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Energy, Economy, and Society: Examining Strategic Resources and Global Trends

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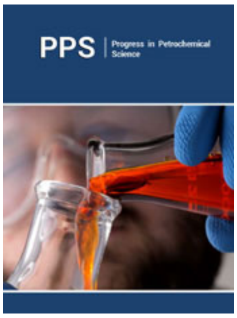

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Abstract

This paper explores the complex relationships between energy, economy, and society, emphasizing the role of strategic resources and global trends. It examines the environmental and societal challenges tied to energy production and consumption, highlighting the ongoing debates on U.S. Liquefied Natural Gas (LNG) exports. These discussions weigh the environmental concerns against economic interests and energy security, suggesting that increased LNG exports could enhance global energy stability while supporting the U.S. economy. The paper also addresses the rising energy demands driven by technological advancements, particularly the growth of data centers fueled by Artificial Intelligence (AI) and cloud computing. This shift presents challenges for current power grids and underscores the importance of reliable energy sources for digital infrastructure. Additionally, the paper touches on the influence of cultural changes, such as shifts in musical preferences, reflecting broader societal transformations in the digital age. The conclusion emphasizes the need for strategic decision-making to balance economic growth, environmental sustainability, and societal well-being in a rapidly changing global landscape.

Keywords: Energy policy; LNG exports; Energy efficiency

Introduction

The global energy landscape is undergoing a complex transformation driven by the interplay of economic growth, environmental policies, and technological advancements. While the transition to renewable energy is often framed as an inevitable shift, a closer examination reveals that fossil fuels remain fundamental to the global economy. The notion that the world is rapidly moving away from hydrocarbons is misleading; rather, the current trajectory indicates an era of energy expansion rather than a wholesale transition. As societies strive to balance energy security with climate concerns, it is crucial to critically assess the role of oil, gas, and other conventional energy sources in maintaining economic stability and technological progress [1]. Despite ongoing discussions on carbon neutrality and decarbonization strategies, fossil fuels continue to be the backbone of global energy systems. The accelerating pace of industrialization, urbanization, and population growth ensures that energy demand remains high. While renewable sources such as wind and solar have made significant advancements, their intermittency and infrastructure challenges prevent them from fully replacing hydrocarbons in the near future. The adaptability of the oil and gas industry, particularly through technological innovations in exploration and production, further reinforces its ongoing relevance in the evolving energy landscape [2].

One of the most frequently cited pathways for reducing fossil fuel dependence is the electrification of transportation. However, significant challenges remain, including supply chain constraints, battery technology limitations, and inadequate charging infrastructure. These barriers highlight the need for a balanced approach that prioritizes both sustainability and economic feasibility [3]. At the same time, sustainable development within the oil and gas sector continues to be a focal point, incorporating economic, environmental, and social considerations to optimize resource utilization while minimizing negative externalities [4]. Technological advancements in oil and gas exploration and production have played a crucial role in shaping the industry's future. Innovations such as enhanced recovery techniques, digitalization, and artificial intelligence-driven optimization have improved efficiency and reduced environmental impacts. These developments demonstrate that the fossil fuel sector is not static but rather evolving to meet the demands of a changing world. As energy needs continue to rise, ensuring the integration of emerging technologies into traditional energy systems will be essential for long-term sustainability [5]. The global energy transition is not a simple linear process but rather a multidimensional shift that requires careful navigation. While renewables are growing in importance, they coexist with hydrocarbons rather than outright replacing them. Policymakers and industry leaders must adopt a pragmatic approach that balances energy security, economic growth, and environmental considerations [6]. As climate change debates continue, it is also essential to recognize the shifting patterns of human adaptability to temperature extremes and how these factors influence energy demand [7]. Ultimately, understanding the power dynamics of energy markets and their broader implications is key to addressing global challenges effectively [8].

Environmental and Societal Challenges

The United Nations Convention to Combat Desertification (UNCCD) reported that at least 100 million hectares of healthy and productive land are lost annually, warning that "land is degrading faster than we can restore" [9]. However, such reports often lack context, leading to alarmist conclusions. The assumption that climate change is the primary driver of all environmental degradation oversimplifies a complex issue. To put this into perspective, data from OurWorldInData [10] and the United Nations Food and Agricultural Organization (FAO) [11] indicate that global agricultural land use currently spans approximately 4-5 billion hectares. The reported annual loss of 100 million hectares accounts for roughly a 2% reduction in agricultural land per year. While this may seem concerning, it is largely a result of technological and agricultural innovations rather than an outright crisis.

