The Contribution of Innovation, Science and Technology in Enhancing Renewable Energy

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Abstract – This article focuses on the importance of research, innovation, and technology in increasing the proportion of sources of renewables in the transnational spectrum of energy. It looks at the current state of renewable energy, where it's headed, what's holding it back, and what's pushing it forward, all in an effort to provide an overview of the state of the art. The paper covers a wide range of themes associated with renewables, including marketplace designs, and policy formulation, technical challenges to the incorporation of these renewables in the power system, mini-grid and off-grid uses, and residential use. This research argues that various nations would have distinct national renewable paths based on their contextual circumstances and goals. The paper proposes that a variety of policies are needed to facilitate the spread of renewable energy. The importance of international collaboration in enhancing the connectivity of grid infrastructures, as well as in information sharing, policy education, capacity building, and technological advancement, is emphasized.

Keywords – Renewable Energy, Research, Innovation and Technology, Electric Grid, Grid Infrastructure, Industry 4.0.

I. INTRODUCTION

The European Wind Energy Association (EWEA) [1] and the International Energy Agency (IEA) [2] have both concluded from their studies that by 2050, renewable energy will provide the vast majority of the world's power. One of the most critical environmental and social problems we face today is ensuring a steady supply of renewable energy. Industry is seeking for methods to enhance output without increasing environmental damage in light of the changing climate and major environmental challenges, making renewable energy generation crucial. In this context, we set out to find ways to improve renewable energy generation that would allow for more consistent and secure power generation, storage, distribution, and monetization.

Industry 4.0 [3] has ushered in a new era of interest in renewable energy. Renewable energy sources are challenging to collect because of their intermittent nature. In contrast to solar power, which is limited only by the amount of sunlight available, wind and thermal energy are based on geographic location, while hydroelectric power generation is impacted by weather constraints [4]. As a result, there are obstacles to power generation and the commercialization of renewable energy sources due to these constraints. By integrating previously separate and inefficient energy sources into a unified network, the new age of smart manufacturing and intelligent production processes known as "Industry 4.0" overcomes these constraints. Abusing limited resources is not only wasteful but also harmful to the environment; nevertheless, if a circular economy is combined with Industry 4.0, it may improve resource productivity.

According to the Global Competitiveness Report 2017-2018 [5], a number of countries are making strides in adopting Industry 4.0. From 2022 to 2029, the global Industrial revolution 4.0 market is expected to develop at a CAGR (compound annualized growth rate) of 16%, from $130 billion in 2022 to $377 billion. The manufacturing sector's share of the worldwide IoT market is presently at $10.45 billion, while the compound annual growth rate in North America is 29%. As a component of the environmentally friendly circular economy for waste disposal in Indonesia, the use of IoT and other kinds of ICT have been suggested. Using IIoT infrastructures, machine learning strategies, and big data tools, a platform for processing data analytics in the spirit of Industry 4.0 might be used to create soft sensing for waste-to-energy facilities.

There are three main phases involved in the exploitation of sources of renewable energy: production, transmission, and distribution. As there are numerous obstacles to overcome in the efficient and reliable generation of electricity from renewable sources, the secondary but vital processes of energy storage and energy trading are of utmost importance. Power shortages during peak hours and surpluses during off-peak hours are possible outcomes of unstable resource availability, which may also contribute to inefficient power generation. As a result, the generated energy is either not put to good use or is lost. It is important to remember that the business losses caused by the unreliability of renewable resources also impact the worldwide market for renewable energy. The losses tend to discourage societies from migrating to renewable sources of energy like solar and wind, and instead keep them dependent on old fuels like coal.

