



The role of artificial intelligence in bridging the carbon gap in oil - a case study of Saudi Aramco.

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Abstract:

This study aims to demonstrate the role of artificial intelligence in bridging the carbon gap in oil in what is known as the carbon economy, as the transition towards the latter provides opportunities that enable the development of new energy systems based on innovation and technologies that use all energy sources, while increasing the achievement of sustainable development goals. , and addressing climate change.

Unlike the linear carbon economy model, which depends on the use of materials and then disposal, the carbon recycling economy encourages the adoption of a circular model that focuses on reducing carbon dioxide emissions, reusing them, recycling them, and removing them from the environment.

Keywords: carbon bridging - artificial intelligence - Saudi Aramco.

I. Introduction:

With the increasing risks of climate change and resource depletion due to human activities and business practices, sustainability has gained widespread importance. The concept of the circular economy has emerged as one of the key drivers of sustainable development, contrasting with the traditional linear economy prevailing since the industrial revolution, which follows the methodology of "produce, use, and dispose." The circular economy aims to minimize waste and strives for the continuous use of resources to create a closed-loop system.

In light of the above, adopting a circular approach represents a revolution in terms of raw material utilization, contributing to the reduction of environmental damage and having positive repercussions on the overall economy. The concept of a carbon circular economy is described as a fundamental pillar that helps restore balance to the carbon cycle in the world. The goal of adopting a circular carbon economy is to restore the natural carbon cycle to a level of balance between the Earth's surface and its atmosphere, thereby maintaining the sustainability of the existing ecological balance.

To address various aspects of the topic, the following problematic issues are raised:

Role of Artificial Intelligence in Bridging the Carbon Gap in the Oil Industry:

To answer the main question, several sub-questions are posed:

- **What is the carbon economy?**
- **What is the current state of artificial intelligence in Saudi Aramco?**
- **How does artificial intelligence impact the circular carbon economy?**

1. General concepts about artificial intelligence:

The technological revolution is rapidly changing our lives, significantly altering the ways we work, learn, and live together. Artificial intelligence undergoes tremendous growth and innovation.

New applications are emerging in an increasing number of sectors, including security, environment, research, education, health, culture, and commerce, alongside the growing complexity of big data usage.

1.1 Definition of Artificial Intelligence (AI):

Some may think that the term Artificial Intelligence (AI) is relatively new to our world. In reality, the concept of artificial intelligence dates back to the researcher John McCarthy in 1956, where scientists focused on how to grant machines human-like intelligence. The first attempt to build an intelligent machine that could mimic human intelligence was made by Frank Rosenblatt in 1957 when he developed a simplified model of a neural network closely resembling human brain cells.

In a similar context, Professor Kevin Warwick, a control systems expert at the University of Reading in the UK, conducted a study in 1998 to explore the interaction between the computer and the human nervous system. This involved implanting an electronic chip in his arm, wirelessly connected to a computer, with the goal of transmitting signals from the brain received by the computer and converting them into movements. The result was the ability to open doors and turn on lights simply by walking around the university (Majdi, 2020, page 5). In the mid-20th century, research in artificial intelligence witnessed significant progress, and the field of machine control evolved, capitalizing on advancements in digital computers. The attempts and experiments multiplied until artificial intelligence became widely used, encompassing medical diagnosis, data collection, and various other areas where machines replaced humans in performing routine tasks.

Artificial Intelligence is defined as follows: Artificial Intelligence is a scientific system that includes methods for manufacturing and engineering what is known as intelligent devices and software. The goal of artificial intelligence is to produce independent machines capable of performing complex tasks using reflective processes similar to those of humans. The design of learning programs and artificial intelligence applications is based on studying how the human

mind thinks, decides, and acts while attempting to solve a problem. The results of this study are then used as a foundation for developing intelligent software and systems (Bilal, 2019, page 20). Arnaous considers it to be a part of computer science that deals with intelligent computer systems—systems possessing properties associated with intelligence, decision-making, and some resemblance to human behavior in the areas of language, learning, thinking, and problem-solving (Bashir, 2007, page 9).