Research by Taylor & Rising [12] provides critical insight into this trend, supporting the Borlaug hypothesis. Their findings demonstrate that as societies advance economically, agricultural land use initially expands before reaching a peak, after which it stabilizes or declines. Despite this reduction, crop production continues to increase due to enhanced efficiency, higher yields, and improved agricultural practices. Figure 1 from their study illustrates this transition, showing how developed nations ultimately shift toward land conservation and reforestation, a process they refer to as "greening." This shift is evident in wealthier nations, where agricultural land is increasingly being repurposed for conservation efforts, including national parks and protected areas. This phenomenon highlights the positive impact of economic growth on environmental restoration, contradicting the notion that land degradation is purely a climate-induced catastrophe.

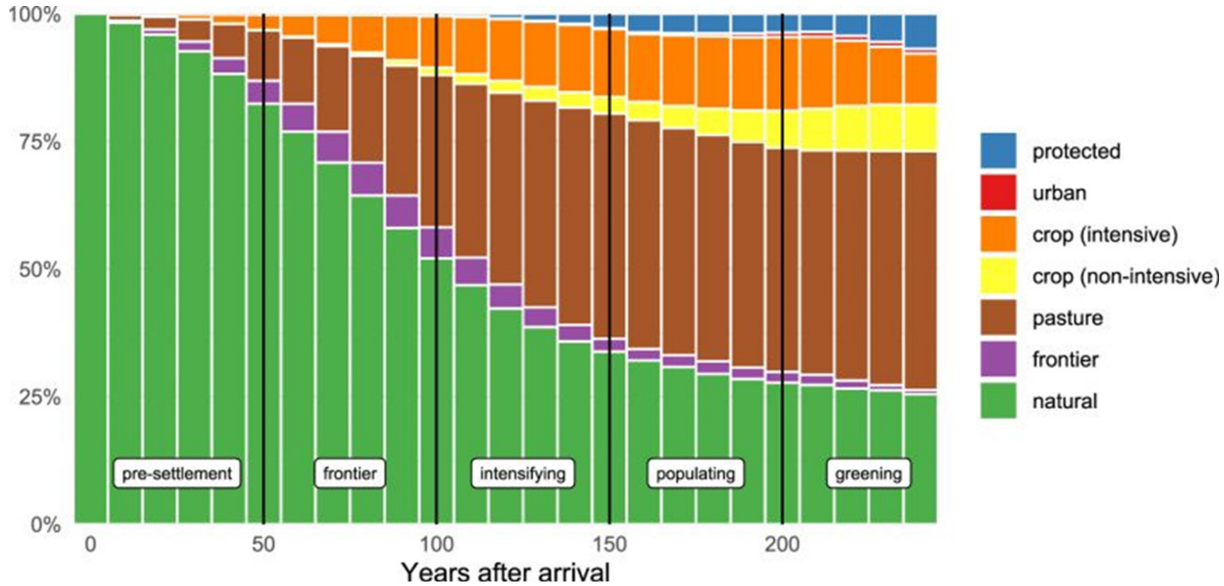

Figure 1: Land conservation and reforestation of developed nations [8].

It is also important to critically evaluate the narratives presented by international organizations. While the UN plays a crucial role in addressing global challenges, concerns have been raised regarding its approach to climate discourse. The organization has been actively advocating against what it deems "mis- and disinformation," raising questions about the framing of environmental issues (UNCCD, 2023) [13]. Whether this approach is designed to garner attention or reflects deeper policy motivations remains an open debate. The historical trajectory of child mortality reveals a remarkable yet unequal transformation over the past two centuries. While infant and child mortality rates were once devastatingly high, with nearly half of all children dying before puberty two millennia ago, advancements in medicine, sanitation, and nutrition have significantly improved survival rates worldwide. Today, however, an estimated six million children under the age of fifteen still die prematurely each year. The disparity between high- and low-income nations remains stark-child mortality rates before the age of five average around 0.5% in developed economies, whereas in low-income countries, this figure rises to approximately 6.5% [14].

Over the past decade, global child mortality has continued to decline, though at a slightly decelerating pace, decreasing from 4.7% to 3.7%. Despite this progress, the factors contributing to these improvements are multifaceted and deeply interconnected. Platforms such as OurWorldInData and Gapminder provide extensive datasets visualizing these historical trends, allowing for a comprehensive assessment of the reduction in child mortality over time [15]. Figure 2 from OurWorldInData illustrates this dramatic historical change, showcasing the significant progress made while also highlighting the persistent inequalities in different regions. While statistical tracking captures the scale of these improvements, it does not necessarily explain the underlying drivers of change. The reduction in child mortality is likely attributed to a combination of factors, including advancements in vaccination programs, improved maternal healthcare, better access to clean drinking water, and the overall rise in living standards. However, the precise mechanisms driving this trend may be as intricate as the layers of an onion, with economic, political, and technological developments all playing a crucial role in shaping health outcomes. Understanding these root causes is essential to further accelerating progress and ensuring that vulnerable populations are not left behind [16].

