

# Power Dynamics and Global Challenges: A Critical Exploration of Energy, Climate and Industry

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## ABSTRACT

This paper explores the multifaceted challenges and realities of the global energy transition, focusing on the interplay between renewable energy sources and fossil fuels. While renewable energy technologies such as solar and wind power offer promising solutions for reducing carbon emissions, their intermittency and reliability issues present significant challenges in ensuring a consistent power supply. Using Germany's energy grid as a case study, the paper highlights how the integration of solar and wind power requires careful management to address gaps in energy availability. Additionally, the paper discusses the ongoing growth of fossil fuel production, challenging the notion of an "energy transition" and suggesting that the world is experiencing an "energy addition," where fossil fuel production continues to rise alongside renewable energy adoption. The continued relevance of fossil fuels, including propane for heating and cooking, is underscored, particularly in remote regions and underdeveloped areas. Ultimately, this paper advocates for a balanced approach to energy policy, recognizing the ongoing importance of fossil fuels while promoting the advancement and integration of renewable technologies to achieve long-term energy sustainability and security.

**Keywords:** Fossil fuels; Renewable energy; Energy efficiency; Global challenges; Climate changes

## 1. Introduction

The global energy landscape is at a crossroads, where the interplay between economic growth, environmental policies and technological advancements continues to shape the future of energy consumption and production. While the transition to renewable energy is often presented as inevitable, a deeper analysis reveals that fossil fuels remain indispensable to the global economy. The idea that the world is moving away from hydrocarbons entirely is misleading; rather, current trends indicate an era of energy addition rather than an outright transition. As society grapples with the dual challenge of ensuring energy security while addressing climate concerns, it is crucial to critically assess the role of oil, gas and other

conventional energy sources in sustaining economic stability and technological progress<sup>1</sup>.

Despite widespread discussions on carbon neutrality and decarbonization strategies, the reality of energy demand and supply dynamics suggests that fossil fuels will remain a cornerstone of global energy systems for decades to come. Rapid industrialization, urbanization and population growth continue to drive increasing energy consumption and while renewable sources have gained traction, their intermittency and infrastructure challenges prevent them from fully replacing hydrocarbons in the foreseeable future. The oil and gas sector, particularly through innovations in exploration and production, has demonstrated remarkable adaptability, ensuring its relevance in the evolving energy landscape<sup>2</sup>.

Moreover, the electrification of transportation—often cited as a key driver of reduced fossil fuel dependence—faces significant hurdles, including supply chain constraints, battery technology limitations and infrastructure readiness<sup>3</sup>. These challenges underscore the need for a pragmatic approach that balances sustainability with economic feasibility. Additionally, the concept of sustainable development in the oil and gas sector remains a critical focus, integrating economic, environmental and social considerations to optimize resource utilization while minimizing negative externalities<sup>4</sup>.

A review of historical and contemporary trends highlights that technological innovation in hydrocarbon extraction and processing continues to enhance efficiency, reduce emissions and improve resource recovery rates<sup>5</sup>. Furthermore, as governments and industries navigate the energy transition, it is evident that fossil fuels will play a crucial role in ensuring a stable and reliable energy supply, particularly in developing regions where alternative energy infrastructure remains underdeveloped<sup>6</sup>.

