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Research Article

CO2 in The Realm of Net-Zero

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ABSTRACT

The paper titled "CO2 in the realm of Net Zero" provides a detailed analysis of the efforts to reduce CO2 emissions and achieve net-zero emissions. The paper emphasizes the importance of reducing CO2 emissions to mitigate the impacts of climate change. The paper discusses the role of Carbon Capture, Utilization and Storage (CCUS) technology in reducing CO2 emissions in the energy sector and analyzes different approaches towards achieving a net-zero emissions target. The paper also evaluates the challenges and opportunities for reducing CO2 emissions in the manufacturing and transportation industries. Additionally, the paper explores the concept of the circular carbon economy and its potential to reduce CO2 emissions. Finally, the paper summarizes the key findings from various case studies and analyses and highlights the overall challenges and opportunities for reducing CO2 emissions in various industries. The paper concludes by emphasizing the importance of continued efforts in this area and highlighting the implications for future initiatives in reducing CO2 emissions and achieving net-zero.

Introduction

The reduction of CO_2 emissions is critical to slow down global warming and mitigate its consequences, such as rising sea levels, melting ice caps and more frequent and severe natural disasters. Achieving net-zero CO_2 emissions is essential to achieve this objective. CO_2 is a significant contributor to global warming and it is necessary to reduce its emissions to slow down the progression of global warming. The increasing amount of CO_2 in the atmosphere results in rising global temperatures, leading to more frequent and severe natural disasters, as well as rising sea levels and melting ice caps.

Net zero CO_2 emissions mean reducing emissions to the point where they are balanced with the amount removed from the atmosphere, helping to stabilize CO_2 concentrations and mitigate climate impacts. To achieve net-zero emissions, significant changes are required in the energy, manufacturing and transportation sectors, which emit the majority of emissions. This entails a transition to renewable energy, the implementation of carbon capture and storage technologies and the adoption of sustainable practices in industry and transportation. Reducing CO_2 emissions is significant in mitigating climate change for several reasons. Firstly, it decreases the amount of heat trapped in the atmosphere, slowing down global warming and reducing its impacts. Secondly, it stabilizes CO_2 concentrations, slowing down the pace of climate change. Lastly, it secures a sustainable future for future generations by mitigating the potential for widespread social, economic and environmental damage caused by climate change.

In conclusion, reducing CO_2 emissions is critical in mitigating the impact of climate change. By slowing down global warming and reducing its impacts, we can ensure a sustainable future for all. The coming sections of this paper will review the latest research and developments in regard to CO_2 emissions and their relation to net zero.

The Need for Net-Zero

The need for net-zero is a growing concern in today's world, as the effects of climate change become more and more apparent. Carbon dioxide (CO_2) emissions have increased quickly, which has had a devastating impact on the ecosystem by raising sea levels, melting ice caps and increasing the frequency of natural disasters.

Achieving net-zero means reducing emissions to a level where they are equal to the amount being removed from the atmosphere. This requires significant changes in the energy, manufacturing and transportation sectors, which are the primary sources of emissions. The shift towards renewable energy, the adoption of carbon capture and storage technologies and the implementation of sustainable practices are crucial steps in reaching net-zero. Net-zero is required for a number of social and economic reasons in addition to environmental ones. It is possible for climate change to have a significant negative impact on human communities, economy and the natural world. Achieving net-zero is not only necessary for mitigating these impacts, but also for securing a better future for future generations.

The necessity for net-zero and the efforts being done to minimize greenhouse gas emissions, particularly carbon dioxide, will be addressed in this article (CO_2). We will also discuss the challenges and opportunities in reaching a net-zero future. In the coming sections, we will summarize some key aspects of this topic, including the current state of emissions and the steps being taken to reduce them. By examining the need for net-zero and the progress being made towards this goal, we hope to provide a comprehensive overview of this crucial issue.

Net zero emission

The idea of "net zero emission" attempts to completely eliminate all greenhouse gas emissions caused by humans from the atmosphere through emission reductions, carbon offsetting or even no emissions at all. This leads to an overall carbon neutrality and a zero-carbon footprint by producing a net zero emission of carbon dioxide, methane and other greenhouse gases. The phrases carbon neutrality and net zero carbon footprint are interchangeable when referring to this concept. The objective is to achieve climatic balance and zero emission technologies, such as solar, wind and electric vehicles. Towards the middle of the century, the Paris Agreement seeks to achieve net zero global emissions[1]. **(Figure 1)** depicts the sectoral distribution of CO_2 emissions on a global level.

Energy usage, particularly the burning of fossil fuels, has fueled social and economic advancement but also resulted in the emission of too many greenhouse gases (GHGs), which contribute to climate change. Bushfires, hurricanes, heatwaves and floods are more common as the globe warms more rapidly as a result of higher GHG emissions. The primary cause of the postindustrial temperature rise is the cumulative release of human CO_2. Net carbon dioxide emissions from human activities, such as energy usage, industrial output, land use and agriculture, must decrease to zero in order to stabilize world temperatures. The need to reduce GHG emissions and the rising global energy demand are critical issues. According to the Intergovernmental Panel on Climate Change (IPCC), in order to stop the planet from warming, net global carbon emissions must be zero. According to the Paris Agreement, the average global temperature increase should be kept well below $_2$ degrees Celsius and should ideally be kept to 1.5 degrees Celsius above pre-industrial levels. By $_2$050, global CO_2 emissions must be at zero due to climate change and high-carbon development in order to achieve this target.

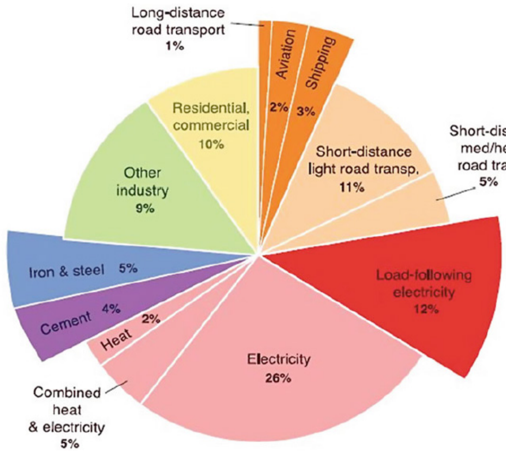

Figure 1: Emissions from fossil fuels and industries globally in $_2$014[1].

To achieve net-zero emissions by $_2$050, it is crucial to implement low-carbon pathways that involve the large-scale use of clean energy sources as a substitute for fossil fuels. This requires reducing energy demand through increased efficiency and changes in consumer behavior. One way to achieve this is through emission offsetting, which involves reducing or avoiding emissions of greenhouse gases in one sector to compensate for emissions made somewhere else. Carbon sequestration or removal aims to remove and store atmospheric CO_2 to mitigate the effects of global warming. Industrial, agricultural and other processes must be adjusted to minimize greenhouse gas emissions. These changes include using renewable energy sources and energy-efficient techniques. Governments at all levels must prioritize technical advancements aligned with global climate goals and environmental protection must become a fundamental part of corporate and individual behavior.

Achieving net-zero emissions is crucial to combat global warming. The energy sector is responsible for the majority of global emissions and therefore it is necessary to decarbonize the world's energy system. However, there are several barriers to achieving net-zero emissions, including the high cost of current technologies, inadequate energy efficiency and conflicting interests between food security and bioenergy production. Implementing carbon pricing legislation has also proven challenging. To fully decarbonize the environment, technological cost reductions through research and innovation are required. Additionally, it is vital to change the global trend of greenhouse gas emissions and achieve net zero by mid-century. The removal of carbon from the atmosphere, as well as emission reduction through energy efficiency and the use of renewable energy sources, are some of the methods to reach net-zero emissions. To achieve this goal, governments, business groups and individuals all need to work together.

In the transition to net-zero emissions, evaluating the costs and environmental impact of low- and negative-carbon fuels

According to[2], there was a study that focused on evaluating the economic and environmental impact of different fuel production pathways. The study specifically examined the production of Fischer-Tropsch liquid (FTL) fuels, synthetic natural gas (SNG) and hydrogen (H_2) from natural gas, biomass or electricity in conjunction with carbon capture and storage (CCS). The investigation produced some noteworthy and intriguing findings. For starters, the study found that the paths for producing H_2 offer the greatest reduction in greenhouse gas emissions per supplied unit of fuel. Also, they are less expensive to decarbonize than the identical input feedstock FTL and SNG routes. To put it another way, producing H_2 is a more economical strategy to cut greenhouse gas emissions. The analysis also showed that the pathways for producing fuel that begin with biomass and include CCS have the greatest potential for reducing carbon emissions. This is fantastic news because, above a certain price threshold for carbon output, these paths also have the lowest manufacturing costs. This means that we can reduce carbon emissions while also saving money. The study concludes by emphasizing the importance of hydrogen production using biomass and CCS in macro-energy system models for achieving net-zero emissions. By investing in these pathways, we can make significant progress towards a more sustainable future.

In this study, three different approaches to producing clean fuels-hydrogen, Fischer-Tropsch liquids and synthetic natural gas-are assessed. The approaches' main input feedstocks are natural gas, biomass or electricity. According to the report, hydrogen is produced from natural gas with CO_2 capture and storage and has the lowest carbon mitigation costs. It also plays a key role in the switch to decarbonized fuel systems. The most cost-effective ways to produce decarbonized Fischer-Tropsch liquids and synthetic natural gas involve using biomass with CO_2 capture and storage. However, these paths may not be economically viable due to high breakeven carbon prices without enough negative emissions. The study also shows that the competitiveness of the approaches is impacted by feedstock costs, capital costs and capacity considerations. The study suggests that further research should focus on improving cost and performance estimates while considering infrastructure emissions and other environmental indicators.

Adopting net-zero in emerging economies

Finding the key success factors (CSFs) for the automobile industry's adoption of net-zero practices was the goal of a study[3]. Linkages between the discovered components were established using the Fuzzy decision-making trial and evaluation laboratory (DEMATEL) approach. The top three crucial success elements were research and development efforts, international partnerships and strategic planning with an effective roadmap. The study offers theoretical and practical recommendations for industries to successfully execute net-zero practices in the Indian automotive sector. The report emphasizes the significance of research and development, international partnerships and strategic planning to accomplish this goal. The paper examines the CSFs required for implementing net-zero practices in the Indian vehicle sector by identifying and assessing 17 CSFs using a fuzzy decision-making technique. The study concludes that advanced manufacturing technologies were most influenced by other CSFs, while research and development efforts had the greatest influence on other CSFs. However, the report acknowledges the limitations of the research and proposes further directions for investigation, including exploring the relationship between Industry 4.0 and net-zero goals, researching other industrial sectors and locations and utilizing alternative decision-making methodologies.

Energy Systems Towards Net-Zero Co_2 Emissions

Energy systems encompass the processes and infrastructure involved in generating, transmitting and distributing electricity and heat. Technology for carbon capture, utilization and storage (CCUS) is essential for lowering carbon dioxide (CO_2) emissions. With the help of this technology, CO_2 emissions from factories and power plants are transported to storage facilities and kept out of the environment. A number of countries and areas have made the commitment to develop energy systems with net-zero CO_2 emissions. For instance, the United Kingdom and the European Union want to reach net-zero emissions by the year $_2$050, while the Canadian province of Alberta wants to cut oil and gas industry emissions by 20% by the year $_2$030 with the ultimate goal of reaching net-zero emissions. Nonetheless, there are several opportunities and problems involved in reducing CO_2 emissions from energy systems. One of the major challenges is the high cost and technical complexities associated with implementing CCUS technology. Furthermore, there is a need for increased public and political support for low-carbon energy solutions. On the other hand, there are also opportunities for new business models and job creation in the low-carbon energy sector. Governments can play a crucial role in creating an enabling environment for reducing CO_2 emissions in energy systems through policy measures such as carbon pricing, research and development incentives and investment in renewable energy.

In conclusion, CCUS is essential for reducing CO_2 emissions in energy systems and several countries and regions have set ambitious targets towards achieving net-zero emissions. Although there are challenges to overcome, there are also significant opportunities for the government and the private sector to develop low-carbon energy solutions and create a sustainable future. To gain a better understanding of the impact of these efforts, it is important to analyze the initiatives and outcomes of the countries and regions working towards reducing CO_2 emissions in energy systems. In the following sections, we will examine case studies and analyze the challenges and opportunities involved in reducing CO_2 emissions in energy systems.

Energy systems under net-zero CO_2 emission scenarios

In the framework of current energy policies, the research[4] explores the energy systems of 177 net-zero CO_2 emissions scenarios as well as the technological and regional characteristics of those systems. According to the level of anticipated global warming, correlations between key socioeconomic and energy-related global indicators in the year of net-zero emissions are depicted in **(Figure 2)**. It also includes overshoot scenarios that would return warming to the desired amount by the end of the century. Additionally, it shows that 60% of primary energy at net-zero is often provided by renewable energy sources and that nearly half of all energy consumed is electricity. Biomass accounts for little less than half of that renewable energy. As noted in the text, discussions of burden-sharing, equity and human development may be significantly impacted by the fact that residual emissions and offsetting negative emissions are not distributed equally throughout global regions.

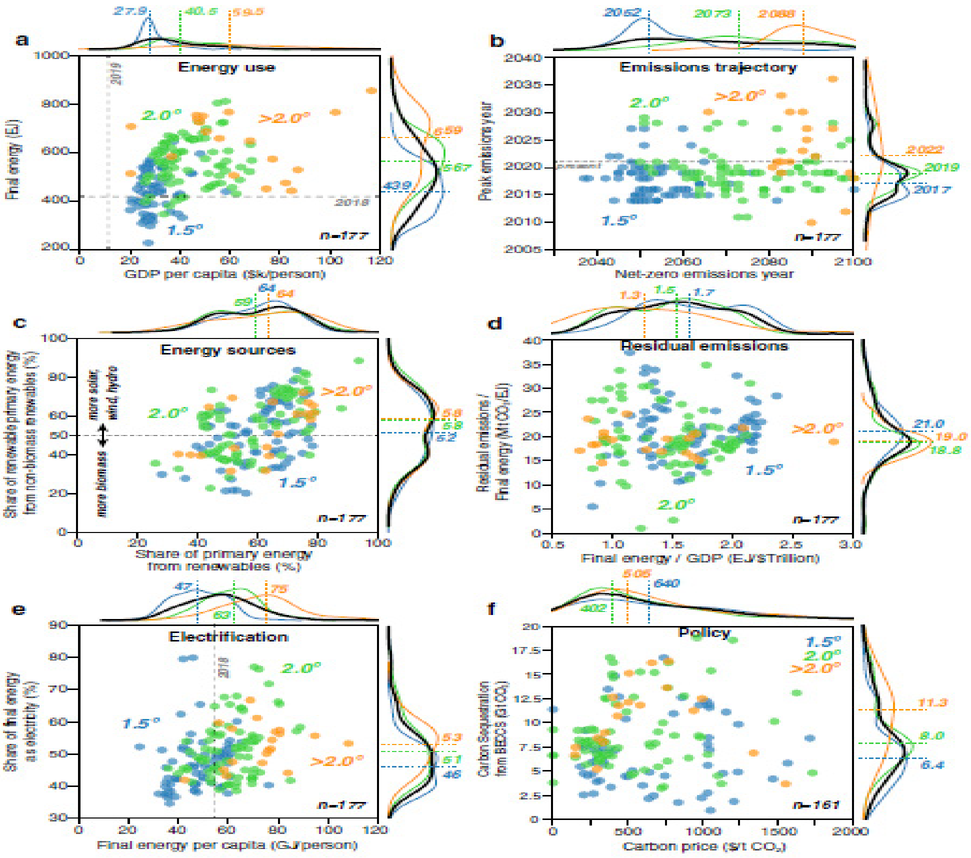

Figure 2: Energy system parameters in scenarios with net-zero global CO_2 emissions[4].

According to the expected severity of global warming, the timescale for achieving net-zero emissions is divided by the study's findings[4], which look at the relationships between socioeconomic factors, global energy usage and these variables. It demonstrates that the global energy demand and GDP per capita are often lower in scenarios that try to stay below 1.5°C warming than they are in scenarios that intend to go above that barrier. The text also notes that while the peak emission period varies depending on the scenario, the timeframe of net-zero emissions occurs later in scenarios with higher global warming. The most ambitious mitigation scenarios, according to the article, could provide helpful information for creating net-zero emissions policies.

The research examines the consumption, sources, policy, obstacles and prospects for reaching net-zero CO_2 emissions in the energy sector, as well as negative emissions themselves. It comes to the conclusion that electricity makes up 35-80% of total energy and that 60% of primary energy at net–zero emissions comes from renewable sources, predominantly biomass. The report also emphasizes how regional variations in energy and emissions as well as shadow carbon prices representing the marginal cost of abatement cause carbon prices to range from zero to over $1000 per tonne of CO_2. In order to achieve net-zero emissions, the paper underlines the need to reduce final energy use, the unequal distribution of residual emissions and negative emissions and the potential consequences for burden-sharing and equity.