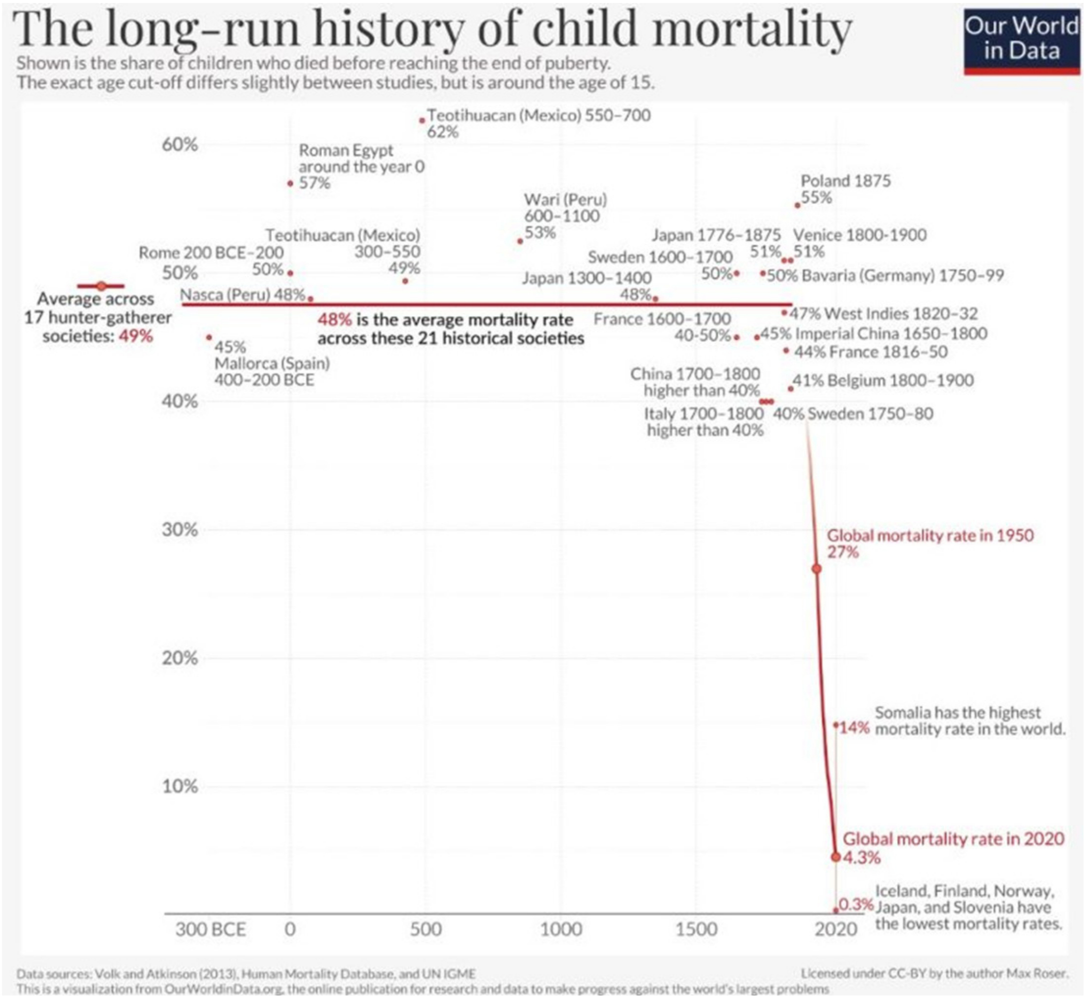

Figure 2: History of child morality [16].

Energy Realities and Misconceptions

The variability of solar energy presents fundamental limitations, particularly in high-latitude regions where seasonal fluctuations in sunlight are significant. To illustrate this challenge, consider a hypothetical 100-watt device powered solely by solar energy. During winter months, its output could drop to as low as 5 watts in December, whereas on a midsummer day, it may briefly peak at 60 watts for a limited duration of approximately 15 minutes. This inconsistency highlights the challenge of relying on solar power without adequate energy storage or backup generation. In northern latitudes, such as the Netherlands and Germany (approximately 53°N), the winter sun remains low in the sky, rising only 15° above the horizon in December. Under these conditions, solar panels may generate more electricity when mounted vertically rather than in a traditional horizontal orientation, demonstrating the inherent inefficiencies of solar power in such regions. Moreover, even during the limited daylight hours-spanning from approximately 8:45a.m. to 4:14p.m.-persistent cloud cover and seasonal weather patterns can further restrict solar generation.

