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The Role of Renewable Energy in Driving Global Energy Transformations

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Abstract
The research thoroughly examined the worldwide movement towards renewable energy and found notable differences in adoption rates and technical improvements across countries. It also highlighted the possibility of a dramatic change in energy paradigms. Using information from the renewable energy map scenario, research suggests that 2050 renewable energy sources may account for as much as two-thirds of the world's primary energy supply, a significant increase above the reference scenario's modest prediction of 24%. Germany and Denmark, in particular, members of the European Union, stand out as leaders in this shift because of their excellent renewable mix and integration of wind energy. Fast progress is being made in Asia, where nations like China and India show yearly growth rates in the solar and wind industries exceeding 30%. The Americas—well represented by the US, Canada, and Brazil—showcase a variety of renewable integration, with each country's contributions differing. Meanwhile, Middle Eastern nations are gradually broadening their energy portfolios, and although Africa shows promise, the shift is hindered by infrastructure issues. The report highlights the clear worldwide trend towards renewable energy sources. Still, it also draws attention to the persistent inequalities shaped by a wide range of geopolitical, technical, and economic factors. The study findings clarify the present situation and future direction of renewable energy adoption. Still, they also emphasize how crucial it is to implement specific regulations, make targeted investments, and form partnerships to hasten this worldwide change.

Keywords: Renewable energy, Energy transition, Geopolitical, Technical

1.Introduction

The world is at a crossroads in the energy sector as we enter the third decade of this century (Bilgili et al., 2022). There has been a heightened worldwide discussion over the future of our energy supplies due to the increasing seriousness of climate change problems and the concurrent need for energy security and economic stability. At the heart of this conversation is the move towards renewable energy, which is becoming seen as more than simply a replacement for conventional power sources; it is also a critical component in radically altering our cultural values, economic standing, and connection to the environment (Pata & Samour, 2022). Solar, wind, hydro, geothermal, and biomass power, among others, play an essential part in guiding the course of this worldwide energy shift. More than merely technological alternatives, these sources signify a sea change in energy production and use, reflecting a more considerable dedication to resilience, sustainability, and a better balance with nature. To a large extent, the economic and technical advancements of the contemporary world can be traced back to the fossil fuels—coal, oil, and natural gas—that have long been essential to the creation and maintenance of the globe's energy infrastructure. In 2019, these fossil fuels provided an astounding 81% of the world's primary energy supply, according to a study by the International Energy Agency (IEA) (Oyewo et al., 2024). A substantial environmental cost has been associated with the excessive use of these non-renewable resources, even though they have been critical in driving economic expansion, enabling technical improvements, and sustaining urban development. An essential factor in the acceleration of climate change is the release of carbon dioxide into the atmosphere, caused mainly by fossil fuel combustion. Furthermore, there has been extensive pollution and significant loss of biodiversity due to these fuels' extraction and usage, which poses an existential danger to the planet's ecosystems.

1.1.The environmental effects of energy from fossil fuels

There has been a domino effect of adverse environmental impact caused by climate change, primarily due to the long-term and heavy usage of fossil fuels. Large quantities of greenhouse gases, especially carbon dioxide, are released into the atmosphere when fossil fuels are burned. These gases trap heat and cause the Earth's temperature to increase. Several extreme weather phenomena, including hurricanes, droughts, heat waves, and heavy rains, have been brought about by this rise in temperature. The melting of glaciers and polar ice caps, a result of global warming, has also contributed to the dramatic increase in sea levels. More frequent and severe floods and erosion are consequences of this rise, threatening coastal ecosystems and the people living there. The disruption of natural ecosystems and animals has been exacerbated by the shift in temperature patterns, affecting biodiversity and the delicate balance of different habitats. In its 2018 Special Report, the Intergovernmental Panel on Climate Change (IPCC) emphasized the critical need to keep global warming below 1.5°Cover pre-industrial levels to prevent destructive environmental impacts (Güney, 2022). Nations, organizations, and people have been encouraged to choose renewable energy as the route ahead because of the urgency of this message. The dominance of renewable energy sources is evident. Renewable Energy Policy Network for the 21st Century (REN21) reported in 2022 that renewable energy capacity worldwide has dramatically increased over the previous decade. Hydroelectric dams, wind farms, and solar photovoltaic (PV) projects have begun to dot landscapes around the globe, from the fjords of Scandinavia to the African deserts. Renewable energy sources, such as solar photovoltaics (PV) and wind power, have become economically competitive with conventional fossil fuels in several areas due to their fast cost drop.

Moving away from fossil fuels and towards renewable energy sources will have far-reaching social and economic effects comparable to those of an industrial revolution. Because energy availability is such a pivotal factor in determining socioeconomic growth and quality of life, it fundamentally connects with these concepts. The seventh Sustainable Development Goal (SDG7) of the United Nations seeks to "ensure access to affordable, reliable, sustainable, and modern energy for all" by 2030 demonstrating the worldwide recognition of its importance. The objective recognizes that energy is fundamental to the progress and welfare of society rather than just a commodity. An essential component in accomplishing this objective is using renewable energy, mainly via decentralized and off-grid alternatives. Renewable energy presents a once-in-a-lifetime chance for many underserved areas and towns that have long been unable to participate in the advantages of nationally distributed power systems. By passing the conventional phases of development, which are often marked by the slow and centralized construction of energy infrastructure, these communities can immediately access more sophisticated, long-term, and self-sufficient energy options. This leapfrog is about more than simply adopting new technology; it's about a significant social and economic revolution that will open doors to improved healthcare, education, and employment prospects made possible by consistent and affordable electricity. This transition to renewable energy sources has far-reaching and equally significant geopolitical consequences. The race for oil and gas resources shaped international relations, wars, and economic dynamics throughout the twentieth century, and its pursuit profoundly impacted geopolitics. Significant shifts in global diplomacy may exist due to the shift towards renewable energy sources and the consequent reduction in demand for imported fossil fuels. During this change, the balance of power may move away from nations with abundant fossil fuel reserves and towards those with the most advanced renewable energy infrastructure. A new geopolitical hotspot is emerging: the competition for renewable energy solution technical superiority. This trend will impact economic plans, security policies, and international relations. Several countries are pouring money into renewable energy technology to gain a competitive edge, lessen their reliance on foreign energy, and establish themselves as pioneers in the new green economy. As renewable energy technology advancements interact with national security and economic growth, new alliances and rivalries are expected to emerge throughout this transition. A break with previous patterns of geopolitical dominance is marked by the fact that in this new age, mastery of energy technology is replacing control over energy resources.

1.2. Challenges in predicting energy transition timelines

Because of the complicated interaction of many components, it is inherently challenging to accurately forecast the precise duration and magnitude of these electrical shifts. The change from biomass to coal or charcoal to oil as the main source of electricity is an example of a past occurrence that is not purely attributable to technical progress. These shifts may have been shaped by a myriad of factors such as evolving market dynamics and availability of supplies, shifting opinions and policy selections, the impact of global occurrences like wars or environmental catastrophes on objectives and materials. Energy shifts are complex phenomena affected by a wide range of global and local elements; as a result, their course is neither uniform nor predictable, putting accurate predictions a difficult task. Solar PV (photovoltaic) panels and wind power have seen their prices fall due to manufacturing innovations and economies of scale. Another factor is the growing global consciousness of warming temperatures and its devastating consequences. While green electricity' potential as technologies has been clear for a long time, their broad acceptance has been impacted by other factors (Haig, 1979). The intrinsic inertia of present-day electrical supplies adds another layer of complication; the framework is already in place, but it was built for certain energy supplies and will be there for a long time, so implementing rapid shifts will be expensive and difficult administratively (Estrada-Ruiz et al., 2010). Also, influential groups that support fossil fuels may use their financial and political power to block new energy technology from entering the market (Rubalcava-Knoth & Cevallos-Ferriz, 2024). Additionally, the global nature of power economics makes them quite unpredictable. Changes in government or incidents happening in one region may have far-reaching effects on electricity environments throughout the globe, impacting logistics networks, pricing, and adoption rates (Grabowski et al., 2019). Predicting precisely the length and breadth of energy transitions becomes an enormous challenge in light of this complex web of variables that influence them, many of which are intrinsically unreliable or subject to fast change. This calls for complicated examination and continuous adjustment to a worldwide electrical power framework that is constantly changing.

