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Unveiling the Contemporary Carbon Dioxide Conundrum: Impacts, Challenges and Innovations for a Bio-sustainable Future

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Abstract : Carbon dioxide (CO_2), once considered a ubiquitous and essential environmental component, has now transcended its usual presence to unprecedented levels in modern times. Intriguingly, this surge is further exacerbated by unforeseen events like forest fires and explosions, complicating the environmental dynamics surrounding this compound. While CO_2 remains indispensable for life, its dual role as both a facilitator and disruptor to living beings is contingent upon its quantity and immediate ecosystem. The disruption of the balance maintained by natural sources necessitates a closer examination of the ensuing consequences. In this review, we delve into the intricate interplay of CO_2 in contemporary environments, highlighting the multifaceted impacts of its elevated levels. We explore how forest fires, explosions, and other unpredictable events contribute to the complex dynamics of CO_2 in the environment, further intensifying its pervasive influence. Moreover, we underscore the imperative to minimize CO_2 emissions, with a particular focus on innovative strategies and implementations. These strategies not only hold promise for achieving emission reduction goals but also play a pivotal role in addressing broader environmental challenges stemming from excessive carbon dioxide. Through collaborative efforts and the integration of innovative technologies embedded in these implementations, we envision a pathway towards a more bio-sustainable and balanced environmental future. This review serves as a comprehensive synthesis of the current understanding of CO_2 dynamics, offering insights into mitigating its adverse impacts and fostering resilience in the face of evolving environmental challenges.

Keywords: Carbondioxide, electric vehicle, grid technology, EV.

1. Introduction

In the intricate web of global economics and the daily lives of individuals, the term "energy" assumes a pivotal role, existing in diverse forms and embodying numerous classifications. A fundamental division emerges in the realm of energy, the dichotomy between renewable and non-renewable sources. The essence of renewability lies in the rapid regeneration of energy sources, often with minimal downtime. The accessibility of renewable energy resources requires less effort, their transformation into usable forms, particularly electricity, demands substantial technological infrastructure. The utilization of renewable energy not only contributes to environmental well-being but also catalyzes economic strength and the enhancement of a nation's GDP. In this dynamic landscape, continuous strides in technology underscore the commitment to expanding the footprint of renewable energy. Governments worldwide are not mere spectators; they actively partake in shaping this landscape by implementing policies and amending constitutions to support the adoption of renewable resources for energy production. This intricate interplay of factors forms the backdrop against which the narrative of renewable energy unfolds, intertwining environmental sustainability, economic prosperity, and technological innovation.Notably, In the 1.5°C pathway proposed by IRENA (Internation Renewable Energy Agency), sustainable biomass, hydrogen, and renewable energy sources would facilitate the energy transition, with electrification and efficiency serving as major forces(Gielen et al. 2022). This option would reduce yearly CO_2 emissions by almost 37 gigatonnes by 2050, but it would necessitate a significant shift in how societies create and use energy. Electrifying end-use sectors (e.g., electric vehicles and heat pumps) can help achieve these reductions. Other strategies include: 1) significantly increasing the generation and direct uses of electricity based on renewables; 2) significantly improving energy efficiency; 3) electrifying end-use sectors; 4) clean hydrogen and its derivatives; 5) bioenergy combined with carbon capture and storage; and 6) last-mile use of carbon capture and storage (shown in Fig. 1)

