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Editorial Article

Sustainable Development and the Surge in Electricity Demand Across Emerging Economies

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Sustainable Development and the Surge in Electricity Demand Across Emerging Economies

Electricity plays a pivotal role in the operation and development of contemporary societies and economies, with its significance escalating as electricity-dependent technologies like electric vehicles and heat pumps gain prominence [1-5]. Currently, power generation stands as the foremost contributor to global carbon dioxide (CO_2) emissions. However, it concurrently spearheads the transition towards achieving net zero emissions by swiftly expanding renewable energy sources like solar and wind power. Balancing the imperatives of ensuring secure and cost-effective electricity access for consumers while simultaneously mitigating global CO_2 emissions represent a fundamental challenge in navigating the energy transition [6-12]. Figure 1 illustrates the emissions from different sources in the energy sector for the years 2021 and 2022.

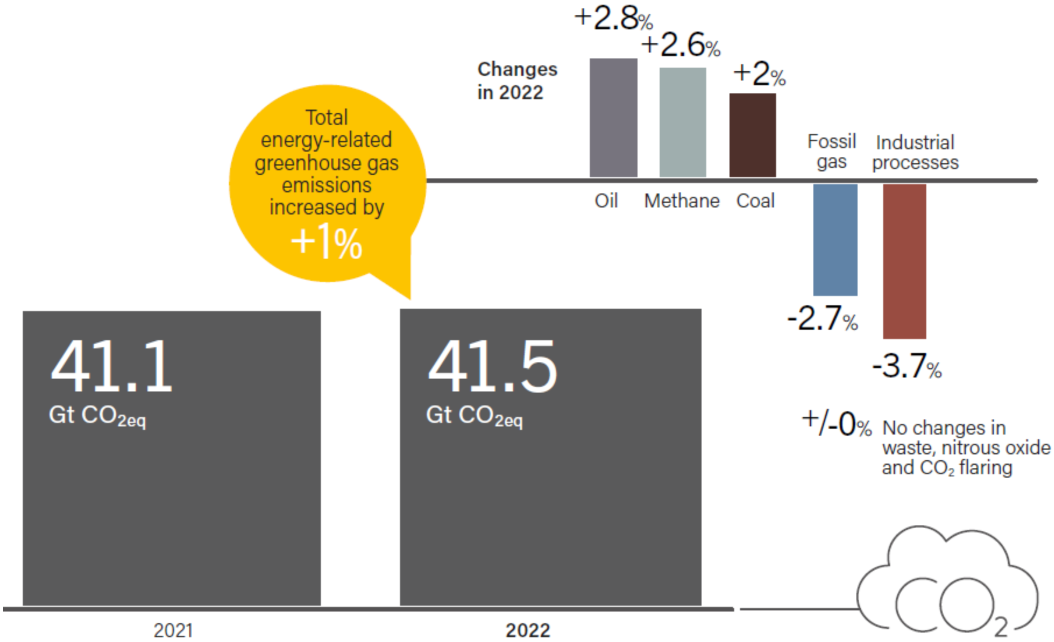

Figure 1. The emissions from different sources in the energy sector for the years 2021 and 2022.

In 2022, the aggregate greenhouse gas emissions stemming from energy-related activities exhibited a marginal 1% augmentation, culminating in a historic high of 41.5 gigatonnes of carbon dioxide (CO_2) equivalent. Nonetheless, this expansion was notably more subdued in comparison to the preceding year's resurgence, which surpassed 6%. Predominantly, emissions emanating from energy combustion and industrial procedures collectively accounted for 89% of the total energy-related emissions, predominantly comprised of CO_2. Specifically, emissions originating from energy combustion escalated by 423 million tonnes, whereas emissions attributable to industrial processes experienced a decrement of 102 million tonnes [13-16]. This decline primarily ensued from reduced industrial output, particularly evident in China, marked by a 10% reduction in cement production and a 2% decline in steel manufacturing.