The distribution of residual and negative emissions in net-zero scenarios, particularly those involving energy systems and land use, is investigated in the research. The text indicates that while negative emissions from agriculture and land use are reduced in warmer climates, leftover emissions are bigger and require BECCS adjustment. The analysis stresses the regional diversity of emissions, with South America having the biggest potential negative emissions from land use and Asia having the largest source of residual emissions. The paper also shows how Integrated Assessment Models (IAMs) have limitations in understanding net-zero emissions balance and the path to reaching it, as well as the relationship between negative emissions and other parameters in the context of SR1.5 models. IAMs are helpful in defining long-term mitigation routes at the global level, but they are sparse in terms of technological, temporal and spatial detail and do not take into consideration the political economy and sociological dynamics that underpin country initiatives for reducing emissions.

Justice for the environment and net zero emissions

The goal of net zero, which aims to balance carbon emissions with carbon removal to prevent dangerous global warming by 2050, has gained prominence in global climate politics. However, different interpretations of the goal exist and its implementation must be done carefully to promote climate justice. For a just transition, the authors advise addressing inconsistencies in the definition of net zero, prioritizing early action in wealthier nations, reducing reliance on unproven negative emissions approaches and safeguarding the lives of the world's poor. In order to fulfill the promise of net zero, the authors emphasize how crucial it is to achieve climate justice.

The article[5] argues for the urgency to reach the goal of net zero emissions by 2050 to prevent dangerous levels of global warming. To achieve this goal, important political decisions must be made that prioritize early and aggressive mitigation efforts in wealthy countries, minimize reliance on unproven negative emissions techniques and consider climate justice implications, including protecting the livelihoods of the poor. The article stresses the need to resolve ambiguities in the net zero goal, including avoiding delays and dilution of commitments, minimizing cumulative emissions, reducing residual emissions and avoiding an unfair distribution of mitigation efforts. The authors suggest a pathway of narrow convergence that balances emissions reductions with modest use of negative emissions techniques, while also reducing luxury emissions in wealthier nations and avoiding harm to vulnerable populations. The article emphasizes the importance of political decisions in achieving net zero emissions and ensuring a just transition towards sustainability.

The article[5] presents a sustainable and just approach to reaching net zero emissions by 2050. The authors argue for a narrow convergence that involves cutting emissions to a low level and balancing them with limited use of negative emissions techniques (NETs). The article highlights the potential negative impacts of NETs, such as harm to forests and indigenous communities and suggests a portfolio of different technologies. The authors also reject the use of carbon trading mechanisms and avoidance offsets and emphasize the need for emissions to be linked to subsistence-related projects. The authors believe that reducing emissions can bring many benefits, including improved health and increased skilled jobs. The authors also acknowledge that reaching net zero emissions is not enough to solve all climate justice issues and that a more ethical approach is needed. The authors contend that the best possibility of achieving climate stability while avoiding escalating current socio-economic issues and inequities is to resolve net zero ambiguity and pursue a pathway of narrow convergence.

Use of CCUS technology and development of countermeasures in china's petroleum industry

The use of carbon capture, utilization and storage (CCUS) in the petroleum industry is being promoted in China as part of the government's two-carbon goals strategy, according to this article[6], which also examines the issue of greenhouse gas emissions and their impact on global issues. It talks about China's energy consumption, carbon emissions and the oil industry's contribution to lowering carbon emissions. The article also lists the applications, advantages and disadvantages of carbon capture, carbon utilization and carbon sequestration technologies in China's petroleum sector. It also discusses the challenges and hazards that CCUS projects in the sector must overcome and offers suitable solutions. Its goal is to act as a manual and resource for CCUS application in China's petroleum sector. Figure 3 shows how much energy China uses and how much carbon it emits as a result of its extensive industrial production and quick economic growth.

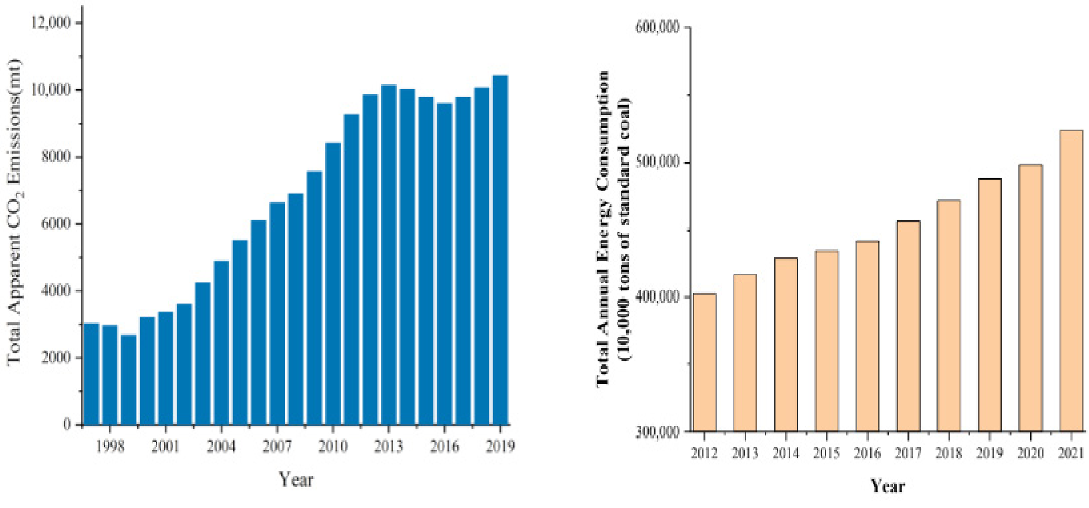

Figure 3: China's energy consumption and total apparent CO_2 emissions over the years[6].

The difficulties and potential remedies for the advancement and application of carbon capture, utilization and storage (CCUS) technology in China's petroleum industry are discussed in the article. It highlights the usage of CO_2 oil displacement technology for simultaneous storage and utilization by businesses like Sinopec and PetroChina as well as the chemical absorption method, which is the most popular approach for CO_2 collection. High investment prices, a lack of CO_2 gas sources, a lack of technical advancement, environmental dangers, a lack of market participation, a lack of cooperation and a lack of defined rules and policies are just a few of the difficulties identified. Investing in important technological research, creating standards and financial systems, speeding up pipeline and infrastructure development, integrating CCUS into the carbon emission trading system and enhancing fiscal and tax policies are some of the suggested answers.

Some crucial concerns for the development of CCUS in China that aim for carbon neutrality

The potential of carbon capture, utilization and storage (CCUS) technology **(Figure 4)** is discussed in this research[7] with regard to China's attaining carbon neutrality. The paper analyzes the opportunities and challenges of CCUS development in China with a focus on repositioning CCUS under the carbon neutral target, understanding the status and costs of technology development, the role of utilization and storage, approaches to resource constraints and source-sink mismatch and new business models for large-scale deployment of CCUS. The study offers policy recommendations as well to hasten the creation of a thorough and organized enabling environment for CCUS.

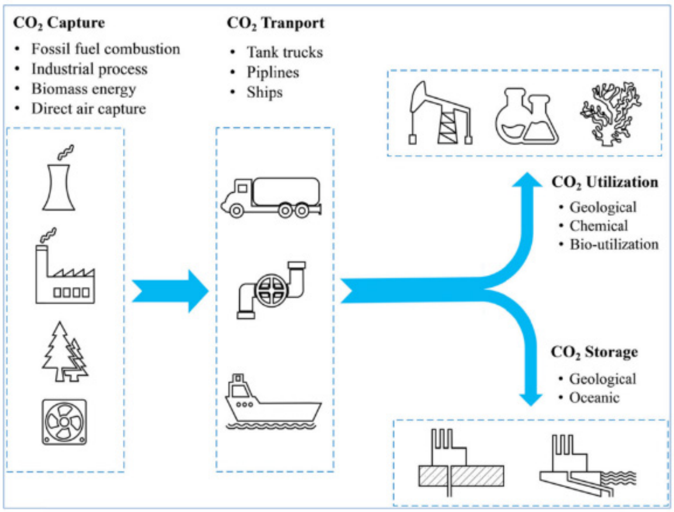

Figure 4: CCUS Technology System for Carbon Neutrality[7].

The CCUS demonstration projects in China are often limited in scale and expensive, with the majority of the expense coming from the CCUS's economic and environmental costs. Environmental cost comprises environmental risk and energy usage emission, whereas economic cost includes fixed cost and operational cost. The main operating costs are capture, transportation, storage and utilization. Costs for CO_2 capture are predicted to be RMB 90-390 per ton in 2030 and RMB 20-130 per ton in 2060. The cost of transporting CO_2 by pipeline is predicted to be RMB 0.5/ton-km in 2030 and RMB 0.3/ton-km in 2060. CO_2 sequestration is predicted to cost RMB 40-50 per ton in 2030 and RMB 20-25 per ton in 2060. Innovative capturing technology, the scale effect and new business models are some approaches to cut expenses.

In light of China's declaration of carbon neutrality, the article[7] makes the case that more focus should be placed on CCUS (Carbon Capture, Utilization and Storage). A bubble diagram of the finished and upcoming CCUS technology demonstration projects in China is shown in **(Figure 5)**. The bubbles' size illustrates how much carbon is being captured at the demonstration facilities. Additionally, it implies that in order to advance CCUS, awareness-raising and capacity building are crucial. Important areas for raising awareness in this regard are the potential of fresh techno-economic paradigms, the role of CCUS in carbon neutrality and the dynamic cost evaluation of CCUS. The paper advises distributing technical knowledge to possible application industries, offering data on all-inclusive technical solutions and connecting CCUS to the financial sector as a means of growing capacity. The article also makes the case for the necessity to deploy additional sizable initiatives with a commercialization focus and to reinforce the policy design for CCUS. The article also recommends that technology and business model innovation be updated further and that a diverse collaboration with a range of stakeholders be developed.

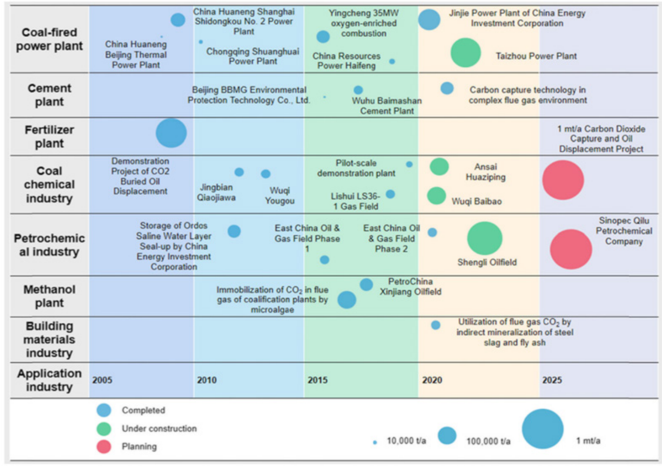

Figure 5: Bubble diagram of CCUS technology demonstrations completed and planned in China[7].

An SD-CGE model's analysis of the implications of CCUS and the penetration of renewable energy under the carbon peak

This study[8] employs a "dynamic system-computable general equilibrium" (SD-CGE) model to analyze the financial and environmental effects of various CCUS implementation strategies in China's electricity sector. The study comes to the conclusion that, notwithstanding the difficulties involved in creating a totally green power system, adopting CCUS in conjunction with renewable energy sources is essential to achieving the power sector's carbon peak goal. The carbon peak year for the power sector is predicted to be $_{2}0_{2}5$ and green power will dominate the energy supply by $_{2}030$. "Medium-Medium" policy intensity is the recommended level. The study provides assistance with policymaking and acts as a helpful resource for other countries conducting relevant research.

The significance of carbon capture, utilization and storage (CCUS) as a de-carbonization technique in the electricity sector is discussed in this study. It acknowledges that the electricity sector significantly contributes to carbon emissions and that CCUS is a useful tool for reducing them, but that the high cost of the technology has prevented its widespread adoption. The document also notes that China has suggested a strategy to create a "new power system" dominated by "green power," with the goal of reaching carbon neutrality by 2060 and reaching a peak in carbon emissions by 2030. The book does point out that China continues to rely significantly on fossil fuels, mainly coal and that the stability of the power grid is being weakened by the rising share of renewable energy. The report also discusses ways that CCUS can mitigate this problem. The paper claims that while achieving a system in which green power predominates in China's power sector is a challenging goal, a mix of CCUS and renewable energy penetration is the optimal course of action for decarbonizing the industry. The analysis found that the combined penetration of CCUS and renewable energy will cause the electricity industry to reach its carbon peak by 2030. The study examines the environmental and economic effects of various policy intensities using an SD-CGE framework. Nonetheless, the study did find that policy intensities are higher the earlier the peak is attained. The study also contends that connecting the policy branch of renewable penetration can sometimes alleviate the adverse economic effects brought on by an increase in the cost of power generation. The study suggests taking into account both the environmental and economic implications while developing a system that relies heavily on green power as well as removing any detrimental effects on the wellbeing of people by taking additional steps.

According to the report, China needs a policy of adopting CCUS along with a penetration of renewable energy sources in order to decarbonize its power sector. Installing CCUS facilities, developing CCUS in combination with renewable energy and taking steps to lessen opposition to policy execution in light industry, construction and non-coal energy mining all require financial backing. Also, due to the high penetration rate of renewable energy, steps must be taken to ensure the stability of the power system. The study is limited in that it only assesses the equilibrium solution of the effects of policy and does not take the temporary nature of policy implementation into account. System theory or nonlinear system dynamics should be used in future studies to analyze this phenomenon. Also, it is important to consider global viewpoints, such as the appropriate CCUS development intensity for intercontinental power networks.

Reaching net zero emissions requires the knowledge and competencies of the oil and gas industry

In order to guarantee a stable global climate and raise living standards for everyone, the world must reach net-zero greenhouse gas emissions by $_2$050, according to the paper[9]. In order to stop emissions and achieve climate security, industrial-scale carbon capture and storage is required to accomplish this goal. According to the article, only the oil and gas production industry has the knowledge and global reach required to locate the geological storage structures and construct the facilities, pipelines and wells required to achieve this goal. The article estimates the volume of storage, technology and infrastructure needed to achieve this goal. In order to be commercially viable over the long term and to transform from a climate pariah to a worldwide hero, the sector must switch from generating hydrocarbons to producing energy with net-zero emissions and storing carbon dioxide.

The advantages of a net-zero emission strategy for a developing country

In order to achieve rapid economic growth, better socioeconomic conditions and increased climate resilience, emerging nations have difficulties in meeting net-zero emissions targets, which are covered in the article[10]. The authors focused on both the energy sector and the non-energy sector for structures of emissions to estimate energy-consuming activities and associated emissions because each sector has a different impact on the case study **(Figures 6 and 7)**. Additionally, the authors assess Nepal's newly unveiled "Long-term Plan for Net-zero Emissions" using the Low Emissions Analysis Platform (LEAP) and estimate the expected co-benefits in terms of reducing air pollution emissions and enhancing energy security and equity. According to the analysis, the annual CO_2 emissions under the reference scenario (REF) are expected to significantly increase by $_2$050, along with emissions of air pollutants and dependency on imported energy. However, under the "With Additional Measures (WAM)" strategy scenario, air pollution would be decreased and energy security indicators and energy equality would significantly improve. Researchers, the corporate sector, social actors and politicians are expected to benefit from the study's findings in order for initiatives for paths toward sustainable socio-economic transformation to be implemented successfully.