Even in summer, solar power rarely operates at its nameplate capacity. In (Figure 3), grid data from Germany in 2022 illustrates this constraint (German Grid Report) [17]. On July 17, 2022, solar generation peaked at only 59% of its theoretical maximum, even at 1:00p.m., when solar intensity was at its highest. Despite Germany's substantial installed solar capacity of 68 GW that year, solar contributed only 10% of the country's total electricity generation. In contrast, nuclear power-if deployed at a comparable capacity-could have provided a stable and reliable energy supply. Nevertheless, Germany has prioritized rapid solar expansion, even though its capacity factor remains low, averaging approximately 10%. While increasing installed capacity might appear to be a solution, it does not alter the fundamental reality that solar energy remains intermittent and dependent on environmental conditions. Even with a tenfold increase in solar infrastructure, the challenge of intermittency persists, reinforcing the need for complementary energy sources, storage solutions, or diversified energy strategies. This raises critical questions regarding the feasibility of over-relying on solar power in regions where natural limitations cannot be overcome by sheer expansion alone [18].

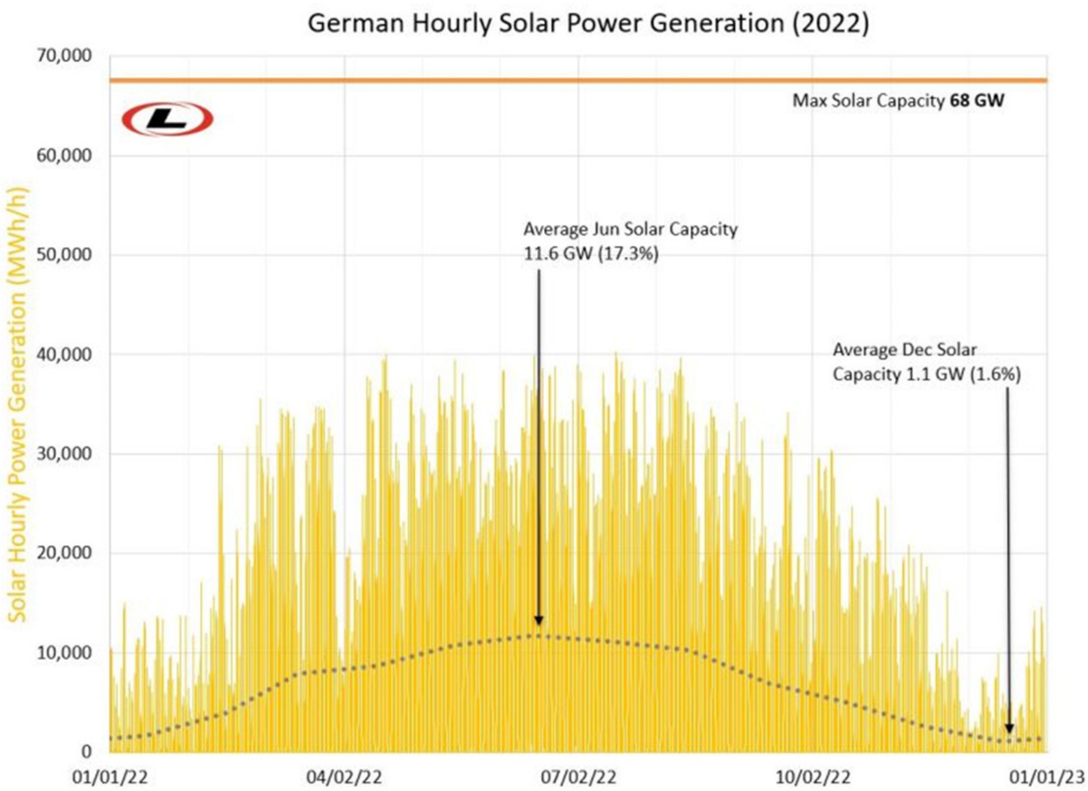

Figure 3: German hourly solar power generation [18].

South Australia has often been regarded as a model for a renewable energy-driven future, serving as a large-scale experiment in the viability of intermittent energy sources. With its considerable wind resources-yielding an average capacity factor of approximately 26%-and solar energy contributions from both utility-scale (20%) and rooftop installations (11%), the region has rapidly expanded its renewable infrastructure [19]. Despite accounting for only about 11% of Australia's total electricity generation capacity, South Australia contributes approximately 7% of the nation's total electricity production, positioning it as a key case study in the integration of renewables [20]. Since the introduction of large-scale renewable energy in 2009, the weighted capacity factor of all power sources in the region has declined significantly from 40% to approximately 25%. This reduction highlights the overbuilding of infrastructure to compensate for renewable intermittency, effectively resulting in a grid that now requires nearly threefold backup capacity to ensure reliability. The daily and seasonal shifts in energy production further underscore the challenges of maintaining grid stability. During daylight hours, renewable energy sources dominate electricity generation, while a limited amount of battery storage assists in managing the steep decline in solar output at dusk. However, as night falls, the grid primarily relies on wind power, natural gas, and electricity imports from neighboring states. During the winter months (April to July), when solar generation is substantially lower, reliance on non-renewable sources and interprovincial electricity imports increases even further [21].

