Circular Carbon Economy

Research & Development

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Introduction

Climate change mitigation focused mainly on faster deployment of renewables and replacement of hydrocarbons in the power and transportation sectors. However, global emissions are still growing and greenhouse gas (GHG) concentrations are still at high levels. It seems the current approach is not working.

Mitigation strategies should consider practical and effective solutions that create a holistic approach and make use of all the opportunities for solving this issue. This approach would accommodate a diverse energy mix of renewable and traditional fuel sources, would lessen atmospheric levels of GHGs, while also sustaining economic growth and prosperity.

As important as renewables are, and as much progress as they have made in recent years, few analysts believe that the world can achieve the Paris Agreement's goal of a balance between sources and sinks by 2050 through renewables alone. The global path toward a carbon balance will inevitably include fossil fuels, and their carbon emissions must be managed. The concept of the circular carbon economy, an outgrowth of the idea of the circular economy, is a useful framework for understanding how all carbon mitigation options can be linked together in a system that achieves the climate goals laid out in the Paris Agreement.

Circular Carbon Economy (CCE) offers a new way of approaching climate goals that implicitly values all options and encourages all efforts to mitigate carbon accumulation in the atmosphere. The circular carbon economy extends the concept of a circular economy (reduce, reuse, recycle) by including remove and focusing exclusively on carbon and energy flows.

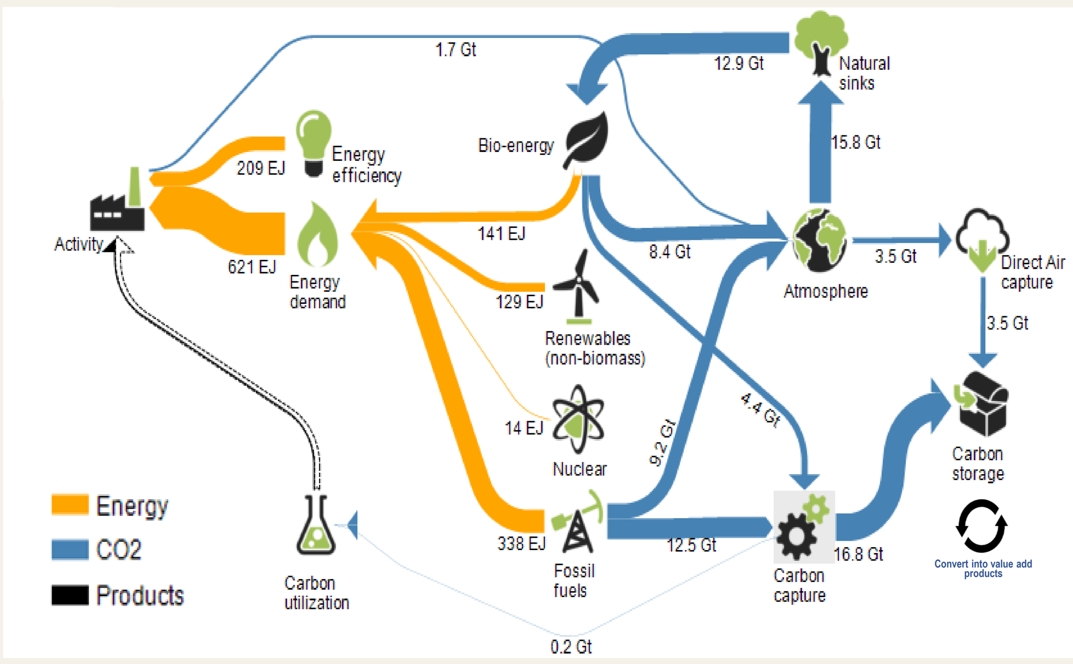

Fig 1: Circular Carbon Economy Chart.

Source: TERI 1.5D low carbon transportation policy scenario; International Energy Agency; KAPSARC analysis.

4 Rs

Reduce Recycle Reuse Remove

The four Rs of the circular carbon economy serve as categories of mitigation options, while the three Rs (minus 'remove') of the circular economy are principles that govern the behavior of firms and households.

Reduce – Energy efficient technologies can mitigate the amount of carbon entering the atmosphere, while noncarbon emitting renewables and nuclear can also play a part.

Reuse – By capturing carbon through innovative technologies, it can then be used to create useful products, or be injected back into oil and gas reservoirs to increase productivity (through enhanced oil recovery techniques).