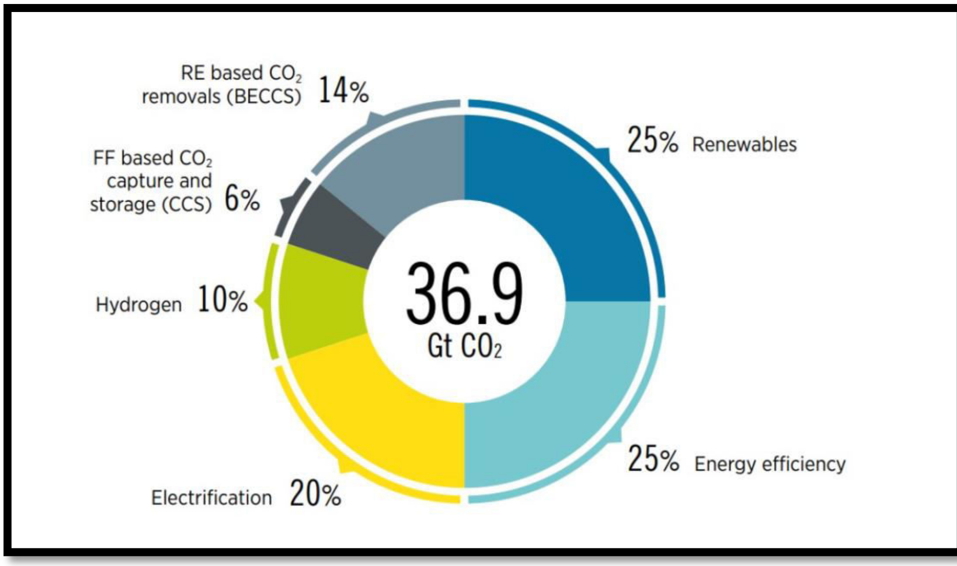

Figure 1. Six technology avenues for reduce emissions by 2050 (Source IRENA, 2022).

1.1 Background

Carbondioxide (CO_2), a regularly available and essential compound of the environment, is also becoming more than necessary these days. The three main valleys of carbondioxide apart from humans are fuel combustors, industries and natural gas processors, whereas other sources of this gas collectively contribute to the availability of CO_2(Devarajan & Madhavan, 2022). Before the times of fossil fuel burning, natural sources were only the major producers of carbon dioxide which gave out only a limited but sufficient quantity of it in the environment. The new normal since then has been experiencing a hiked amount of the compound. However, uninvited guests like forest fires, blastsetc., add to the content out of the blue. Carbon dioxide is a usable as well as a troublemaker to living beings, based on the quantity of its existence and its immediate ecosystem. This compound follows a predictable life cycle and undergoes different transformations. Researchers have developed a system that can generate electricity and hydrogen from carbon dioxidea major contributor to global warming. The Na-CO_2 hybrid system can continue to generate electricity and hydrogen by efficiently converting carbon dioxide for more than 1,000 hours under stable operation, according to the researchers. Carbon Capture Utilization and Sequestration (CCUS) technologies have garnered significant interest in the recent past as a means of addressing climate change on a global scale. Therefore, using electric vehicles is crucial to reducing carbon dioxide emissions.

1.2 The Challenges for Renewable Integration

The complexities predominantly stem from the unpredictable and uncertain nature of real-time renewable energy availability. The inherent variability of these energy sources significantly impacts the operation and planning of the power grid, necessitating a closer examination of the three key operational planning horizons relevant to their integration. By delving into these planning stages, we can unravel the multifaceted ways in which renewable energy sources influence the overall planning process of the power grid.

1.3 Power System Operations and Energy System Planning

At one extraordinary, ongoing dynamic and responsive power demand should be in steady parity to guarantee that the frequency and voltage are inside worthy cut-off points. These kinds of dynamic strength issues must be considered and overseen on the milliseconds to seconds timescale. The next degree of operational arranging incorporates unit responsibility, monetary dispatch, and ideal power stream examinations. Unit responsibility, which might be done on 60 minutes to week-ahead premise, figures out which generators must work each time venture inside the arranging skyline to serve determined interest at least expense. A day-ahead unit duty that models hour-long time steps is average, even though these subtleties shift among power frameworks. When the dedication (on/off status) of every generator is chosen by the unit responsibility model, every generator's vitality creation must be resolved. This is done in a financial dispatch model and the subsequent power streams on the transmission network components are displayed to guarantee that they are inside the physical furthest reaches of the framework. This dispatch cycle should be possible an hour-ahead. In numerous frameworks the dispatch is additionally recomputed movingly each five to 15 minutes, utilizing the most as of late accessible framework data. The ongoing unique dependability, unit responsibility, and intraday monetary dispatch measures have a progressive interdependency among them. For example, a unit responsibility model regularly has a rearranged power stream model implanted in it to guarantee that the framework can be plausibly dispatched continuously without abusing transmission limitations. The unit responsibility model likewise incorporates hold necessities that guarantee that the generators submitted in each time step have adequate abundance limit and inclining ability to serve load under an assortment of unforeseen possibilities. Generally, generator or transmission disappointments or unforeseen burden increments are the sorts of possibilities considered. There is a further interdependency between these operational arranging stages and framework dynamic dependability: generator responsibilities and dispatch must give adequate grace side adaptability. These prerequisites are demonstrated by remembering limitations for the operational models necessitating that the generators submitted have the option to give more excellent holds with very quick reaction times. Because of the conceivably long lead times included, venture choices might be made 10 years or longer ahead of the time of task finish. Even though age and transmission development can be tedious, delays related to administrative endorsement, financing, and neighbourhood restriction to a task can represent the main part of this lead time. Similarly, as with the unit responsibility measure, there is a progressive interdependency in this drawn-out arrangement. Consequently, venture arranging ought to preferably incorporate unit responsibility, dispatch, power stream and dynamic solidness investigations. The heuristics dependent on load-term bends and the capital and working expenses of various age advancements are frequently used to catch unit responsibility and dispatch costs (Yilmaz M, & Krein PT,2012). These heuristics may likewise be enhanced with unwavering quality models, which decide how much overabundance limit ought to be introduced to dependably serve load despite generator and transmission disappointments.