1.2 Characteristics of Artificial Intelligence:

Artificial intelligence possesses numerous characteristics that have made it an effective investment in many fields (Burns, Laskowski, & Tucci, s.d.):

- Applying artificial intelligence to devices and machines enables them to plan and analyze problems using logic.
- It recognizes voices and speech, with the ability to move objects.
- Devices adopting artificial intelligence can understand and analyze inputs well to provide outputs that efficiently meet user needs. It enables continuous learning, with the learning process being automatic and self-driven without the need for monitoring and supervision.
- It can process vast amounts of information.
- It can observe similar patterns in data and analyze them more effectively than human brains.
- It can find solutions to unfamiliar problems using its cognitive abilities.

1.3 Applications of Artificial Intelligence:

Artificial intelligence is used in various technological and vital applications, facilitating many aspects of life and performing different tasks that were previously limited to the human mind alone. Among the most important applications of artificial intelligence (Rawat, 2021)

- Robotics: Used in various industries such as healthcare, finance, and marketing.
- Space exploration: Including machines sent into space, satellites, mapping, and location tracking technology.
- Customer service: Utilizing robots in chat response operations, customer service tasks, and electronic marketing.
- Stock market and finance: Involving algorithms used for stock market analysis, profit and loss analysis, and prediction.
- Digital media: Displaying targeted ads by analyzing individual data and understanding online search trends.
- Healthcare sector: Health care machines analyzing patient data, predicting future diseases, and determining treatment types.
- Face recognition: Used in various devices like smartphones, learning and perceiving patterns for quick and efficient results.

2. The Role of Artificial Intelligence in Bridging the Carbon Gap in Oil:

Most countries, especially developing and Arab countries in particular, still follow a "linear economy" as the basis for dealing with production, distribution, and consumption stages. Given the depletion of many natural resources, potential resource savings, and the acceleration of population growth, continuing with the linear economy mechanism is no longer appropriate and acceptable. The concept of adopting a circular economy historically returns, aiming to address the challenges posed by the depletion of resources and the need for sustainable development.

In theory, for example, looking at the pioneers of input-output tables such as "Vassily Leontief" since the 1930s, especially his paper published in (Leontief, 1991) on "Economics as a Circular Flow." Then contributions from (Pearce and Turner, 1989) within their book on natural and environmental resources, emphasizing the importance of this economy compared to the linear economy.

2.1 Definition of Circular Economy:

Recently, the concept of the circular economy began to be traded since its adoption by the "Allen MacArthur Foundation" in 1991. This concept involves production, consumption, and distribution with the aim of raising awareness of the principles underlying this economy and its differences from the traditional linear economy. Through an initiative adopted by this foundation, around 133 companies participated, including major partners such as Renault, Philips, Google, and A.G.B.

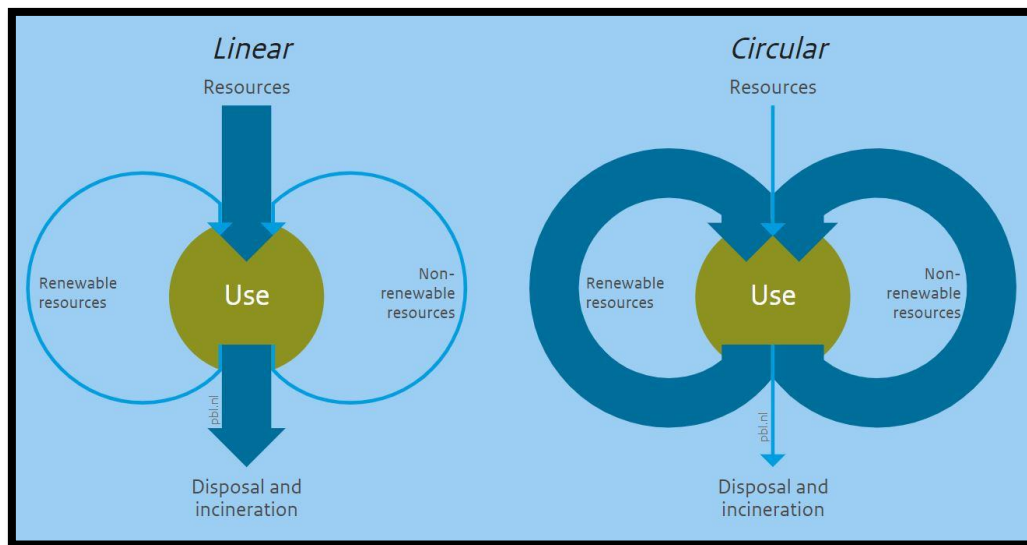
The circular economy is based on three main principles (to adapt to many challenges of the global economy) according to (Alkwaz, 2019):

- Preserving natural capital.
- Enhancing natural capital.
- Obtaining the best return from usage and reducing negative economic externalities.