Recycle – Represents the natural carbon cycle, in which natural sinks draw carbon from the atmosphere and then release it again through decomposition and combustion.

Remove – The removal of carbon from the atmosphere can be both engineered – such as through direct air capture and sequestration – or natural, through carbon sinks such as mangrove forests.

Reduce

'Reduce' represents all of the carbon mitigation options that reduce the amount of carbon entering the atmosphere system. Energy efficiency will reduce energy consumption and as a result will reduce the associated carbon emissions. Similarly, energy supply options that do not emit carbon, such as non-biomass renewables and nuclear power , also reduce the flow of carbon into the system, though they can indirectly result in carbon emissions during their manufacture, construction, and installation.

Saudi Aramco have long been pioneers in gas flaring reduction. Knowing that gas flaring is the combustion of associated gas generated through oil production, which is both wasteful and a source of CO_2 emissions.

KACST is working on creating clean & efficient fuels by separating the Hydrogen from the Oxygen in water (H_2O) using a process called "electrolysis" which requires two key inputs: 1) Water (sub-prime water e.g. brackish or wastewater is acceptable) and 2) Energy (provided through solar). The clean fuels (Hydrogen and Oxygen can then either be piped as a fuel to meet a nearby energy requirement or stored in cylinders (fig 2).

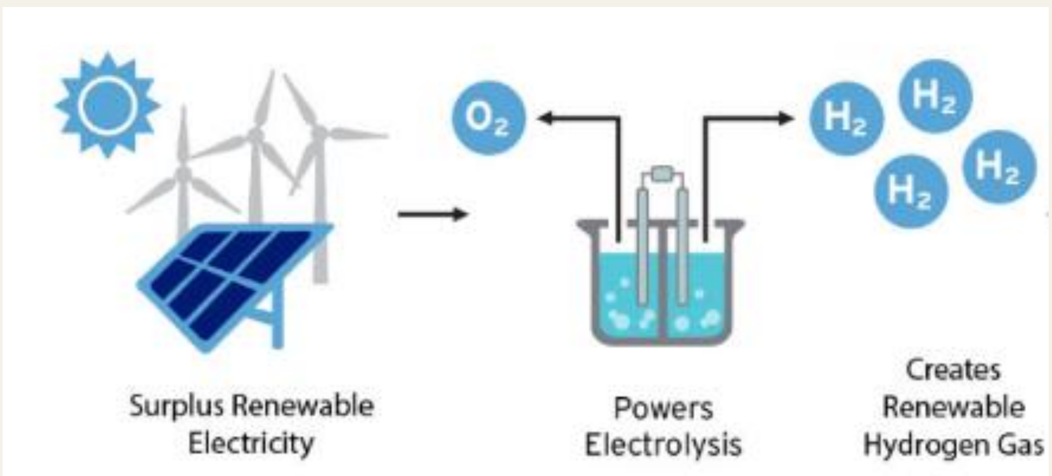

Fig 2: Renewable Hydrogen Production
Source: KACST SIP publication

Reuse

'Reuse' refers to capturing and using carbon as an input to a chemical or industrial process that converts the carbon to another useful feedstock for industry. Carbon utilization fits squarely within the tradition of industrial ecology by 'metabolizing' carbon from a waste to a valuable input.

For example, the Saudi Arabian Basic Industries Corporation (SABIC) completed an innovative and unique new cross-site project that converts CO_2 waste from one facility into valuable products in other facilities. This project will significantly improve the resource efficiency, decrease GHG intensity, improve economic performance, and provide inspiration for similar solutions that can help build a sustainable future for the planet. The plant converts 0.5 million tonnes of CO_2 annually into valuable products such as fertilizers and methanol (Smeets 2019). Researchers are actively developing carbon-to-fuel technology.

A research project conducted by KACST aims to develop catalyst based technology that can efficiently convert CO_2 to synthetic fuels and commodities chemicals. The most effective way to make use of CO_2 is so-called Flue Gas Reforming through the conversion of exiting flue gas mixtures into synthesis gas ("syngas") and then to synthetics fuels or chemicals in a single pass.