1.4 Effects of Renewables on Power System Operations and Planning

Incorporating sustainable power sources into electric power frameworks can additionally confuse these activities and arranging measures. Keeping up constant vitality flexibly and request parity and framework solidness can be more troublesome, since renewables increment gracefully side fluctuation. Additionally, SOs must record for inexhaustible inconstancy when settling on unit responsibility and monetary dispatch choices. Since it can take hours to fire up some generators, the arrangement of generators that is submitted must have adequate abundance limit and sloping capacity to react to sudden decreases or increments in inexhaustible accessibility. In certain frameworks, this adaptability is guaranteed by modifying hold necessities in the operational arranging models, while others have presented new save or adaptability items. When this limitation was fused into continuous activities, the California ISO proposed adding it to the day-ahead unit duty also. Notwithstanding arranging troubles, these operational changes likewise have monetary ramifications. Many power frameworks today depend solely on adaptable gaseous petrol and oil-terminated generators to adjust inexhaustible changeability. Renewables additionally influence long-haul age and transmission speculation. Various investigations, which the commitment of wind toward dependably serving load in an assortment of frameworks. These investigations find that the negligible limit value of the principal augmentation of wind will in general range somewhere in the range of 15% and half of the nameplate limit of the breeze plant. Wind's peripheral limit esteem drops rapidly as more is added to the framework, in any case. Examinations of solar oriented directed higher limit esteem than wind, because of more noteworthy happenstance between solar-oriented accessibility and power request in many power frameworks. Belittling the limit commitment of renewables can bring about higher ratepayer costs since abundance-producing limits must be manufactured. This impact relies upon how sustainable changeability and vulnerability are obliged in the day-ahead and constant operational skylines

Renewable integration can necessitate major investments in transmission facilities. This is because the most extravagant inexhaustible assets in numerous pieces of the world are a long way from populace focuses where power request is most noteworthy (Vaz et al., 2022;Rubin et al.,2012). To act as an illustration of this, Mai et al., (2012) model the age and transmission extension expected to accomplish a power framework over the United States that serves somewhere in the range of 30% and 90% of power requests utilizing renewables. This investigation gauges between 10 million and 200 million MW-miles of bandwidth and is expected to convey this measure of sustainable power source to end clients. The last case speaks to a multiplying of the roughly 200 million MW-miles of existing capacity.

1.5 Exploring Various Approaches to Emission Reduction and Renewable Energy Generation

In the quest to mitigate anthropogenic carbon dioxide (CO_2) emissions, carbon capture and storage (CCS) emerges as a pivotal strategy, as extensively discussed by Bui et al. (2018). Krishna and Long (2011) delve into the screening of metal-organic frameworks for gas mixture adsorption, shedding light on the transient breakthrough in fixed-bed adsorbers. Meanwhile, Zhang and Webley (2008) concentrate on developing and designing cycles for CO_2 capture from flue gas using vacuum swing adsorption. In the realm of innovative sorbents, Amrhein et al. (1996) synthesize zeolites from coal fly ash, elucidating their properties and environmental implications. Cavenati, Grande, and Rodrigues (2004) analyze the equilibrium of methane, carbon dioxide, and nitrogen adsorption, presenting a detailed examination of zeolite 13X at high pressures. Lu et al. (2008) scrutinize the comparative efficiency of carbon nanotubes, activated carbons, and zeolites in capturing CO_2. Moving beyond conventional adsorption, Yang and Doong (1985) propose a pore-diffusion model for gas separation via pressure swing adsorption. Additionally, Siriwardane and Stevens (2009) introduce regenerable magnesium hydroxide sorbents for CO_2 capture at elevated temperatures. Soo et al. (2008) highlights the development of regenerate MgO-based sorbents promoted with K_2CO_3 for efficient CO_2 capture at low temperatures. Contributing to the discourse, Wang et al. (2016a) experimentally determine and correlate the solubilities of CO_2