The economic consequences of this energy transition have been significant. As illustrated in Figure 4, electricity prices in South Australia have risen between 100% and 300% since the large-scale adoption of renewables. While daytime energy prices frequently turn negative-rendering excess solar generation financially unviable-battery storage solutions remain costly, making it more economically feasible to overbuild renewable capacity and curtail excess production when necessary. In contrast, electricity prices surge at night and during winter, particularly when renewable generation is insufficient to meet demand. This increasing volatility in energy costs raises critical concerns regarding the long-term sustainability of a system heavily dependent on intermittent renewable energy without sufficient baseload or dispatchable generation. A key question remains: Can South Australia maintain energy self-sufficiency without reliance on grid stability support from New South Wales, Victoria, and Queensland? The region's future energy security will largely depend on advancements in storage technologies, grid management strategies, and policy decisions that address the fundamental intermittency of renewable energy [22].

Figure 4: Electricity prices of South Australia [22].

Geopolitics and Energy Policy

The recent decision by the Biden administration to pause approvals for new Liquefied Natural Gas (LNG) export projects has significant implications for global energy markets and U.S. geopolitical strategy. This decision, influenced by White House climate adviser John Podesta, was initially framed as a temporary measure to allow for further study of the economic and environmental impacts of increased LNG exports [23]. However, the findings of the Department of Energy's own study conflict with the administration's ultimate stance, raising questions about the policy's underlying motivations and long-term consequences. Under the Natural Gas Act, the DOE has the authority to approve LNG export permits to non-Free-Trade-Agreement (non-FTA) countries only if the exports are deemed to be in the "public interest." The recent study supports the idea that LNG exports meet this criterion, yet Energy Secretary Jennifer Granholm has argued otherwise, citing potential increases in domestic natural gas and electricity prices [23]. However, U.S. natural gas prices remain near record lows despite surging LNG exports, primarily due to the continued growth of domestic production, which has more than offset rising demand [24]. The DOE study projects that even with increased LNG exports, wholesale natural gas prices in the U.S. would only rise by approximately 31% by 2050-from $3.53 per Million British thermal units (MMBtu) to $4.62 in 2022 dollars-leaving U.S. gas prices significantly lower than those in Europe.

The administration's concerns over the global supply of LNG also face strong opposition from international stakeholders. European and Japanese policymakers emphasize the critical role of U.S. LNG in enhancing energy security and reducing reliance on coal. The DOE study itself acknowledges that U.S. LNG has contributed to lowering global coal consumption by providing an alternative energy source for countries seeking to balance their energy mix with renewables and natural gas. Furthermore, Granholm's assertion that increased LNG exports would displace renewable energy more than coal is contradicted by the study's findings, which indicate that U.S. LNG would primarily replace other fossil fuels and have a negligible impact on global CO_2 emissions-potentially increasing them by only 0.05% cumulatively through 2050. By contrast, China's ongoing construction of hundreds of new coal-fired power plants will have a far greater climate impact. Economic and employment factors further highlight the strategic benefits of expanding LNG exports. The DOE study finds that increased natural gas production tends to stimulate job growth and wage increases in regions where production occurs, while LNG export terminal projects contribute to high-wage employment and generate new revenue streams for local governments [23]. Additionally, restricting U.S. LNG exports could inadvertently strengthen China's reliance on coal, undermining global decarbonization efforts. Given that China is the world's largest LNG importer, limiting exports to the country could force it to turn to more polluting energy sources [25].

Despite growing evidence in favor of expanded LNG exports, internal disagreements within the Biden administration persist. Reports suggest that officials from the National Security Council and the Energy Department's National Laboratories do not share Granholm's restrictive position. However, given the significant influence of climate-focused advocacy groups within Democratic Party politics, it remains uncertain whether a future administration-particularly under Vice President Kamala Harris-would shift toward a more export-friendly LNG policy. A potential shift in leadership under a Trump administration, with figures such as Chris Wright in key energy policy positions, could dramatically alter the trajectory of U.S. LNG policy, reshaping both domestic economic conditions and global energy security [26]. The concept of a superpower has evolved significantly over the past century, becoming more complex and demanding in an era of economic globalization, technological advancements, and shifting geopolitical landscapes. A superpower is defined [27] as a nation that exerts influence through a combination of economic, military, technological, political, and cultural strength, as well as diplomatic and soft power. However, the foundation of all these forms of influence remains rooted in hard power, which is fundamentally dependent on access to reliable and flexible energy sources-chiefly oil [28].