Fig 3: CO2 conversion techniques and materials

Recycle

'Recycle' represents the natural carbon cycle, in which natural sinks (e.g., plants, soil and oceans) draw carbon from the atmosphere and then release it again through decomposition and combustion. The carbon is effectively recycled, and the bio-energy subsystem can be considered carbon neutral, as long as an equal amount of biomass grows to replace what is harvested as bio-feedstock (e.g., wood, fuel crops, algae, etc.) for bio-energy.

A project called "Biological carbon sequestration in soils" aims to sequestrate carbon in soil by plants through photosynthesis and can be stored as soil organic carbon (SOC). Soil can store carbon as carbonates. It is one of the most effective mechanisms for climate change mitigation and improving the status of desert ecosystems. Carbonates are inorganic and have the ability to store carbon for more than a thousand years, while soil organic matter typically stores carbon for several decades. Researcher are working on new approaches to accelerate the carbonate forming process.

Remove

The final 'R' of the circular carbon economy represents the removal of carbon from the system. Captured carbon can be either converted to feedstock, as discussed above in 'reuse,' or removed by storing it geologically. Carbon can be captured directly from industrial processes and points of combustion, but it can also be captured directly from the air with direct air capture . Carbon captured from the combustion of bio-energy results in net negative carbon emissions within the bio-energy subsystem. Land can also be managed in such a way that it can become a net natural sink for atmospheric carbon. Natural sinks, bio-energy CCS and direct air capture can close the loop on emissions elsewhere that may be too difficult or too expensive to capture directly, such as aviation emissions.

For example Saudi Aramco is working on a number of technologies around CCUS which capture CO_2 and sequester it in geological formations, thus removing emissions from the atmosphere.

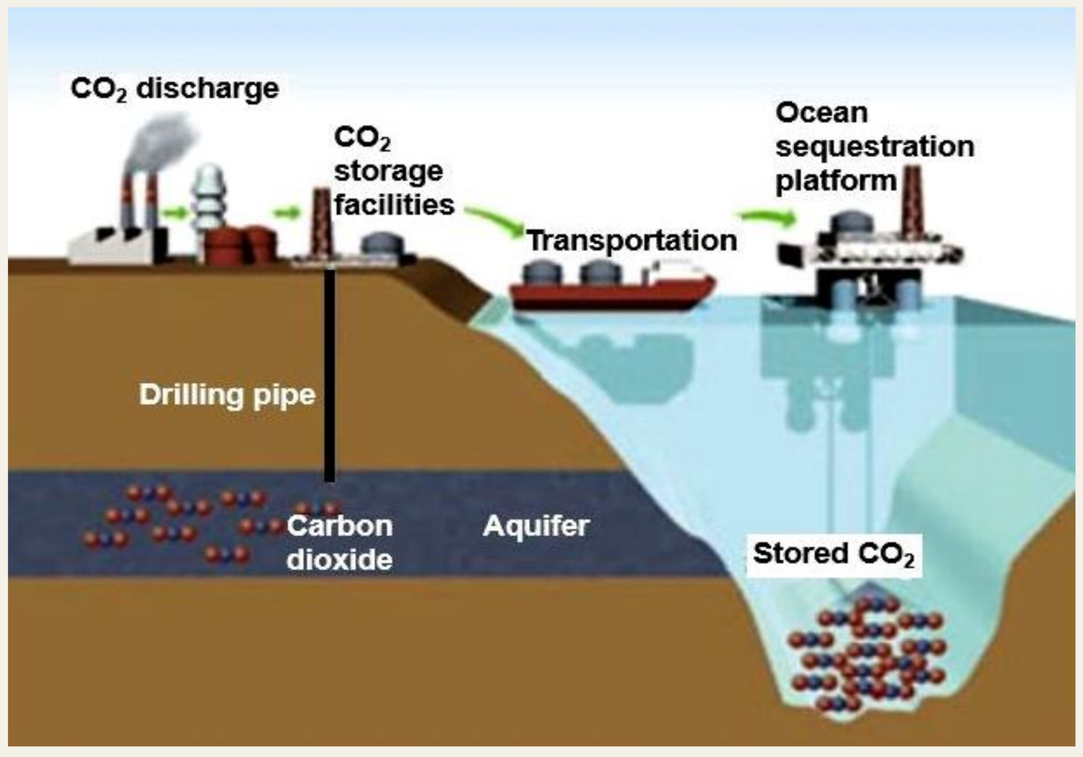

Fig 3: Illustration of CO_2 Sequestration Methods.

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