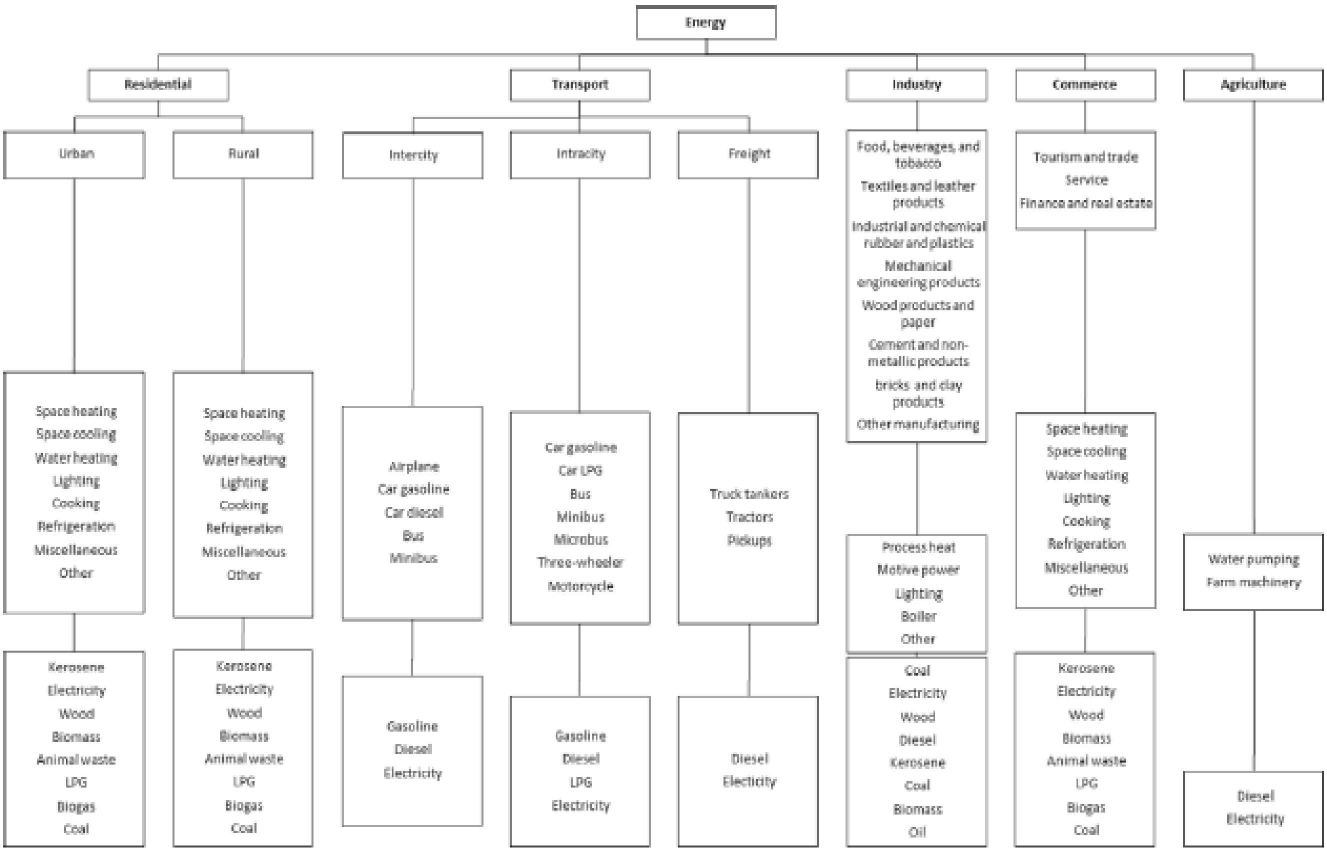

Figure 6: Energy sector structure[10].

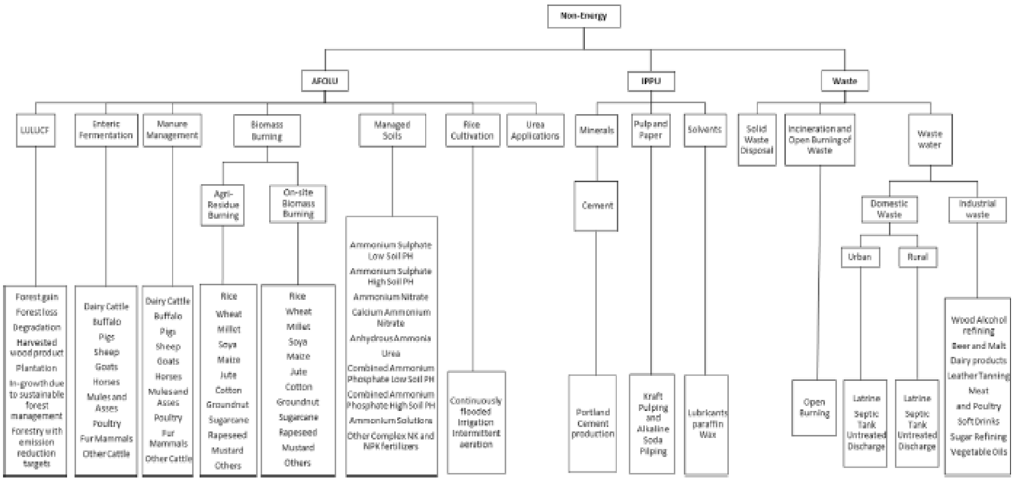

Figure 7: Non-energy sector structure[10].

This study[10] examines the challenges faced by poor countries, particularly Nepal, in attaining net-zero emissions targets in an effort to support the Paris Climate Agreement's goal of reducing the rise in the global average temperature. Using the Low Emissions Analysis Platform, the study investigates any potential negative implications of Nepal's recently released "Long-term Strategy for Net-zero Emissions" (LEAP). The findings demonstrate that putting this technique into practice will significantly reduce emissions of air pollutants, increase energy security and equity and provide additional advantages including averted health effects and crop production losses. According to the paper, energy security indices would significantly improve with a decrease in the net energy import ratio and an increase in the amount of renewable energy. Yet, a significant decrease in the use of fossil fuels would lead to a slight change in the energy mix. Ultimately, the study concludes that by addressing numerous co-benefits, net-zero emission programs can support sustainable socio-economic transformation pathways.

The study examined Nepal's newly announced "Long-term Plan for Net-zero Emissions" and estimated the co-benefits that would emerge from its implementation using the Low Emissions Analysis Platform (LEAP). According to the report, compared to the reference scenario, the plan would result in a significant decrease in air pollution emissions as well as gains in energy security and equity. Also, the technique would prevent negative health consequences and crop productivity losses, according to the study. The report recommended additional research to evaluate the health and agricultural benefits of the net-zero pathway and offered assistance for decision makers throughout the examination of policy choices and investment decisions.

Evaluation and prognosis of the oil and gas pathway to net-zero

This study[11] looks at the issue of transitioning away from fossil fuels, specifically oil and gas, in order to reduce carbon emissions and address climate change. It acknowledges that a complete shift to renewables and clean energy is not currently feasible due to limitations in technology and resources. The study critically reviews the current state of oil and gas resources, technologies and policies and looks at potential pathways for the industry to reach net-zero emissions. For instance, **(Figure 8)** demonstrates the CO_2 emissions reductions by using mitigation measures. It also discusses worldwide reserves and production, various oil and gas technologies, carbon emissions and mitigation measures and offers a possible route for the oil and gas sector to transition to a carbon-neutral future. For specialists and laypeople interested in learning about the energy transition, the research seeks to offer a thorough overview.

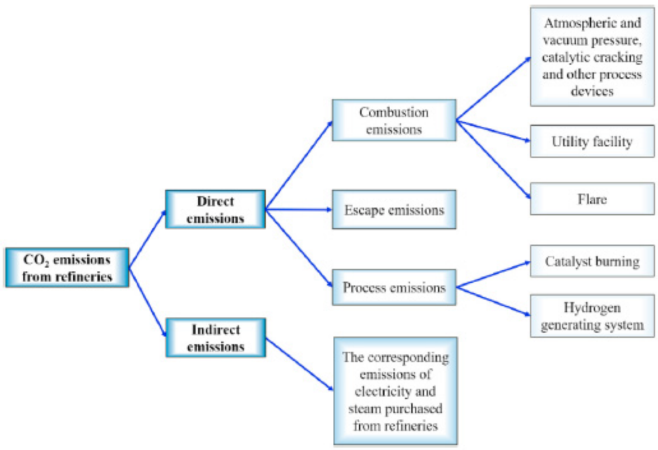

Figure 8: Reductions in CO_2 emissions achieved through mitigation measures[11].

The worldwide oil and gas sector is transitioning, with various regions seeing varying degrees of development and decarbonization. North America has the ability to expand oil and gas decarbonization, while the Asia-Pacific region is now in a high growth stage. The majority of the Middle East's energy output is exported. The majority of industry-wide recovery methods can be paired with carbon emission reduction techniques to further cut emissions. The majority of the world's energy still comes from fossil fuels, but nuclear and renewable energy are leading a transition to a low-carbon energy mix. Almost 60% of the world's carbon emissions come from the oil and gas sector and from $_{2}0_{2}0$ to $_{2}040$, this sector will be the focus of efforts to reduce emissions. By 2050, most nations hope to be carbon neutral. Major oil firms have also set targets for becoming carbon neutral through the employment of beyond-oil low-carbon transition technologies and low-carbon use of high-carbon energy sources.

Methods for the indian power sector to achieve net zero emissions

This article[12] examines the role of various technologies, including CO_2 capture and storage (CCS), nuclear, solar PV and thermal, battery storage, pumped storage, hydro, etc., along with energy efficiency, in achieving this goal by different target years, $_2$050 and $_2$060, as well as their economic implications. It also discusses India's commitment to achieve net zero emissions by $_2$070. It investigates three scenarios, including a business-as-usual scenario and two Net Zero scenarios, to achieve net zero emissions by $_2$050 and $_2$060. The findings demonstrate that the key technologies for achieving net zero emissions are solar photovoltaics (PV), onshore and offshore wind and battery storage. Nuclear power and coal plants with CCS are two key dispatchable technologies. So that careful planning can be done, the study also outlines the battery storage's storage hour requirements. Decarbonization entails significant additional expenditures and investment requirements compared to the Business-As-Usual scenario, with cumulative investment requirements rising to approximately 1.6 trillion USD and 1.4 trillion USD in the two Net Zero scenarios, respectively. The required regulations and measures are also covered.

It is required to determine the least expensive energy technologies, the volume of capacity that must be deployed at certain milestone years and the economic ramifications of these decisions in order to achieve net zero emissions in the Indian power sector by $_2$050 and $_2$060. In this essay, each of these elements is examined. The article's major conclusions are that India may decarbonize its power system by $_2$050 and at slightly lower costs by $_2$060 by installing low-carbon technologies including solar PV, wind, coal CCS, nuclear and storage options such pump hydro storage and battery storage. The paper also estimates that India will need to construct $_2$60 GW of solar capacity, 140 GW of wind capacity, 64 GW of large hydro capacity and $_2$0 GW of nuclear power in order to fulfill its goal of 500 GW from non-fossil fuel capacity by $_2$030. According to the study, India will need to develop a sizable amount of solar PV and wind capacity, with capacities of 1000 GW and 400 GW, respectively, by $_2$040, $_2$000 GW and 800 GW by $_2$050 and 3000 GW and 1350 GW by $_2$060, in order to reach net zero emissions.

This paper discusses the optimal pathways for India's power sector to achieve net zero emissions by $_2$050 or $_2$060. It suggests that solar PV, wind onshore and offshore, battery storage, coal CCS, nuclear and hydro are key technologies needed to reach the goal. The paper also estimates the amount of capacity of each technology required at different milestone years and the economic implications of achieving net zero emissions such as investment requirements and energy supply costs. The analysis comes to the conclusion that although storage solutions will be necessary, solar and wind will play a significant part in decarbonizing the power system. The research also emphasizes that while de-carbonization of the power system would result in significant increases in investment and energy supply costs, it will support the continued existence of those employed in the coal industry.

The power sector in India needs to greatly increase its solar and wind capacity to decarbonize, but current estimates for potentials are outdated. Improvements in technology and assessment methods are needed to determine the true potential for solar PV and wind (onshore and offshore) and to develop appropriate policies and measures. Although India increased its solar PV and wind capacity by 10 GW and 1.5 GW, respectively, in $_2$0$_2$1, significant supply chain and manufacturing capacity expansion will be required to satisfy future expansion needs and meet de-carbonization targets.

Battery storage deployment in India is still in its infancy and more work is still needed in fields including technology, production, standards and market expansion. India is striving to address the issue of the lack of raw materials for battery manufacturing through the Minerals Security Partnership (MSP). Although there is a lot of promise for pump storage in India, it is now less cost-effective than battery storage. In order to avoid relying solely on one technology for storage and to lessen reliance on the minerals required for battery production, efforts should be undertaken to lower the costs of pump-storage. Moreover, Carbon Capture and Storage (CCS) technology is an unproven option in India, but it is important to comprehend its technical and financial viability and evaluate its CO_2 storage capacity. Policies and regulations must be developed and implemented if it is determined that CCS is practical. For the energy system to become carbon-free, traditional coal-based capacity must decline after $_2$030 and coal demand from these plants must cease entirely by $_2$050. It may not be necessary to shut down an industry that currently employs 13 million people by deploying coal power plants with CCS technology, which also increases system stability by producing dispatchable electricity in a future power system dominated by intermittent technology.

Although India's progress in developing its nuclear power capacity has been modest, it has positive technological and economic effects on decarbonization. The nation requires improved resource and storage potential assessments as well as technological assistance from the international community. The government must develop local expertise in R&D, product manufacturing, laws, incentives and public policy. A considerable additional investment as well as worldwide low-cost long-term climate finance support are needed to build a net-zero energy system. Notwithstanding the low cost of low-emission power generation and storage technologies, efforts must be taken to reach net-zero emissions by $_2$050.

Net-Zero Co_2 in the Manufacturing Industry

The production sector accounts for a sizable portion of the world's greenhouse gas emissions. The effects of climate change have made attempts to reduce CO_2 emissions in this industry more crucial in recent years. The manufacturing sector has adopted a number of measures targeted at minimizing their carbon footprint in order to reach net-zero CO_2 emissions. Using renewable energy sources during production is one such attempt. To reduce their reliance on fossil fuels, several businesses, for instance, have started utilizing solar or wind energy to power their manufacturing[13].

Another successful initiative is the implementation of energy-efficient technologies, such as LED lighting and more efficient machinery. This not only reduces CO_2 emissions but also saves the companies money in the long run[14]. Reducing CO_2 emissions in the manufacturing sector is fraught with difficulties. The high cost of switching to renewable energy sources and energy-saving technologies is one of the main obstacles. Small and medium-sized businesses in particular struggle with this because they could lack the funding to invest in these technologies[15]. Additionally, there are often cultural and political challenges to implementing these initiatives. For example, there may be resistance from employees who are used to traditional production methods or from government policies that favor traditional energy sources over renewable alternatives[16]. Despite these challenges, there are also many opportunities for reducing

CO_2 emissions in the manufacturing industry. For example, companies that adopt environmentally friendly practices can benefit from increased customer loyalty and improved brand reputation[17]. Additionally, investing in renewable energy sources and energy-efficient technologies can lead to cost savings in the long term[14].

In the coming sections, we will explain other research on this topic, including a more in-depth analysis of the challenges and opportunities for reducing CO_2 emissions in the manufacturing industry.

A plan for oil refineries to achieve net-zero emissions

According to this research[18], high-capture rate post-combustion carbon capture and storage (CCS) is required, together with other mitigation strategies like fuel substitution and emission offsets, to significantly reduce CO_2 emissions from oil refinery operations. In order to increase energy access and affordability, these technologies should be set up to reduce scope $_2$ emissions and shifting of environmental burdens. To reduce scope 3 emissions from the burning of refinery products and flaring, long-term solutions are also necessary. They include the use of synthetic fuels and alternative feed stocks such liquefied plastic waste in a circular carbon economy.

The paper discusses the challenges and potential solutions for reducing CO_2 emissions from oil refinery operations. It suggests that a combination of post-combustion carbon capture and storage (CCS) with a high capture rate, along with other measures such as fuel substitution and emission offsets, is needed to achieve carbon-neutral refinery operations. However, it also notes that CCS may not be practical for all emissions sources and that a multipronged approach, including fuel switching, may be necessary to address all emissions effectively. Additionally, the paper highlights the importance of considering both direct (scope 1) and indirect (scope $_2$) emissions in order to fully align with net-zero ambitions and to ensure that any solutions are cost-effective and minimize environmental burden shifting. The paper also suggests that further research is needed to better understand the trade-offs between different abatement measures.

This passage discusses the merits and limitations of using post-combustion CCS in a model refinery, assuming that all point-source emissions are captured. It is noted that achieving high CO_2 avoidance rates requires high capture rates in the CCS unit, which can be difficult to achieve in practice. The passage also notes that the use of post-combustion CCS increases the primary energy requirements of a refinery and that a multipronged approach, including fuel switching and negative emissions technologies, is necessary to achieve net-zero emissions. It is also mentioned that the CO_2 avoidance rate is dependent on the fuel used to power the CHP plant and that upstream emissions from the fuel supply chain also play a role in determining the overall CO_2 avoidance rate.

Under a wildly idealistic scenario in which all point-source emissions from a refinery are caught, the article analyzes the benefits and drawbacks of post-combustion carbon capture and storage (CCS). The case study makes the assumption that a specific combined heat and power (CHP) plant powers the CCS unit and that any CO_2 emissions from the CHP plant are also aimed at the CCS unit. The two possibilities are compared in the article, one using natural gas as the fuel and the other using hydrogen. The research concludes that, unless hydrogen has a low indirect emission intensity, such as green hydrogen (electrolytically generated using renewable electricity), switching to hydrogen fuel would not be as effective as using natural gas in the CHP plant and absorbing the associated CO_2 emissions. According to the report, a thorough techno-economic analysis and life-cycle assessment of renewable electricity, green hydrogen and blue hydrogen are necessary in order to identify the optimum future energy vectors for refineries.