2.Research gap and study objective

In many sociopolitical and social contexts, there is a lack of thorough knowledge and quantification of the complex implications of green power deployment. Less attention has been given to the ways that green energy sources connect with and alter current energy structures, even if there exists a lot of information on the financial and technical elements of such supplies. This is especially true in emerging economies that have their own set of problems. Further research on the worldwide variations in the legal structures and markets that promote the widespread use of clean energy sources is also necessary. In addition, studies often fail to account for the societal and cultural effects of shifting to green power sources, including concerns about the general public's shifts in job trends, and community upheaval. This void calls concentrate on the need for a more comprehensive strategy that investigates the factors affecting the acceptance and efficacy of alternative in many global contexts, including but not limited to the technical and financial elements of that source of energy.

"The Renewable Energy Role in the Global Energy Transformation" aims to thoroughly examine and assess how green energy sources may propel the world's transition beyond the use of fossil fuels to cleaner, more environmentally conscious power grids. We want to learn more about the factors that help or hurt environmentally friendly energy development by analyzing recent technical developments, business viability, and legislative environments. The goal is to have a better understanding of renewable energy production and implementation developments, difficulties, and possibilities in various areas and economic growth, which includes both developed and developing countries. Meeting global climate objectives, improving reliability of energy, and fostering economic growth are all goals of the study. Renewable energy resources are also expected to provide light on these issues. Our main objective is to provide an accurate and evidence-based analysis of sustainable electricals' position in the world's energy system, with the aim of highlighting programs and efforts that might hasten this vital shift.

3.Methodology overview

The methodology's based on information technique relies on building a Renewable Energy Map (REM) using extensive information. This method is fundamental for grasping the exciting potential of renewable energy and developing plans for exploiting it. Here is a thorough explanation of the approach was in terms of collecting information, this study relies heavily on the well-known and comprehensive databases maintained by the International Renewable Energy Agency (IRENA). Also included are data sets from the Joint Research Centre (JRC) and EUROSTAT AS WELL. This synthesis guarantees that the study is focused on the European context while still having a worldwide reach. When it comes to utilization trends, the current energy infrastructure, and policy frameworks inside the EU, the statistics from EUROSTAT, WHICH RELEASED as well as the Joint Research Committee (JRC) supply further levels of knowledge.

3.1. Creating a Renewable Energy Map (REM)

This study entails creating a detailed REM using information provided by IRENA, is EUROSTAT, WHICH WAS as well as JRC. An essential part of the study, this map shows where initiatives involving renewable energies may be most fruitful. The REM is a great tool for finding affordable alternative power options since it is based on unique datasets that include data related to technologies and project prices. The next step is to examine and comprehend the data that has been obtained. This requires looking at clean energy initiatives across all regions of the world and seeing how they stack up in terms of engineering capability, theoretical expansion, and practicality. Finding the most practical and economical places to build renewable sources of energy is the primary goal of the study.

Lessons for Politics and Manufacturing:

The study report provides suggestions for participants in both the public and private sectors considering the findings from the data analysis and the REM. In order to make the most of resources for renewable energy, these suggestions should be considered while making expenditures, growth, and governance choices.

• Assessing the Capacity of Clean Energy to Drive the International Electricity Revolution: The last part of the technique involves assessing the potential of solar and wind power to significantly contribute to the energy change that is happening on a global scale. Evaluating its effects on achieving environmental goals, boosting revenue generation, and decreasing reliance on oil and gas is part of this process. Policymakers and industry stakeholders may use these databases to determine the areas that have the best chance of being developed for sustainable energy sources at the lowest possible cost (Barthès et al., 2024). These geographical representations greatly aid in the strategic deployment of renewable energy solutions by identifying locations where advantageous development prices and technical breakthroughs combine (J. Zhang et al., 2022). Further, the specificity of the IRENA in order EUROSTAT, and JRC databases guarantees that various alternative power sources—solar, hydroelectricity, and wind power or bioenergy—are assessed according to their individual strengths, guaranteeing that their capacities are fully used. A more sustainable and energy-secure future is within reach, thanks to REM, which provide governments as well as entities with the information they need to maximize the prospective of clean energy sources and reduce associated costs. We are rapidly approaching the crucial periods of twenty-first century, 2040, an increase and 2050, and the probable size of these deployments are growing more apparent. The technology's promise is centered on the possibilities and capabilities of integrating advanced technologies into the energy environment. A thorough knowledge of the pathways and feasibility of renewable technology adoption across varied worldwide areas has been provided by the joint research center (JRC), the International Energy Agency's (IRENA), and THE EUROPEAN UNION'S who have compiled market data from more than 100 nations (Nziguheba et al., 2000). In particular, the organization has spearheaded the adoption of the REM approach, a technique that integrates international in nature, technological, and monetary information to guide energy strategy over the next 75 years. The Group of Twenty (G20) nations and other large socioeconomic conglomerate have found this combined strategy particularly relevant because of the increased need for strategic technology deployments caused by the interplay amongst economic development, energy consumption, and ecological consciousness. With increasing populations and plenty of renewable energy sources like solar, wind, and hydroelectricity Africa is a prime example of how the use of technology may help with both energy access and economic growth. The European Union looks to the JRC for advice in several areas, especially via the European Commission. The Joint Investigation Centre (JRC) provides scientific research, data, and policy assistance as an essential component of the European Commission. In other words, the JRC's scientific and technological understanding is vital to EU strategic endeavors like the Green Deal, which includes helping to shape policies, make educated technologies options, ranging and guide expenditures toward carbon-neutral development. As a result, the European Union's strategy for achieving its long-term financial and conservation goals centers on the JRC's work, not the dependence on IRENA information (Hueck et al., 2022). The Americas are well-positioned to take use of both conventional and renewable energy sources, thanks to their abundant potential for water power and growing solar capacity; IRENA recommendations are helping smooth the way by pinpointing regions featuring the best chance of successful implementation (Zahid et al., 2023). Lastly, understanding technology deployment potentials is highly valuable for Asian nations, which have a diverse range of energy surroundings. This diversity includes both smaller, globally particular nations like the Maldives and larger, more industrialized economies like China as well as India. Overall, in light of the fact that our planet is facing the twin crises of worldwide warming and energy independence, the information about the possibilities for deploying technological devices, which has been made available through organizations like IRENA and is customized to different neighborhood contexts, offers a road map for a future where our energy is both environmentally conscious and adaptive.

Many frameworks and approaches have been developed to help evaluate environmentally friendly and alternative energy strategies in response to the need for a more environmentally friendly electricity environment. Integrating Evaluation Modeling (IAM) are notable on a global basis because they provide detailed predictions of possible possibilities and show how different paths might meet the goals of several multilateral accords, most notably the Paris Agreement. A common feature among such IAMs is the integration of energy, economic, and environmental aspects; for example, they may provide simulations that aim to reduce the emissions of greenhouse gases while

simultaneously increasing revenue. Continuing with the theme regarding international tools, the IEA's World Energy Model (WEM) predicts electricity trends through 2040 by analyzing present policies and technology developments (Li et al., 2022).
Different continents and economic behemoths have their own individual economic environments, which need geographically unique approaches. In Europe, the TRIGGERS paradigm is used to define bloc plans and guidelines.
Depending on their own economic characteristics, topographical details, and advancement goals, nations use specific approaches to map out their electrical power conversion plans. As an example, China has increased its renewable power generation to more than 30% in the past few decades, a significant accomplishment, and it uses the China Energy System Model to guide its lofty set of objectives as it leads the revolution of clean energy [56]. This is made possible by the country's abundant hydroelectric supplies. However, there are still many obstacles to overcome on the road to ecologically friendly paths, including but not limited to monetary and technical factors, international concerns, market structure, and social rejections, particularly with these advanced technologies. Although these mathematical equations provide priceless insight, realizing their predictions on location depends on a myriad of conditions. Nevertheless, it is clear that these factors examples and instruments are crucial in guiding us towards an environmentally friendly future, especially when we consider that some regions and countries are already using more than 34% of their own electricity (Y. Zhang et al., 2022) and that international organizations like IRENA have reported that capacity for renewable energy on the global level has surpassed 2,500 GW (Dong et al., 2020).