The global expansion of electricity demand experienced a relatively modest increase of 2.2% in the fiscal year 2023, a slight deceleration from the 2.4% growth observed in the preceding fiscal period of 2022 [17-20]. Notwithstanding this moderation, anticipations indicate a prospective upturn in growth rates to a higher magnitude of 3.4% throughout the forecast period spanning 2024 to 2026. In addition, this trajectory of expansion is anticipated to be chiefly propelled by emerging markets, which persist in assuming a dominant role in the escalation of electricity demand, akin to their position in the year 2023.

The pervasive ramifications of the energy crisis endured unabated throughout the fiscal year 2023, as manifested in the persistent inflationary pressures, elevated interest rates, and substantial debt encumbrances, collectively exerting downward pressure on economies across the global spectrum. Nevertheless, emerging market economies exhibited notable resilience, characterized by robust increases in electricity demand [21-26]. In stark contrast, the majority of advanced economies recorded contractions, attributable to the lackluster macroeconomic milieu and feeble performance of industrial and manufacturing sectors, notwithstanding the ongoing process of electrification. Moreover, mitigated climatic conditions relative to the antecedent fiscal period contributed to a reduction in electricity consumption across certain regions, notably the United States. Figure 2 shows the annual variation in electricity consumption by region from 2022 to 2026. It is noteworthy to highlight that a significant emerging contributor to heightened electricity utilization emanates from energy-intensive data centers, artificial intelligence (AI) technologies [27-37], and cryptocurrency operations, a trend anticipated to potentially undergo a twofold increase by the year 2026.

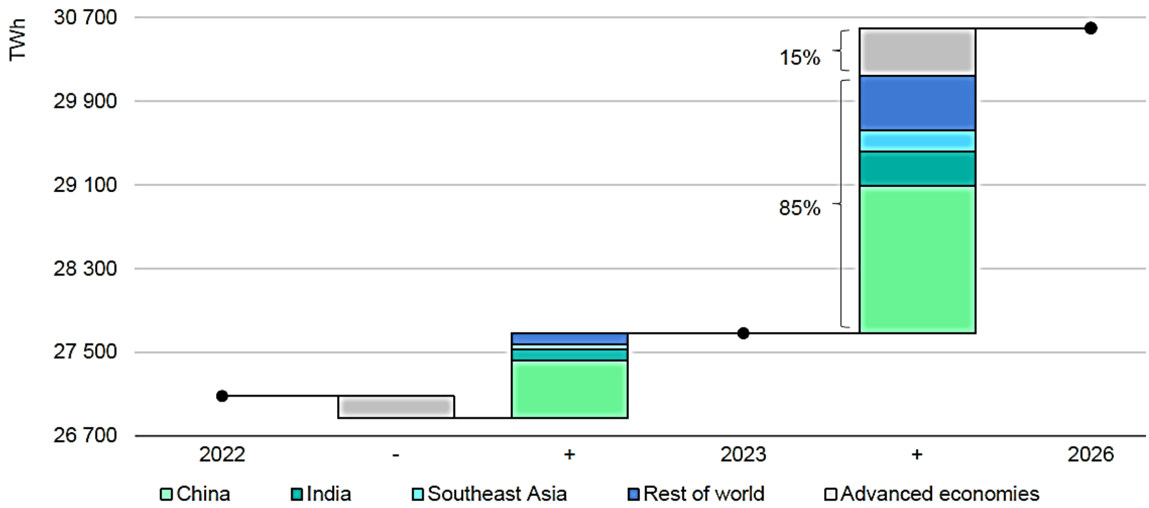

Figure 2. The annual variation in electricity consumption by region from 2022 to 2026.

Approximately 85% of the forthcoming increment in electricity demand until the conclusion of 2026 is anticipated to originate from regions beyond the purview of advanced economies, prominently including China, India, and Southeast Asia [38-42]. The October 2023 forecast by the International Monetary Fund (IMF) delineates a gradual convalescence of economic conditions within advanced economies, with GDP growth rates projected at 1.5% for the fiscal year 2023, followed by a slight diminution to 1.4% in 2024, culminating in an annual average of 1.8% over the interval spanning 2025 to 2026. In contrast, for emerging economies, the IMF prognosticates a continuation of robust expansion, envisaging an average annual growth rate of 4%, or marginally higher at 4.1%, throughout the period extending from 2024 to 2026, aligning with the estimated 4% growth observed in 2023 [43].