The article covers methods for decarbonizing current oil refineries by combining CO_2 removal technologies with emission mitigation techniques like post-combustion CCS and fuel switching. It mentions that low-carbon energy sources like solar or wind electricity may be advantageous for more recent refineries. The article also notes that CCS results in some environmental burden shifting, with greater consequences on indicators other than possible global warming and higher energy and infrastructure needs. The paper recommends adopting the planetary boundaries paradigm in order to comprehend the wider environmental effects of decarbonizing refineries. The article also makes clear that scope 3 emissions must eventually be removed or offset in order to meet with the net-zero goal because decarbonizing refineries only addresses scope 1 and $_2$ emissions.

The discussion emphasizes the necessity of a combination of emission mitigation techniques, such as post-combustion CCS, fuel switching and CO_2 removal technology, to successfully decarbonize existing oil refineries. The utilization of low-carbon energy sources like solar or wind electricity can be advantageous for more recent refineries. The efficient integration of these technologies within a refinery is a significant problem, though. Moreover, there may be some environmental load shifting as a result of CCS implementation. To comprehend the wider environmental ramifications of these tactics, more research is required. Technologies for utilizing CO_2, like BECCS and synthetic fuels, have the potential to produce emissions that are close to zero over the course of their lifetimes, but they are constrained by high energy consumption and manufacturing costs. Recycling plastic garbage can also reduce scope 3 emissions and promote a circular economy for carbon. The costs of the transition to net-zero should be managed in a socially equitable way and the sustainability of CO_2 mitigation measures should take into account the social component in addition to economic and environmental trade-offs. In order to succeed, it will be essential to create regulatory and policy frameworks that support the refining sector's sustainable transition to net-zero.

Designed for net-zero: A pathway analysis of future greenhouse gas emissions

The goal of this research[19] is to determine how Nigeria, the continent's leading cement producer, can achieve its decarbonization objectives in the cement industry. The study reviews the literature and evaluates the sector's potential for decarbonization as well as demand factors. The report outlines two growth trajectories for cement production by 2050 and three approaches for the sector's decarbonization using a scenario analysis methodology. The outcomes demonstrate that the most aggressive scenario, which includes lowering emissions from energy-related processes, carbon capture and storage and demand management, causes a 21% increase in emissions by $_2$050 (compared to 2015 levels) and puts the industry on a path to net-zero emissions after 2050. By 2050, emissions rise by

84% under a moderately ambitious scenario that mostly depends on energy-related emissions. Emissions virtually triple under the Business-as-Usual scenario by $_2$050. The analysis identifies important areas of uncertainty, including production rates and fuel mix and emphasizes the possibility for regulations to enhance energy efficiency and the clinker-to-cement ratio.

This analysis discovers that Nigeria's fast expanding cement industry can achieve net-zero emissions under an ambitious but realistic scenario. The findings indicate that, under the best-case scenario, emissions from this industry might peak in the 2030s and climb by $_2$1% by $_2$050, despite a nearly tripling of cement demand as a result of population expansion and rising demand per capita. Demand management, energy efficiency, cleaner fuels and carbon capture and storage are the three main decarbonization strategies that must be implemented in order to realize this scenario. It will take large investments, better finances, policies and an enabling environment to implement these initiatives. A moderately ambitious scenario results in an 84% increase in emissions by $_2$050 and a business-as-usual scenario results in nearly a tripling of emissions by $_2$050, according to the findings, which also show that alternative scenarios where not all decarbonization levers are implemented result in much higher emissions.

The rapidly expanding cement industry in Nigeria has a significant opportunity to cut emissions and increase energy efficiency, according to this study. In spite of an almost tripling in cement consumption, the study's best-case scenario shows that emissions from the sector might peak by the 2030s and increase by 21% by 2050. Demand management, energy efficiency, cleaner fuels and carbon capture and storage are the three main levers that must be used to decarbonize the industry. The research also points to a forthcoming investment window in the middle of the $_2$0$_2$0s as a chance to get the industry moving toward a significant reduction in carbon emissions. However, the report also acknowledges that there is a dearth of research on decarbonization of the cement industry in Nigeria and other comparable economies and that the study's assumptions are subject to some uncertainty.

In conclusion, this study discovers that Nigeria's fast expanding cement industry has a significant potential for decarbonization, but the findings' applicability is constrained by the absence of published statistics on the industry. The analysis proposes a bold but realistic scenario that might lead the industry to net-zero emissions by $_2$050. Yet for the cement sector to decarbonize, effort must be taken on all three major levers: demand management, energy efficiency, use of cleaner fuels and carbon capture and storage. The study also emphasizes the need for more analysis of the financial costs and decarbonization investment requirements, as well as the involvement and feedback of a wide range of stakeholders.

Buildings with net zero energy are a concept

The concept of Net Zero Energy Buildings (NZEBs) is covered in the paper[20], which aims to increase energy efficiency in buildings by utilizing renewable energy sources to become self-sufficient and net zero. The report reviews the relevant literature and emphasizes the value of NZEBs in lowering energy use and carbon emissions in the built environment. It also lists the various building-service systems that have been investigated for use in NZEBs and utilize renewable energy sources. In order to meet the NZEB objective, the report focuses on the importance of using smart systems and renewable energy analysesIt also emphasizes how crucial it is to take into account the effects and implications of NZEBs on various climatic conditions around the world. The feasibility of Net Zero Energy Buildings is explained by this analysis (NZEBs). The net zero building toward intelligent sustainable building is shown in **(Figure 9)**. It is possible to generate energy for buildings using renewable sources, reduce energy consumption and lower environmental emissions by creating NZEBs rather than conventional structures. The report offers a thorough assessment of the literature on NZEBs, highlighting their advantages such as lower energy prices, less carbon emissions and the opportunity to make money by selling excess energy. Additionally, it covers the rules and regulations governing NZEBs and how to implement them in already-existing structures. In order to increase energy efficiency, occupant comfort and reduce reliance on the grid and municipal water supply, the study also investigates the possibility of smart technologies, load matching and grid interaction at the building level. The importance of energy efficiency in the context of climate change and energy scarcity is covered in the conclusion.

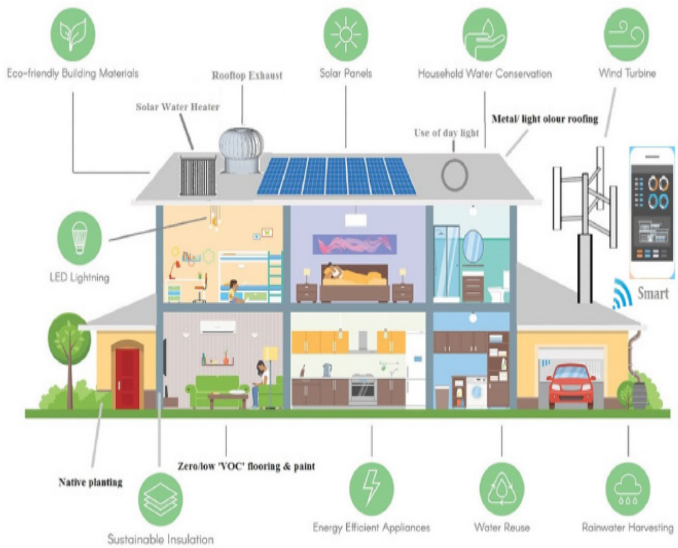

Figure 9: NZEB illustration$_2$[0].

Developing a competitive edge through the move to net zero manufacturing

In order to help manufacturers achieve sustainability targets like net-zero emissions and a circular economy, this study[21] examines how digital technology may support those efforts. In order to explore the possible role of digital technologies in achieving competitive advantage and net-zero manufacturing emissions, the study employs a resource-based perspective. According to the study, which examines the viewpoints and experiences of 13 manufacturing companies, it is crucial for businesses to include intangible asset management and development in their digital transformation strategy. According to the study, RBV can be applied as a lens for assessing the potential for competitive advantage of corporate sustainability activities and creating relevant strategies.

This study highlights the value of intangible assets and contends that organizations can only gain a sustainable competitive advantage by integrating resources and talents into core competencies. It makes the case that adopting circular business models might give an advantage over competitors and that sustainability and the circular economy have taken over as the main drivers of innovation. The survey also underlines the operational difficulties that manufacturers face in utilizing digital technology to its full potential, including issues with data collection, utilization, analysis and storage, as well as privacy and security worries. According to the report, policies that place a focus on emissions reduction and offer advice on how to store and utilize data appropriately may help to promote the use of digital choices that support the circular economy and net-zero emissions.

In order to achieve net-zero manufacturing emissions and a circular economy, the study investigates the possible role of digital technology in the development of a manufacturing firm's competitive advantage and the use of already-available internal resources and core capabilities. It was discovered that adopting a resource-based perspective can help the establishment of substantial competitive advantage and that digital technology can give industrial enterprises targeting net-zero emissions a competitive edge. The study does, however, have certain flaws, including perception bias and the need for more information to fully grasp how transferable or replicable a firm's digital talents are. Despite these drawbacks, the study offers a theoretical contribution that explores the interaction between the circular economy and the resource-based view to shed light on the role that digital resources and capabilities play for businesses in creating a competitive advantage based on digital transformation.

Net-Zero Co_2 in the Transportation Industry

The transportation industry plays a significant role in global carbon dioxide (CO_2) emissions, with road transportation being a major contributor. In order to combat the effects of climate change, it is crucial for the transportation industry to shift towards a net-zero CO_2 emission model. There have been successful initiatives aimed at reducing CO_2 emissions in the transportation industry. For example, some cities have implemented programs that promote the use of electric vehicles, while others have established bike-sharing systems and expanded public transportation options[22]. Additionally, many companies have made a commitment to reducing their carbon footprint through the use of electric and hybrid vehicles, as well as investing in renewable energy sources for their operations[23].

However, there are still many challenges and obstacles to overcome in order to achieve net-zero CO_2 emissions in the transportation industry. The limited range and high cost of electric vehicles, the lack of charging infrastructure and the dependence on fossil fuels are just a few of the issues that must be addressed[24]. Additionally, there is a need for more research and development in areas such as alternative fuel sources and more efficient transportation systems[25]. Despite these challenges, there are also many opportunities for reducing CO_2 emissions in the transportation industry. The growth of renewable energy sources, advancements in battery technology and the increasing consumer demand for environmentally-friendly transportation options are just a few examples[26].

In conclusion, reducing CO_2 emissions in the transportation industry is a critical aspect of the global effort to combat climate change. We will explain others research in the coming sections.

Is it time for a new business model in net-zero aviation?

This paper[27] discusses the challenges facing the decarbonization of aviation, including early-stage technology readiness, uncertain scalability and financial constraints. Carbon taxes and the replacement of fossil fuels with biomass-based and non-biogenic synthetic fuels are reviewed and the results are used to determine whether the aviation industry can attain net-zero emissions without addressing growth. The sector needs to reassess capacity and profitability and maybe adopt an alternative business model to stay under 1.5°C warming. If the current business model of volume expansion with low profit margins is maintained, it is likely that aviation's contribution to climate change would increase.

This paper examines the challenges and barriers to achieving carbon-neutral flight and explores pathways to net-zero emissions in the aviation sector. It argues that the replacement of fossil fuels with sustainable aviation fuels is necessary for the sector to reach net-zero emissions, but that scalability and cost of these fuels, as well as the aviation industry's financial situation and business model, are significant barriers to achieving this goal. The paper suggests that limiting growth and introducing a carbon tax could help make the transition to net-zero more achievable while aligning the goal with profitability for airlines. It also suggests that this transition may require a new business model for the aviation industry, which may lead to new equilibria in global travel.

An example of demand and supply for macro and micro net-zero activities in the automotive sector is to "walk and chew gum"

In order to demonstrate how net-zero initiatives can be regarded from both a "micro" and "macro" perspective, this research[28] examines the idea of net-zero initiatives in the automotive industry. It draws attention to the distinction between green car and green certificate programs and indicates that a practical approach to mini net-zero may be necessary given that alternative energy cars and fossil fuel-powered vehicles are likely to coexist in the short term. The article also does a CO_2 auditing exercise using data from the US Department of Energy and it is suggested that green fees for new automobiles in dealership showrooms would not be excessive relative to the cost of the car, either in absolute terms or as a percentage. Additionally, it suggests using green fees to privatize a Pigouvian tax by giving them to organizations that promote tree planting. The suggested paradigm clarifies energy policy concerns relating to both old and modern technology and can be helpful for static efficiency. It also implies that additional industries might benefit from this micro net zero viewpoint.

In order to combat climate change in the automotive sector, this paper suggests a "micro net-zero" strategy that places a strong emphasis on customer responsibility for their environmental impact. The strategy entails doing a CO_2 audit at the point of sale for automobiles and connecting externalities typically addressed by a tax to purchasing decisions for the consumption side. In order to account for the environmental impact of cars, the paper also offers the idea of "Green Certificate" as a hybrid economic/marketing tool. This can be added as an augmented product at the time of car purchase. While pointing out the shortcomings of market economics in terms of dynamic efficiency, the study indicates that this method might be effective for static efficiency.

In order to internalize a basic Pigouvian tax problem, where externalities are related to purchasing decisions made at the point of sale for the consuming side of the auto industry, the study suggests a micro net-zero CO_2 audit accounting approach. The paper defines "Green Certificate" as a hybrid economic/marketing tool and offers tactical implementation guidelines for a fruitful "Green Certificate" initiative. The paper contends that a micro net-zero approach to the vehicle industry may be implemented without the support of the entire sector and that its strategic proposals serve as a springboard for any entrepreneurial attempt to establish a trend and achieve a competitive advantage. The article also makes the case that not-for-profit organizations (NGOs) may implement this idea and that a social business model would be in line with the goals of green certifications for fossil fuel vehicles. The paper makes the case that the use of green certificates enables the application of a micro net zero strategy to the automotive sector. The strategy completely supports market mechanisms and gives private initiatives the chance to "internalize" Pigouvian levies. The report also makes the case for transparency and the necessity of a transparent carbon auditing organization that will enhance the product's credibility and distinguishability. The revenue will be invested on a scalable, less risky technique of carbon capture. The difficulty and constraint of the strategy is the "transaction costs" of persuading fossil fuel car enthusiasts to change their ways of thinking. In order to establish a trend and achieve a competitive edge, the paper provides the groundwork for entrepreneurial initiatives and not-for-profit organizations. The study focuses on outlining the underlying ideas of the idea and laying the groundwork for its application in practice, providing future research in the field of marketing with a new line of investigation.

Prospects for 1.5-degree net-zero emission actualization by $_2$050 with low- and zero-carbon renewable fuels

Under the Paris Climate Agreement, global temperature increases are to be limited to less than 2° Celsius, ideally °١،٥ Celsius. Significant emission reductions are needed for this **(Figure 10)**. The article[29] investigates low- and zero-carbon renewable fuels, such as hydrogen, green ammonia, green methanol, biomethane, natural gas and synthetic methane, as other methods of reaching the Paris Agreement's objectives while also achieving other sustainability goals. The findings indicate that by 2050, non-electric energy use in buildings and industries must account for about 25% of total non-electric energy consumption and about 90% of total non-electric energy generation. However, low- and zero-carbon renewable fuels presently only make up approximately 15% of the world's energy consumption and to attain the $_2$050 target, 10% more capacity will be needed. To reach the $_2$0% emission reduction goal, the transportation sector will need to take significant actions in the direction of energy efficiency and fuel switching. To make this massive transition, substantial new commitments to effective low-carbon alternatives will be required. This article shows that if the 1.5 °C target is to be achieved, investment in energy efficiency and low-carbon alternative energy must increase by a factor of roughly five by 2050 compared to 2015 levels.

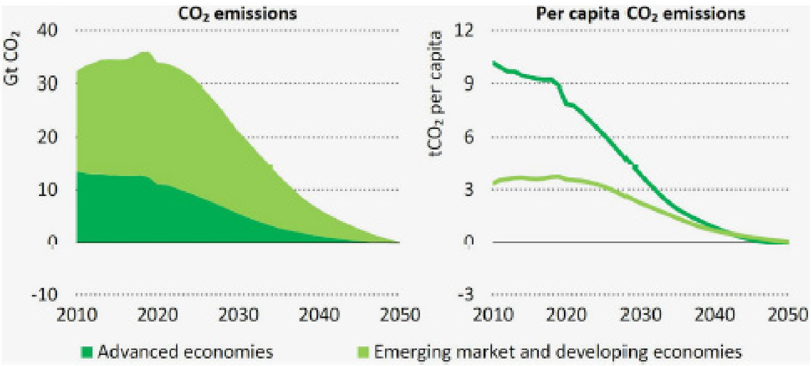

Figure 10: Plan for net zero emission$_2$[9]

The goal of achieving net-zero emissions by 2050 is discussed in the study, which will call for a massive overhaul of the energy sector. It highlights the significance of putting all readily available, dependable and sustainable energy technology into use and fostering more clean energy innovation. In areas where direct electrification is challenging, the report also emphasizes the usefulness of low-emission fuels like biogas in decarbonizing industries. In addition to providing energy, biogas aids in waste management, the reduction of greenhouse gases and the creation of jobs and income prospects. The document also outlines the strategies necessary to achieve NetZero CO_2 emissions by 2050 and to achieve universal access to renewable energy by 2030.