In the past ten years, Industry 4.0 has helped integrate different types of renewable energy, leading to cleaner, cheaper electricity from things like virtual power plants and microgrids. Industry 4.0 may boost production efficiency by integrating various energy sources, such as geothermal, solar, wind, biomass, and hydropower energy. Internet of Things (IoT) technology may help alleviate power shortages by enhancing the reliability, safety, and efficiency of energy production architecture. Monitoring activities done in real-time may boost productivity by keeping an eye on demand and supply in a consistent manner. Moreover, transmission system management may be enhanced with the help of Industry 4.0. For instance, industrial SCADA (supervisory control and data acquisition) models [6] may help make the most of renewable energy integration projects. Fault detection and energy losses in the lines of transmission are two areas where Industry 4.0 technology may significantly improve the efficacy of the energy distribution system. Decentralized microgrids for energy storage also have the flexibility to act as backup generators or stand-alone systems. Specifically, new tools like the energy internet and blockchain have greatly facilitated the exchange of renewable sources of energy.

The Board on Science and Technology for developmental projects prioritized [7] "The role of science, technology, and innovation in increasing substantially the share of renewable energy by 2030" during the intersessional period between its 2017 and 2018 sessions. This decision was made at the Commission's twentieth session, in Switzerland, in 2017. To help the Commission better grasp this prioritized topic and aid its debates during its twenty-first session, the Commission secretariat held an intersessional panel in Geneva from November 6 to 8, 2017. This paper was compiled using data from the topics paper written by the Commission secretariat, panel discussions, national case study issued by the members of the commission, and other scholarly papers. Key concerns regarding the objectives of innovation, technology and science in increasingly advancing amounts of sources for renewable energy in the globalized energy mix by the year 2040, mostly in developing nations, are identified, analyzed, and presented in this study for debate.

The rest of the paper has been organized as follows: Section II focuses on providing a background analysis of the drivers in the deployment of renewable energy; including the novel and emerging technologies on renewable energy. Section III concerns the major challenges facing the deployment and advancement of renewable energy. Section IV provides a discussion of the key policy considerations such as (a) nations have distinct pathways for local renewable energy; (b) policy mix is fundamental in supporting the deployment of renewable energy; and (c) regional and global cooperation has a major obligation. Lastly, Section V provides a conclusion to the article as well as recommendation for future research.

II. BACKGROUND ANALYSIS

According to the World Bank Group [8], approximately 1.1 billion people in the globe now lack access to modern forms of power. Over eighty-five percent of the globe’s population still faces difficulties to access to modern power, and the majority of those people are based in rural regions in Africa. There are approximately 3 billion people who do not have easy accessibility to sustainable cooking energy. The health, social, and environmental costs of continuing to use conventional biomass and inefficient methods are significant. The 2030 agenda on the objectives for sustainable development were arranged based on a meeting in 2015, and expanding access to sustainable energy sources is a crucial step toward reaching these goals. The primary objective of Goal 7 is to provide all people with access to modern, cheap, and dependable energy services that do not compromise the environment. To "significantly enhance the percentage of renewable energy in the global energy mix" by 2030 is a goal under this framework. Realizing universal access to energy and expanding renewable energy sources is expected to have beneficial effects on a variety of other dimensions of sustainable development and other Goals. It is essential to invest in modern infrastructure if we are to achieve Goal 1 and reduce poverty. The use of renewable energy sources may be crucial in creating these facilities.

However, as recent studies by UNCTAD have shown, it's also important for bolstering productive capacity and opening up new avenues for making money. By displacing the employment of fossil fuels for purposes such as lighting and cooking in households, for instance, renewable energy could make a significant contribution to smart health and the well-being of humans (Goal 3). It is also important for advancing gender parity (Goal 5). Modern renewable energy sources may lessen the burden on women and girls to harvest wood by replacing conventional energy sources like wood fuel. Lights made possible by renewable energy sources may also free up more time for women to devote to housework. Climate action (Goal 13) and the enhancement of novel infrastructure and technologies (Goal 9) complement one another in important ways (Goal 13). The spread of renewable sources of energy is a component of various countrywide programs to minimize the emission of greenhouse gases, which have a significant impact to climate changes, and renewable energy is a focus of many national innovation policies and international efforts.