The results of applying these principles are sometimes referred to as "growth from within." Estimates for advanced regions and countries, such as the European Union, suggest that adopting this type of economy could result in annual benefits of around 1.8 billion euros by 2030. However, only 9.1% of the global economy currently applies the circular economy (thus, there is still a wide gap in its implementation).

Circular economy can be defined as a set of efforts and practices aimed at either reducing the depletion of depleted or renewable natural resources when their consumption rate is greater than their renewal rate. It also aims to reduce the negative side effects of human consumption. One of the key components of the circular economy, compared to the linear economy, is illustrated in the following figure.

Figure (1): Key Components of the Circular Economy Compared to the Linear Economy.



Source: (Al-Khamis, 2020)

The linear economy operates on the basis of extracting raw materials in large quantities, transforming them into goods, and using them until they are ultimately disposed of as waste. In contrast, the circular economy works to reduce the extraction of raw resources, transform them into goods, share and then recycle them into other energy sources or raw materials, minimizing the amount of waste that needs to be disposed of. (Al-Khamis, 2020)

2.2 Carbon Circular Economy Definition:

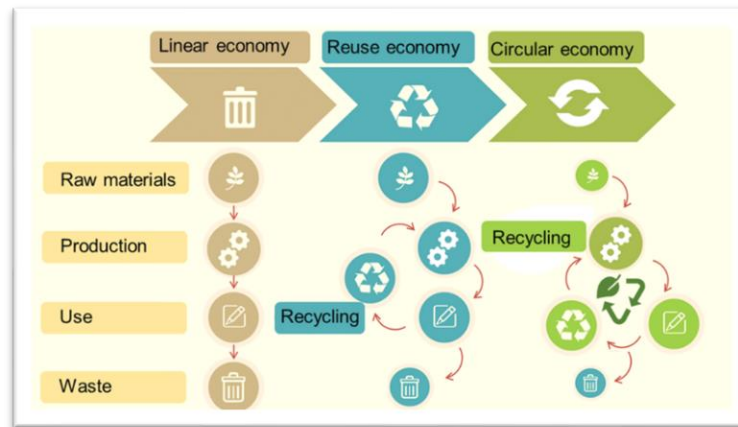
The transition to a circular carbon economy provides opportunities to develop new energy systems based on innovation and technologies that utilize all energy sources. This aims to achieve sustainable development goals, address climate change, and consider national conditions. The carbon economy is expected to be more circular based on "four strategies," adding the "removal

strategy" to the three strategies of the circular economy. The four strategies for the circular carbon economy are as follows: (Dandy, 2021)

- **Reduction:** This involves reducing the level of emissions entering the system by using low environmental impact fuel types and energy-efficient technologies.
- **Reuse:** Transforming emissions into useful industrial raw materials without altering the carbon state chemically, such as carbon capture and utilization.
- **Recycling:** Repurposing emissions to create new products with added value, involving a chemical change in the carbon state through processes like decomposition, combustion, and natural processes, for example, biofuels and blue hydrogen.
- **Removal:** Removing emissions from the system through natural sinks, carbon capture, and storage.

To achieve this goal, carbon dioxide produced from hydrocarbon combustion can be captured, reused, and recycled into other forms of energy or value-added products. It can also be stored underground to efficiently close the carbon cycle. The following diagram and figure illustrate the transition from a linear carbon economy to a circular carbon economy:

Figure (2): Transition Diagram from Linear Carbon Economy to Circular Carbon Economy.