The actions necessary for the global energy sector to attain net-zero CO_2 emissions by 2050 are laid out in the NetZero Emissions (NZE) by $_2$050 plan. This entails accelerating clean energy innovation as well as the massive, immediate implementation of all affordable, dependable and sustainable energy technologies. The proposal calls for a 7% overall reduction in energy supply between $_2$0$_2$0 and $_2$030, which would continue until $_2$050. By $_2$050, solar PV and wind energy will make up around 70% of all electricity generated worldwide. By $_2$050, the plan calls for a 90% drop in coal consumption, a 75% drop in oil demand and a 55% drop in natural gas demand. Through $_2$030, energy efficiency, solar power and wind energy together contribute to around half of the NZE's emissions reductions; between 2030 and 2050, greater electrification, hydrogen use and CCUS consumption contribute to more than half of the reductions. By $_2$050, the strategy calls for removing 1.9 Gt of CO_2 and consuming 5$_2$0 million tonnes of low-carbon hydrogen. Yet, the path to $_2$050 is uncertain and the cost of the energy shift will increase if sustainable bioenergy is harder to get.

Carbon Capture, Utilization and Storage (Ccus)

Up to 2020, the linear economy produced things, produced energy and produced heat using fossil fuels, which resulted in the release of CO_2 into the atmosphere **(Figure 11)**. By capturing carbon dioxide emissions from industrial operations and either using them or storing them, Carbon Capture, Utilization and Storage (CCUS) technology seeks to reduce CO_2 emissions. CCUS aims to stop the emission of carbon dioxide into the atmosphere, where it contributes to climate change and global warming.

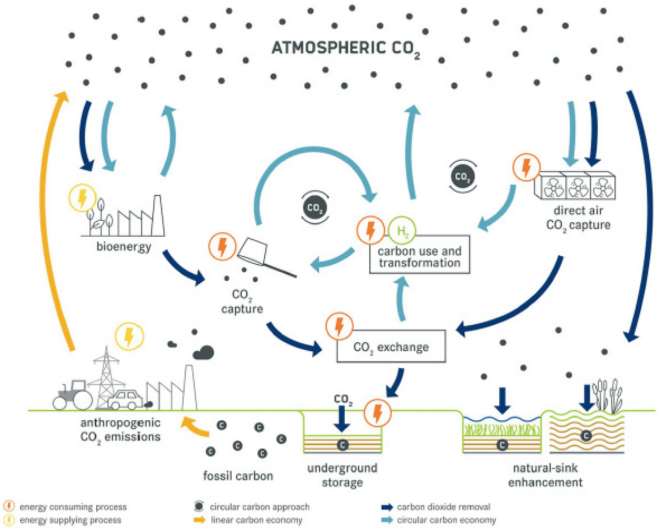

Figure 11: An illustration of the past linear carbon economy, which relied on burning fossil fuels (yellow arrows), as well as contemporary strategies that support a more circular carbon economy (light blue arrows) and carbon dioxide abatement measures (represented by dark blue arrows)[34].

One successful initiative in implementing CCUS technology is the Petra Nova project in Texas, USA, which captures CO_2 emissions from a coal-fired power plant and uses the captured CO_2 to enhance oil recovery in nearby oil fields[30]. This not only reduces CO_2 emissions but also increases the production of oil, providing a dual benefit. Another example is the Aker Solutions project in Norway, which captures CO_2 emissions from industrial processes and stores them deep underground, where they cannot contribute to global warming[30]. However, implementing CCUS technology is not without challenges. One major challenge is the high cost of capturing, utilizing and storing CO_2 emissions, which can make it difficult for companies to adopt this technology[31]. Additionally, there may be public opposition to the storage of CO_2 emissions, particularly if there are concerns about the safety and potential impact on local communities[32]. Despite these challenges, there are also many opportunities for reducing CO_2 emissions through CCUS technology. For example, companies that adopt CCUS technology can benefit from improved environmental and social responsibility, which can lead to increased customer loyalty and improved brand reputation[33]. Additionally, implementing CCUS technology can help companies comply with regulations aimed at reducing CO_2 emissions, which may become increasingly stringent in the future[3]$_2$.

In the coming sections, we will explain other research on this topic, including a more in-depth analysis of the challenges and opportunities for reducing CO_2 emissions through CCUS technology.

Germany at net-Zero CO_2 in retrospect by the year $_2$050

According to a study described in the publication[34], Germany might achieve its net-zero CO_2 emissions target by 2050. The study looks at the steps taken to achieve this net-zero system as well as the efforts put forth to implement this portfolio of steps. The study adopts a backcasting viewpoint, assuming a potential but still speculative net-zero carbon future and examines how this objective was accomplished in the past. It employs three CO_2 emission reduction, elimination and avoidance tactics. The study pulls together the various elements required to achieve net-zero CO_2 across the energy, industry, agricultural and transport sectors and was conducted by interdisciplinary scientists from the Helmholtz Climate Initiative's Net-Zero-2050 cluster. Based on the most recent literature, the study offers expert assessments of the German carbon dioxide removal (CDR) potentials, including alternatives for large-scale CDR in the form of technical CDR and the improvement of natural carbon sinks. The goal of the study is to illustrate the advantages of net-zero solutions for Germany as a case study, the related implementation efforts required for such a hypothetical net-zero CO_2 system and potential challenges that need to be overcome.

Germany has net-zero CO_2 emissions in 2050 thanks to a balance of human-caused sources and sinks. Energy-saving measures, electrification, sector coupling and the development of synthetic energy carriers as alternative fuels and energy storage all received attention. With these actions, annual CO_2 emissions from the burning of fossil fuels that had previously occurred were reduced by over 600 Mt. Nonetheless, emissions from ongoing fuel combustion operations, waste combustion, industrial processes, land use and agricultural practices persisted. These emissions were offset by grossly negative emissions, which were attained by taking actions that improve natural sinks such rewetting peatlands, restoring and recovering seagrass and using bioenergy in conjunction with carbon capture and storage. According to the net-zero approach, the biggest factor in helping industrialized nations like Germany achieve net-zero emissions was reducing CO_2 emissions.

Scenarios for net-zero CO_2 emissions in switzerland

Switzerland has a relatively low CO_2 intensity among industrialized countries, but transitioning to net-zero emissions is difficult due to limited domestic mitigation options that tend to be expensive, raise energy security concerns and trigger socio-economic barriers in policy implementation. The constraints of the Swiss energy transition are highlighted by the authors using energy systems modeling in a variety of technological, socioeconomic and geopolitical situations. They then offer workable technical solutions based on efficiency, flexibility and low-carbon technology. By 2050, energy efficiency, domestic renewable energy and hydrogen technologies would need to receive an extra cumulative discounted investment of 300 billion CHF$_2$019 in order to achieve import independence and net-zero emissions. Depending on domestic mitigation alternatives, Switzerland's inclusion into global energy markets, energy security and resilience ambition, the average annual cost of net-zero emissions per person is between 320 and 1390 CHF2019.

The paper[35] describes the challenges Switzerland faces in achieving its goal of net-zero emissions by $_2$050. These challenges include the phase-out of nuclear power, the need to decarbonize industry, buildings and transport, limited domestic renewable resources, uncertainty surrounding CO_2 capture and storage and population growth. The text also mentions that the Swiss voters rejected key measures included in the amended CO_2

Act in June 2021, revealing major societal concerns about the feasibility and costs of the energy transition. The text suggests that robust, feasible and affordable solutions are needed for Switzerland's energy transition and that such solutions can be identified through the use of frameworks like the Swiss TIMES Energy Systems Model (STEM) which includes important features such as long-time horizon, high temporal resolution, consumer segmentation and more.

Calculating steel constructions made of oil and gas that have been retired's greenhouse gas emissions

Based on the UN's International Resource Panel's Value Retention technique, this report[36] proposes a novel methodology for computing emissions from decommissioning oil and gas structures. The methodology integrates the waste hierarchy, life cycle assessment and circular economy concepts to comprehensively compute the GHG emissions created during the production of primary and secondary steel, the production of a product from this steel and related transit emissions. The findings indicate that, excluding emissions from removal processes and transportation, the reuse of a steel jacket structure in place can retain 55,040 tCO_2(eq) in GHG emissions. The authors contend that new laws are urgently required to modernize existing standards and offer a method for disclosing emissions data.

In order to appropriately compute the greenhouse gas emissions from the decommissioning of oil and gas structures, new regulations and legislation are urgently needed, as this study has shown. The existing regulations are insufficient and do not take into account all pertinent emissions. The study proposes a new Value Retention approach based on the International Resource Panel of the UN, which examines the context of a circular economy and waste hierarchy, as well as the value of materials and products as well as reusing choices. This method enables a deeper comprehension of GHG emissions and can be applied to the creation of a strategy for their reduction. The methodology is adaptable to different sectors of the economy and geographical settings.

The bio steel cycle: 7 steps to steel manufacturing with net-zero CO_2 emissions

The issue of carbon emissions from the steel sector, which accounts for 8-11% of worldwide CO_2 emissions due to high fossil-fuel and energy consumption, is covered in the article[37]. The Bio Steel Cycle, a technique of producing steel that minimizes CO_2 emissions, is suggested in the article as a way to reduce carbon emissions in the steelmaking process **(Figure 12)**. The paper also offers a 7-step implementation plan for reducing carbon emissions from steel production to zero during the next several years. The study's findings indicate that CO_2 emissions from the steelmaking process have historically been underreported and underestimated, but these emissions can be reduced if the right plans are put in place for net-zero steel production by 2050.

The Bio Steel Cycle (BiSC) offers a plan for reducing carbon emissions from the manufacture of steel to zero in the short- to medium-term. The seven steps outlined in BiSC have been demonstrated to be technically and practically feasible, including switching to green energy suppliers, installing renewable energy technology, replacing coal and coke with biomass, implementing carbon capture flue stack filters, utilizing captured carbon in concrete and food production, improving steel manufacturing processes and producing biogas and green hydrogen. Governments are attempting to bolster these initiatives through green loans and subsidies while industry leaders have already made investments in sustainable technologies. The study emphasizes the requirement for a roadmap to direct the federal government, state and local lawmakers and steel producers in reaching net-zero emissions in the steel sector.

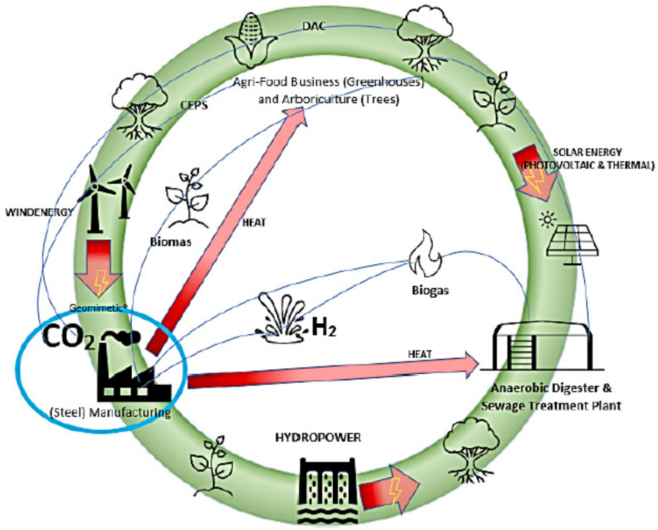

Figure 12: Concept of the Bio Steel Cycle and flow of cyclical resource use[37].

Towards net zero energy library buildings

This paper[38] presents the concept of "net zero energy" buildings, reviews related literature on sustainability and provides case studies to support the idea of moving towards sustainable buildings that produce their own renewable energy to meet their energy demand. It also encourages librarians to consider this concept in their next renovation projects.

The article argues that library and information professionals can play an important role in promoting environmental sustainability by embracing the concept of net zero energy library buildings. The authors found that many sectors, including government and industry, have been working towards this goal for more than two decades. However, developing a net zero energy building is challenging and requires detailed planning to meet energy codes and standards. The authors found that libraries, both public and academic, are increasingly moving towards this goal. They suggest that libraries should investigate options for sustainable development and consider the benefits of net zero energy library buildings. They recommend future research to investigate the possibility of starting a comprehensive program for net zero energy buildings. They also suggest that libraries can make a broader impact on reducing greenhouse gas emissions and fighting climate change through small initiatives such as installing bike racks, creating green roofs and supporting community gardening projects.

In the context of long-term CCUS supply chain design, advanced optimization of multiple sink CO_2-EOR operations

This work[39] presents a MILP formulation for the optimization of CO_2 Enhanced Oil Recovery (EOR) tactical planning. The goal is to develop a decision support system for the long-term design of a supply chain network for the carbon capture, utilization and storage management. The formulation addresses strategic and tactical decisions such as the selection of carbon capture technologies, development of multi-modal transport infrastructure and tactical planning of EOR operations with CO_2 injection. The novelty of this paper is the integration of all the decisions, both from the capture and the utilization side and a comprehensive modeling of the CO_2-EOR operations to maximize the net present value considering costs, revenues and carbon credits. The model was tested in a large case study, obtaining near-optimal results in reasonable CPU times.

This study presents an optimization framework using MILP (mixed-integer linear programming) to efficiently combine supply chain network design with EOR (enhanced oil recovery) operations. The framework integrates the optimization of tactical decisions for CO_2-EOR operations at multiple sinks, with the design of a long-term CCUS (carbon capture, utilization and storage) supply chain. The framework includes constraints such as petrophysical properties, oil and CO_2 production profiles and operating conditions. A generalized supply chain network design is proposed, with no set number of echelons for CO_2 transportation. Future research will focus on additional CO_2 utilization alternatives, improved solutions strategies and computational performance. The final MILP model is noted as being suitable for actual infrastructure planning for CO_2-EOR operations and the ability to estimate realistic economic indicators is highly valued due to the large costs involved.

Chinese CCUS cluster projects' potential for cost reduction: A case study

This study[40] demonstrates that sharing pipes and storage facilities among coal-fired power plants can greatly cut costs when developing CCUS cluster projects in the Pearl River Mouth Basin area of Guangdong province. The findings also suggest that future CCUS cluster initiatives will have greater potential for cost reduction as capture scale rises.

In conclusion, our study demonstrates that CCUS project cluster building is a practical means of achieving carbon neutrality. Since the majority of cutting-edge CO_2 utilization technologies are unable to manage the required amounts of captured CO_2, the economic utilization of CO_2 is not considered in this study. Yet, the cost of CCUS cluster projects will keep declining due to the rising carbon price in the China National Emission Trading System and the quick development of large-scale CO_2 utilization technology. In addition to significantly lowering the cost per unit of CO_2 reduction, more businesses participating in the cluster construction of CCUS projects will also enhance the projects' economic models and anti-risk capabilities. The government should begin developing specific plans and binding development goals connected to CCUS cluster construction during the 14th China Five-Year Plan Period (2021-2025). In order to create a financial assurance for high-concentration emission sources to accomplish emission reductions, this entails thorough research, comprehensive specifications for a number of regional CCUS clusters and the formulation and implementation of effective CCUS incentive policies. As a result, the transformation of industrial sectors to low-carbon production will proceed more quickly and China will successfully reach carbon neutrality.

Frameworks for a post-pandemic green economic recovery in science

This article[41] presents a framework for designing economic recovery strategies that align with climate stabilization objectives. The authors analyze green recovery strategies for an EU country based on climate resilience and socioeconomic sustainability standards using quantitative energy and economic models and a multi-criteria decision-making method. The outcomes show trade-offs between short- and long-term consequences, economic and environmental goals, as well as between professional judgment and society priorities. In their recommendations, the authors emphasize the significance of institutional and regulatory changes as well as the gradual implementation of carbon pricing in order to accomplish economic growth while ensuring environmental sustainability. Insights on prospects for greening the post-pandemic recovery are also provided by the analysis, but it should be supplemented by a more thorough examination of all recovery indicators, including those not specifically focused on energy and climate change. The research indicates that policymakers can evaluate recovery measures and support sustained economic recovery and climate-compatible growth by combining straightforward methodologies and more complex models. The strategy can be modified for usage in nations or areas outside the EU and used to address economic recovery in a wider context, such as conflict-affected areas.

