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NetZero Emissions: Current Trends, Barriers, and Opportunities

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ABSTRACT
The Paris Agreement's goal of achieving net zero emissions to reduce the dangers of climate change seems to be becoming harder to meet as nations and economic sectors lag behind expectations. In this article, review various literature's study on current trends, barriers, and opportunities in NetZero emissions. It concluded that achieving net-zero emissions requires carbon removal via afforestation, enhanced mineral weathering, and direct air capture, alongside emission reduction through energy efficiency and renewable energy. Rapidly urbanizing economies like India must optimize building stock and integrate renewables. Economic and knowledge barriers, including high costs, financial constraints, and lack of standardized valuation, hinder progress. Advancements in DC technology, energy storage, and digital innovations will shape the future, necessitating clear strategies and regulatory frameworks for widespread adoption and a successful low-carbon transition.
Keywords: NetZero emissions, Paris agreement, Climate change, low-carbon transition, greenhouses gases (GHGs), Clean energy, etc.

I. INTRODUCTION

Energy consumption has been a key factor in both social and economic advancement. The human species has been able to live a comfortable and pleasurable existence as a result. Because fossil fuels are abundant and widely used, technical advancement has increased, which in turn fuelled the industrial revolution [1]. However, the extensive use of fossil fuels has resulted in the discharge of harmful substances into the atmosphere, including excess greenhouse gases (GHGs). These GHGs have the potential to increase atmospheric heat retention, which might have a detrimental effect on the climate and raise world temperatures. Climate change is the name given to this phenomenon [2]. Increased GHG production causes the planet to warm more, which increases the likelihood of negative effects including floods, heat waves, bushfires, and storms. It has been shown that the primary cause of the postindustrial anthropogenic temperature rise is cumulative emissions of anthropogenic CO2 [3], [4].
Significant greenhouse gas (GHG) emissions have resulted from rapid industrialisation and the use of fossil fuels since the beginning of the industrial revolution, harming all living things and inflicting lasting environmental damage. Extreme weather occurrences have become more common as a consequence of the resulting climate change [5]. In the Paris Accord, which was signed by 196 countries, it was agreed that the average global temperature increase should be kept far below 2 degrees Celsius above preindustrial levels, with a target of 1.5 degrees Celsius. The Paris Agreement's goals must be met by implementing policies that address climate change and high-carbon development in order to reach net-zero CO2 emissions globally by 2050 [6]. At the same time, the "Race to Zero" campaign has united several sectors, including as cities and corporations, in support of the shared goal of reaching net zero. In Glasgow at COP26, India declared a 2070 net-zero target. With the statement

that it will add 500 GW of non-fossil capacity by the end of this decade, India updated its NDC ambitions in 2022. Several modelling studies indicate that, even with these objectives and other policies in place, India's emissions are unlikely to peak and decarbonise towards the 2070 net zero goal if current policies are followed on a business-as-usual (BAU) trajectory [7]. The worldwide CO2 emission distribution by sector is shown in Figure 1 [3].

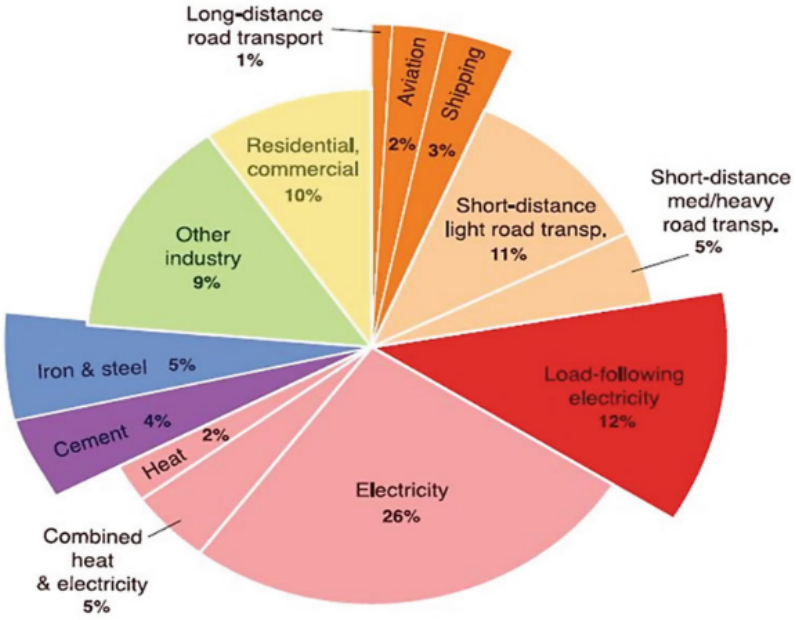

Figure 1 Global fossil fuels and industrial emissions, [3]