The recent push to boost the deployment of renewable sources of energy has been initiated by the interlinked demand to develop the security of energy and diversify sources of energy, enhance long-lasting economic enhancement, and safeguard the ecosystem and climate from effects arising from the consumption or use of fossil fuels. Due to these factors, a wide variety of renewable energy technologies has advanced significantly and is now widely used. In addition, the legislative interventions led to the huge cost minimization of different renewable energy initiatives as well as prompt technological adoption. Renewable energy may come from a variety of different sources, including the sun, the wind, the earth, water, and biological matter (biomass). As a result, there is a wide range of technologies that may be distinguished based on attributes such as whether they are changeable or consolidated or dispatchable, decentralized, indirect, or direct and classical or cutting-edge. Traditional biomass, which relies on the inefficient direct burning of wood and charcoal, is one example of a non-clean renewable energy source and technology. The whole energy infrastructure may benefit from the use of renewable energy sources. It may be put to use in the production of power, transportation, heating and cooling, and even in the kitchen. It is safe to say that renewable sources of energy have been utilized since the advent of energy systems itself, far before the advent of fossil fuels.

The considerable share of renewable sources of energy in the international major energy supplies has increased significantly over the past few years, from approximately 1.1 million tones as in 1990 to 1.8 million tons as in 2015. Its percentage of that grew from 12.8% in 1990 to 13.4% in 2015, but only little. In 2016, renewable energy met 14% of worldwide primary energy consumption, citing IEA data (9%, in case traditional types of solid bio-energy are eliminated). Almost 60% of all renewable energy is put to use in the electric power industry. They include hydropower (16%), tidal, solar, geothermal and wind energy (5%) inclusively, and bioenergy and waste (2%) for a total of 24% of the world's electricity. Although renewables provide 9 percent of the heat demand in manufacturing and construction, they only meet 3 percent of the need in transportation.

The latter is mostly comprised of biofuels. The regional data on the utilization of renewable energy shows substantial diversity across nations. This is because elements including location, climate, economy, development objectives, culture, institutions, and policy and regulation all have a role in whether or not renewable energy sources are put to use. In 2015, renewable energy accounted for 9% of the primary energy supply in OECD nations. In contrast, just 8% of energy in China and 25% in India come from renewable sources. Traditional kinds of bioenergy are often the most popular in underdeveloped nations for renewable energy consumption. There is a wide range in the proportion of renewable sources to sum up to the major energy supply, from 28% to 53% to 82% in Vietnam, Costa Rica, and Kenya, respectively.

Drivers in the Deployment of Renewable Energy

Certain types of renewable energy technology have seen rapid expansion in implementation in recent years. A wide variety of technological and non-technological elements, such as affordability and pricing, technical maturity, funding, incorporation into energy networks, ecological skills, and sustainability have either facilitated or impeded the development and deployment of renewables. Until recently, renewable energy sources were often more expensive than fossil fuels. As a result of falling costs and application deployment incentives in an increased number of nations, the gap has begun to decrease, particularly for solar photovoltaics and wind energy. Comparatively, the mean costs of the solar photovoltaic energy minimized by more than 80% from 2008 to 2015, while the costs of land-oriented wind energy minimized by 35% during the same time period.

However, the high prices of existing off-grid and mini-grid alternatives render them out of reach for many impoverished rural populations in developing nations. The investment environment for some renewable energy technologies has improved thanks to decades of regulatory support in a number of nations and falling costs. From approximately $153 billion in 2007 to approximately $304 billion in 2018, the investments in sources of renewable energy have almost doubled. Almost ninety percent of 2015's worldwide investment in renewable energy came from solar photovoltaic and wind power. Financing has been a major obstacle to deployment in many nations, necessitating state involvement to give more confidence for investors. It is still a big problem in many third-world nations. Renewables sources such as wind energy, hydropower, and solar power are now regarded to be mature markets. Certain technologies, like geothermal energy or bioenergy, however, still need a lot of work before they can be used on a large scale; they need to be proven and tested extensively first.