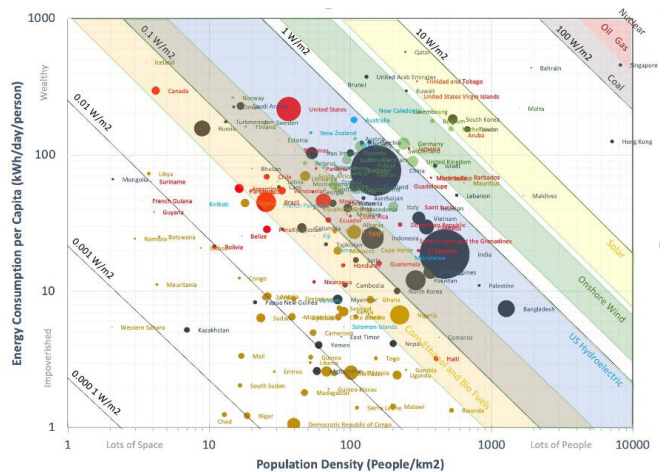
Another key dimension to consider is the impact of energy policies on human well-being. While much attention is given to the potential dangers of climate change, recent studies suggest that cold-related mortality remains a significant concern, particularly in regions that depend on affordable energy for heating<sup>7</sup>. These findings challenge the prevailing narrative surrounding global warming and emphasize the importance of a balanced energy strategy that prioritizes both economic growth and human welfare.

This paper seeks to explore the multifaceted nature of global energy challenges, providing a critical examination of energy policies, technological advancements and the geopolitical factors shaping the future of energy. By assessing both the limitations and opportunities presented by fossil fuels and renewables, this study aims to offer a comprehensive perspective on the evolving power dynamics in the global energy sector.

## Energy Crisis and The Future Of Energy Demand

The global energy crisis has brought into focus the growing tension between energy security, economic stability and environmental ambitions. As nations strive to transition toward renewable energy sources, the challenge of power density emerges as a fundamental constraint. High-energy-density sources such as fossil fuels and nuclear power have historically dominated the global energy landscape, supplying the vast majority of primary energy needs. In contrast, renewables such as wind and solar require significantly larger land areas to generate comparable power, creating spatial limitations for densely populated and industrialized regions<sup>8</sup>.

A detailed power density analysis (**Figure 1**) illustrates this dilemma, mapping per capita energy consumption against population density. Countries with high energy demands, such as Singapore, cannot achieve energy self-sufficiency with renewables alone due to land constraints. Similarly, the Netherlands lacks the necessary space to rely entirely on onshore wind power. Even in nations with more available land, the scalability of renewables is restricted by intermittency and low energy return on investment. Consequently, while the pursuit of sustainable energy is critical, the idea that renewables alone can meet global demand remains impractical for many regions<sup>8</sup>.



**Figure 1: Population Density Analysis<sup>8</sup>.**

The consequences of an energy policy that prioritizes decarbonization over energy security are evident in Britain's ongoing energy crisis. The aggressive push toward net zero has led to soaring electricity prices, industrial decline and an increased reliance on energy imports. Major industries, such as chemical manufacturing, are facing extinction as energy costs render domestic production unviable. Rather than achieving meaningful environmental progress, Britain's policies have merely outsourced emissions and economic opportunities to other nations<sup>9</sup>. Furthermore, the failure to account for future energy demands—particularly in emerging fields like artificial intelligence—has exacerbated the crisis. The rapid expansion of AI-driven industries will require vast amounts of energy, yet Britain's current energy policies threaten its ability to support this growth<sup>9</sup>.

The contrast between Britain's energy struggles and the U.S. energy boom underscores the impact of policy choices on economic and industrial resilience. While the U.S. leveraged technological innovations to unlock shale gas resources and secure energy independence, Britain's restrictive approach has squandered similar opportunities. The potential for large-scale shale gas development in the UK, once touted as a transformative economic prospect, has been hindered by regulatory obstacles and policy hesitancy<sup>9</sup>. This divergence highlights the importance of balanced energy policies that prioritize both sustainability and economic viability. The future of energy demand will not be defined solely by the transition to renewables but by pragmatic strategies that integrate multiple energy sources to ensure reliability and affordability.

## Adaptation and Resilience In The Face of Climate Change

Adaptation, rather than alarmism, presents a pragmatic and effective approach to addressing climate change. While mitigation strategies often dominate discussions, the reality of climate change is that it progresses slowly and unevenly, with nations like China and India continuing to prioritize energy security through coal-based power generation to meet the needs of their growing populations. This emphasizes the importance of adapting to the changing environment instead of waiting for an idealized global solution. Adaptation is not only more feasible but also cost-effective. For instance, the Netherlands, with its long history of battling rising sea levels, offers a model of resilience and proactive adaptation.