Opportunities and challenges to support CCUS strategy

The development of CO_2 Enhanced Oil Recovery (EOR) projects as part of Carbon Capture, Utilization and Storage (CCUS) strategies is faced with both opportunities and challenges, as discussed in the paper[42]. Since 2016, ADNOC Onshore has been a leader in CO_2 injection and the ongoing pilots have been utilized to improve surface facilities, choose the best materials for well completions and identify constraints so that new technologies may be deployed and CCUS plans are made possible. The continuous pilots' expertise has been leveraged to reduce expenses for well design while maintaining integrity and reliability. Strategies for preventing potential corrosion problems were suggested after reviewing the fluid conditions and CO_2 content. Drillex costs were found to be greatly reduced by using L-80 1Cr materials in WAG Injectors and the use of viscous fluid spacers was suggested as a way to reduce contact between CO_2 and water during cycle changes. Long-term injectivity was not greatly impacted by the CO_2 cooling effect, either. The removal of CO_2 heaters has improved the CAPEX of active CO_2 projects.

As a key enabler for ADNOC's carbon capture, utilization and storage (CCUS) strategy, it has been demonstrated in this article that considerable cost savings may be realized for CO_2 enhanced oil recovery (EOR) projects currently under expansion at ADNOC Onshore. For WAG injectors, the Drillex costs can be greatly reduced by employing L-80/L-80 1Cr materials. Mitigation techniques, such as the use of viscous fluid spacers to restrict contact between CO_2 and water during cycle shifts, have been proposed to ensure well integrity. Temperature surveys have revealed that the long-term CO_2 injectivity has not been considerably impacted and that the cooling effect of CO_2 under the ADNOC Onshore field circumstances is not a concern. In order to maximize capital investment for current CO_2 project research, CO_2 heaters have been removed.

Site selection for CO_2 collection, utilization and storage (CCUS) using grey relational analysis based on DEMATEL and ARIMA technique evaluation of carbon emissions

The issue of selecting the best location for carbon capture, utilization and storage (CCUS) systems in Turkey is covered in this study[43]. Adiyaman, Aksaray, Diyarbakir, Afyon and Tekirdag were five alternative places that the study considered and evaluated using 11 sub-assessment criteria under the major criteria of carbon capture, carbon storage and carbon use. The weights of the assessment criteria were determined using the DEMATEL approach and the alternatives were ranked using both the unweighted gray relational analysis (GRA) method and the DEMATEL-based GRA method. The findings indicated that for both approaches, the Aksaray region is the best viable alternative CCUS area. The auto-regressive integrated moving average (ARIMA) approach was used in the study to estimate the CO_2 amount values for the next period for the Aksaray region. The study's utilization of actual data boosts the effectiveness of the suggested strategy.

This study looked at the issue of deciding where in Turkey to locate CCUS (Carbon Capture, Utilization and Storage) systems. Adiyaman, Aksaray, Diyarbakir, Afyon and Tekirdag were five probable locations that were considered. The study employed the MCDM (Multi-Criteria Decision Making) method, which considers factors like cost, CO_2 state, regional risk, availability of infrastructure and reservoir permeability. They used the GRA (Gray Relational Analysis) method to rank the options and the DEMATEL approach to weight the criteria. Aksaray Province was the location for the use of both techniques. The findings of an estimation using the ARIMA approach for the Aksaray area indicate that the region is appropriate for the CCUS system. The study offers an all-encompassing remedy that can be used to address comparable issues in other nations as well.

Opportunities, issues and future plans for the hydrocarbon industry's carbon capture, use and sequestration (CCUS) in the direction of a sustainable future

In the hydrocarbon business, carbon capture and sequestration (CCS) and carbon capture, use and storage (CCUS) present both potential and obstacles. It looks at the several CCS technologies, their readiness and their potential for mobilizing subterranean oil. The economic implications of these technologies and their effects on various industries are also examined by the writers. The purpose of the article is to provide policymakers with guidance on how to lessen the oil industry's carbon footprint until more environmentally friendly energy sources take its place.

This study suggests a method to increase the financial viability of carbon capture and sequestration (CCS): using collected CO_2 in subsurface applications like increased oil recovery. The study examines different technologies for removing CO_2 from a flue stream, including a discussion of their Technological Readiness Level (TRL) and suggested means of moving the removed CO_2, like reinforced, corrosion-resistant steel and specially designed ships. The transition from enhanced oil recovery (EOR) to storage as well as various CO_2 injection-based enhanced oil recovery (EOR) techniques, with a focus on immiscible CO_2 EOR for low-pressure oil fields, are also covered in the paper **(Figure 13)**. The paper also examines the CO_2-CH4 exchange reaction in natural gas hydrates as a viable CCS system, outlining contemporary developments and initiatives to enhance commercial feasibility. The study intends to advance the widespread adoption of CCS by assisting academics, politicians and industrial personnel in understanding the long-term potential of CCUS via CO_2 EOR.

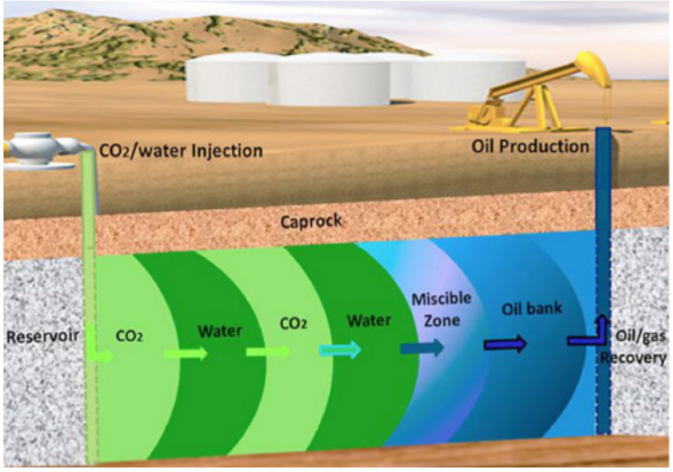

Figure 1$_2$: Illustration of CO_2 EOR application[44].

What are the results of chinese and american research on carbon capture, use and storage (CCUS)?

The current state and recent developments in Carbon Dioxide Capture, Utilization and Storage (CCUS) technology in China and the United States are systematically analyzed in this work[45]. The study examined peer-reviewed articles published in both nations between 2000 and 2022 on the Web of Science using bibliometric techniques. According to the survey, research interest in CCUS has significantly increased in both China and the United States, making these two nations the most major players in the field. The study also discovered that the CCUS research hotspots in China and the United States exhibit features of diversification and differentiation, with the two nations focusing on various research hotspots or areas of interest at various times. Future CCUS research should, according to the study, concentrate on developing new capture materials and technologies, monitoring and early warning systems for geological storage, CO_2 utilization and new energy development, sustainable business models, incentive policies and measures and public awareness.

The evolution of CCUS technology in China and the United States from 2000 to 2022 was analyzed and compared in this study using bibliometric approaches. The findings reveal a broad increasing trend broken into three stages: gradual growth, quick rise and strong development, indicating that research in the topic has deepened in both countries. Although China has eclipsed the United States in terms of publications since $_2$016, the United States has been a leader in the sector. The study also discovered that CCUS technology has developed from a single technology to a multidisciplinary field that incorporates a number of disciplines, including engineering, energy, environmental science, chemistry, materials science, business and economics and geology. According to the study's findings, China and the United States are major actors in CCUS research and the field is anticipated to continue expanding in significance because of the focus on combating climate change.

The literature on CCUS in China and the US from 2000 to 2022 is examined in this paper using bibliometric techniques. It was discovered that over the past 20 years, both China and the US have increased their level of CCUS research. Although US research in the subject of CCUS predates Chinese research, Chinese publications have overtaken American publications since 2016. Both nations have made exceptional contributions to the CCUS field and have had a significant influence on the CCUS field internationally. On the other hand, American academics and institutions have a greater overall impact. CO_2 capture, CO_2 geological storage, CO_2 emission, flue gas, model, climate change, numerical simulation, model development, cost analysis, etc. are some of the research topics in the field of CCUS in China and the United States. To encourage learning exchange and variety, it is advised that institutions and teams in both nations expand their cooperation. Future research should concentrate on innovative carbon capture materials, interdisciplinary research and low energy and low-cost carbon capture technology. Cross-industry and cross-domain coupling optimization and thorough integration of CCUS technology and other carbon emission reduction technologies are used to increase energy efficiency and lower the cost of CCUS technology throughout its life cycle.

With the purpose of achieving future net-zero CO_2 emissions, a techno-economic assessment of carbon capture, utilization and storage methods is presented

A general techno-economic analysis of carbon capture, utilization and storage (CCUS) systems as a technique of lowering CO_2 emissions is provided in this article[46]. The article discusses the energy needs, costs and technical performance of various CO_2 capture, separation, transport, utilization and storage solutions. It also addresses the many methods for storing CO_2, such as increased oil recovery, deep ocean storage, saline formations, basalt and ultramafic rocks, coal seams and depleted oil and gas fields. The article's conclusion states that while present CCUS technologies have drawbacks, these might be solved by creating a hybrid system that integrates several technologies and is economically feasible, but further research is required for industrial applications.

In this article, the present status of carbon capture and storage (CCS) and carbon capture, utilization and storage (CCUS) systems is discussed, along with how well they would be able to cut CO_2 emissions. It talks about the various CO_2 capture, separation, transport, use and storage systems, as well as their opportunities and drawbacks. The essay concludes that even while many of the technologies offer promise, the global rollout of CCS/CCUS projects is not moving quickly enough to achieve the goal of net-zero CO_2 emissions by $_2$050. The creation of a hybrid CCS/CCUS system comprising two or more processes is one potential remedy for enhancing system performance overall, particularly in terms of cost and energy effectiveness. To assess this method's technical and financial potential for commercial use, more research is necessary.

Is COVID-19 a challenge or an opportunity in the race to net-zero emissions by $_2$050 for the BRICS?

The BRICS nations-Brazil, Russia, India, China and South Africa-have a big influence on the global economic and environmental trends and their carbon-intensive economies make a big difference in the amount of greenhouse gases released into the atmosphere. The target of having net-zero emissions by 2050 is not without opportunities and problems. The study focuses on the effects of COVID-19 on the net-zero emission trajectories of South Africa and India. According to the report, the difficulties include resource diversion, retaliatory emissions for recovery and limiting the transfer of technology in the energy sector. Opportunities include a shift in consumer, producer and investment behavior with an emphasis on low-carbon alternatives. The report suggests that in order to attain net-zero emissions by $_2$050, governments and stakeholders should concentrate on removing obstacles and utilizing the opportunities provided by the pandemic[47].

The COVID-19 epidemic has presented chances and challenges for India and South Africa's growing economies to move toward net-zero emissions. GHG emissions did decline during the pandemic, according to empirical studies, but the difficulties in promoting the net-zero message, the restrained technological transfer and the decreased energy options are seen as only transitory dips in emissions. Therefore, the pandemic has created both possibilities and obstacles for achieving net-zero emissions by $_2$050 and the government and other stakeholders must concentrate on removing these obstacles while seizing these chances. The COVID-19 epidemic has presented opportunities and problems for growing economies like South Africa and India as they work to achieve net-zero emissions by the year 2050. GHG emissions have decreased as a result of the epidemic, but it has also made it more difficult to spread the net-zero message and transfer technologies. It has, however, also opened up opportunities, such as shifting investment, consumption and manufacturing practices toward low-carbon alternatives and raising green energy investment. Recovery efforts should concentrate on seizing these chances to aid in the transition to sustainable energy and create stronger, more resilient economies with solid health systems.

The world needs to focus its efforts on removing obstacles and seizing opportunities in order to achieve the net-zero by 2050 target. The COVID-19 epidemic has made it clear that sustainable economic ideals and standards need to be reevaluated and established. The creation of ambitious and revolutionary policies and initiatives that support the net-zero objective and seize post-pandemic low carbon prospects can be sparked by shifting norms, attitudes and perceptions.

Comparative analysis of global net-zero building strategies: Knowledge-sharing project to create design tactics for greenhouse gas emission reduction

The notion of net-zero, climate-neutral buildings is discussed in the article[48], along with the steps taken to make them a reality in four particular nations: Norway, the United Kingdom, the United States and Singapore. It evaluates each nation's building laws, regulations and voluntary frameworks and reviews its net-zero definitions, methods, plans and equipment. According to the study, standards that is transparent and harmonized is necessary to provide consistency in building life cycle assessments. It also discovers that integrating passive and active design techniques is a frequent strategy for achieving net-zero, but that in some cases, embodied environmental consequences and potential reduction strategies are not considered. The article offers helpful suggestions for developing construction regulations and environmental effect mitigation plans in upcoming climate-neutral, net-zero building projects.

The idea of net-zero, climate-neutral buildings is discussed in the article along with the difficulties and gaps preventing industry adoption and the global decarbonization of the built environment. The study gives a general review of the building laws, regulations and voluntary frameworks in four chosen nations: Singapore, the United States, the United Kingdom and Norway. The study's findings show that there are significant differences between the system boundaries for embodied and operational indicators (such as energy use or greenhouse gas emissions) presented in the investigated net-zero frameworks and that coherence can be achieved by performing life cycle assessments of buildings. The study also showed that some net-zero building frameworks in the US and Singapore do not take embodied energy or emissions into account in their approach, whereas research groups with industry involvement are leading the approaches in Norway and the UK. The study also discovered that the majority of the investigated techniques primarily focused on climate reduction requirements without taking into account the potential need for resilience and adaptation to climate change consequences.

The idea of net-zero, climate-neutral buildings is discussed in the article, as well as the difficulties in making them a reality. The study examined building laws, policies and voluntary frameworks in four nations: Singapore, the United States, the United Kingdom and Norway. It discovered that the frameworks' main performance indicators varied and lacked consistency. The report also emphasizes the necessity of balancing resilience, adaptation and mitigation in building design and construction and suggests that net-zero building assessments should take embodied emissions and national benchmarks into account. According to the article's conclusion, there is a pressing need for clear and standardized standards to guarantee uniformity in building life cycle assessments.

The main conclusions of the analysis demonstrate that a hierarchical approach based on increasing energy efficiency, reducing embodied GHG emissions/energy, increasing renewable energy generation on-site, maximizing renewable energy generation off-site and offsetting remaining GHG emissions/energy is used to achieve net-zero balance among the investigated countries. Developing nations that do not yet have market-based net-zero regimes can extensively embrace these guidelines. The emphasis should be on reducing energy needs by putting in place energy efficiency measures in places with an electric infrastructure based on fossil fuels and high primary energy/GHG emissions.

The analysis revealed that increasing energy efficiency, reducing embodied GHG emissions/energy, increasing on-site renewable energy generation, maximizing off-site renewable energy generation and offsetting remaining GHG emissions/energy are all part of the general approach for achieving net-zero emissions among the investigated countries. The vast majority of developing nations that do not yet have net-zero frameworks can adopt this strategy. The emphasis should be on reducing energy needs through energy efficiency measures in areas with fossil fuel-based energy grids and significant primary energy/GHG emissions. For operational energy or GHG emission reduction, design techniques frequently include passive and active design strategies, with an emphasis on high-tech solutions in rich countries and cost-effective strategies in poor countries. In order to increase transparency and credibility in achieving net-zero GHG emissions, standardized LCA standards and guidelines for the construction sector are required. However, the consideration of embodied environmental impacts and potential reduction strategies is frequently absent in examples of net-zero buildings. Making the whole lifecycle design approach a requirement for both new construction and renovation projects will require cooperation from all parties involved in the construction process.

In summary, the study suggests that net-zero building design and construction needs to consider both climate change resilience and adaptation in addition to mitigation. The study also found that there is a lack of consistency and transparency in net-zero building approaches and a need for harmonized international and national standards. The study recommends that a whole lifecycle design approach should be mandatory for new and retrofitted buildings and suggests that a joint effort between different actors in the construction process is needed to achieve this transformation. Furthermore, the study suggests that international knowledge sharing and collaboration on a global approach to reducing GHG emissions in the built environment is needed.

New green industries moving toward a net-zero economy

In order to create net-zero economies through sustainable production and consumption, this study[49] intended to close a gap in the literature by integrating the expanding multidisciplinary literature on the major variables driving the green industry. Using a systematic review methodology, the study examined 211 peer-reviewed papers and 16 pieces of grey literature published between 2009 and July 2022. The study identified several significant gaps in the literature that have implications for both theory and practice for future research. These include the need for more research on potential barriers to a successful green transition, the need for holistic frameworks and systems thinking to study the varied and fragmented factors underlying the green industry, the need to consider the social structures in which the green industry is embedded and the need for additional research on the theoretical foundations.

This study is a thorough analysis of the literature on the green industry, with an emphasis on the driving forces behind the sector and potential barriers to a net-zero economy. The study identified six major gaps in the literature, including potential barriers to a successful green transition, a lack of a holistic and thorough understanding of the factors driving the green industry, a focus on the growth-environmental conundrum and a failure to consider the social implications of the transition, contested theoretical foundations for green growth and regrowth, a lack of regional and local perspectives and a dearth of multidisciplinary approaches and mixed methods involving fieldwork. In order to support a successful green transition to a net-zero economy, the report recommends a comprehensive elements framework and urges for additional research to fill in these gaps.