A demonstration project in South Africa, for instance, is researching the economic feasibility of algal farming and energy product production. Additionally, renewable technologies may occasionally create new issues to power systems and markets, e.g., the impediment within the network system and the restrictions to the ability to effectively absorb unprotected renewable sources of energy. Scrutiny over the usage of various renewable energy sources has been stoked by worries about their impact on the environment, which is an example of a non-technical hurdle. Concerns have been raised concerning, among other things: the ability to construct, operate, and maintain technological advances in renewable energy; the consequences of major hydropower installations on regional environments; the absence of adequate skills and competencies to utilize such innovations; and the lack of understanding of the advantages of transforming to renewables. Moreover, new skills and talents are necessary for the widespread adoption the technology of renewables and the enhancement of policies to support these goals.

Novel and Emerging Technologies on Renewable Energy

There is still a lot of room for development that may make renewable energy sources more efficient and cheaper. Some examples of this include the advancement of solar photovoltaic cell material research, the connection of electric cars to the electrical grid, and the incorporation of digital technology into energy infrastructure. 3G thin cellular films with Earth-based materials show some promise, even though silicon-oriented solar photovoltaic energy is projected to become significantly dominant for the foreseeable future. For instance, between 2012 and 2015, the photoelectric efficiency of perovskite solar cells increased from 10 percent to over 20 percent, significantly lowering production costs. Nevertheless, perovskites are still in the preliminary phases of development, thus questions about their durability and scalability remain.

Third-generation solar photovoltaic cells are working toward a number of goals at once, including increased power conversion efficiency, decreased material and production costs, and simplified production. Only with increased investment in R&D will solar photovoltaic technology reach its full potential for widespread use. Incorporation of renewable sources of energy with intelligent infrastructures, e.g., grid-to-vehicle incorporation, is another prevailing concern. The typical private car spends just one hour a day on the road, while the other 23 hours are spent parked in garages or otherwise near buildings with access to an electrical power source. Vehicle-to-grid (V2G) systems are gaining popularity since they allow for a two-way flow of energy between a vehicle and the power grid.

Electric cars might be employed as storage devices, with their unused power being sold back to the grid during times of high demand. Some of these advantages include the development of innovative business models that provide financial incentives to car owners, the expansion of the usage of electric cars beyond personal transportation, and the incorporation of such vehicles into smart infrastructure and cities. A growing number of nations are moving toward a complete ban on the use of gasoline and diesel cars, which is one argument in favor of the widespread adoption of electric vehicles. Countries like India and China have set goals of doing so by 2030 and 2040, respectively. France and the UK have set goals of doing so by 2040.

The phase-out is scheduled to end at various times in various nations. Future research should focus on the digitization of energy frameworks, which are highly-interconnected, sustainable, and predictable as technologies for renewable energy sources continue to grow based on digital technologies. More and more, automated, connected, electric, and shared mobility are being utilized as leverage over transport infrastructure and electric automobiles. Since mobility cuts across so many industries, intelligent energy grids could integrate and match intermitted energy sources such as wind and solar energy with systems of transportation onto the grand scale. Improvements in energy efficiency and optimized energy usage are two possible outcomes. However the widespread adoption of automated, linked, electrified, and shared transportation will rely on governmental measures, technology advancements, and customer willingness.