Over the past 160 years, the Netherlands has experienced a gradual sea-level rise of about 16 inches (400 mm) or roughly an inch (25 mm) per decade. Since the catastrophic flood of 1953, the Dutch have undertaken an extensive program to fortify their defenses, including raising dikes, dunes and dams. These efforts continue to evolve, with the nation setting an ambitious standard to prevent flooding events that could occur once every 100,000 years—a far greater level of protection than most nations could envision. This ongoing investment has significantly outpaced the pace of sea-level rise, making the Netherlands one of the most resilient countries in the face of environmental threats. By 2050, the Dutch plan to further elevate 2,000 km (1,200 miles) of dikes and dams, with costs estimated at €32 billion—around €1.2 billion annually. This strategic spending is part of a larger effort to safeguard a trillion economy predominantly situated below sea level.

The Dutch example underscores that resilience can be achieved by taking proactive measures to strengthen a nation’s infrastructure and enhance its capacity to cope with environmental challenges. Through this approach, the Netherlands not only protects its economy but also empowers its citizens by ensuring they are not dependent on external forces for protection. This dynamic optimism—focusing on actionable adaptation rather than passive reliance on global mitigation efforts—illustrates the power of resilience in the face of climate change (Figure 2).

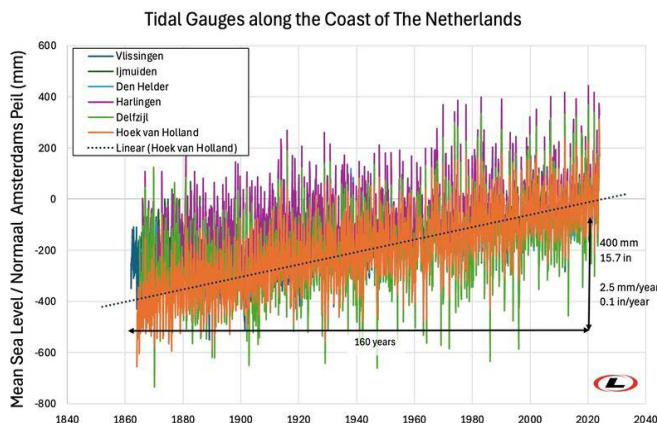


Figure 2: Power of resilience<sup>10</sup>

### Energy Efficiency and Technological Advancements In Energy Production

The advancement of energy production technologies plays a crucial role in driving the efficiency and sustainability of the sector. In the context of U.S. tight oil production, significant gains in frac fleet efficiency have been pivotal in enhancing overall output while reducing operational costs. The improvement in the performance of liquid-rich frac fleets is a direct result of technological advancements and operational refinements. According to data from the Energy Information Administration (EIA), production per fleet has increased from approximately 5,000 barrels of oil per day (BOPD) to 24,000 BOPD, marking a dramatic leap in efficiency. This improvement has been facilitated by not only the introduction of fleets with higher horsepower but also by optimizing operational practices, reducing personnel and enhancing fleet utilization. As a result, despite the inevitable production declines from older wells, the efficiency gains outpace depletion effects, making U.S. tight oil more competitive globally. Projections suggest that maintaining current fleet numbers will stabilize production, while the addition

of new fleets could increase U.S. tight oil production by around 175,000 BOPD by 2025 (Figure 3).