During the latter half of 2021 through 2022, electricity and natural gas prices within the European Union attained unprecedented peaks. Notably, the mean household electricity tariffs surged from EUR 23.5 to EUR 28.4 (USD 25.1 to USD 30.3) per 100 kilowatt-hours (kWh), while average fossil gas rates escalated from EUR 7.8 to EUR 11.4 (USD 8.3 to USD 12.2) per 100 kWh. Various factors contributed to this surge in prices, including the global economic rebound following the COVID-19 pandemic, which precipitated heightened energy consumption. Additionally, geopolitical tensions between the Russian Federation and Ukraine exacerbated concerns over gas supplies. Moreover, the diminished output of renewable energy sources, attributable to adverse weather conditions, further exacerbated the situation. Within the European Union, subsequent to a contraction of 3.1% in the year 2022, there ensued an additional decline of 3.2% in electricity demand throughout 2023. Anticipations suggest a resurgence in demand during 2024, projected at 1.8%, predicated upon the presumption of a partial recuperation within the industrial sector, facilitated by the amelioration of energy costs and the burgeoning integration of electrification within the transportation and heating domains [44-50].

In 2023, the escalation in electricity demand within India amounted to a 7% increase in contrast to the previous year's figure of 8.6%. The enduring drivers behind this growth trajectory predominantly encompassed sustained rapid economic advancement alongside a resilient demand for space cooling services. Following two successive years marked by substantial advancements, India's electricity consumption exceeded the combined consumption levels of Japan and Korea by the conclusion of 2023 as depicted in the references [51-57].

In the year 2023, the dynamics of electricity demand demonstrated disparate trajectories, characterized by pronounced contractions within advanced economies juxtaposed with robust expansion in emerging market nations, notably exemplified by China and India. This surge in demand for electricity in emerging markets was primarily fueled by heightened economic activity. China, in particular, exhibited a noteworthy escalation in electricity demand, registering a growth rate of 6.4% during the aforementioned fiscal period, a notable contrast to the 3.7% year-on-year increase documented in 2022 consistent with the sources provided in references [58-64]. Notwithstanding this decelerated rate of expansion, China's projected augmentation in electricity demand, estimated at approximately 1,400 terawatt-hours (TWh) until 2026, persists as an entity encompassing over 50% of the extant aggregate annual electricity consumption within the European Union. Moreover, by the conclusion of 2022, the per capita electricity consumption in China had already surpassed that of the European Union.

In the fiscal year 2023, Japan experienced a decline of 3.7% in electricity demand, a notable deviation from the 1% increment observed in 2022. Despite elevated temperatures during the summer months, which typically stimulate demand for cooling services, the confluence of factors including a deceleration in the manufacturing sector and persistent efforts toward energy conservation exerted substantial downward pressure on electricity consumption levels [65-70]. However, the per capita electricity consumption across the African continent in 2023 is approximated to be 530 kilowatt-hours (kWh), with sub-Saharan Africa, excluding South Africa, exhibiting a mean consumption level of approximately 190 kWh [71-73].

In 2022, the expansion of primary energy demand exhibited a decelerated pace, registering a mere 1.1% increment in contrast to the 5.5% upsurge observed in 2021. Renewables, excluding hydropower, constituted 7.5% of the total primary energy supply, marking an increase of nearly 1% from the preceding year, while fossil fuels maintained a predominant share of 82%. Heightened concerns regarding potential disruptions in supply chains, coupled with notable fluctuations in fossil fuel prices, prompted a growing number of energy consumers on a global scale to embrace on-site renewable energy installations and transition towards electrified technologies across various end-use sectors [74-77]. Figure 3 displays the total energy consumption by source for the years 2011, 2019, and 2021.