4.Energy technology trend for low-carbon energy

As a result of energy transitions spurred by growing environmental consciousness and technical innovation, low-carbon energy technologies are gaining ground. The bigger picture is moving toward a greener, more sustainable energy grid worldwide. Technology advancements in energy efficiency and renewable energy sources are pivotal to this change. There has been an incredible boom in renewable energy sources, with a contribution of nearly 2,800 GW as of the current configuration [60]. Among the pioneers, solar photovoltaics and wind power stand out. Particularly noteworthy is the 80% decline in the levelized cost of energy (LCOE) from solar PV throughout the last decade [61]. As a result, solar power is now competitive with or even cheaper than fossil fuels in many areas, and its affordability is on the rise. There has also been a considerable increase in the use of wind power. Wind energy capacity has surpassed 600 GW worldwide, thanks to the proliferation of offshore wind farms, especially in areas like Europe. Batteries and other energy storage systems have become popular because of their crucial role in stabilizing networks supplied by renewable sources, which are becoming increasingly intermittent.
The REM study provides projections in this area. Their analysis indicated that by 2050, the percentage of renewable energy in global power production must reach 86% if the world is to meet the goals outlined in the Paris Agreement. Huge expenditures, new technical developments, and legislative frameworks focused on a sustainable energy future would be required. It should be noted that this energy revolution isn't limited to only electricity production. Electric vehicles (EVs) have increased dramatically in the transportation sector. Electric cars are poised to enter the mainstream due to developments in battery technology, better infrastructure, and falling prices. The worldwide tally of electric cars on the road has surpassed 7 million, highlighting a paradigm change in the transportation industry. This exemplifies the larger plan to reduce the carbon impact of transportation and also signals a shift towards electric vehicles. There is also a lot of new development happening in energy efficiency technology. Everything is geared at getting the most out of every watt of power, from intelligent grids that streamline power delivery to energy-efficient home appliances that cut down on waste. There is no denying the forward momentum towards a world without carbon, yet there are still obstacles. There is still an urgent need for coordinated

international efforts in the following areas: capacity building, technological transfer, policy consistency, and infrastructure development. Additionally, nations must ensure that energy access remains equal as they shift.

A massive shift is occurring in the energy scene throughout the world. The path to a low-carbon future seems clear with renewables rising to prominence, efficiency increasing, and industries like transport taking a turn towards greener options. However, to achieve a sustainable energy future for everyone, we must persevere through the challenges that lie ahead by being innovative, working together, and having a common goal [68].

5.Pathways of energy transition

The amount of greenhouse gases associated with our present consumption of electricity is fundamental to this change. These days, energy use is the main culprit behind most CO2 emissions. For a long time, our homes, businesses, and public transit functioned by consuming fossil fuels, which had a heavy impact on our surroundings. Deterioration of air quality, affecting community wellness and perhaps shortening the average lifespan, is a result of local airborne pollutants, which frequently arises by energy use in urban areas. The wider impact on the world's climate is obvious, and not only in specific areas. Everyone agrees that we need to drastically cut down on greenhouse gas emissions (GHGs) since their atmospheric level has reached record highs. The model scenario for 2050 and other predictions highlight the critical nature of the situation. The first graph shows that energy associated greenhouse gases are projected to rise from 32 Gt in 2020 to 37 Gt by 2050, a 6% increase, provided present trends continue unabated (Le Blanc, 2015). This goes against the grain of what is needed to match with worldwide goals to minimize the harshest consequences of warming temperatures, which is a 2.5% yearly drop in production of CO2 from energy sources. Attempts to obtain cleaner air in urbanized zones are hindered by such a progress, which impacts millions of people and worsens global warming.

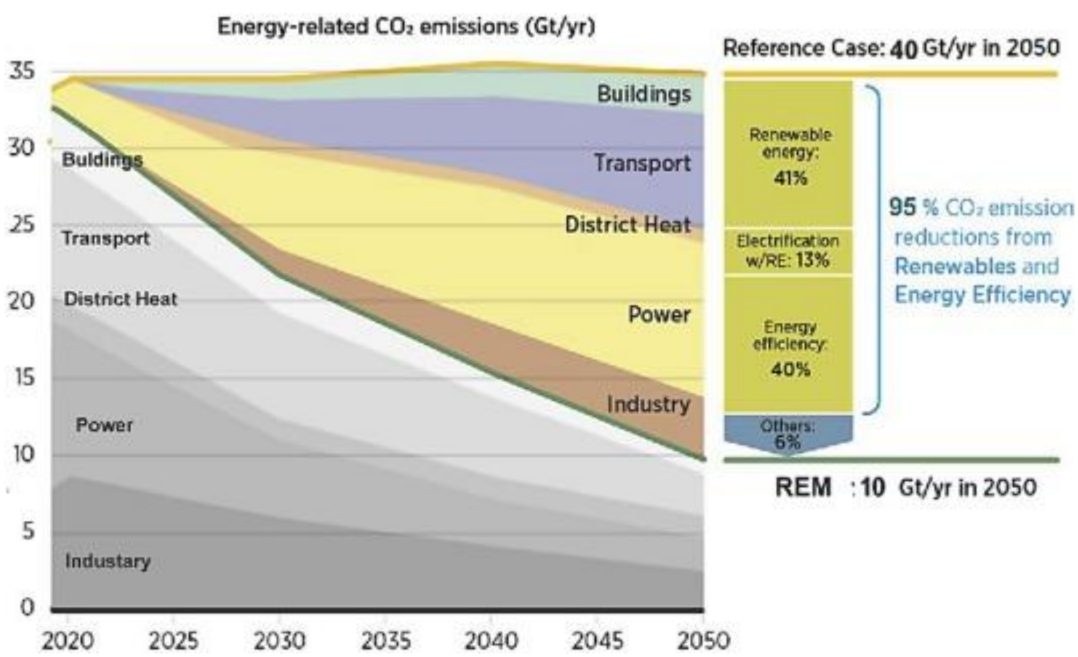

Figure 1. Possible technological reductions in CO2 greenhouse gases: comparing the underlying model with the Renaissance future.

The power generated transformation can't begin on an environmentally conscious trajectory without first concentrating on reducing emissions significantly. This necessitates a quick increase in the consumption of clean energy sources, a general improvement in efficiency of energy use, and new developments in environmentally friendly technology. For example, the price of wind

and solar power has dropped significantly, making them more accessible than ever before. These alternatives, when combined with improvements for energy storage, have the ability to substitute for the majority of electrical infrastructures that rely on fossil fuels.
An increased proportion of energy generated from renewable sources and greater emphasis on energy conservation are the bedrocks of a game-changing energy future in the REM paradigm. Compared to the standard scenario's projections, this partnership has the power to achieve remarkable 95% reductions in emissions by 2050, as seen clearly in the first diagram. The significant decrease highlights the importance of green power and energy effectiveness and provides quantitative evidence of their effects. When combined, efficiency enhancements and sources of clean electricity don't only supplement one another; they rule the field of possible options. Renewable sources of power charge forward to meet energy needs with little carbon traces of footprints while efficient use of energy lays the groundwork by reducing needless expenditure and waste. Figure 2 shows that by 2050, thanks to this harmony, renewable may directly contribute to a decrease in emission margin ranging from 41% to a huge 55% of total emissions. As a result of their higher capacity and falling prices, green energy sources like as solar and wind are gaining worldwide support, which is in line with the decreased cost aim. At the same time, smart technology integration, consumption pattern optimization, and achieving more while using less are at the center of efficiency initiatives in transport, the household, and other businesses. These two factors, when combined, provide the most effective plan for a greener, more equitable economy by reshaping how we use and create electricity.