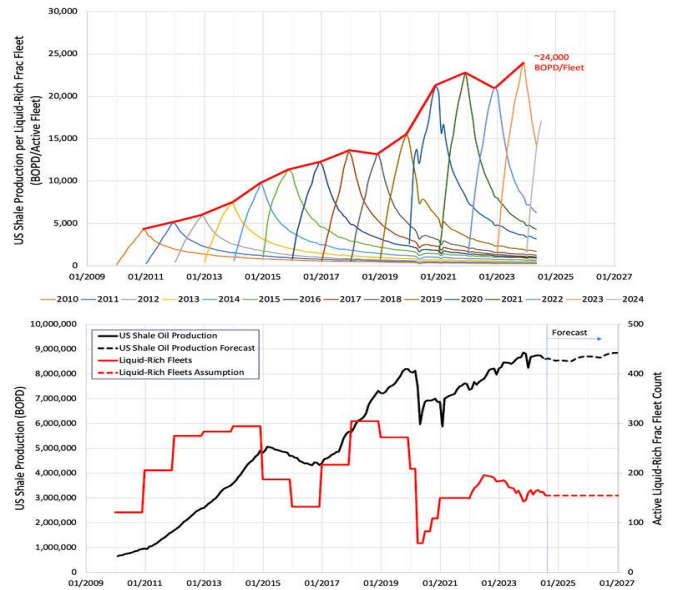


Figure 3: Liquid Rich Frac Fleet vs US Shale Production<sup>11</sup>.

On the other hand, California’s energy transition and its pursuit of renewable energy solutions exemplify the complex trade-offs between sustainability and economic feasibility. While the state has made remarkable strides in expanding wind, solar and battery storage capacities, it faces the challenge of ensuring grid reliability and managing the increasing costs of renewable energy infrastructure. A notable trend is the rise in electricity prices for consumers, particularly when compared to states like Florida, which made natural gas-based energy choices 15 years ago. This price disparity raises concerns about the regressive nature of energy costs for lower-income households, who are disproportionately affected by rising energy bills. Furthermore, the expansion of renewable energy infrastructure also necessitates significant investments in power transmission networks, which can introduce new risks, such as the potential for wildfires caused by power lines in remote areas. The reliance on imported electricity and the long-term sustainability of battery storage systems further complicate California’s energy strategy, underscoring the importance of considering the real costs and environmental implications of such transitions (Figure 4).

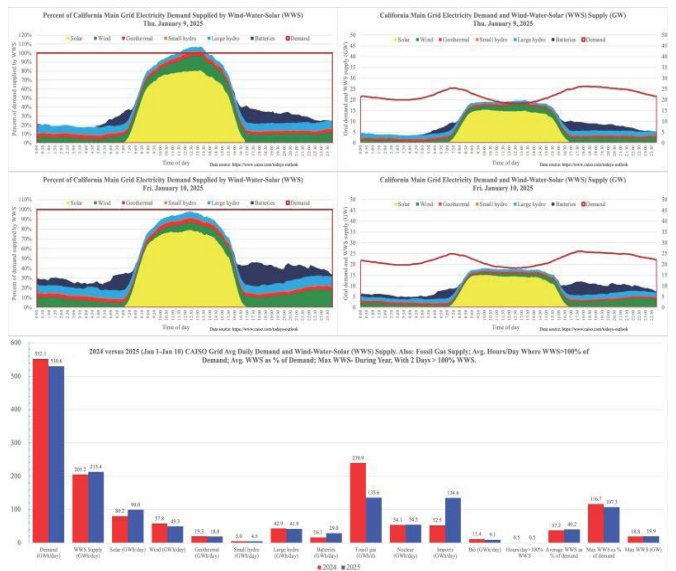


Figure 4: California’s Energy Strategy<sup>12</sup>.

In addition to these challenges, the application of desalination technology in California’s water management system presents a fascinating intersection of economics, energy and technology. Desalination, though often criticized for its environmental impacts, offers a viable solution to California’s ongoing water scarcity issues. By converting seawater into fresh water at an estimated cost of \$10 per 1,000 gallons, desalination could provide a reliable and consistent water supply, especially in areas like the San Joaquin Valley. Interestingly, the economic value of water used in various industries-such as oil production-further highlights the trade-offs between resource allocation. For instance, 1,000 gallons of water used in a shale frac operation can yield approximately 45 barrels of crude oil, valued at \$3,400. This illustrates the potential of leveraging technological advancements to maximize the value derived from natural resources while addressing critical issues such as water scarcity (Figure 5). As California navigates its energy and water challenges, balancing technological innovation with economic and environmental priorities will be key to fostering a sustainable future.