Source: (Al-Khamis, 2020)

Furthermore, the Circular Carbon Economy can support the Sustainable Development Goals (SDGs) 2030 by:

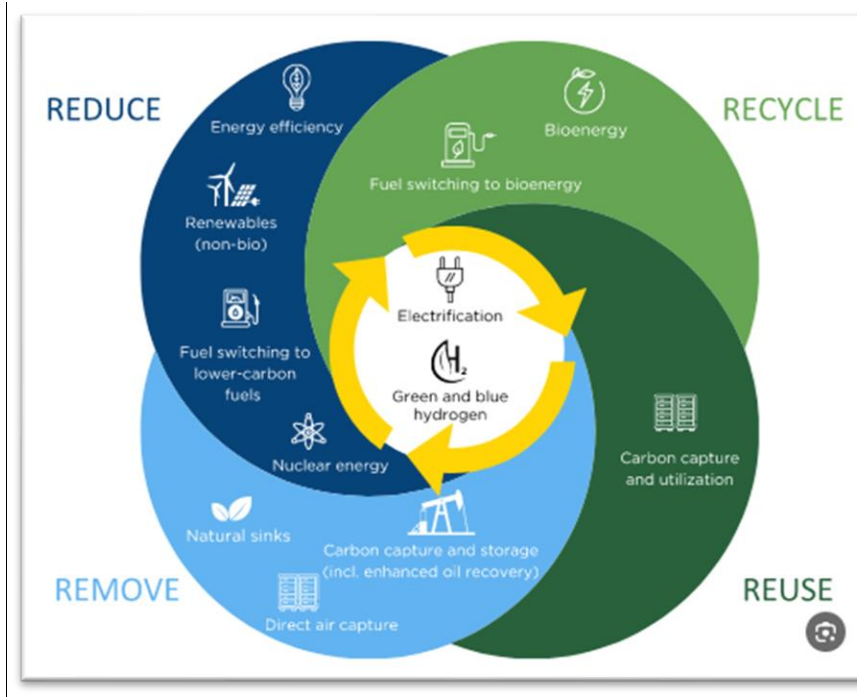
- Ensuring universal access to energy (Goal 7)
- Promoting economic growth and decent work (Goal 8)
- Enhancing innovation (Goal 9)
- Promoting responsible consumption and production (Goal 12)
- Promoting action to combat climate change (Goal 13).

2.3 Circular Carbon Economy Index:

The Circular Carbon Economy Index serves two main functions: Firstly, the index aims to stimulate discussions about the methods that identify the strengths and weaknesses of countries in terms of the Circular Carbon Economy. It measures and compares these aspects to help identify areas where progress is being made and pinpoint the need for further policy efforts or benefits. Secondly, the index enhances additional understanding of the Circular Carbon Economy concept and the general idea of adopting a comprehensive approach to managing emissions across energy systems and economies, achieving carbon circularity (kapsarc, 2021).

The following figure provides a concise representation of the proposed conceptual framework for the Circular Carbon Economy Index. The index illustrates the sub-performance at the element level accompanied by links to the four pillars of the Circular Carbon Economy.

Figure (3): Circular Carbon Economy Index.



Source: (<https://cceindex.kapsarc.org/cceindex/home>)

2.4 Role of Artificial Intelligence in Bridging the Carbon Gap:

Technical innovation is defined as a systematic process aimed at successfully translating innovative ideas into commercial products, services, and operations. Modern patterns of technical innovation are characterized by high dynamics and complexity, reflecting the diverse and heterogeneous nature of economic activities. The diversity of technical innovation models varies across sectors and countries. Therefore, there is a need to invest in systematic and effective scientific research towards the necessary technological package to close the carbon loop and industrially recycle carbon dioxide. This goes beyond greening oil and preserving its value; it includes the possibility of creating additional markets for its consumption, such as using it in hydrogen economies and various energy storage technologies.

The main idea of this strategy is to integrate a package of technologies by redefining the chemistry of oil usage, such as extracting hydrogen and petrochemicals directly from oil.