A. Net zero

In current discussions about mitigating climate change, the idea of "net zero" is central, but a closer look shows a number of distinctions that need careful consideration. Although the term appears to advocate for a simple input-output equilibrium of greenhouse gas emissions, its practical application encompasses a variety of economic, social, and ethical considerations. Fundamental beginning points for comprehending the need and difficulties of achieving net zero include ideas such as the "Tragedy of the Commons" and the Jevons Paradox [8]. While the "Jevons Paradox" exposes the contradictory idea that advances in resource efficiency might, ironically, result in increased total consumption, the "Tragedy of the Commons" emphasises the need of government in controlling shared natural resources. Both frameworks have their uses, but they may not adequately convey the problem's multifaceted nature [7], [9]. In order to effectively manage the complex layers of economic restrictions, technical hurdles, and social fairness issues, a multidisciplinary, nuanced approach is required. Debates about methodology and how to get net zero make the discussion much more difficult [10]. CCS and other technological solutions have potential, but they also bring up ethical and practical concerns, especially if they promote the continuing use of fossil fuels. However, drastic emission reductions come with their own set of difficulties, such as fairness issues and economic ramifications that must be properly evaluated [6]. According to Table 1, this means that governments should encourage "research and development (R&D)" investment in both the public and private sectors, with a focus on removing barriers in the primary emitting industries [11].

"Table 1 Examples of sector-specific zero-emissions technologies [11]"

Major sectors	Zero emission technologies	Issue to be overcome

Transport	Electricity (automobiles, light trucks) Biofuels (heavy truck, ships and planes)	Need for large capacity batteries. large-scale production of cellulose based biofuels. lowering cost.
Industries • Iron and steel Cement	Electrolysis Direct reduction by hydrogen CCS	Lowering cost. Large scale use of carbon-free power. Reduction in CCs cost.
Power generation	Renewables (hydro, geothermal, solar, wind, biomass),	Demand-supply gap: battery coast. Frequency instability due to lack of inertia.
	Nuclear	Nuclear waste disposal, etc.

B. Achieving Net Zero Emission

The adoption of low carbon emission pathways that promote the widespread use of "renewable energy sources" in place of fossil fuels is necessary to attain net zero emissions by 2050. Additionally, consumer behaviour and increased energy efficiency must be changed to lower overall energy demand [12]. The attainment of net zero emissions requires a change in policy direction at all levels, technical progress that aligns with global climate objectives, and environmental protection in both individual and business behaviour. However, there are three basic strategies to get net zero emissions [3]:

- **Emission offsetting:** In order to make up for emissions from other sectors, CO2 or other GHGs are reduced or avoided in one sector. Investing in low-emission technologies, renewable energy sources, or energy efficiency may help accomplish this. The European Union's Emission Trading mechanism (ETS) is a prime example of an emission offsetting mechanism. The unit of measurement for emission offsets is tonnes of carbon dioxide equivalent (CO2e) [13]. Emission offsetting functions at two levels of the market. To meet their emission limitations, governments, businesses, and other organisations may buy emission offsets in the greater compliance market. To make up for their emissions from transportation, power, and other emission contributions, governments, businesses, and people may purchase emission offsets in the lower voluntary compliance market [14].
- **Carbon removal/sequestration:** This is the process of taking atmospheric CO2 out of the atmosphere and storing it for a long time in order to lessen its effects. Carbon sequestration happens naturally as well as via man-made methods. Naturally occurring biological, chemical, and physical processes remove CO2 from the atmosphere [11]. It is then deposited mostly in green plants and trees, organic detritus in soils, dormant geologic formations, and the seas. In order to best sustain life, nature has balanced atmospheric CO2 via this mechanism. To accomplish the same goal, however, a number of artificial methods have been created, such as direct air capture, underground saline aquifers, or reservoirs for the large-scale artificial sequestration of industrial CO2 emissions [15].
- **Emission reduction:** This is the reduction of CO2 and other greenhouse gas emissions by modifying industrial, agricultural, and other activities; for instance, using energy-efficient processes and renewable energy sources (such solar and wind) to cut emissions. While emissions are produced by both fossil fuels and non-fossil fuel-based energy sources, the emissions from non-fossil fuel-based energy sources are far lower [16].