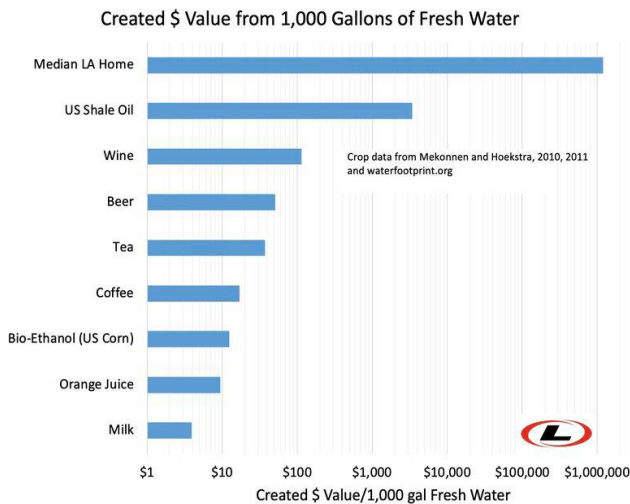


Figure 5: Water Scarcity Analysis<sup>13</sup>.

### Cultural and Societal Perspectives On Energy and Popularization

Cultural and societal factors play a significant role in shaping the discourse surrounding energy, particularly in how energy-related topics are presented to the public. As the global conversation around energy transitions and sustainability continues, understanding the nuances of cultural influence on energy acceptance and implementation becomes increasingly essential. One intriguing perspective emerges from the intersection of music and language, exemplified by the pop group ABBA. Despite being non-native English speakers, ABBA’s success in the global music industry highlights the power of language in shaping mass appeal. By mastering English lyrics and crafting universally recognizable hooks, ABBA effectively bridged cultural and linguistic barriers, solidifying their place in global music history with over 150 million records sold (Figure 6). This phenomenon of cultural adaptation extends beyond entertainment into the energy sector, where effective communication is essential for public engagement and understanding of complex energy issues.

Energy popularization, particularly through figures such as Bill Nye, demonstrates the role of influential personalities in

shaping societal perspectives. Nye, known for making science accessible and appealing to a broad audience, has brought attention to climate change and energy-related topics through his media presence. However, his recent alignment with a singular viewpoint on climate change and CO2 mitigation has sparked debate over the limitations of popularization. Nye’s messaging, while effective in raising awareness, has also been critiqued for oversimplifying the complexities of climate science and the energy debate, which includes questioning whether CO2 is the sole factor in global temperature regulation. The challenge in balancing the simplification necessary for mass communication with the complexities of energy science is highlighted in his statements that have blurred the lines between popularization and politicization (Figure 7). These issues underscore the importance of a nuanced approach to energy messaging that maintains scientific integrity while still engaging the public.

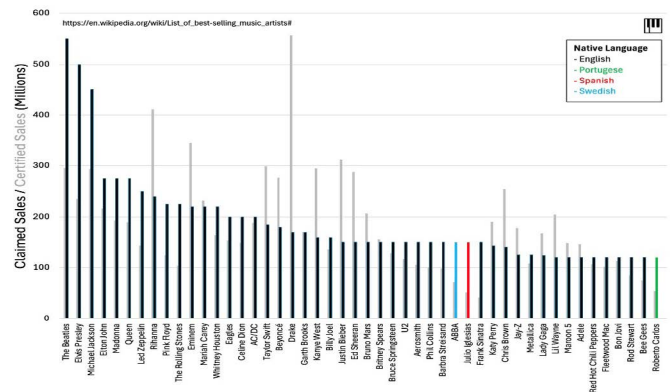


Figure 6: Linguistic Barriers<sup>14</sup>.