Projected Impacts of Renewable Energy Intervention

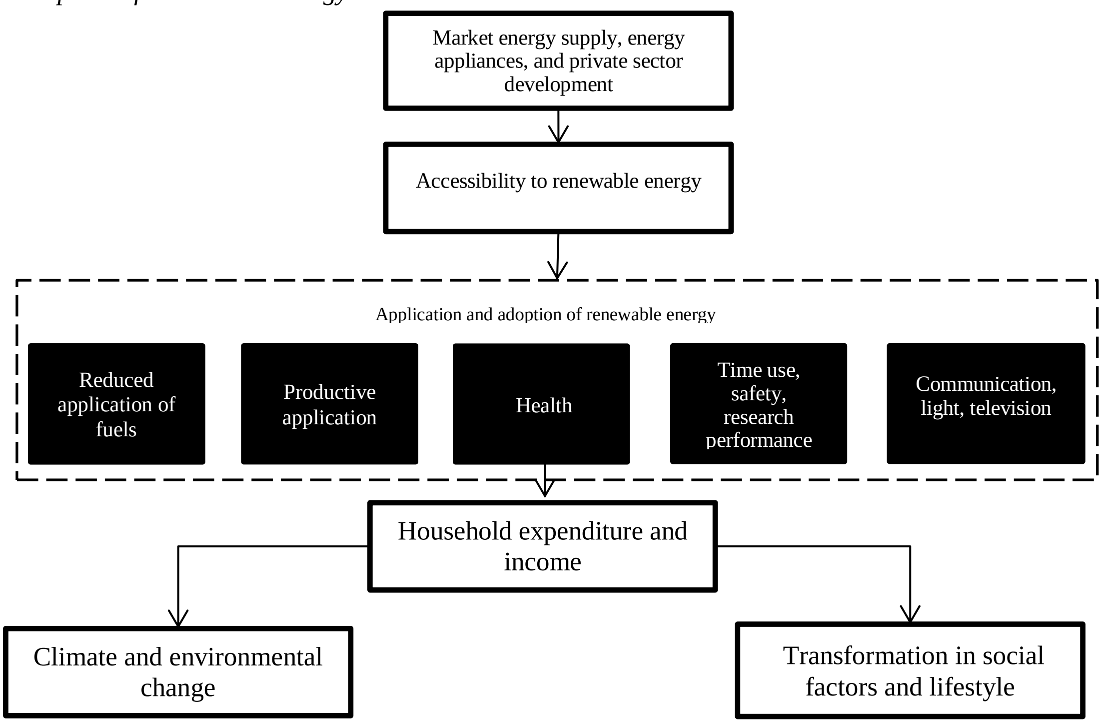

Fig 1. Projected outcome of renewable energy intervention

The stated predicted outcomes chain in **Fig 1** was used to generate research questions before the review was conducted by authors. The report's organization is based on these research questions. The following broad conclusions were drawn from the investigation:

There is a dearth of strong data on the efficacy of initiatives including renewable energy, and what research there is focuses mostly on health concerns and a select number of nations

At present, renewable energy is the exclusive focus of at least 13 scholarly publications. Evidenced by the prevalence of articles on the issue in academic publications and in the report sections of websites for international development organizations, there is a clear public fascination in renewable energy. Just 558 out of tens of thousands of papers (including policy documents, opinion pieces, technical studies, and project summaries) were found to be actual appraisals. Sixty-six papers met the requirements for inclusion in the systematic review after going through the screening process. A thorough analysis of an intervention's effects will compare the situation both with and without it, as well as before and after it was implemented. This "double difference" comparison was utilized in 41% of the chosen research, whereas only 15% of the studies employed a "single difference" method. The application of enhanced stoves to minimize indoor air pollution and, through extension, health impacts is the focus of the majority of the 66 studies that were considered for inclusion. The topic of "rural electrification" (articles with some duplication with solar energy e.g., by Yuan [9]) also receives positive assessments. Nevertheless, this is not the case with pico-scale energy sources like biogas, micro-hydropower, and photovoltaics (solar lamps).

The present understanding of the effects of renewable energy on underdeveloped countries is incomplete.

Thus, this presents a barrier for impact-oriented research in the future. Many gaps or inaccuracies in the evaluative knowledge of renewable energy in developing nations have been uncovered by the assessment. Further rigorous studies assessing the effects of biogas, pico-PV, and pico-hydro systems are urgently needed. There is a wealth of room for comparative evaluative study due to the fact that the consequences of renewable energy initiatives are diverse and context specific, varying not just across nations but also within them. Security, reduced stress, and improved health are just a few of the many positive outcomes that are hoped for as a result of renewable energy treatments, and many of these advantages are targeted specifically at women. Unfortunately, the chosen reviews seldom offer gender disaggregated data, with the exception of research focusing on health-related factors. There was just one study from the World Bank in 2008, but no analysis of the effects on the growth of the private sector in the power marketplace. The evaluation of renewable energy's long-term effects is unique. Research along these lines may help provide light on how the effects of energy interventions evolve over time [16].