C. Barrier in NetZero emission

1. Economic Barriers

Because carbon credits are becoming more and more in demand, carbon offsetting presents a financial obstacle to reaching net zero. Without outside finance or technological transfers, achieving net zero is a difficult goal since funding in sustainable technologies also put a pressure on resources. Risk aversion, institutional inertia, societal norms, and individual commitment are just a few of the many variables that affect these investment choices [17]. SMEs and businesses in developing nations, especially those in the unorganised sector, find it challenging to strike a balance between continuing operations and investing in cleaner technology [18]. Due to the high upfront costs and uncertain returns associated with environmental projects, firms with limited resources are more inclined to prioritise core business operations above these initiatives, especially when green management is lacking. COVID-19's economic disruptions call for a concerted policy response for equitable and sustainable development [9], [19].

2. Policy and framework barriers

Businesses aiming to achieve net-zero emissions must make a number of policy changes. Everyone from supply chain partners to communities to industrial organisations to workers has to be taken into account while making these changes, and a clear plan for reaching agreed-upon goals by a certain date needs to be provided [19]. A further possible barrier to reaching net-zero targets is shown by recent study, which indicates that the development of climate policy has gotten disproportionate attention in comparison to their real effect [6]. The lack of defined regulations and framework standards remains a major barrier, since only a small number of nations have detailed specific roadmaps. Additionally, uncertainty regarding the value of investments in technological advancements and the implementation of environmentally friendly practices undermines commitment [17].

3. Organizational Barriers

Due mainly to an absence of publicly available data, our current understanding of organisational carbon and/or GHG emissions is often inadequate and restricted. Due to the importance of high-quality data in making informed decisions, the current data shortage is a major concern. The preparation, creation, and distribution of net-zero systems are compromised without this information [6]. Furthermore, many industries provide special difficulties for emissions accounting; for example, it is extremely challenging to measure emissions from international commerce, aviation, and international shipping. In addition to industry-level statistics, there are insufficient methods for estimating personal energy use, which makes effective decarbonisation planning even more difficult [17]. Despite the strong governmental will to cut emissions, many industries continue to struggle with uneven methods of monitoring them. These disparities, especially in emissions intensities, are often seen in the current measurement methodologies used by organisations. In order to achieve net-zero goals in a number of industries, this discrepancy might seriously hinder evaluation and forecasting capacities [19].

4. Technological Barriers

For businesses looking to achieve net-zero goals, digital innovation is a vital enabler. This essay emphasises how important it is to fund low-carbon innovation in order to advance a net-zero global economy [9]. Nevertheless, technological constraints pose substantial obstacles for numerous organisations, in addition to cost considerations. For instance, research conducted in sectors such as residential construction, road works, and electric vehicles has outlined the technical challenges associated with achieving net-zero status using current technologies [17]. Moreover, the financial

hazard that businesses confront when investing in new low- and zero-carbon alternatives may not be apparent for years after the implementation of emergent technologies. To cut the carbon footprint of smelting operations by 85%, for example, the aluminium sector has been approached with the idea of substituting inert anodes for high-emitting carbon anodes. However, numerous aluminium producers are still hesitant [19]. The issue stems from the lack of an affordable method for thorough metal cleaning at the moment. This is because it's difficult to produce materials that are suitably inert without sacrificing the purity of aluminium. This industry's organisations that are striving to achieve net-zero targets are further hindered by this technological uncertainty [6].