Throughout the 20th century, oil played a decisive role in shaping global power dynamics. During World War I and World War II, the United States produced up to 60% of the world's oil, providing a significant strategic advantage. As Yergin [28] highlights in the Prize, oil was a crucial factor in securing victory, with the U.S. producing nearly 100 times more oil than its adversaries. However, after the peak oil era of the 1970s, U.S. production declined, allowing countries like Russia and Saudi Arabia to surpass it in output [29]. The emergence of the Shale Revolution reversed this trend, increasing U.S. oil production from around 8% to nearly 20% of the world's total output (Figure 5), [30]. While this resurgence has reestablished the U.S. as a leading energy producer, it no longer enjoys the overwhelming dominance it once did. The question of whether oil remains the most strategic energy resource in the 21st century is an ongoing debate. The Cold War era saw the rise of nuclear power as a critical element of geopolitical influence, while renewable energy sources such as solar and wind are increasingly integrated into national energy strategies [31]. However, the inherent intermittency and infrastructure limitations of renewables raise questions about their ability to fully replace oil's role in supporting military operations, economic stability, and global energy security. As superpowers continue to navigate a rapidly evolving energy landscape, oil remains a crucial factor in determining the balance of global power [32].

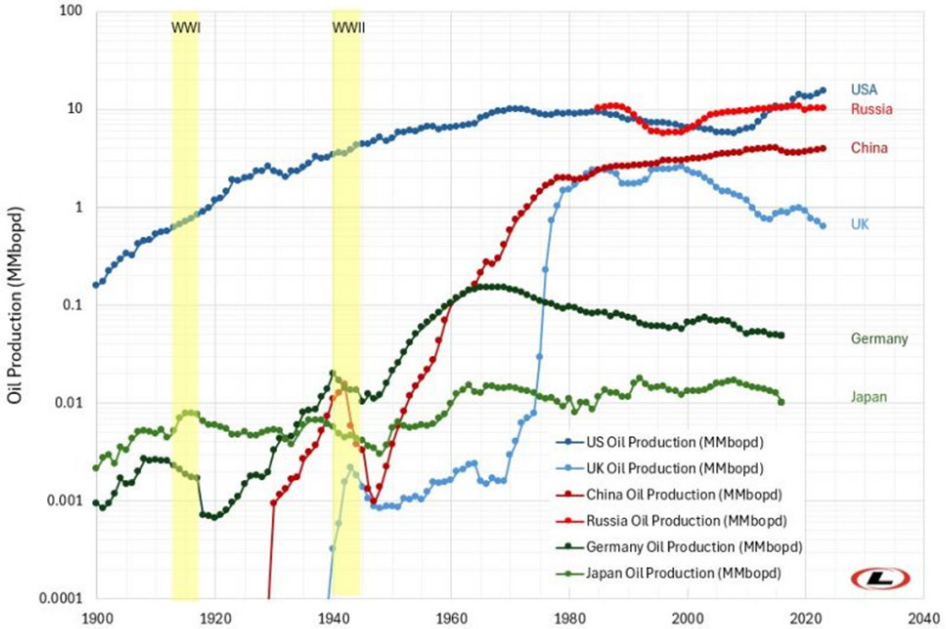

Figure 5: US oil production [32].

Energy Demands of Data Centers Amid Technological and Cultural Shifts

The rapid expansion of Artificial Intelligence (AI) and cloud computing is reshaping the global digital landscape, bringing profound technological and cultural shifts. However, the increasing reliance on data centers raises critical concerns about future energy demands. Forecasting electricity consumption remains uncertain due to varying assumptions regarding growth rates, efficiency improvements, and the accelerating impact of AI-driven workloads [33]. This uncertainty presents significant challenges for power grid planning, as infrastructure investments must be made years in advance despite the unpredictability of future energy needs [34]. Projections for U.S. data center electricity consumption through 2030 vary significantly. Most analyses use a Compound Annual Growth Rate (CAGR) to account for the compounding effects of annual increases. The Electric Power Research Institute presents four scenarios, ranging from a conservative 3.7% CAGR (196 TWh) to a high-growth 15% CAGR (404TWh), reflecting the potential impacts of AI expansion and limited efficiency gains. Goldman Sachs [34] similarly estimates a 15% CAGR, projecting total consumption at 455 TWh by 2030, which could constitute up to 8% of total U.S. electricity demand. McKinsey [35] offers a more aggressive outlook, forecasting a 22.3% CAGR, with data center consumption reaching 606TWh and accounting for up to 40% of net new U.S. electricity demand. The U.S. Department of Energy [36] projects that by 2030, data center demand will reach 675 TWh, or approximately 9% of total U.S. electricity consumption. Rystad Energy [37] provides a more moderate estimate, forecasting electricity demand rising to 307 TWh by 2030, an increase of 177 TWh from 2023 levels (Figure 6).