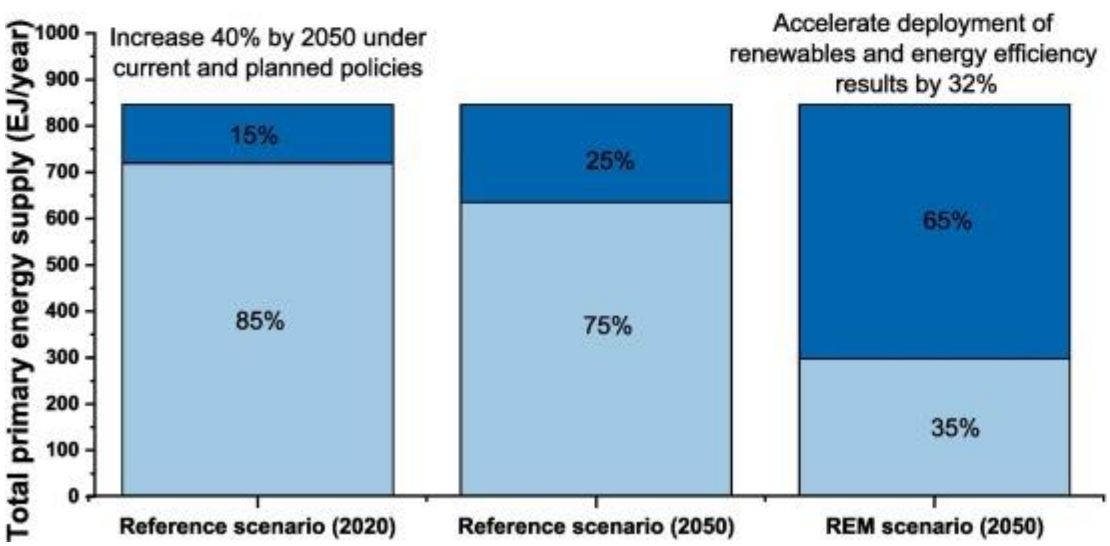

Figure 2. Examination of the world's principal sources of electricity from 2015–2050: comparison between the starting point forecast and the renewable energy future concept.
On the road to renewable energy, the electricity sector will play a major role, with an expected contribution of more than 15 Gt toward the 30 Gt decreased pollution predicted by 2050 as well. Such dramatic shifts highlight the game-changing possibilities that result from this industry's shift to renewable energies, a trend with far-reaching effects beyond electricity production. Although various industries are also playing a significant role in this revolutionary process, the electricity industry is the central actor. Improvements in energy-efficient designs and technology may be used by houses to meet specific heating, cooling, and power needs. There is a great deal of room for innovation in low-carbon technology, energy savings, and environmentally friendly energy integration in the industrial sector, thanks to its many processing and production operations. The transportation industry has the potential to significantly reduce its historically large impact on the environment as it rapidly electrifies and transitions to alternate sources. Other industries, including wastewater medication, garbage disposal, and food production, have great potential as well,

particularly with the extension and optimization of district air conditioning and similar technologies.

When it comes to green power implementation, the nations that make up the G20 stand head and shoulders above the others. Their combined contribution of 85% is quite remarkable. Looking closer at these figures, the country's 27% participation shows its dedication and ability as a renewable energy superpower. Following closely behind with a 16% contribution, the US demonstrates its technical prowess and shifts in policy. One fifth goes to India, a country with a huge population and a growing need energy that is shown great progress in integrating renewable sources like wind and sunshine. With its single ecological a schedule, the European Union (EU), a collection of countries with varied resource environments, provides 10%. Three percent of this total comes from the nation's hydro, wind, and solar opportunities. Brazil, Russia, and Australia are all G20 members that have significant biofuels resources, hydroelectric prospective, but wind and solar energy capacity, respectively, and thus can shape this sustainable destiny. The fact that environmentally friendly energy initiatives are concentrated throughout a few of the biggest economies highlights the weight of accountability and clout these nations carry. Their choices, expenditures, and regulations have a profound impact on the worldwide energy transition story, not to mention their own resource environment.

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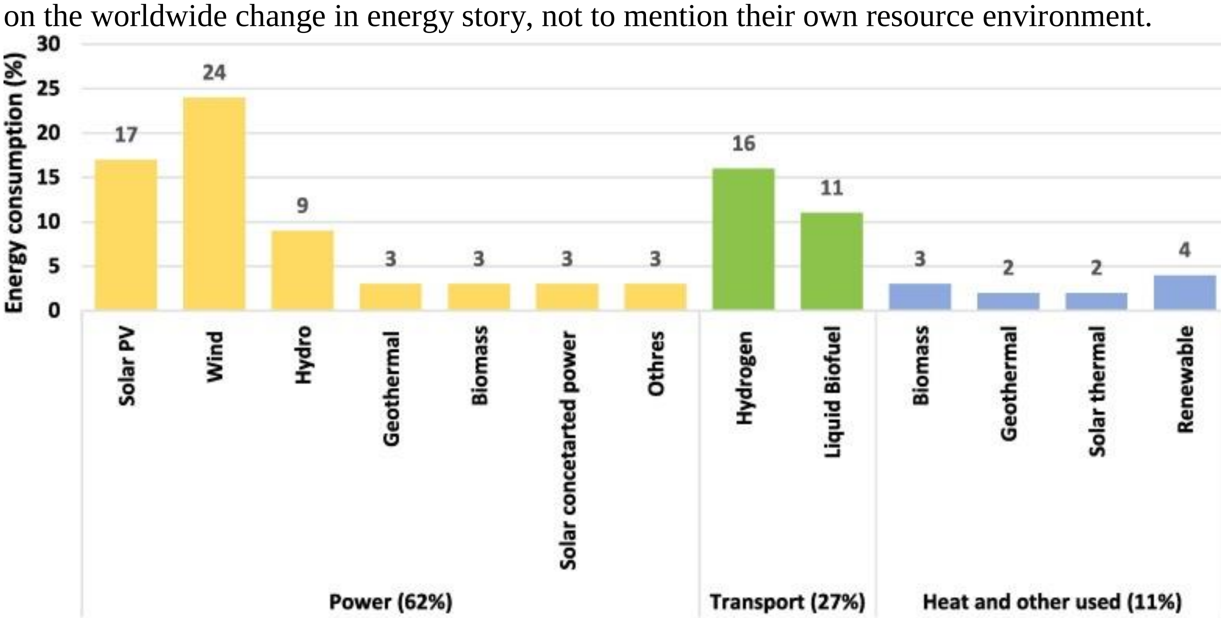

Figure 3. Examining the role of clean energy sources in the overall energy consumption has two a look forward to 2050 from the REM viewpoint.

A whopping 62% of all energy from renewable sources comes from the electricity sector, making it the clear leader. The use of wind power is the most prominent technology in this area, accounting for 24% of the total, while solar PV comes in second, accounting for 17%. Approximately nine percent will come from hydropower, with three percent each expected to come from geothermal, biomass, solar concentrated electricity, and other renewables. As a result, both present and future innovations play an increasingly important part in the electrical power sector's drive toward diversifying. On the other hand, 27% from the projected power mix comes from the transportation sector. With an expected 16% their contribution, hydrogen plays a significant role. Similarly, biofuels in the form of liquid account for 11%. Warmth along with additional uses account for the remaining 11% of the energy mix. Bioenergy and geothermal warmth both account for 3% of this group of energies. An estimated 2% will come from solar thermal and other green power, while 4% will come from other technologies. The diverse contributions from different industries highlight the need for a comprehensive strategy to achieve a world powered by green power by 2050, according to

Table 1 provides a thorough comparison of the international shift in energy forecasts for 2040 from four important parties: the International Energy Authority (IEA), the International Renewable Energy Agency. The metrics used to gauge these shifts are diverse, however they are all very important. A year's fundamental energy production of 750 EJ/yr is predicted by the IEA after a thorough examination of the data, which is somewhat lower compared with the enthusiastic prediction of 850 EJ/yr made by IRENA. BP and Shell float across these configurations. The reported quarterly final energy consumption figures are quite close to one another, falling between 600 EJ/yr (IRENA) and 620 EJ/yr (IEA).