in glycol ethers under high pressure. In the sphere of biofuel production, Wang et al. (2016b) report on enhancing bio-butanol production from Chlorella Vulgaris JSC-6 through sequential alkali pre-treatment and acid hydrolysis. Tang et al. (2011) investigate CO_2biofixation and fatty acid composition in Scenedesmus obliquus and Chlorella pyrenoidosa in response to different CO_2 levels. Singh and Dhar (2019) offer an insightful overview of Carbon Capture Technology, emphasizing the Microalgal Biorefinery Concept and its state-of-the-art applications. Vuppaladadiyam et al. (2018) explore the impact of flue gas compounds on microalgae and elucidate mechanisms for carbon assimilation and utilization. Expanding the scope to energy alternatives, Campbell et al.(2011) present a life cycle assessment of biodiesel production from microalgae in ponds. Viebahn et al. (2007) conducted a comprehensive comparison of carbon capture and storage with renewable energy technologies, considering structural, economic, and ecological aspects in Germany. Elbashir et al. (2018) delve into CO_2 Utilization through the dry reforming of the methane process within the context of the Qatar Foundation. Jaramillo, Griffin, and McCoy (2009) contribute a life cycle inventory of CO_2 in an enhanced oil recovery system. Khoo et al. (2011) explore the preliminary life cycle of CO_2, energy, and cost results of potential mineral carbonation in carbon capture and utilisation. Nduagu, Bergerson, and Zevenhoven (2012) conducted a life cycle assessment of CO_2 sequestration in magnesium silicate rock, offering comparative insights.

Renewable energy has emerged as a critical component in addressing the pressing challenges of environmental degradation and fossil fuel depletion. As societies strive to transition towards more sustainable energy systems, renewable sources offer promising alternatives that are both environmentally friendly and economically viable. This comprehensive exploration delves into the various facets of renewable energy, from its types and potentials to the role of hydrogen and fuel cells in energy storage, the integration of electric vehicles into the grid, and the revolutionary advancements in grid technology. The growing awareness of environmental concerns and the finite nature of fossil fuel reserves have spurred interest in renewable energy sources (Desai 2020). This section provides an overview of renewable energy and its significance in combating climate change and promoting energy security.

Renewable energy encompasses a diverse array of sources, each with its unique characteristics and applications. In our exploration of the four most prominent renewable energy sources, wind energy emerges as a rapidly growing sector, fuelled by advancements in turbine technology and supportive policy frameworks (Asmelash et al. 2020). Solar energy, on the other hand, presents immense potential for clean and sustainable electricity generation, with concentrating solar power (CSP) and photovoltaics (PV) leading the way in recent developments and widespread installations (IEA, 2021). Hydropower, as one of the oldest forms of renewable energy, remains a cornerstone, with pumped-storage hydropower enhancing grid stability and reliability (Klees et al. 2012). Biomass energy, derived from organic materials like agricultural residues and forest biomass, offers diverse applications, including electricity generation, heating, and transportation fuels, albeit with sustainability concerns (Robins et al.2021). As renewable energy penetration increases, the need for effective energy storage solutions becomes paramount. Reformers play a vital role in converting hydrocarbon fuels into hydrogen for fuel cell applications, offering potential implications for the transportation sector (Kurtz et al.2019).

1.6 Integration of Electric Vehicles into the Grid

Electric vehicles (EVs) represent a key enabler of a sustainable transportation future. This section examines the integration of EVs into the power grid, including:

1.6.1 Vehicle-to-Grid (V2G) Technology

V2G technology allows bidirectional energy flow between EVs and the grid, enabling dynamic grid management and demand response capabilities. We discuss the benefits of V2G integration, potential revenue streams for EV owners, and the challenges of grid interoperability (Murarka et al.2020).