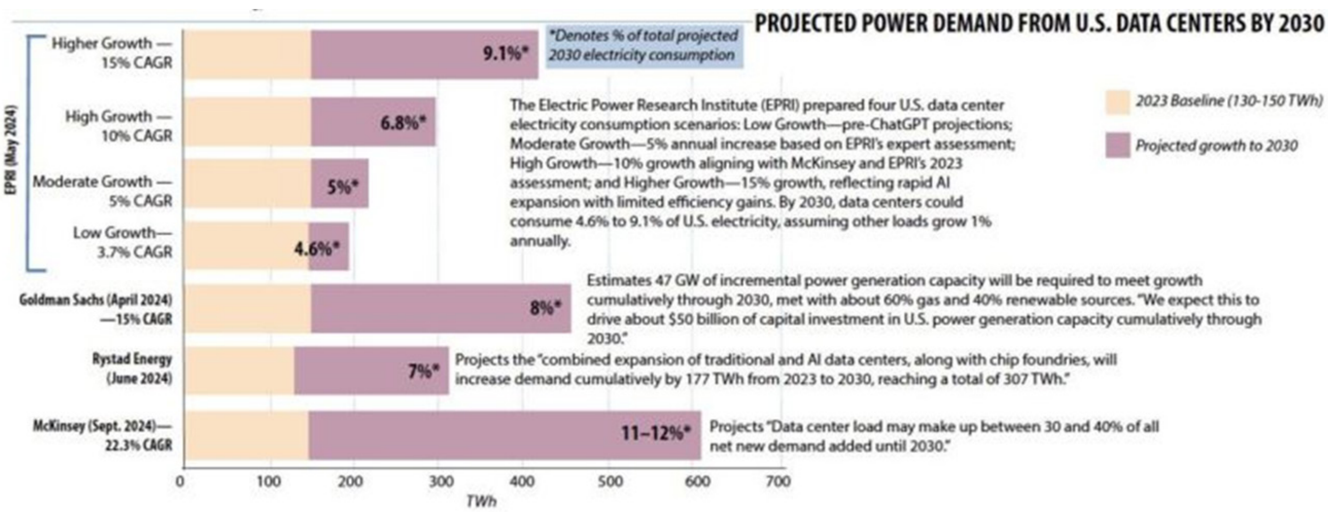

Figure 6: Power demand projections [38].

These projections highlight the technological shift toward data-centric industries and the growing cultural dependence on AI-driven services. As societies become increasingly digitized, the strain on power grids intensifies, necessitating innovative energy solutions to maintain reliability and sustainability. Addressing these challenges will require coordinated efforts from policymakers, industry leaders, and energy providers to balance technological advancements with environmental and economic considerations [38]. The impact of musical instruments on cultural and technological shifts is often overlooked, yet it plays a crucial role in shaping artistic movements and consumer preferences. The dominance of the guitar in rock music, particularly in the streaming era, exemplifies how certain instruments become synonymous with cultural phenomena. While the piano has been integral to music history, its role in rock stardom has been relatively limited compared to the electric guitar. The trajectory of Eddie & Alex Van Halen [39] serves as an illustrative case-both were classically trained pianists before transitioning to guitar and drums, a shift that contributed to their legendary status in rock history.

An analysis of Spotify's monthly listeners in the "classic rock" category highlights this instrumental bias [40]. The majority of top-streamed artists and bands feature guitarists as their primary instrumentalists (marked in black), while those incorporating the piano (marked in red) represent a significantly smaller share of the listener base. Even under the generous assumption that half of these listeners are drawn to piano-driven rock, the instrument accounts for only approximately 15% of total engagement. Iconic exceptions, including Elton John, Queen, Billy Joel, Hall & Oates, and Supertramp, demonstrate that piano-led rock acts can achieve commercial success, but they remain anomalies rather than the norm (Figure 7). This disparity underscores broader cultural trends in music consumption and artist visibility. Guitarists are more frequently associated with rock stardom due to their prominent stage presence and the instrument's adaptability to high-energy performances. In contrast, pianists often adopt a more supporting role, contributing to harmonic complexity and depth rather than serving as the focal point of the performance. The streaming era reinforces this trend, as listener engagement metrics suggest that guitar-driven music continues to dominate public interest and algorithmic recommendations. As digital platforms reshape musical consumption patterns, the relationship between instrumental choice and cultural influence remains an area of evolving significance. Future research could further explore how technological advancements, such as AI-generated music and digital instruments, might alter these trends and redefine the role of traditional instruments in popular culture [41].