Table 1. BP, Shell, IRENA, and IEA insights on global energy *transition scenarios for* 2050.

Parameter	*IEA Scen*	*IRENA Scen*	*BP Scena*	*Shell Scen*
Annual Primary Energy Output (*EJ*/*yr*)	700	860	920	630
Annual Final Energy Use (*EJ*/*yr*)	500	420	710	815
Percentage of Renewables in Energy Mix (	32	41	36	38
*Predicted CO*2 *Emissions from Fossil Fuels*	70	46	49	48
*Actual CO*2 *Emissions from Fossil Fuels fo*	36	43	39	37
Reductions Attributed to Renewable Energ	21	32	26	29
Reductions Attributed to Energy − saving Measures (%)	12	16	13	15
Reductions Attributed to Other Sources (%	6	9	7	8
Funding Towards Carbon Neutral Initiativ	13	16	15	12
Yearly Advancements in Energy Efficiency (/yr)	3.6	4	3.9	3.8
Adoption Rate of Electric Transport (%)	26	33	27	28
Annual Biomass Energy Requirement (EJ /yr)	51	56	53	54

The money that will go into being carbon neutral is another interesting thing to consider. While the IEA, Shell, and BP are all pushing for different amounts, IRENA seems to be the most invested at 15 trillion USD. Once again, IRENA leads the pack in terms of annual gains to energy efficiency, this time by 3%, while the other three groups have more cautious estimates, between 2.5% and 2.8%. The increasing popularity of electric vehicles is a clear indicator of the transportation industry's green movement. A little ahead of BP (28%), Shell (26%), and the IEA (25%), IRENA predicts that 30% of transportation will be electric by 2050. Finally, IRENA predicts the greatest annual demand for biomass energy at 55 EJ/yr, followed closely by the other three institutes' projections of 50-53 EJ/yr. While the specific beliefs may differ, the overarching message from all four organizations is clear: a sustainable energy future is not only possible, but on the horizon.

5.Economic implications and advantages of the energy shift

A two-pronged approach that emphasizes increasing efficiency in energy usage and incorporating sources of renewable power is required for the rapid shift to a more sustainable energy strategy. Various countries have implemented strong regulations and mechanisms to speed up the conversion to energy from natural sources. Investors have poured money into clean energy sources thanks to regulations that encourage it, including taxes credits brings feed-in prices, and subsidized grants. At the same time, it has been critical to improve technological advancements. For example, solar energy system prices have dropped significantly over the past 10 years due to increasing spending on research into solar energy technologies. Additionally, it is critical to invest in construction of infrastructure, particularly updating the grid and technological advances in energy storage, to guarantee the reliable and effective distribution of renewable energy. For energy effectiveness, a comprehensive strategy that incorporates stringent The consumption of energy could get significantly reduced as a consequence of building regulations, technological standards, and workplace conservation efforts (L. Li et al., 2018). Recognizing programs including the one led by the United Nations Sustainable Energy for All program is crucial to mobilizing members of the public and fostering an atmosphere that is power-conscious. To actually advance this transformation, legislators, corporate titans, plus the general public will ultimately need to work together.

6.Approaches to expedite the implementation of renewable energy and enhance energy efficiency

Table 2 provides a detailed analysis of the growth and potential of energy from renewable sources from 2015 to 2050. With the global wind energy market expected to reach 169.4 GW/yr in 2050, up from 58.3 GW/yr in 2020, it is evident that the sector has developed significantly. From 2022 to 2050, the percentage of renewable energy resources in the total amount of electricity used will rise to 0.363, according to this growth direction, which has an average improvement of a factor 3.3. Concentrated solar power increased its dominance in the renewable power mix by 108.9 GW/yr in 2020 to a forecasted 231 GW/yr by 2050, expanding its impact on 0.231 percentage points.

Table 2. Review of the literature on the REM Scenario for renewable energy development from 2020 to 2050 in depth.

Key renewable	Uni	Recent D	Required Fu	Speed of grov	Contribution to the rise of renewab
		2020	2021-2050		
Wind Energy	GW/yr	57.4	168.5	4.4	0.367
Photovoltaic Solar	GW/yr	109.8	241	3.3	0.232

Key renewable	Uni	Recent D	Required Fu	Speed of grov	Contribution to the rise of renewab
		2020	2021-2050		
Advanced Biomass (end-use applications)	-	-	--		0.208
Liquid Bio-energy and Biogas Solutions	billion liters/yr	6.7	25.5	6.6	0.133
Solar Heating Systems	million m^2	34	321.4	8.8	0.12
Hydropower	GW/yr	37.6	28.8	0.78	0.056
Green Hydrogen	-	-	-	-	0.055
Geothermal Heating Solutions	PJ/yr	38.7	180.4	8.8	0.045
Concentrated Solar Power (CSP)	GW/yr	2.3	23	23	0.045
Additional Sources (including marine & hybrid technologies)	GW/yr	0.12	40.9	307	0.045
Power Generation through Geothermal	GW/yr	0.65	8.8	14.3	0.043
Power Generation through Bioenergy	GW/yr	6.7	12.3	3.3	0.034
Conventional Biomass	-	-		-	-0.243

Key renewable	Uni	Recent D	Required Fu	Speed of grov	Contribution to the rise of renewab
		2020	2021-2050		
Total Renewable Energy Output	-	-	--	-	2.112
Measures for Enhancing Energy Efficiency	-	-	-	-	0.386
Cumulative Total	-	-	-	-	1.55

Geothermal heating solutions and power production using groundwater and biomass should be included. We expect these two areas to contribute 0.044 and 0.033 for each, and both will likely see considerable jumps forward. Nevertheless, a negative contribution of -0.242 is shown by Traditional Bioenergy. For a total of 1.111 from energy from renewable sources and an extra 0.385 from energy efficiency measures, the total prospective commitment is 1.54.

Some critical renewable energy sources are seeing rates of acceptance that are in line with expectations. The renewable energy industry is seeing remarkable progress, with solar PV and wind power taking the lead. The steady expansion of solar heating and groundwater techniques is another evidence of the trend towards cleaner, more environmentally conscious energy. It is evident that clean electricity is a major motivator whenever looking at energy from renewable sources from a larger viewpoint. About 0.8% of the standard annual growth in renewable energy sources is attributable to it. To put it in context, half of the overall increase in the intermittent industry is attributable to solar power, which is mostly driven by these critical breakthroughs.

The projected REM Futures calls for a dramatic shift in the power consuming environment by the year 2050. The usage of electricity in end-use industries is projected to skyrocket, surpassing an incredible 45,000 TWh. When compared to levels seen in the year 2020 this is an astounding tripling. The growing reliance on electrical power is shown by this expansion direction, which occurs when a greater number of companies, homes, and public transit electrify. This is indicative of an evolving worldwide economy that views electric as a key engine of development, rather than just an indication of increased consumption.

At the same time, the electrical power sector's tremendous drop in greenhouse gas emissions represents a particularly praiseworthy change. The Renaissance Scenario highlights the impressive progress being made in sustainable energy generation by predicting an 86% decrease in greenhouse gases from the electrical power sector. The increasing importance of energy from green sources is key to this change. By 2050, clean energy sources are expected to dominate the electrical power generating surroundings, producing 85% of the nation's power needs. Sustainable electricity production has recently increased eightfold, going from 2002 GW to a projected 16,000 GW, further amplifying this transition. To break it through, solar photovoltaics (PV) are anticipated to account for 8,233 GW, with wind power following closely at 7,448 Gbps. By increasing their annual capacity increases by a factor of two or three, accordingly, from 2020 to 2022, these settings demonstrate not just the promise but also the confidence in these breakthroughs.