Furthermore, defining carbon dioxide as a potential raw material for many economically viable industries contributes to offsetting the cost of carbon dioxide capture. Greening oil must be a future strategic goal to avoid its forced sequestration underground. Greening oil involves the integration of the following technological package: (Al-Khamis, N., 2020)

- Carbon Dioxide Capture
- Carbon Dioxide Utilization and Storage Technologies
- Hydrogen Extraction from Oil
- Direct Derivation of Petrochemicals from Oil

These technologies exhibit varying levels of technological innovation. Some are in advanced stages, such as hydrogen extraction from oil using the "high-pressure steam methane reforming" process, while others, like some carbon capture techniques and the direct derivation of petrochemicals from oil, are still in early stages.

The methodology for technological innovation aims at cost-effectiveness through technology integration, improving the value chain of fossil fuel use in the energy sector, and preparing for long-term investments in the required infrastructure. Additionally, direct support policies and

indirect government support policies are crucial at this stage to embrace this goal and overcome obstacles hindering its adoption.

In this early stage of scientific research and technological development, conducting a comprehensive techno-economic analysis is vital to clarify the long-term potential for achieving this goal (Al-Khamis, N., 2020). Since climate change and the economy are global issues, it is more prudent to globalize the process of technological innovation to improve the cost-effectiveness of the oil value chain. This involves developing relationships and scientific communication with business communities. Establishing a global network for technological innovation in the economy is essential.

The Circular Carbon Economy (CCE) will assist in consolidating efforts, accelerating, and expanding the scope of greening oil. It reduces the dispersion of technological innovation efforts, especially since the strategic goal is common and lies in mitigating climate change without harming the global economy. The known benefits of innovation include cognitive participation, reducing investment risks in scientific research, and helping expand and accelerate scientific research. Therefore, participating in scientific research resources helps reduce the cost of the innovation process and minimize the chances of failure.

3. Artificial Intelligence and Its Role in Bridging the Carbon Gap at Saudi Aramco

Most economies dispose of raw materials as waste after use. Saudi Arabia and Aramco have adopted the Circular Carbon Economy framework as a means to reduce carbon emissions' impact.

3.1 Introduction to Aramco

Saudi Aramco is a leading energy and chemicals production company contributing to global trade and improving the daily lives of millions worldwide. The company is committed to supporting energy efficiency and addressing the global challenge of emission reduction. Leveraging its position as a leading oil and gas producer, Aramco believes it is qualified to contribute effectively to finding a comprehensive solution to this issue (Aramco, 2021).

Starting from engineering giant projects and innovating technologies that change industry rules, to launching innovative new products, Aramco strives for success by maximizing the long-term positive effects of resource utilization.

3.2 Artificial Intelligence and Research at Aramco

Saudi Aramco signed a memorandum of understanding with King Abdullah University of Science and Technology (KAUST) to support advanced artificial intelligence technologies. The memorandum aims to establish a new center for excellence at the university's headquarters to support research and development efforts and promote and market advanced artificial intelligence technologies.

Aramco's strategy aims to sustainably develop its business by harnessing technology and innovation to mitigate the climate impact of its operations. Technologies such as low carbon density oil extraction techniques, used and developed by Saudi Aramco, contribute to reducing carbon emissions throughout various stages of the company's value chains. The vast scale and growing potential of clean energy capabilities open new business opportunities for Aramco and its partners (Aramco, 2021).

Aramco utilizes its global network of research and technology centers worldwide. The company excels in:

- Achieving necessary technological breakthroughs and leveraging the company's enhanced flexibility in terms of discoveries, diversification, and sustainability.
- Harnessing fourth industrial revolution capabilities through technologies such as big data, advanced analytical tools, and artificial intelligence.
- Utilizing the Digital Twin technology in monitoring, predicting, and diagnosing operations, especially in the Khurais smart oilfield, one of the world's largest smart oilfields.

3.3 Carbon Economy at Aramco

The carbon recycling economy is an active framework to encourage global emission reduction and support sustainable development and economic growth. Aramco has launched several initiatives aimed at establishing a framework for the carbon recycling economy.

The company is developing several carbon extraction technologies that capture and store carbon dioxide in geological formations. Aramco also employs fourth industrial revolution technologies, such as artificial intelligence and big data, to reduce emissions through monitoring.