For offshore oil and gas production, usage of low-carbon energy generation

This paper[50] reviews low-carbon power generating ideas for offshore oil and gas operations, analyzes their potential to cut greenhouse gas (GHG) emissions and assesses their suitability for offshore application. According to the study, only a mature concept-power from shore-can achieve very high emission reductions of more than 95%; however, other concepts, including fuel switching, CO_2 capture and storage and renewable power coupled with energy storage, have the potential to achieve similarly significant emission reductions. To meet net zero emission ambitions, more low emission technologies are required as efficiency gains and shore power alone are insufficient. The study also provides a database of specifications and a technique for evaluating low carbon power generating options.

The study studies and evaluates a variety of offshore power generating technologies in terms of their applicability offshore and potential for emission reductions. It is discovered that while a number of concepts have the ability to cut emissions in comparison to typical natural gas-fired gas turbines, their emission reduction potential, technological maturity for implementation offshore and lack of benefits compared to present technologies vary. Although qualified and capable of achieving both intermediate and long-term climate goals, power from the beach is not appropriate in all circumstances. Technically sound approaches for partial emission reductions have already been deployed offshore, such as combined cycle solutions and wind power paired with gas turbines. Some ideas, including switching to hydrogen or ammonia as fuel, CCS and renewable energy sources paired with energy storage, have the potential to significantly reduce emissions but face obstacles and need further study and development before being put into practice. For net zero emission ambitions, it is advised to concentrate on technologies that allow for large emission reductions.

Latin American net-zero deep decarbonization pathways: Opportunities and Problems

In order to satisfy the goals of the Paris Agreement and local development aspirations, this study[51] analyzes the possibility for profound decarbonization in six Latin American nations (Argentina, Colombia, Costa Rica, Ecuador, Mexico and Peru). The energy system, forestry, agriculture and land use were the main topics. The study identified these sectors as top priority for future research since it indicated that large emissions will still be produced in 2050 in sectors like manufacturing, agriculture, forestry and land use, freight and oil and gas production. The research also highlights key areas for international cooperation and offers suggestions for designing domestic policy packages.

With a thorough examination of the energy sector, agriculture, forestry and land use, as well as passenger transportation in six countries, the DDP-LAC project evaluates the potential for Latin American nations to achieve net-zero GHG emissions by 2050. The findings demonstrate that these nations may achieve decarbonization while also enhancing economic expansion, air quality and transportation. The report identifies opportunities for further research and international collaboration as well as insights for the creation of domestic policy packages. The outcomes can help these nations create long-term objectives and formulate policy.

Engineering the sequestration of carbon

Over the past two decades, significant advancements in CO_2-production-reducing technologies have emerged, particularly in subsurface storage-a key solution offered by the oil and gas industry due to its expertise in handling large-scale, high-pressure, high-temperature systems involving complex fluid behaviors. CO_2 mitigation and sequestration require complex measures addressing root causes to reduce GHG emissions, adaptation strategies and CO_2 sequestration involving separation technologies, transportation and subsurface engineering. Understanding the interactions of principal fluids in the reservoir, including hydrocarbons and water, is crucial for effective surveillance and modeling. Capture technologies like post-combustion, pre-combustion and oxy-fuel combustion are essential for creating concentrated CO_2 streams for storage, with ongoing research aimed at improving efficiency and reducing costs. CO_2 transport, primarily through pipelines, must ensure purity to minimize corrosion and maintain safety. Engineering education must incorporate carbon footprint calculations and interdisciplinary skills to prepare future engineers for CCUS projects, emphasizing the need for a global, collaborative approach to tackle GHG challenges.

The Circular Carbon Economy and the Net-Zero Emissions Target

A closed-loop system in which carbon emissions are minimized, captured and reused sustainably is referred to as a “circular carbon economy.” Reducing greenhouse gas emissions and building a sustainable, low-carbon future are the objectives of a circular carbon economy. In order to meet the net-zero emissions target-which attempts to balance emissions with removals-and keep global warming to 1.5°C above pre-industrial levels, the idea of a circular carbon economy has gained popularity in recent years.

One of the key challenges to reducing CO_2 emissions through a circular carbon economy is the need for significant investments in new technologies and infrastructure. This can be a barrier for many countries and industries, particularly those that are heavily reliant on fossil fuels. However, there are also many opportunities for reducing emissions through a circular carbon economy. For example, the reuse of carbon emissions in the production of chemicals, fuels and materials has the potential to significantly reduce emissions while also creating economic benefits[52]. Different approaches towards achieving a net-zero emissions target are being explored and implemented in different parts of the world. For example, some countries are focusing on decarbonizing their energy mix through the use of renewable energy sources, while others are investing in carbon capture and storage (CCS) technology. Some countries, such as the UK, are pursuing both of these approaches in order to achieve their net-zero emissions targets[53].

In conclusion, the circular carbon economy has the potential to play a crucial role in reducing CO_2 emissions and achieving a net-zero emissions target. However, significant investments and policy support will be needed in order to overcome the challenges and fully realize the potential of this concept. We will explore these challenges and opportunities in more detail in the coming sections, along with other research and initiatives aimed at reducing emissions and promoting a circular carbon economy[54].

In the following sections, we will delve deeper into various aspects of the circular carbon economy and its impact on reducing CO_2 emissions. We will examine the challenges and opportunities of implementing a circular carbon economy and compare various approaches aimed at reaching the goal of net-zero emissions.

A theory to help move society from a linear to a circular carbon economy

The notion for creating new, sustainable value chains in the chemical industry is presented in the article[55] by using coal and carbon-containing waste as substitute raw materials. By completing the carbon cycle, lowering the carbon footprint and boosting resource efficiency and conservation, this strategy is considered as a means to help the transition from a linear economy to a circular carbon economy. The paper gives a case analysis of using domestic coal and waste as an alternative to imported crude oil for chemical manufacturing in Germany as well as the technological breakthroughs and developments that are required to facilitate this transition. The paper also covers path dependency and other technological, institutional and human difficulties that may emerge in the sociotechnical system during the shift to a circular carbon economy[55].

In order to aid in the shift from a linear to a circular carbon economy, this article proposes the use of coal and carbon-containing trash as substitute raw materials in the chemical industry. Reduced greenhouse gas emissions, increased resource efficiency and conservation and a halt to the wasteful burning of priceless carbon resources for energy or waste disposal are the objectives. The paper addresses the technological advancements and breakthroughs required to support a successful transition and suggests the coupling of the energy, chemical and waste management sectors as a realistic and future-oriented perspective for ending the carbon cycle. The difficulties that the sociotechnical system can face during this shift are also covered.

The essay focuses on how Germany's rapid adoption of renewable energy sources, rising coal emissions from the country's electrical sector and predominance of waste burning create a potential for a sector coupling of the waste management, chemical and energy industries. This chance is made possible by gasification technology, which turns garbage and coal into synthesis gas that can be used in the chemical sector to create products with added value **(Figure 13)**. The chemical industry can diversify its feedstock and lessen its reliance on imported primary carbon resources like crude oil and natural gas by using indigenous coal and waste resources as substitute feedstock for chemical manufacturing. By encapsulating waste-derived carbon in chemical substances, this strategy also lowers CO_2 emissions related to trash incineration, decreases the demand for landfill area and improves resource efficiency. Additionally, by including green hydrogen produced from renewable sources into the production process, it offers an alternate chemical storage method for excess renewable electricity and aids in the accomplishment of zero CO_2 emissions. Also, this strategy offers domestic lignite mining regions a fresh growth outlook that is consistent with Germany's climate goals.

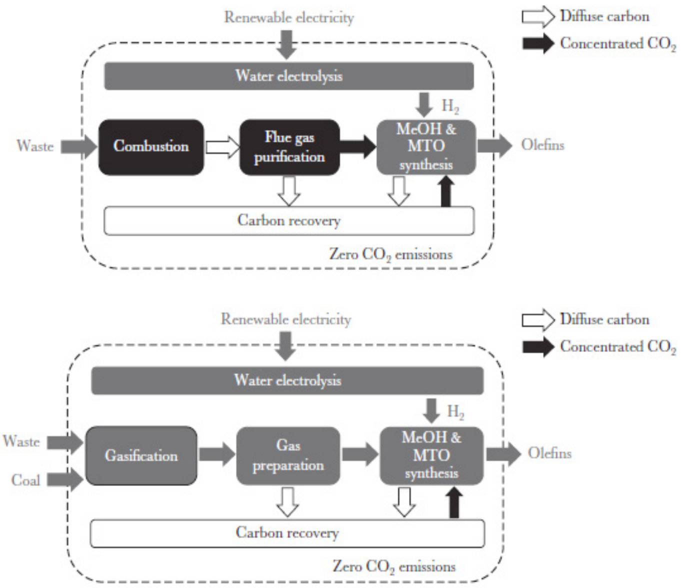

Figure 13: Illustration of scenario for carbon capture and utilization and gasification[55].

An assessment of the UK's net zero policy

This article[56] examines the UK's net-zero emissions policy for the heating and construction industries, focusing on important topics including future building codes, heat pumps and hydrogen utilization. The study examines the difficulties and most current policy developments and offers insight into the general progression toward sustainability and decarbonization of the built environment in the UK by 2050. The results are visualized and a clear image of the prospective impact of the policy is presented using the foresight model Future Wheels.

Energy use in homes in the UK alone accounts for 29% of all energy consumption and 20% of UK greenhouse gas emissions, making the built environment sector largely to blame for the world's energy consumption. The majority of this energy is used for space and water heating and improvements in building engineering technology can aid in lowering pollution levels and managing resource use to safeguard the environment. The performance of building envelopes can be improved to reduce energy consumption in buildings; however, many previous energy efficiency programs have failed to significantly cut carbon emissions and are therefore unsustainable.

In conclusion, the built environment sector significantly contributes to global energy consumption and greenhouse gas emissions, with space and water heating accounting for a sizable share of energy use in UK households. Focus should be put on material selection, the use of low thermal conductivity materials in building envelopes, as well as the use of renewable energy sources for heating and hot water, in order to decrease energy consumption and emissions. Heat pumps might be a workable solution, but it's unclear whether their widespread use is feasible or practicable. Although blending green hydrogen with current gas infrastructure may be more effective, obtaining it still poses a hurdle. In addition to highlighting the challenges and unknowns of employing new technologies to reach carbon neutrality in the UK, the research report also points out that markets for fossil fuels, consumer behavior and government regulations all have an impact on the process of decarbonization.

The strategy for achieving zero carbon in the UK is complex and uncertain and there is a lack of detailed plans for the construction and choice of materials, particularly insulation. The UK's infrastructure is not prepared for the shift to heat pumps and there are concerns about the high costs and limited availability of insulation materials. The report doesn't offer a detailed strategy for decarbonizing off-grid homes and there isn't much academic research on CCS. To meet $_2$050 goals, extensive retrofitting of existing dwellings is required and government programs like ECO must be reinforced. Future studies should concentrate on the advantages and disadvantages of energy storage and green hydrogen technologies, as well as the ability of the UK's current infrastructure to handle the added demand from heat pumps. Concerns exist over the dangers, costs and cost uncertainty associated with these technologies.

From phase-out of coal to net zero

According to article[57], worldwide net greenhouse gas emissions must be zero by $_2$050 in order to achieve the goals outlined in the Paris Agreement. The UK is among the first nations to not only phase out coal by $_2$0$_2$4 but also establish a net-zero objective for $_2$050, which is a crucial step in achieving this goal. The coal phase-out was not largely driven by the choice to phase out coal in $_2$015, but rather by policies and other contextual circumstances, according to the article's analysis of the factors and actors that contributed to these decisions. The Conservative

Party's wish to demonstrate its climate protection aspirations, the Committee on Climate Change's recommendations and the overall political atmosphere advocating for greater climate protection all played significant roles in the choice to go net-zero. Yet, from the standpoint of climate justice, industrialized countries like the UK should achieve carbon neutrality before 2050, given their historical culpability for carbon emissions and the economic advantages that they enjoy over those of the Global South.

By phasing out coal earlier than expected and establishing a net zero aim for $_2$050, the UK has served as an example for other nations. Initiated in the 1980s, the phase-out of coal in the UK was propelled by legislation like the carbon price floor, EU air pollution rules and rising renewable energy usage. The remaining coal-fired power plants will be converted or shut down by $_2$0$_2$4, marking the end of the phase-out. Public outcry, cross-party agreement and the prime minister's determination to protect her legacy all played a role in the decision to set a net zero aim. Both decisions were influenced significantly by scientific advice, social movements and political consensus among key parties. The UK's experience might serve as inspiration for other nations.

Early decisions have been made in the UK to phase out coal by $_2$0$_2$4 and establish a net zero goal for $_2$050. Yet, there are still numerous obstacles in the way of attaining these objectives because going net zero necessitates a complete overhaul of the energy infrastructure. The government is in the midst of creating implementation strategies, however some of the suggested actions have drawn criticism for being insufficient. The world's greenhouse gas emissions must reach net zero by the middle of the century and from the standpoint of global equality, the year $_2$050 might be too late for an industrialized nation like the UK.

Adapting Net-Zero in Emerging Economies

An important objective for reducing the effects of climate change is to reach net-zero or a situation in which the production of greenhouse gas emissions is equal to the removal of greenhouse gas emissions from the atmosphere. Due to their rapid economic growth and rising energy use, emerging economies face a particularly difficult time transitioning to net-zero economies. Emerging economies have numerous chances to guide the transition to a net-zero future, nevertheless. For instance, numerous developing nations are making investments in clean energy sources like wind and solar, which can assist to cut greenhouse gas emissions[58].

Moreover, emerging economies can gain from the most recent technical developments in low-carbon transportation and energy efficiency, which can lower emissions while raising general quality of life[59]. Notwithstanding these possibilities, implementing net-zero in emerging economies is fraught with serious difficulties. The absence of funding and infrastructure required to facilitate the shift to a low-carbon economy is one of the biggest problems. The adoption of new technologies and practices that potentially upend current economic models may also encounter pushback from some stakeholders, such as traditional energy producers and manufacturers[58].

In the coming sections, we will explore other research on this topic, including a more in-depth analysis of the challenges and opportunities for adapting net-zero in emerging economies.

Modeling approach to the right-sized facilities: Approaching net zero

The article[60] emphasizes the significance of combining data from many industries to accurately model carbon emissions and examine potential for reduction. The authors describe a web-based application called the Net-zero Engineering Support Tool (NEST), which is intended to assist INL stakeholders in strategic planning to accomplish carbon emission reduction, using the campus of the Idaho National Laboratory (INL) as a test case. NEST incorporates several strategies and timetables for energy conservation, fleet decarbonization and other greenhouse gas reduction efforts while using historical data as the basis for modeling CO_2 emissions. Stakeholders can visualize carbon emissions, power use and prices using NEST to aid in decision-making while laying up a plan for achieving carbon net zero. The authors utilize the tool to examine various replacement schedules for converting the INL campus fleet to electric vehicles in order to illustrate how to use it. Using the tool, decision-makers can test various replacement schedules and give the highest priority to those that result in a specific level of capital expenditure while hitting predetermined milestones. The demonstration focuses on the electrification of vehicles, but the authors point out that the framework can be utilized for further quantitative study of other GHG reduction initiatives.

NEST is a web-based data visualization and processing tool developed by INL to aid in the strategic planning of carbon emissions reduction. It integrates data from multiple sources such as Excel, P6, SkySpark and iMap using a multi-level framework and Deep Lynx data warehouse. NEST allows stakeholders to adjust project schedules and predict future CO_2 emissions based on input data. It was used as a test case to demonstrate its advantages in transitioning to an electric vehicle fleet by analyzing replacement schedules and obtaining capital expenditure quantities. NEST can be used by other organizations and companies to improve decision-making capabilities in achieving carbon neutrality goals.

Using the expanded exergy accounting model, we can move toward sustainable net-zero districts.

For the net-zero energy framework, the study[61] presents an enlarged exergy accounting approach that takes into account all technological, economic, environmental and social factors. This approach is used in a district in Iran and the outcomes are contrasted with those of the exergy and net-zero source energy approaches. The new method offers the highest self-consumption index and has proven to be effective in creating long-lasting net-zero systems.