The projected increase in renewable energy production capacity from 2020 to 2050 is shown in the following chart, which also shows the geographical spread of this rise. By using this visualization, we can see at a glance whether areas are spearheading or behind the shift to renewable energy. An anticipated increase of 5991.6 GW makes China stand out, highlighting the country's enormous power generation capability and its massive efforts to switch to alternative sources of energy. The United States is expected to add an extra 3007.2 GW, followed China, demonstrating its determination to lessen reliance on fossil fuels and put money into sustainable development. In keeping with its lofty green power goals, India too displays a striking layout with an additional 2154 GW.

Figure 4. Differences in regional capability for further renewable energy generation between 2020 and 2050.

Projections show that each of the 28 countries of the European Union will add 1384.8 GW, which is a result of all of their attempts to improve resilience. Denmark is expected to provide a huge 211.2 GW, thanks to its abundant sunshine and wind materials, whereas Brazilian is anticipated to contribute 279.6 GW, because to its abundant hydroelectric and other renewable sources. Meanwhile, areas like México and Argentine are becoming more important players in the field of sustainable energy worldwide, with projected contributions of 222 GW and 74.4 GW, accordingly. Donations from other nations, including Saudi Arabia, the Soviet Union, the Republic of Indonesia, and Japan, range from 256.8 GW to 356.4 GW. Renewable energy production is becoming more important in both African and Middle Eastern environments, as shown by Marrakech and Turkey, which occupies with appropriate capacities of 105.6 GW and 126 GW. A total of 1876.8 GW is projected for the "Rest of the Worldwide (non-G20)" category, which represents the worldwide drive into clean energy in countries that aren't specifically named. There will be a global increase of almost 16988.4 GW in renewable energy capacity by the year 2050. This statistic highlights the increasing movement towards energy from natural sources and away from fossil fuels on a worldwide scale.

Figure 5 shows the electricity consumption parameters for two distinct circumstances in 2050: the basic scenario and the REM situation. The thermal concentration factor is 2.34 percent in the Base Scenario, which is assumed to run on conventional or present-day energy usage. When we break down the energy into its various parts, we find that renewable power Producers as well as Alternative Thermal Suppliers both contributes 0.13 percentages. Given a 0.65% their contribution, the Efficiency in Heating/Fuel Electricity Use component stands out as the dominating one, highlighting the importance of maximizing electrical use in thermal operations. An additional 0.26 percent comes from electricity Expenditure effectiveness, which measures how well electricity is used. With more and more people switching to electric cars and networks, the impact of transportation electrification is noticeable at 0.312%. An essential component of the energy matrix, direct power production contributes 0.416%. The anticipated electrical consumption for 2050 rises to 3.77% when these various factors are included in the Renewable Energy Map Scenarios. When comparing the REM scenario to the foundation, this considerable rise shows that renewable adoption, energy efficiency, and technical developments are given more priority in the REM paradigm.

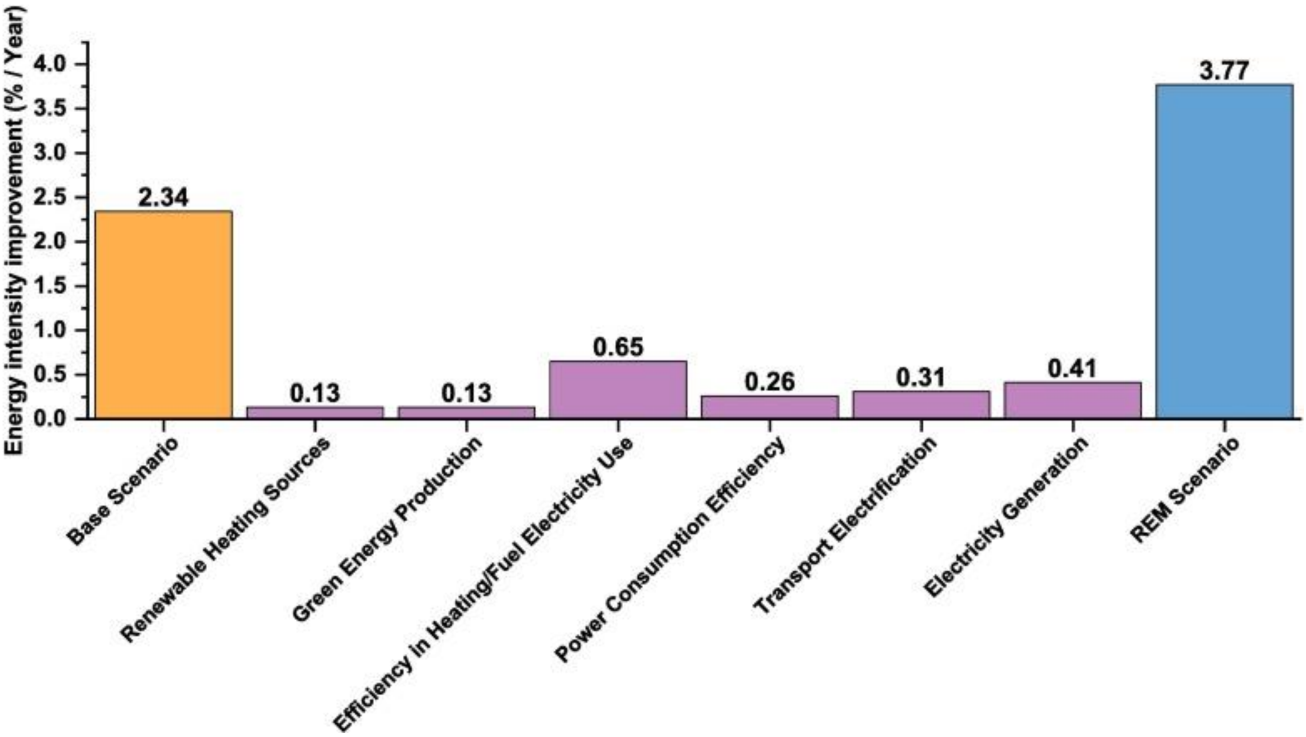

Figure 5. Factors affecting the amount of energy consumed in the base and REM scenarios for the year 2050.The most recent results from IRENA show that there is a good trend for reducing greenhouse gas emissions worldwide, especially in the transportation sector. A major responsibility for nations throughout the world in propelling the transformation is foreseen according to these predictions. Electrical may make up 35% of all energy used by the transportation industry by 2050, up from 1% in 2020—a tremendous increase for governments throughout the globe. Potentially leading the way in this transition are countries like China, the nation of Denmark, and Berlin who have developed sophisticated renewable energy technology.

7.Obstacles and difficulties

Infrastructure needs: updating and integrating the grid

To guarantee a smooth shift from traditional to energy from renewable resources, it is crucial to integrate and modernize the grid with cutting-edge technologies. The intricacies of renewable energy sources might be difficult for current electricity networks to handle, since they were mostly developed for the centralization of energy generated from fossil fuels generation. Because energy sources that are clean like wind and solar energy are both intermittent and dispersed, this becomes much more apparent. The country's dedication to a sustainable energy future is often shown by the successful restructuring of national grids. In order to facilitate the introduction of green energy sources, several countries have upgraded their energy supply systems, as shown in Figure 6 (Sinha & Shahbaz, 2018). Germany is a prime example of how rapid renewable energy adoption need strong grid upgrades, since it has made the most progress (85%) in this area. The captivating story of fast modernization and a determined dedication to environmentally conscious energy is on full display in China, which is developing at 75%.