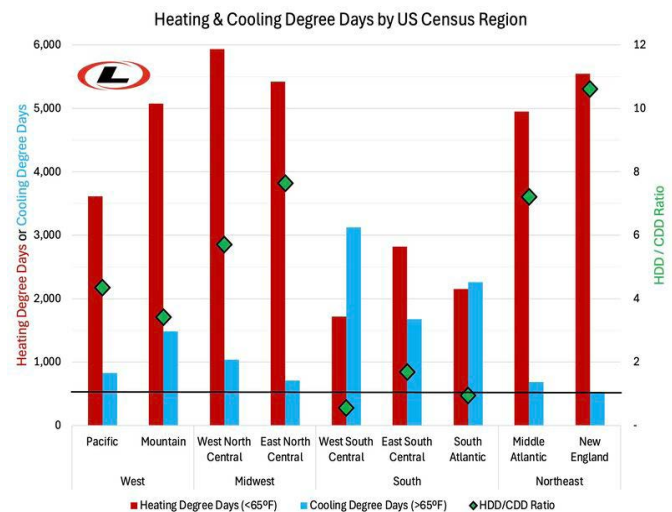
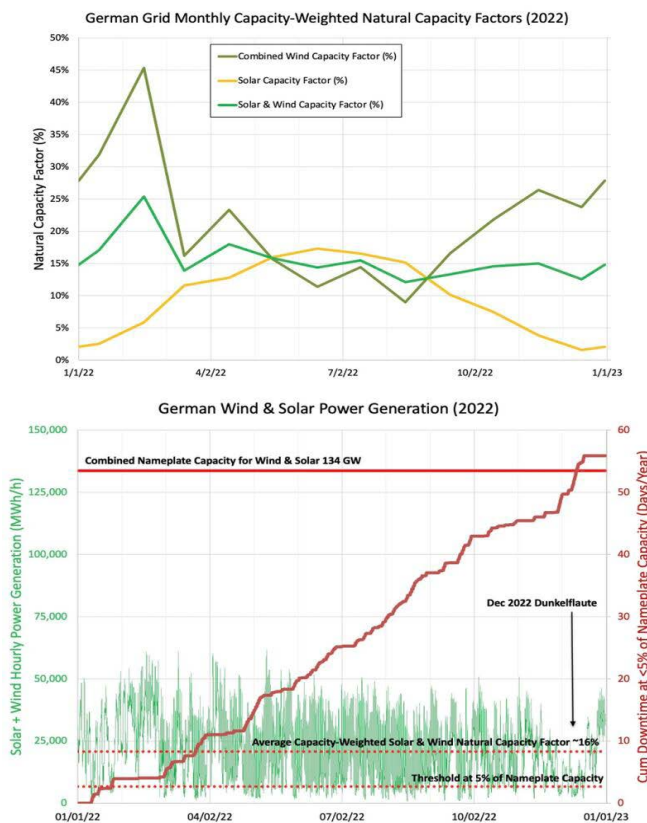


Figure 7: Heating & Cooling Degree Days<sup>15</sup>.

In the context of energy production and consumption, the societal impact of popularized narratives around sustainability, climate change and energy efficiency is undeniable. These narratives not only inform public policy but also influence individual behavior and choices, shaping the future trajectory of global energy systems. As the world continues to grapple with these challenges, the need for responsible energy popularization-one that accurately represents scientific data and fosters informed public debate-becomes ever more critical. The lessons drawn from the music and media industries offer valuable insights into how energy discourse can be made more accessible, engaging and culturally relevant, without losing sight of the complexity inherent in the subject.