The study uses the expanded exergy accounting concept to propose a new definition of net-zero energy that takes into consideration all technological, economic, environmental and social factors. The strategy is used in a district in Iran and contrasted with other ones that are already in use (net-zero source energy and exergy). The findings demonstrate that the new method is more responsive to changes in the parameters of the energy network, energy load profile and renewable energy system. In comparison to the other approaches, the new strategy boosts the site's local renewable energy output and has a higher self-consumption index. The net-zero energy strategy has the lowest self-consumption index but the highest local renewable energy production. The net-zero source energy strategy reduces the site's local renewable energy production by raising the primary energy factor of grid power while remaining insensitive to changes in the renewable energy system's characteristics and the energy load profile. In general, the new method is dependable for creating long-lasting net-zero systems.

This paper offers a novel extended energy accounting concept-based definition of net-zero for buildings and districts. Its sensitivity and technical analyses are compared to those of current net-zero energy techniques and applied to a district in Iran. The findings demonstrate how responsive the new methodology is to modifications in the parameters of the energy network, energy load profile and renewable energy system. The new strategy offers the highest self-consumption index and rationally configures local renewable energy generation based on energy network and system efficiency, making it a trustworthy solution for long-term net-zero systems. Calculating extended exergy efficiency estimates of energy carriers, however, necessitates a substantial amount of precise data and is difficult and imprecise. Future research should concentrate on developing a tool that will make its application easier.

Role of CCUS in carbon neutral power system

It will take cooperation between energy efficiency, renewable energy and carbon capture, utilization and storage (CCUS) technology for China to reach its ambitious $_2$060 carbon neutrality target. Peat and coking coal caused China's high CO_2 emissions, therefore the power industry, which largely relies on coal and accounts for roughly half of CO_2 emissions, is essential to achieving the target **(Figure 14)**. According to the study, CCUS technology is necessary for reaching carbon neutrality in power systems that use fossil fuels, but its high energy consumption and high cost provide significant barriers to widespread use. The study contends that CCUS must be prepared for widespread deployment by lowering energy consumption and prices before the window between $_2$030 and $_2$040 closes or it will be phased out alongside the majority of coal power plants. This scenario represents China's final opportunity to decarbonize fossil fuels and is of significant import.

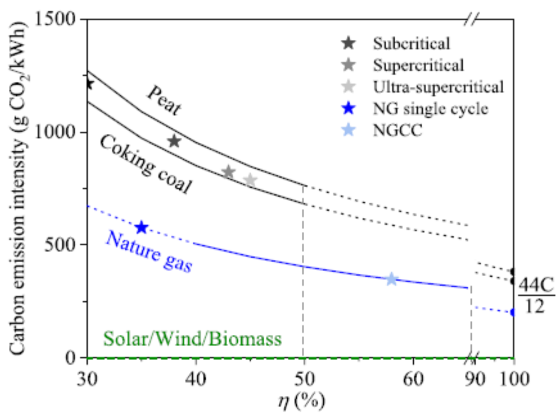

Figure 14: The carbon emission intensity of various energy resource and technologies[62].

The function of Carbon Capture, Utilization and Storage (CCUS) technology in achieving carbon neutrality in power systems is covered in this paper[62]. It implies that carbon neutrality can only be attained by a combination of energy efficiency, renewable energy and CCUS technology, with CCUS being especially crucial for fossil fuel-based power systems. The majority of China's coal power facilities are described in the document as "young," meaning they will need to be upgraded or replaced in order to become carbon neutral by the crucial date range of $_2$030–$_2$040. The article comes to the conclusion that lowering the energy consumption and expenses of CCUS technology is essential for its future viability and to prevent climate change consequences.

An in-depth analysis of the CO_2 EOR/CCUS opportunities in oil reservoirs

In order to identify and rank the candidate fields for CO_2 Enhanced Oil Recovery, Petroleum Development Oman Company (PDO) undertook a portfolio analysis, which is described in this document[63]. (EOR). The study included technical feasibility screening of all oil fields, optimal injection strategy selection based on reservoir and fluid characteristics, analytical methodologies for predicting incremental oil recovery and net CO_2 utilization and storage capacity evaluation. High-level economic screening was also conducted as part of the study to rate prospects according to unit technical cost (UTC). The study's findings demonstrated that numerous fields were likely candidates for various injection procedures and that some of them had desirable UTCs with significant CO_2 storage capacity. The study also shed light on how to pick and improve CO_2 injection plans for EOR.

The goal of this study was to determine which areas in PDO's portfolio would be best suited for CO_2 Enhanced Oil Recovery (EOR), which would reduce greenhouse gas emissions and yield low-carbon oil. A screening and ranking workflow was created, which included evaluating fields for the use of two well-established EOR technologies (Continuous Gas Injection [CGI] and Water Alternating Gas [WAG]) in both miscible and immiscible conditions, predicting oil recovery at the pattern level for each field, developing a concept for CO_2 EOR, which could include the option of enriching CO_2 for miscible WAG and calculating the CAPEX and OPEX for the calculation of Unit (UTC). The study found that many fields were identified as candidates for WAG and CGI in PDO's portfolio, with UTCs in general being more attractive for CGI compared to WAG. The cost of CO_2 capture and transportation can be a major component of the overall cost of CO_2 EOR. Enriching immiscible CO_2 gas by adding propane to perform miscible WAG could unlock larger oil volumes than injection under immiscible conditions and showed an improvement in economics compared to immiscible WAG. A significant amount of CO_2 could be utilized and potentially stored by the different CO_2 EOR opportunities identified in this study. Further in-depth studies are being conducted for the most attractive opportunities to identify CO_2 sources, estimate costs and de-risk the projects.

A CO_2 EOR for a net-zero emission goal driven by storage

The method described in the article[64] is known as "storage-driven CO_2 enhanced oil recovery (EOR)" and it tries to achieve net-zero or negative CO_2 emissions by storing the most CO_2 possible in oil reservoirs while also extracting the most oil possible. Dimethyl ether (DME) is used as a process aid in this procedure to boost the solubility of CO_2 in in situ oil and stop lighter hydrocarbons from escaping from crude oil. The findings demonstrate that the approach recovers more oil than traditional CO_2 EOR and that the amount of CO_2 sequestered outweighs the emissions from burning the produced oil **(Figure 15)**. The research reveals that by changing the development scenarios, more CO_2 sequestration and greater oil recovery can be accomplished.

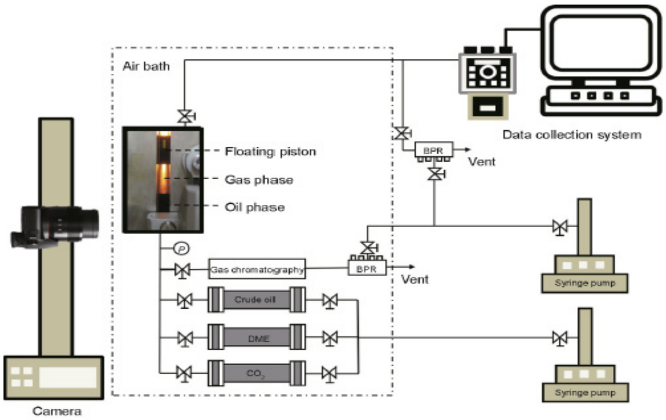

Figure 15: A schematic diagram for determining the phase composition and solubility of CO_2 in crude oil using a PVT setup. The diagram includes a back-pressure regulator (BPR) and pressure (P)[64].

In order to improve oil recovery while also storing CO_2 in oil reservoirs, dimethyl ether (DME) is used as an addition to CO_2 in this work's proposed storage-driven CO_2 enhanced oil recovery (EOR) approach. According to test results, DME increases CO_2 solubility in crude oil and aids in preventing lighter components from escaping the crude oil. According to the results of the simulation, storage-driven CO_2 EOR is superior to traditional CO_2 EOR in terms of expanding sweeping efficiency and boosting oil recovery.

Further enhancing oil recovery is the development scenarios' use of water alternating gas injection. In comparison to traditional CO_2 EOR, the process produces more CO_2 storage in oil reservoirs and the sequestered CO_2 outweighs the emissions from burning the produced oil. In contrast to conventional CO_2 EOR, which does not have any additional CO_2 emission-related taxes or fees, it would not be as financially appealing to investors.

Accelerated emission reduction in Israel: Policy standards vs. carbon pricing

According to this study's findings[65], a moderate carbon pricing strategy is a cost-effective way to reduce Israel's greenhouse gas emissions by 67% by the year 2050 while having little to no effect on the country's economic expansion. Other policies, such as those that the government is currently putting forth and clean energy requirements without carbon pricing, may have a greater influence on income distribution than they do on lowering emissions.

According to the study, carbon pricing is a useful strategy for cutting greenhouse gas emissions in open, small economies like Israel. Significant emissions reductions, an increase in the use of renewable energy sources and economic growth can all be achieved with the implementation of carbon pricing in conjunction with environmentally friendly policies and infrastructure investments. The paper advises governments to adopt carbon taxes as their primary tool for implementing climate policy and to make sure that carbon targets and price are mutually supportive. Moreover, carbon pricing can boost low-income population groups and improve energy security.

There has been a dearth of investment in transportation infrastructure, which accounts for a sizable amount of Israel's usage of fossil fuels. According to the study, the government should devote a significant number of resources to quickly electrifying light-duty cars and public transportation. The study also recommends spending money on effective public transportation as an alternative to driving a car, which will be affected by carbon pricing. The report makes the case for working from home as a practical means of reducing traffic and pollution as well as the unfavorable effects of carbon pricing. A significant share of solar energy in power generation is a difficulty that needs to be addressed and the study emphasizes the need of infrastructure for electricity storage and supply.

According to the analysis, Israel can utilize carbon pricing as a tool for long-term strategic planning to cut greenhouse gas emissions by $_2$050 by electrifying its economy and generating electricity from renewable sources. Something will need to be invested in and may help the economy flourish. The government should give rapid electrification of light-duty cars and public transportation top priority because the transportation industry contributes significantly to emissions. The government should consider the usage of natural gas, business decarbonization prospects and the reduction of local pollutants for improved air quality and health advantages. The industry also contributes significantly to emissions. The COVID-19 situation has also drawn attention to the possible advantages of legislation encouraging remote work in easing traffic and pollution.

The article discusses the potential risks and challenges of transitioning to a low-carbon economy in Israel, including resistance from special interest groups and potential adverse effects on low-income households. The authors recommend strong political will and redistributing the benefits of decarbonization to offset any negative consequences. They also suggest that measures should be taken to support the transition and the ongoing COVID-19 crisis may increase the political feasibility of carbon tax as a new source of revenue.

A bottom-up integrated optimization to look into the role of BECCS in the switch to a net-zero energy system

In order to slow the rise in the global temperature and reach net-zero emissions, this study examines the application of bioenergy with carbon capture and storage (BECCS) in India's current energy infrastructure. In order to connect CO_2 sources and sinks with bioenergy sources, the study suggests a bioenergy-CO_2-EOR system. When employing CO_2 from bioethanol fermentation and an oil price of around \$56 per barrel, the system is economically viable. For bioelectricity plants, the system requires an oil price of about \$90 per barrel. The system can decrease crude oil imports, support ethanol blending, offer extra income options and reduce air pollution. It also has net negative CO_2 emissions. According to the findings of a case study conducted in Ankleshwar, Gujarat, CO_2 from $_2$nd generation bioethanol fermentation may be an economically viable source of CO_2 for increased oil recovery in the near future[66]. Oil prices over \$56/bbl and a carbon pricing in the range of \$20 to \$40/ tCO_2 would make the bioenergy-CO_2-EOR system economical and able to meet short-term demand. The report recommends a nuanced and comprehensive strategy for BECCS that takes into account local characteristics, accessible technologies, regulatory support and biomass resources. The paper suggests industrial-scale demonstration projects, investments in research and development, CCS infrastructure and the implementation of carbon pricing for industrial sectors as a way to establish a market for BECCS and evaluate its capacity to achieve long-term climate goals.

The oil and gas industry's knowledge and skills are required for net zero emissions

The main task of the twenty-first century is to ensure a safe global climate while simultaneously raising the standard of living for all individuals in a fair manner. Carbon capture and storage (CCS) on an industrial scale is necessary to reach net-zero greenhouse gas emissions by 2050. According to the study[67], in order to retain long-term economic viability, the petroleum industry should shift from hydrocarbon production enterprises to net-zero emission energy and carbon dioxide storage enterprises. It has the technical know-how to accomplish this goal. The report comes to the conclusion that CCS is economically competitive with nuclear and renewable energy and that it is necessary to achieve net-zero emissions and increasing energy output by 2050. The petroleum industry has an opportunity to improve their public image by taking on this challenge.

Developing a CO_2 collection and storage system and transitioning to zero-net emissions

This article discusses a study[68] that employed technologies including carbon capture and storage, hydrogen, electric mobility and direct air capture to analyze several scenarios for reaching net-zero emissions in Qatar. According to the research, Qatar may start acting right now by pushing electric and hybrid vehicles, using solar energy to produce power and implementing carbon-free hydrogen production, carbon capture and storage and direct air capture with carbon capture and storage. In a setting of worldwide zero-net emissions, the report also emphasizes the possibility for carbon-free hydrogen exports and emission permit sales to make up for the anticipated revenue losses from gas exports.

The transition to zero-net emissions in Qatar is examined in this article using a linear model that takes into consideration a number of different technologies, including hydrogen, electric vehicles, carbon capture and storage and direct air capture. The model accounts for energy consumption and efficiency loss at various phases of energy extraction, transformation and usage. It is dynamic and operates over a large time horizon. The conclusion is that a technology is "competitive" if it exists in a scenario and helps to achieve the environmental aim at the lowest possible overall cost[69].

The article discusses the ETEM-Qatar technology-rich model, which is employed to evaluate various scenarios for Qatar's transition to zero-net emissions. Electric mobility, hydrogen, carbon capture and storage and direct air capture are some of the primary technologies used in the shift. According to the model, Qatar could begin promoting the use of hybrid and electric vehicles right away. It could also develop solar-powered electricity production, district cooling, the production of ammonia and hydrogen through electrolysis, the introduction of carbon capture and storage in all industrial sectors and the development of direct air capture with carbon capture and storage. By $_2$070, Qatar could have a net-zero emissions system thanks to this.

The ETEM-Qatar technology-rich model is used in this article to assess various scenarios for Qatar's transition to zero-net emissions. The model focuses on a number of important technologies, such as direct air capture, hydrogen, carbon capture and storage and electric mobility. The article demonstrates through numerical simulations how Qatar could promote hybrid and electric vehicles, advance solar-powered electricity generation, implement district cooling, produce ammonia and hydrogen through electrolysis or CO_2 capture and storage, implement CO_2 capture and storage in all industrial sectors and develop direct air capture with CO_2 capture and storage. The article's conclusion is that Qatar's switch to zero-net emissions would be a significant milestone in the fight against global warming.

In a world with zero net emissions, the paper also makes the case that the sale of carbon-free hydrogen may make up for the cash lost from gas exports. By using hybrid and electric vehicles, developing solar energy, district cooling, producing ammonia and hydrogen through carbon capture and storage or electrolysis starting in $_2$040 and implementing CO_2 capture and storage in all industrial sectors starting in $_2$040, this analysis, using a linear model, suggests that Qatar's energy system can transition to net-zero emissions. Also, establishing a global carbon market might bring in money through the sale of carbon-free hydrogen and emission permits. This means that the nations of the Gulf Cooperation Council may take the initiative in climate discussions and encourage the creation of a global emissions trading system based on direct CO_2 capture.

Conclusion

In conclusion, the transition to a net-zero economy is crucial for addressing the global challenge of CO_2 emissions. The need for net-zero is driven by the pressing concerns over climate change and the need to reduce greenhouse gas emissions. To achieve this goal, various industries, including energy, manufacturing, transportation and others, must play a critical role.

The energy sector has a significant impact on CO_2 emissions and has made significant strides towards net-zero through the use of renewable energy sources, energy efficiency and carbon capture, utilization and storage (CCUS) technologies. The manufacturing industry has also shown great promise in reducing CO_2 emissions through the implementation of energy-efficient technologies and processes. The transportation industry, meanwhile, is in the process of transitioning to low-carbon and zero-emission vehicles, which will help to significantly reduce emissions. The circular carbon economy and CCUS technologies are crucial components in reducing CO_2 emissions and achieving net-zero. The CCUS technologies have the potential to capture and store CO_2 emissions, reducing the number of emissions released into the atmosphere. The circular carbon economy, on the other hand, focuses on reducing emissions by promoting the reuse of carbon-based materials and reducing the reliance on finite resources. Emerging economies play a crucial role in the transition to net-zero and their success will have a significant impact on the global effort to reduce CO_2 emissions. These countries are faced with the challenge of balancing economic growth with sustainability, but they also have an opportunity to lead the way in adopting clean and renewable energy sources.

Overall, the transition to a net-zero economy is a complex and challenging process that requires a concerted effort from all stakeholders, including governments, industries and the public. The future initiatives must focus on reducing CO_2 emissions, increasing investment in research and development and promoting greater public awareness and engagement. With continued effort and collaboration, we can create a more sustainable and net-zero future.

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