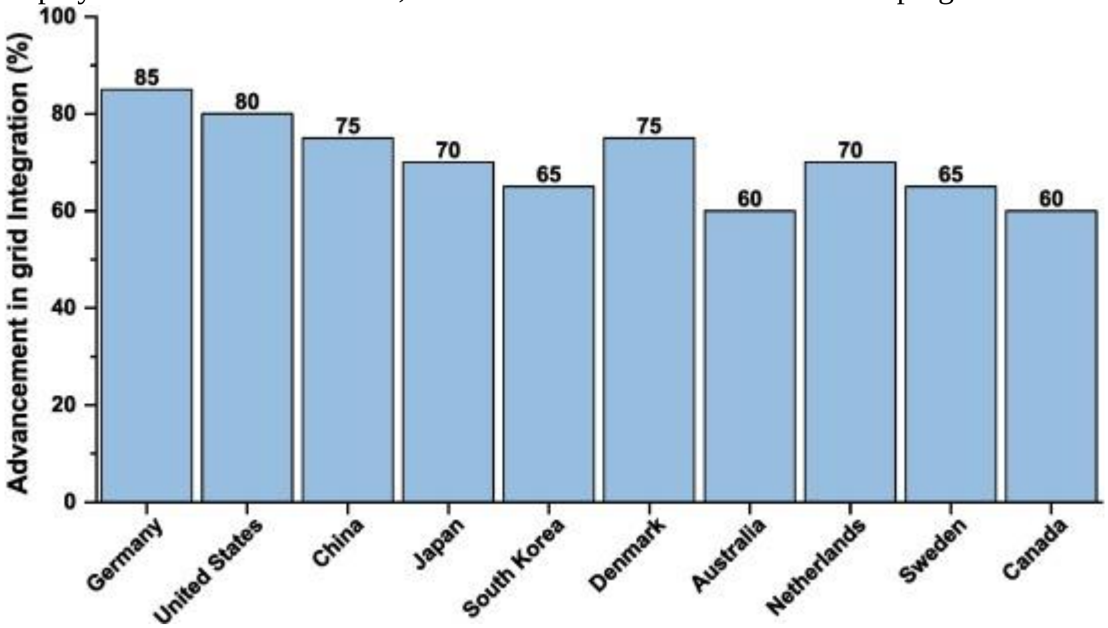

Figure 6. When it comes to modernizing electricity systems to facilitate the incorporation of renewable sources, the nations have made great strides toward 2021.

Their commitment to making sure their systems are ready for the renewable energy future is seen in the high proportion of developments in these nations. Change in energy is a complicated environment, and each nation has its own set of problems and possibilities. The range of solutions and approaches needed to overcome these obstacles is on display here.

8.Economic obstacles include competition from fossil fuels and initial investments.

Though the ecological and technological components of the transition towards renewable electricity get most of the media attention to detail, economic obstacles are just as significant and complex. There are several monetary hurdles that countries and businesses must overcome when trying to switch to alternative power sources. The majority of operating expenses for green power plants are borne upfront, which is in contrast to traditional fossil fuel facilities that bear them mostly in the form of fuel consumption. Nevertheless, getting started may be quite costly, which might be a major hurdle for developing nations. The cost of solar energy systems has been steadily declining, but a widespread photovoltaic farm—including all of the necessary inverters, transformers, and transmission lines—can still need a significant investment.

Projects utilizing renewable energy may not be approved due to cost-benefit evaluations, which is particularly problematic in countries that are currently facing energy shortages or have limited budgets. At the same time, the oil and gas industry casts a long shadow. The globe has been fueled for more than a hundred years by oil, coal, and natural gas. From coal-dependent areas in United States and Australasia to Middle Eastern oil enormous creatures, entire industries have been established based on such environmentally harmful commodities. Renewable sources of electricity are nonetheless in the process of trying to attain efficiencies of scale, in contrast to the petroleum industry, which has been supported by legislation, has been supported by academics for nearly a century, and has developed equipment. As the expense of infrastructure upgrades and energy storage solutions are considered, this developed business's sources of energy may often be offered at lower rates than alternatives. This is because of its broad customer base and well-known supplier networks. In addition, fossilized matter fuel lobby's effect is indisputable. Subsidized tax exemptions, and other advantageous policies are enjoyed by the petroleum and coal business because of the strong political links it has in many nations. Because of these advantages, the electrical power economy may become skewed, making it harder for renewables to compete fairly. Renewable fuel technology cost estimates from 2010–2022, as shown in Table 3.

Table 3. Budget for energy from sustainable sources from 2010 to 2022

Year	Solar PV ($/kWh)	Onshore wind ($/kWh)	Offshore wind ($/kWh)
2010	0.40 - 0.50	0.08 - 0.20	0.16 - 0.26
2011	0.35 - 0.45	0.07 - 0.08	0.22 - 0.32
2012	0.20 - 0.40	0.06 - 0.09	0.20 - 0.30
2013	0.28 - 0.38	0.06 - 0.08	0.08 - 0.28
2014	0.14 - 0.26	0.05 - 0.07	0.09 - 0.16
2015	0.13 - 0.21	0.05 - 0.07	0.08 - 0.15
2016	0.30 - 0.48	0.04 - 0.06	0.07 - 0.82
2017	0.09 - 0.17	0.04 - 0.06	0.06 - 0.20
2018	0.07 - 0.24	0.04 - 0.05	0.05 - 0.08
2019	0.06 - 0.18	0.03 - 0.05	0.05 - 0.09
2020	0.05 - 0.20	0.03 - 0.04	0.04 - 0.08
2021	0.04 - 0.09	0.03 - 0.04	0.04 - 0.07
2022	0.03 - 0.07	0.03 - 0.04	0.03 -$0.06

There are a lot of financial hurdles that sustainable energy implementation must overcome, such as large upfront costs and stiff competition from petroleum and diesel. A combination of creative funding strategies, policy measures, and international collaboration is required to tackle these issues. Although we will inevitably move towards healthier energy in the decades to come, how quickly and effectively we overcome these financial obstacles will determine how much of a shift it will be.

8.1. Social challenges: Acceptance, awareness, and local opposition

Societal issues related to this energy transition are affecting nations all over the world, from developed powers like Germany and Chinese to developing ones in Southeastern Africa and Asian nations. The importance of public knowledge and support for biofuels cannot be overstated, especially in countries with robust official backing for these sources of energy. Renewable energy sources provide long-term benefits to society, including a cleaner environment, more prosperity, and more autonomy from foreign power sources. However, there is still a barrier to consciousness. The general populace is woefully uninformed on the subject of climate change and the transition to alternative energy, even though there is widespread agreement on both issues on a global scale. Some people may be resistant to using green technology because they are misinformed or because they are part of the heritage energy lobby. These issues are made much more difficult by local resistance. Some local populations in the United Kingdom and the United States oppose wind power plants and rooftop solar systems because they are afraid of disturbances, possible disturbances to the scenery, or unfounded health worries (Bai et al., 2022). A strong and quickening movement toward energy-efficient technology is anticipated over the next few decades, according to Figure 7, which offers a thorough review of what is needed for the worldwide energy system. Forecasts indicate that technological penetration will reach 30% by 2025, contributing to a 4.5% rate of expansion in the green industry. The upward trend is only going to become stronger as the past ten years goes on. We project a 45% increase in utilization of technology and an annualized rate of 5.2% by 2030. This pattern of increasing rates of expansion and technology adoption will continue until 2050, when it will reach its pinnacle. There will have been a staggering 95% adoption of environmentally friendly technology in the relevant sectors by that point, and the growth rate is anticipated to reach an astounding 7.5%. A few of important stories are emphasized by these predictions. One thing they do is bring attention to how green electricity is becoming an increasingly important part of our overall energy mix. Furthermore, sources will not only complement, but probably predominate, the world's electricity supply by the the turn of the century thanks to the steadily rising percentage in technological the adoption process, which highlight the potential for technical improvements and advancements in this area.