Energy consumption in the company, reaching the optimal level of consumption, improving the processing and analysis of seismic data, developing crude oil extraction methods, and enhancing energy productivity for oil wells are key focus areas. The company is classified for having the lowest carbon emissions intensity in the energy sector resulting from exploration and production activities.

The company will continue its efforts to innovate and discover effective solutions for carbon management, aiming to minimize its environmental impact to the lowest possible level. Aramco, in 2021, has outlined the following initiatives:

3.3.1 Emission Reduction:

Limiting Flaring Gas: Flaring gas involves burning excess gas associated with crude oil production, leading to the wastage of this valuable resource and contributing to carbon dioxide emissions. Aramco has been a pioneer in reducing gas flaring. Since the 1970s, the company has operated the main gas network, continually developing the gas flaring reduction program to significantly decrease carbon emissions.

These practices are part of the company's ongoing commitment to completely eliminate gas flaring. The Zero Routine Flaring program has been implemented, resulting in a substantial reduction in the amount of gas flared.

3.3.2 Reuse:

Converting Carbon Dioxide into New Materials: Carbon dioxide can be transformed into new products through the Polyols Carbonate Polypropylene production line, using the Converge® technology. This enables the recycling of carbon dioxide, converting it into clean, high-value, and resilient materials characterized by economic efficiency and low carbon emissions.

And the polyols produced using the Converge technology find various everyday applications in both the consumer and industrial sectors, such as adhesives, insulation materials, food packaging materials, leak barriers, and industrial rubber. Moreover, they can store carbon dioxide for an extended period, contributing to the reduction of greenhouse gas emissions and addressing environmental concerns related to global warming.

3.3.3 Recycling:

Water Conservation Saudi Arabia is a land with scarce flowing rivers, intermittent rainfall, and high summer temperatures. Water conservation is a priority for the company. Saudi Aramco is committed to conserving water to alleviate pressure on natural water resources. Water conservation efforts involve reducing water consumption rates, minimizing water waste, maximizing the reuse of treated wastewater, and promoting the use of alternative water sources such as seawater, treated sewage water, and sludge-treated water.

Saudi Aramco also looks forward to utilizing renewable energy sources to enhance the sustainability of water treatment and transportation systems.

3.3.4 Carbon Capture:

Applying Enhanced Oil Recovery Techniques Enhanced oil recovery techniques involve injecting substances into crude oil reservoirs to increase their productivity. Injecting carbon dioxide into the reservoir helps improve and enhance oil extraction while simultaneously isolating carbon dioxide, which is a win-win situation.

The Ghawar Field is the largest conventional onshore oil field discovered in the world. Saudi Aramco manages a project in this field that employs cutting-edge techniques in the Middle East

to capture and re-inject carbon dioxide, showcasing Saudi Aramco's leading role in addressing global climate challenges.

After extracting carbon dioxide at the Natural Gas Liquids (NGL) plant in Hawiyah and processing it, it is pumped to the oil field in Uthmaniyah, located 85 km away, for re-injection into the Ghawar oil reservoir. This contributes to emission reduction and enhances oil extraction rates, with a priority on water preservation, treatment, and reuse.

II. Conclusion:

The circular carbon economy concept emerged from Riyadh to the world, aiming to advocate for all types of energy on Earth, within frameworks built on available resources to make them sustainable. Simultaneously, it aims to reduce climate change impacts, recognizing energy as a crucial pillar for the human mind to achieve sustainability standards. It is a primary source and an essential input for the development of modern cities, which the Kingdom seeks to achieve through a comprehensive and realistic approach towards resource sustainability in economic growth by addressing carbon emissions.

Saudi efforts have added the element of "reuse" to the three elements: "reduce," "recycle," and "dispose," completing the tight circular system. This aids in restoring balance to the carbon cycle in the same way it occurs in nature.

Rebalancing the carbon cycle does not simply mean complete electrification. Most industrial activities require either carbon in their chemistry or high heat, which cannot be economically provided by electricity. Additionally, it is not logical, from a sustainability perspective, to deplete non-renewable mineral resources with inefficient recycling for the sake of complete electrification in the transportation sector. It is time to use directed technological innovation within the circular carbon economy to invent new ways of consuming fossil fuels without emitting greenhouse gases into the atmosphere.

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