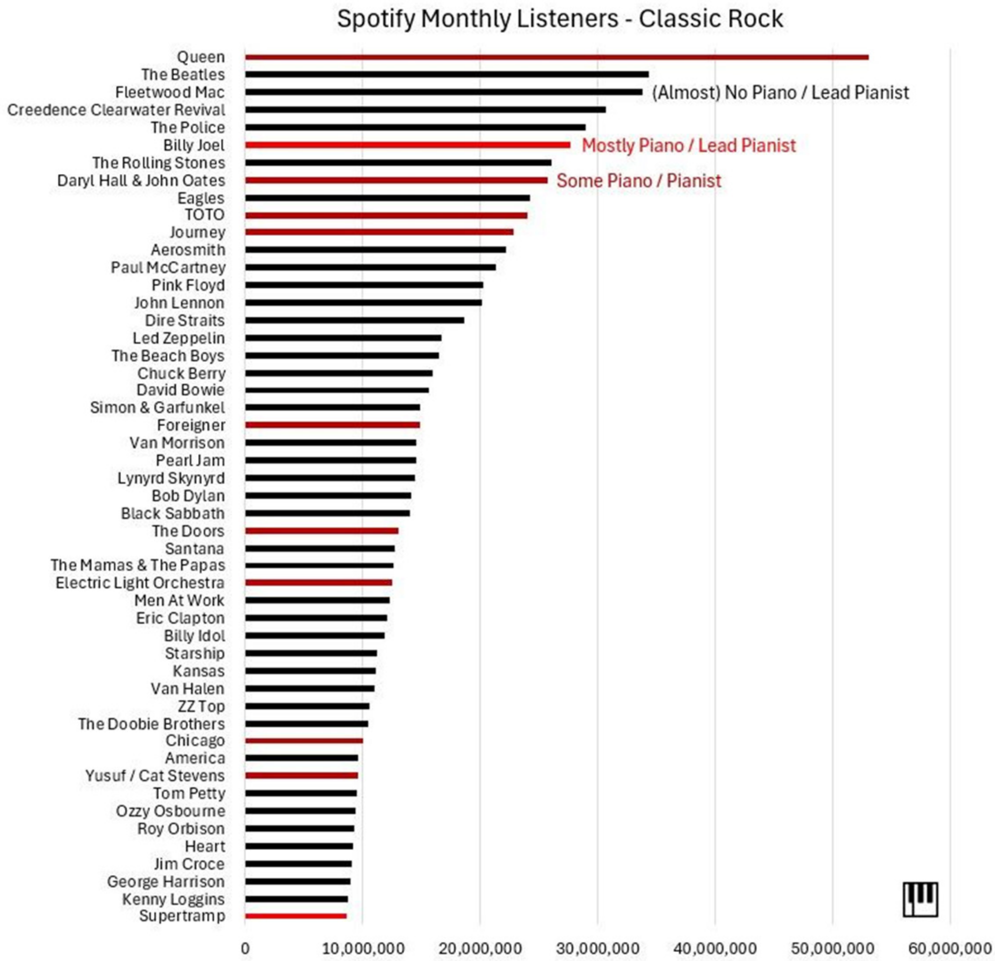

Figure 7: Monthly listeners of spotify [41].

Conclusion

The interplay between geopolitics, energy policy, technological advancements, and cultural shifts continues to shape the modern world in profound ways. The strategic importance of energy resources, particularly Liquefied Natural Gas (LNG) and oil, remains central to national security and economic stability. The ongoing debates surrounding U.S. LNG exports highlight the intersection of environmental concerns, economic interests, and global energy demands. While some policymakers advocate for restricting exports due to potential price impacts and carbon emissions, data suggests that increasing LNG exports could enhance energy security, reduce coal dependence globally, and bolster the U.S. economy. Similarly, the rapid expansion of data centers underscores the technological transformation underway, with projections indicating a significant rise in electricity consumption driven by Artificial Intelligence (AI) and cloud computing. These trends raise critical questions about the sustainability of current power grids and the need for reliable energy sources to support digital infrastructure. Meanwhile, cultural shifts in music consumption, exemplified by the dominance of guitar-driven rock over piano-led performances, reflect broader societal preferences and the evolving nature of artistic expression in the digital era. Together, these discussions highlight the intricate relationships between policy, technology, and culture. As nations navigate energy transitions, technological disruptions, and cultural evolutions, strategic decision-making will be essential to balancing economic growth, environmental sustainability, and societal well-being. Future research should continue exploring the long-term implications of these shifts, ensuring informed policies that align with both national and global interests.

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