1.6.2 Plug-in Electric Vehicles (PEVs) and Plug-in Hybrid Electric Vehicles (PHEVs)

PEVs and PHEVs offer significant advantages over conventional internal combustion engine vehicles. We explore their respective architectures, charging infrastructure requirements, and their potential to reduce greenhouse gas emissions and dependence on fossil fuels (Buysse et al. 2021).

1.7 Revolutionary Grid Technology

The evolution of grid technology is essential for accommodating the increasing penetration of renewable energy and electric vehicles. This section delves into.

1.7.1Smart Grids

Smart grids leverage advanced communication and control technologies to optimize grid operations, enhance reliability, and integrate renewable energy sources seamlessly. We discuss the key components of smart grids, such as advanced metering infrastructure, distribution automation, and demand response (Nguyen et al. 2020).

1.7.2Distributed Generation (DG) and Decentralized Energy Resources

DG and decentralized energy resources play a crucial role in the transition towards a more resilient and sustainable energy infrastructure. We examine their potential to enhance grid flexibility, reduce transmission losses, and empower energy consumers (Koutoudjian et al. 2021).

1.7.3 Challenges and Opportunities

Despite the transformative potential of renewable energy and grid technologies, several challenges persist, including grid reliability, cyber security risks, and regulatory barriers. We explore strategies for overcoming these challenges and seizing the opportunities presented by the transition to a cleaner and more decentralized energy system (Henderson 2021).Hence, renewable energy holds immense promise for addressing the dual challenges of climate change and energy security. By harnessing the power of wind, solar, hydro, and biomass resources, coupled with advanced energy storage and grid technologies, we can create a more sustainable and resilient energy future. The integration of electric vehicles and the evolution of grid infrastructure are pivotal steps towards realizing this vision. As we navigate the complexities of the energy transition, collaboration between governments, industry stakeholders, and the research community will be essential in driving innovation and overcoming obstacles on the path to a cleaner and more sustainable energy future.