## Renewable Energy Challenges and Realities

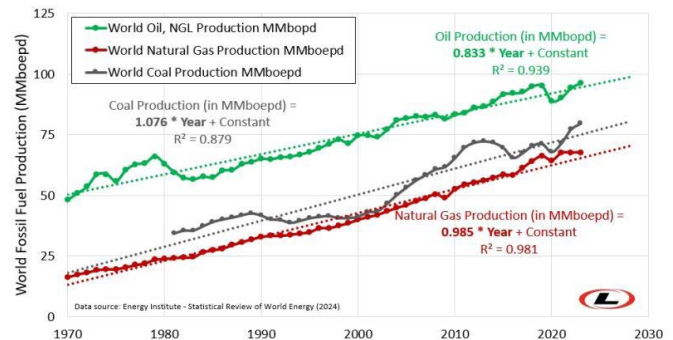
The push for renewable energy, particularly solar and wind power, has been at the forefront of global energy discussions. However, despite their promise, these energy sources face significant challenges when it comes to reliability, especially in regions such as Germany, where solar and wind power are central to the country’s energy strategy. A major issue with solar power in Germany is its intermittency, with long periods of low output, particularly during the winter months when energy demand is high. While proponents of renewable energy argue that the intermittency of solar can be mitigated by pairing it with wind power, an analysis of German grid data reveals mixed results. **(Figure 8)** shows that, on a monthly basis, solar and wind power complement each other, with solar power peaking in the summer and wind power peaking in the winter. However, this temporal complementarity does not resolve the core issue of balancing the grid, which needs to be maintained on a second-by-second basis. When looking at cumulative downtime, the reliability of this combined renewable system falls short. In 2022, for example, German solar and wind combined failed to deliver at least 5% of their nameplate capacity for over 56 days of the year, despite the fact that 5% of nameplate capacity (7 GW out of 134 GW) is considered a low threshold for performance. This highlights the limitations of relying on solar and wind alone to provide consistent and reliable energy, particularly during periods of low production.



**Figure 8:** Solar & Wind Power Generation of German Grid<sup>16</sup>.

The broader context of the global energy transition reveals a similarly challenging reality. The term “energy transition” suggests a shift away from fossil fuels towards renewable energy sources, yet data indicates that fossil fuel production continues to rise at a significant pace. The concept of an energy transition assumes that there is a departure from one dominant energy source-fossil fuels-to another-renewables. However, experts

such as Roger Pielke Jr., Robert Bryce and Scott W. Tinker argue that what we are witnessing is not a transition, but rather an “energy addition.” Over the past five decades, the production of fossil fuels has steadily increased, with natural gas, coal and oil all growing at a rate of approximately 1 million barrels of oil equivalent per day (MMboepd) annually, as illustrated in **(Figure 9)**. Despite the global push for renewables, fossil fuel production continues to expand, driven by growing global energy demand. In fact, fossil fuel growth has outpaced population growth in the last decade, with oil, natural gas and coal production rising by 1.12%, 1.92% and 1.06%, respectively. This growth in fossil fuel production reflects the ongoing reliance on these energy sources and underscores the challenge of transitioning to a low-carbon energy future. While renewable energy technologies continue to improve, their ability to replace fossil fuels on a global scale remains uncertain, highlighting the complexity of the energy transition and the realities of fossil fuel growth.



**Figure 9:** Fossil Fuel Production Rates<sup>17</sup>.

The challenges associated with renewable energy intermittency and the continued growth of fossil fuel production both serve as reminders that the energy transition is not a simple or linear process. As the global energy landscape evolves, it will require a careful balance of renewable and fossil fuel energy sources, alongside technological advancements in energy storage and grid management, to ensure a stable and sustainable energy future.

## The Role of Fossil Fuels In Modern Society

Fossil fuels continue to play a vital and often overlooked role in supporting daily life across the globe, particularly in providing the warmth and energy necessary for human comfort and survival. One such example is propane, a fossil fuel that has been a significant part of traditional celebrations and essential activities in colder climates. A personal tradition of deep-frying dough, known as “oliebollen” or “oil spheres,” on New Year’s Eve serves as an illustration of how propane contributes to modern societies. This tradition, passed down through generations, involves cooking outdoors, often in regions with harsh winters. Propane’s compact transportability and clean-burning characteristics make it an ideal energy source for such activities. Unlike other forms of energy, propane is easily stored in liquid form and can be transported to remote locations, making it invaluable in both industrial and domestic settings.