II. LITERATURE REVIEW

(Ma et al., 2024) [2] In order to achieve carbon neutrality by the middle of the century, first provide a summary of the existing state of building-related carbon emissions worldwide and their characteristics. We can accelerate the general adoption of building electrification and energy system decarbonisation by combining powerful financial assistance mechanisms with technological innovation, including advanced building technology and renewable energy solutions. Decarbonising materials, limiting the increase of the building stock, and prolonging building lifespans are essential steps in lowering embodied carbon. Stress to governments, citizens, and other stakeholders how critical it is to increase building carbon emissions awareness. For the construction industry to become carbon neutral, it is essential to comprehend the obstacles and the pressing need for action.

(Uspenskaia et al., 2021) [20] In demonstration and lighthouse projects, a multitude of smart city initiatives present creative and avant-garde low-carbon solutions. In order to investigate prevalent technological trends and replication strategies for positive energy structures or areas in smart city initiatives, this article implements a case study in Leipzig, one of the SPARCS project's sentinel cities. One of the main conclusions of the article is that in order to have a deeper knowledge of upscaling processes, a thorough replication modelling is required. This article's analysis of three models shows that the solution to be duplicated may be represented in several dimensions.

(Mahmoodi et al., 2024) [17] found several obstacles and difficulties in changing the sector. The aim of this research is to provide a systematic examination of the challenges that organisations face while developing new net-zero emissions frameworks. We located and analysed the relevant journal articles published after the Paris Agreement using a mixed-method data analysis technique combining "quantitative (science mapping) and qualitative (thematic) analysis". "With China, the UK, and Australia" ranked as the top research locations, the results showed that the issue gained increased interest throughout this period. "Economic," "knowledge," and "technical" hurdles were the most talked-about categories, followed by "organisational," "market," "technological," and "legal" restrictions.

(Narassimhan et al., 2024) [7] describes a set of policies that are socioeconomically sensitive and have the potential to help India achieve its net-zero emissions goal within a decade and eliminate its carbon dioxide (CO2) emissions by the mid-century. By 2070, around one gigaton of additional greenhouse gases would need to be decarbonised in order to meet this goal. The policy combination achieves this objective while preserving the budgetary stability of the government and surpassing business-as-usual growth in GDP and employment. To achieve these potential socio-economic benefits of decarbonisation, however, there are still many obstacles that must be overcome, including the nation's lack of clean energy innovation and industrial policies, the disparity between its domestic manufacturing capacity and deployment requirements, the readiness of individual sectors for

decarbonisation, and the distributional implications of government revenue shifts through the energy transition.

(Grove & Clouse, 2021) [21] This study's main objective is to pinpoint the difficulties boards of directors have in monitoring and evaluating their firms' performance and promises to zero net emissions. Boards have a significant issue in assessing whether their firms are really working towards zero net emissions or whether they are engaging in greenwashing, which is the practice of making promises or commitments without any real follow-through performance. A working group comprised of 90% of the world's public market security regulators, the International Organisation of Securities Commissions Organisation (IOSCO), has been formed to develop climate disclosure standards for publicly traded corporations. Metrics for climate disclosure are important and necessary to assist boards and other stakeholders in evaluating the risks, opportunities, and climate performance of businesses.

III. CONCLUSION

A multifaceted strategy is needed to achieve net-zero emissions, which includes reducing emissions via energy efficiency and the use of renewable energy sources in addition to removing carbon through afforestation, increased mineral weathering, and direct air capture. Emerging economies like India must prioritize sustainable urbanization by limiting unnecessary reconstruction and integrating renewables into building designs. Economic and knowledge-related barriers remain significant, with high initial costs, limited financial instruments, and undervaluation of net-zero buildings hindering progress. A lack of standardized assessment methods, accessible data, and skilled expertise further complicates adoption. Additionally, concerns about the durability of low-carbon materials, particularly wood-based alternatives, present engineering challenges. The energy landscape may change as a result of future developments in nuclear fusion, DC technology, and energy storage, if clear legal frameworks and economic feasibility are developed. Digital innovations will also redefine energy consumption and management, enhancing efficiency. In order to expedite the transition to a low-carbon future, it is imperative to address these challenges through technological advancements, financial incentives, and policy support. As we approach COP29, embedding carbon neutrality within national frameworks will be crucial in driving systemic changes, fostering innovative technologies, and ensuring a resilient, sustainable future.

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