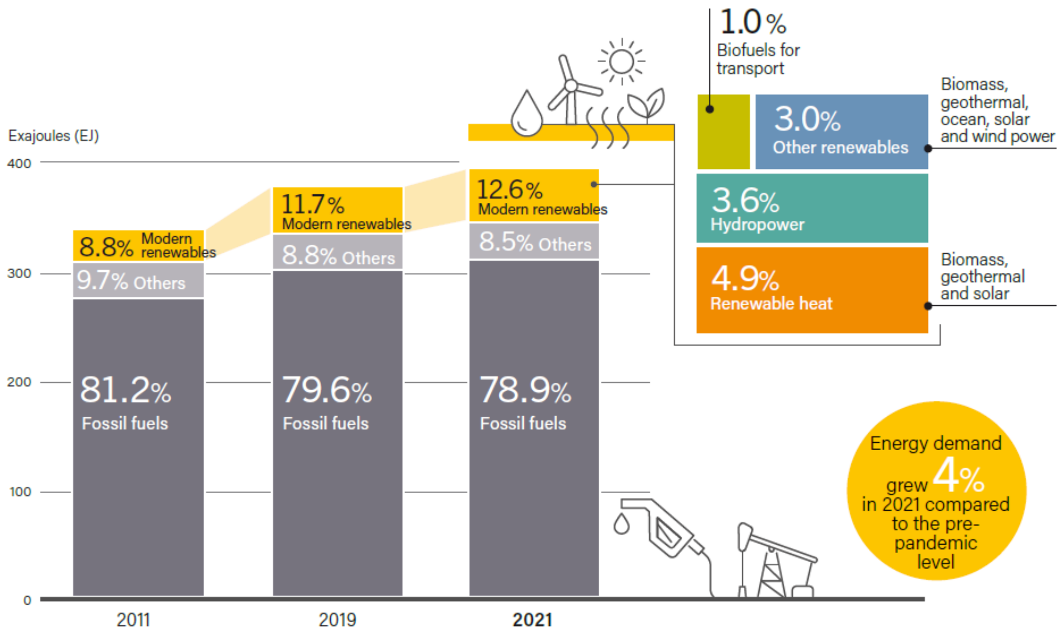

Figure 3. The total energy consumption by source for the years 2011, 2019, and 2021.

The recent report from the International Energy Agency (IEA) has revealed that grid-related technical or equipment failures alone incur economic damages of at least USD 100 billion annually on a global scale [78]. This underscores the imperative to enhance the discernment of failure origins and the components implicated therein. The genesis and constituents contributing to power outages can vary across nations, contingent upon the idiosyncratic conditions and configurations of their power grids [79-86]. Instances of power outages may arise from imbalances between generation and demand, such as fuel scarcities, power plant disruptions, or inadequate system adequacy, or may stem from grid-related challenges [87-94]. Grid-related causes of power interruptions can be classified into three primary categories: natural occurrences, human fallibility, and technical or equipment-related malfunctions. Human-associated factors including vehicular accidents involving utility poles and transformers, substandard craftsmanship, errors in new connections, acts of vandalism, and cyberattacks can precipitate disruptions in power provision [95-100]. In numerous regions, these factors constitute substantial contributors to power outages, warranting heightened scrutiny and remedial action.

In summary, the year 2023 witnessed a substantial surge in the annual augmentation of renewable capacity on a global scale, experiencing an approximate increase of 50%, culminating in a level of approximately 510 gigawatts (GW). This escalation represents the most rapid growth rate observed in the past two decades. Clearly, this milestone signifies the 22nd consecutive year in which additions to renewable capacity have reached unprecedented heights. Remarkable advancements were particularly evident in Europe, the United States, and Brazil, where record-setting escalations in renewable capacity were recorded [101-105]. Of significant note is China's remarkable acceleration in this domain, underscored by the deployment of solar photovoltaic (PV) installations equivalent to the entire global capacity added in the previous year of 2022. Moreover, China's wind power additions witnessed a notable expansion of 66% compared to the preceding year. At a global level, solar PV installations alone accounted for three-quarters of the total renewable capacity added worldwide.

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