is an Aramco pioneered technology - CO2 is separated and removed from vehicle exhaust</td>
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<td><strong>NEOM Innovation and Commercialization Hub</strong></td>
<td>The hub will produce green hydrogen and green methanol, including the direct air capture of CO2</td>
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<td><strong>CO2 to cement products</strong></td>
<td>Technology uses precast concrete curing process using CO2 as curing agent</td>
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<td><strong>Octane demand</strong></td>
<td>Downsized super-charged engines became a standard for automakers to comply with the emission standards.</td>
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Thank you

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