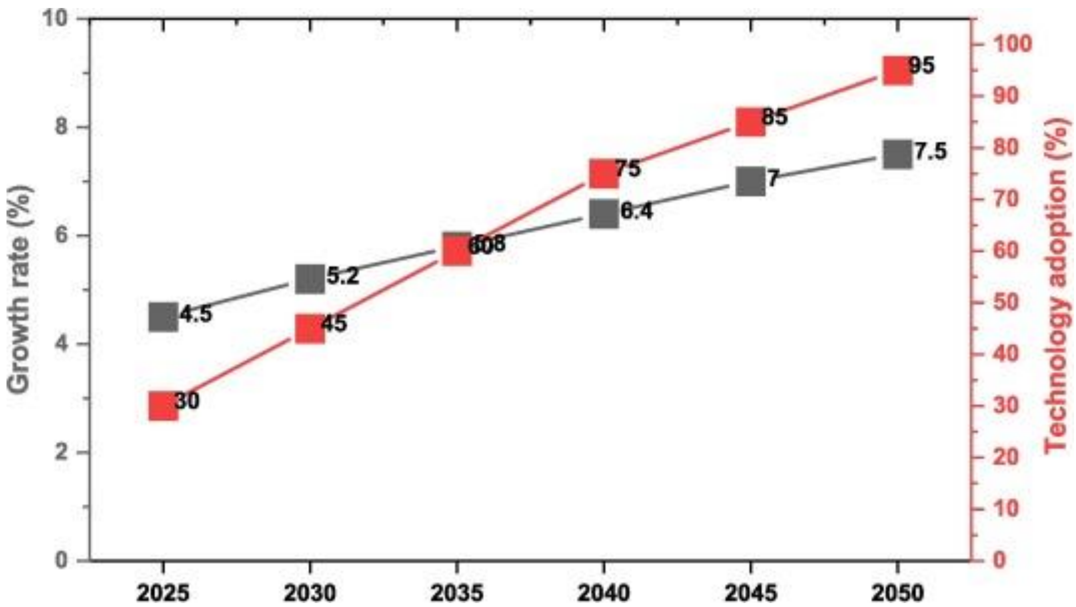

Figure 7. The ecological shift and the widespread use of new technologies: a synopsis.

8.2. **Technology and development in research advances**

The REM paradigm predicts that by 2050, nearly three quarters of the worldwide main electrical power may come from renewable sources. This rosy view is in sharp contrast to the benchmark the situation, which projects that by the exact same year, the percentage of energy generated from renewable sources would only be 24%. Both Denmark and Germany, for example, have led the way in this change. For example, Finland presently gets more than 50% of its power from environmentally friendly sources, while the German steady expenditures have made roughly 40% of its electricity come from green sources. The number of inventions filed typically provides an indicator of how far renewable energy technology has advanced. IRENA realized this and created a unique database designed to record the information. The information contained herein identifies the top innovators in the world, including the US, the nation of Japan, and China. Over the last 10 years, China has had a thirty percent rise in its energy from renewable sources patents in general, compared to increases of fifteen percent and twenty percent in the US and Japan for repairs, accordingly. The breadth of environmentally friendly development is reflected in these patents that have expired which cover everything from wind power plant configurations to novel solar cell technology. However, there are significant obstacles facing certain sectors. The integration of renewables presents challenges for industries that require electricity, which are essential in numerous economies. India, for example, finds it difficult to reduce carbon emissions because of the country's enormous metals manufacturing industry. Similar to this, the aviation business in places like the United Arab Emirates, the road commerce industry in the United States, and the marine transport operations in nations like Singaporean are looking for workable renewable energy sources. These nations have such high energy needs that they could not be completely decarbonized even with a doubling of the present intermittent supply. Recognizing these difficulties, several nations are looking into other options. With Australians seeking to raise the manufacturing of hydrogen by 300% by 2030, both countries are investigating renewable hydrogen as a potential option. Additionally, electrification is planned; by 2040, the EU wants 40% of its industrial operations to be electrified. Technical enhancements, such as EV network charging and effective transmission of electricity systems, must be developed for bringing about these solutions. A lot of attention has shifted to developing infrastructure recently. The country of Holland is leading the way in developing automated charging infrastructures for EVs, with an ambitious goal of tripling the current total of outlets by 2030. During the next ten years, Spain plans to enhance its electricity supply by twenty percent via investments in internationally electric transmission lines. In order to make the most effective use of their abundant wind and solar power, African countries are investigating the possibility of laying high-voltage transmission cables below. Furthermore, Sweden as well as Finland are bolstering their regional thermal networks, and America has detailed plans for managing the production of biomass. Figure 8 beautifully depicts all of these activities, highlighting the worldwide movement towards a more environmentally friendly future.

Figure 8. Progress in the fossil fuel sector.

8.3. The function of nations with growing and developing nations

As the world moves toward a more sustainable electricity future, the importance to developing and rising countries is crucial. Their electrical usage habits and choices have a major influence on world greenhouse gases and the quality of the environment as a result of their fast industrialization, urbanization, and population increase. Numerous industrialized countries attribute their present-day prosperity to the petroleum and natural gas that enabled their early modernization.

As an example, China is not only the biggest coal user in the entire world, but it also produces as well as deploys more solar panels than any other country. Smaller emerging nations seeking environmentally friendly energy options may learn from these countries' decisions. The sustainable energy capacity of emerging countries is enormous and often unrealized, particularly in African and Southeast Asian regions. In addition to helping to reduce carbon emissions worldwide, tapping into such potential will alleviate energy poverty, which is a serious problem in many areas. Distant and underdeveloped locations are often unable to be reached by conventional electricity supplies. Even the most remote areas may have access to electricity thanks to renewable energies, especially microgrids that use sunlight or wind power. Not only does this decentralized method make wider lighting possible, but it also boosts local economies via job creation and decreased reliance on energy imports. There is a chance for these nations to make environmentalism central to their objectives for development as they plan their renewable energy futures. Building environmentally friendly, efficient, and long-lasting networks from the ground up is preferable than the complicated and expensive procedure of modifying assets later on. Because of their proactive stance, these governments are better able to attract international finance and collaborations to support renewable energy projects in developing areas, which are considered key arenas in the combat against environmental degradation (Sreenivasan et al., 2023).

Nevertheless, there are several obstacles along the way. Growth of alternatives in these areas might be hindered by budget restrictions, the absence of technical know-how, and sometimes, local hostility. This highlights the critical need of cooperation across industrialized and economically developing nations. A broad, equitable, and worldwide transition to clean energy may be achieved via the sharing of research, strengthening capacities physical activity and monetary assistance, and technical exchanges.

9.Conclusions

Significant regional differences in the adoption of renewable energy sources are brought to light by the study's thorough examination of the present state of the world's energy landscape. Countries in Europe, including Germany and Denmark, are leading in this shift because of their ambitious policies and programmed. Germany's "Energiewende" programmed, which achieved a 38% renewable mix, and Denmark's outstanding integration of wind power at 45% demonstrate the region's dedication to green power. China and India, on the other hand, are leading the way in renewable energy adoption thanks to their booming solar and wind industries. The fact that both China and India want to achieve 40% renewable capacity by 2030 and 30% yearly growth in these sectors shows that they are serious about coordinating economic development with environmental objectives.

While there is different development throughout the Americas, renewable energy penetration has been particularly impressive in the United States and Canada, thanks to their abundant wind, solar, and hydropower resources. Renewable energy accounts for 29% of Canada's power, compared to 27% in the United States. A third of Brazil's energy comes from renewable sources, with bioenergy playing a significant role in that percentage. Despite Africa's great solar potential, the region needs help owing to infrastructure and financial constraints. The United Arab Emirates (UAE) has reached a 10% renewable capacity, marking the beginning of diversification in the oil-dependent Middle East. These geographical differences highlight the importance of a coordinated strategy for the worldwide shift to renewable energy. Strong legislative frameworks, technical cooperation, and information sharing may fill the gaps in renewable energy adoption

A significant theoretical contribution of the research is the wealth of information it provides on renewable energy developments worldwide, which sheds light on the dynamics of energy transition in various parts of the world. Policy, technology, and market pressures interact in intricate ways, and this research lays a framework for how these factors affect renewable energy landscapes. When planning and executing strategies for more fair and efficient adoption of renewable energy, the study's conclusions are vital for politicians, investors, and international organizations. The findings may not be applicable in the future due to the study's limitations, which include possible biases in data collecting and the ever-changing nature of energy regulations. The research may also need to include country-specific details due to its emphasis on general regional tendencies. Despite these caveats, the study's findings are very consequential, providing a road map for a concerted international effort to attain a sustainable energy future and illuminating the successes and failures thus far on the path to a cleaner world.

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