1.8 Overview of Research Contributions

Some authors provided their sights based on the analyze findings from different aspects, Affanni et al. (2005) discuss battery choice and management for new-generation electric vehicles, emphasizing the importance of selecting appropriate battery technologies to optimize performance and efficiency. Ananthachar& Duffy (2005) evaluate the efficiencies of hydrogen storage systems onboard fuel cell vehicles, exploring the effectiveness of different storage methods for hydrogen in the context of fuel cell vehicle technology. Chen & Blaabjerg (2009) discuss wind farms as a potential future power source, emphasizing their role in renewable energy generation and their integration into future power systems. Chew et al. (2017) examine perspectives on high-value products derived from microalgae biorefinery, highlighting the potential of microalgae-based biorefinery for the production of valuable compounds. Chisti (2007) reviews the production of biodiesel from microalgae, discussing the potential of microalgae as a feedstock for biodiesel production and the technological advancements in this field. De Ridder et al. (2013) explore the potential of electric vehicles in the smart grid using an activity-based model, highlighting the benefits and challenges associated with the integration of electric vehicles into the grid. The source on Efficient CO_2 Utilization via a Hybrid Na-CO_2 System discusses efficient carbon dioxide utilization through a hybrid Na-CO_2 system based on CO_2 dissolution. Fasugba & Krein (2011) analyze the cost benefits and regulatory services of unidirectional charging of electric vehicles, focusing on the potential economic and regulatory advantages of vehicle-to-grid services. Gallardo-Lozano et al. (2012) propose an electric vehicle battery charger for smart grids, highlighting the importance of efficient charging infrastructure for electric vehicles in smart grid systems. Gao et al. (2019) present a process simulation and energy integration study in the mineral carbonation of blast furnace slag, discussing the potential of mineral carbonation as a method for carbon dioxide capture and utilization. Ghiat & Al-Ansari (2021) review carbon capture and utilization as a CO_2 abatement opportunity within the energy-water-food nexus, exploring the potential synergies and challenges in integrating carbon capture technologies with other sectors. Hamann (2015) discusses coordinated predictive control of a hydropower cascade, focusing on optimizing the operation of hydropower plants to maximize energy production and grid stability. The Handbook of Climate Change Mitigation chapter discusses molten carbonate fuel cells as a technology for climate change mitigation, highlighting their potential role in reducing greenhouse gas emissions in various sectors. Honda et al. (2014) investigate the catalytic conversion of CO_2 to organic carbonates with alcohols, focusing on the development of catalytic systems for the synthesis of organic carbonates from carbon dioxide and alcohols. Hu et al. (2008) review microalgal triacylglycerols as feedstocks for biofuel production, discussing the potential of microalgae as a sustainable source of feedstock for biofuel production. Huang & Tan (2014) discuss CO_2 utilization technologies, highlighting various methods for the conversion and utilization of carbon dioxide for valuable products and processes. Lin et al. (2010) presents a Li-ion battery charger with a smooth control circuit and built-in resistance compensator for stable and fast charging, addressing the challenges of charging Li-ion batteries efficiently and safely. Olajire (2013) discusses mineral carbonation technology for the sequestration of CO_2, focusing on the potential of mineral carbonation as a method for long-term carbon dioxide storage and utilization. The report from the Organization of the Petroleum Exporting Countries provides insights into the world oil outlook, offering projections and analysis of global oil production, consumption, and market trends. Panwar et al. (2011) explore the role of renewable energy sources in environmental protection, discussing the environmental benefits and challenges associated with the deployment of renewable energy technologies. Pinto et al. (2013) present a bidirectional battery charger with grid-to-vehicle, vehicle-to-grid, and vehicle-to-home technologies, highlighting the potential of bidirectional charging systems for vehicle-grid integration. Richardson (2013) discusses electric vehicles and their impact on the electric grid, focusing on modeling approaches, grid integration challenges, and the role of renewable energy in supporting electric vehicle deployment. Rubin et al. (2012) review the outlook for improved carbon capture technology, discussing advancements and challenges in carbon capture and storage technology development. Shi et al. (2012) present a photovoltaic charging station for electric vehicles to grid application in smart grids, highlighting the potential of solar energy for powering electric vehicle charging infrastructure. Sortomme (2012) proposes combined bidding of regulation and spinning reserves for unidirectional vehicle-to-grid, addressing the challenges and opportunities of using electric vehicles for grid services. Tang et al. (2011) investigate CO_2biofixation and fatty acid composition of microalgae in response to different CO_2 levels, highlighting the potential of microalgae for carbon dioxide mitigation and biofuel production. The report from the U.S. Energy Information Administration provides insights into the international energy outlook, offering projections and analysis of global energy trends, including production, consumption, and renewable energy deployment. Urban & Mitchell (2011) explore the relationship between climate change, disasters, and electricity generation, highlighting the importance of strengthening climate resilience in energy systems. Vaz Jr et al. (2022) discusses technologies for carbon dioxide capture, focusing on various methods and technologies for capturing and utilizing carbon dioxide emissions in energy sectors. Verma et al. (2011) present grid-to-vehicle and vehicle-to-grid energy transfer using single-phase bidirectional AC-DC and DC-DC converters, addressing the challenges and opportunities of bidirectional energy transfer between electric vehicles and the grid. William & Laurens (2010) discuss microalgae as biodiesel and biomass feedstock, exploring the biochemistry, energy potential, and economic aspects of microalgae-based biofuel production. Yong et al. (2002) investigates the adsorption of carbon dioxide at high temperatures, focusing on the adsorption behavior and potential applications of carbon dioxide adsorption technologies.

Conclusion

In the global pursuit of curbing emissions and fostering environmental sustainability, several nations have instituted an effective emission reduction strategythe Emissions Trading Scheme (ETS), notably prominent in European countries. According to the ETS framework, industries are assigned specific emission limits, and these allowances can be traded among different sectors. Should a particular industry exceed its allocated emission limit, it must either purchase additional allowances from the market or face penalties, all aimed at mitigating carbon dioxide emissions. By achieving emission reduction targets, not only is the environment safeguarded, but it also translates into a tangible reduction in the operational costs of power utilities. This concerted effort aligns with the broader global commitment to environmental responsibility, forging a path toward a sustainable and eco-friendly energy landscape.

Conflicts of interest: There are no conflicts to declare.

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