In addition to its role in festive traditions, propane has become increasingly important in the broader context of global energy supply. The United States, for example, has significantly increased its propane production since the onset of the Shale Revolution, with production expanding by a factor of four. As a result, the US is now the largest producer of propane worldwide.

This increase in production has not only supported domestic demand but has also led to a rise in exports, particularly to countries where access to reliable and clean energy is a challenge. Propane has proven to be an essential energy source for those living in remote or off-grid locations, such as rural African communities and mountain residents in Colorado, where alternatives for heating and cooking are limited.

(Figure 10) demonstrates the substantial growth in US propane production over recent years, particularly driven by shale extraction technologies. In a world where the dangers of winter cold can often outweigh the risks of summer heat, propane is a crucial resource for ensuring that people can stay warm and secure in their homes. As the global energy landscape evolves, fossil fuels like propane continue to serve as a reliable and indispensable part of modern society, even as the world moves toward a greater emphasis on renewable energy sources. The continued role of fossil fuels in addressing basic human needs highlights the complex relationship between energy supply, societal development and environmental sustainability.

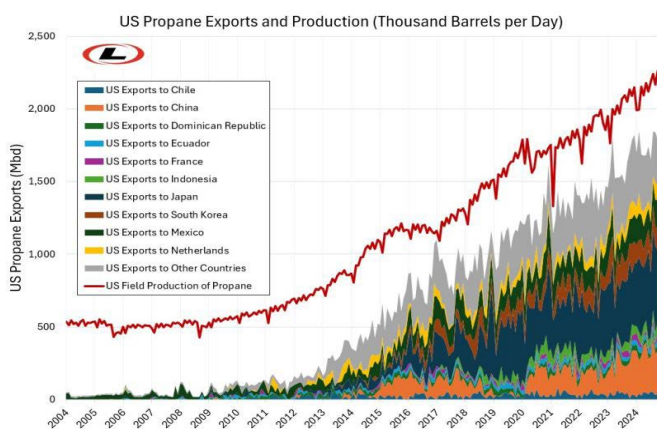


Figure 10: US Propane Exports & Production<sup>18</sup>.

## Conclusion

The global energy transition is a complex and multifaceted issue that requires a nuanced understanding of both renewable and non-renewable energy sources, their contributions to society and the challenges they present. As explored in this paper, while renewable energy technologies such as solar and wind offer promising solutions to reduce carbon emissions, their intermittency and reliability issues continue to pose significant hurdles. The example of Germany's energy grid illustrates how the integration of renewable energy must be carefully managed to ensure a consistent and reliable power supply. Despite the growth of renewable energy, fossil fuels continue to play an essential role in meeting the world's energy needs, providing reliability and stability that current renewable technologies cannot yet fully match.

Moreover, the reality of fossil fuel consumption reveals that, rather than a simple transition, the world is experiencing an "energy addition," where fossil fuel production continues to rise alongside the adoption of renewable sources. This trend is evident in the persistent growth of oil, natural gas and coal production, which supports global energy demand and economic development. The widespread use of fossil fuels, including propane, for heating, cooking and industrial processes underscores their continued relevance in modern society. As we move forward, it is crucial to recognize the vital role that fossil fuels continue to play, especially in regions where access to reliable energy is limited.

In conclusion, while the pursuit of renewable energy solutions is critical for reducing our environmental impact, fossil fuels remain indispensable in providing energy security and supporting economic development. Achieving a sustainable energy future will require a balanced approach that incorporates both renewable and fossil fuel resources, leveraging technological advancements to improve efficiency, reduce emissions and ensure global energy access. As the world navigates the complexities of energy transition, it is essential to maintain a realistic perspective on the challenges and opportunities that lie ahead.

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