To lessen the impact of unpredictability, rural households do not replace their current energy sources with new ones, but rather supplement them with additional sources of energy-related equipment

Having access to a new fuel does not ensure that families will connect to the source (in the case of electricity) or adopt the fuel's usage (in the case of stoves) and maintain its use over time. Even after 10 years of service, approximately 15% to 20% of homes in areas where power has been available report still not being wired in. The name "energy ladder" may imply that switching energy sources occurs in a linear fashion, but in reality, families may "walk back and forth" up the ladder. In most cases, families don't suddenly abandon their current energy sources in favor of a different kind of fuel, but rather supplement them with a new option. "Energy stacking" is the practice of using many different types of energy sources rather than just one [17], [18].

It is possible to employ many fuels at once for various tasks. It is only with the passage of time that certain sources (often the least desirable, such manure) are discarded and irreversibly substituted by another source (this is known as a "fuel flip"). Multi-fuel/multi-technology households are more resilient to external shocks such temporary fuel shortages, price rises, lack of supplies, or a decline in family income, while also maintaining cultural norms and personal preferences for food preparation and consumption. How households react to switching to renewable energy sources depends on whether or not they are also using conventional fuels and technology [19],[20].

There is a bidirectional causal relationship between energy use and economic prosperity

Those in the middle class who are considered "early adopters" of new energy technologies often have greater spending habits in the near term. Nonetheless, this investment pays off since their income grows faster than the incomes of "late" or "none" adopting families over time. Those with higher middle-class incomes in rural regions (public workers, small business owners) are the pioneers in the use of alternative energy. Those that adapt late tend to be the most energy-poor, including mostly low-income families who lack the resources to switch to a greener energy option. According to Yang et al. [10], female decision-makers are more inclined to choose environmentally friendly power sources. When a new source is used, it usually comes with increased investment and, typically, operational expenses. Applications such as food preparation, drying agricultural goods, curing tea and tobacco, and brick manufacturing are the only ones where enhanced heating systems may directly generate cash [21].

Less money spent on fuelwood means less money spent on energy. Two out of four studies examining the effects of upgraded stoves for residential use only found annual savings of EUR 13-45 per family in Kenya, Sudan, and Madagascar, an amount that is substantial when compared to the average annual income of those regions [22]. Evidence from previous research suggests that upgraded wood stoves are not cost-effective in replacing open fires as primary cooking appliances because of a rebound effect (increased energy use in the kitchen as a result of a shift in cooking habits, such as leaving the water heater on all day). A second explanation is that wood is a free resource (in this case the opportunity cost of waiting is essentially nothing)

III. MAJOR CHALLENGES IN DEPLOYMENT AND ADVANCEMENT OF RENEWABLE ENERGY

The discussions below will focus on problems associated with developing and implementing renewable energy sources. These problems are interconnected and cannot be addressed separately. There is a need for a variety of policies as countries chooses the best renewables deployment route for their circumstances; this is because the adoption of technologies of renewable energy is based on the innovation framework, which integrates both non-technological and technological context variables.

Industry 4.0 Digital revolution

The 1st industrial revolution started at the tail ending of the 18th century. The steam engine allowed for the simplification of many formerly labor-intensive tasks, which in turn increased output while simultaneously decreasing production costs. The growth of cities around manufacturing led to improvements in living conditions. The invention of the steam engine paved the way for the growth of the railroad industry, the printing industry, and the press. During the late nineteenth century, the 2nd industrial revolution had begun. Electricity generated from coal and oil was used to power linear assembly lines, which in turn made mass manufacturing more efficient. Technologies like the telephone and telegraph also contributed to the expansion of the steel and synthetic industries. Industry 3.0 ushered up new possibilities for mechanization. At the middle of the twentieth century, advances in electronics and communication technology allowed for widespread technical upgrading in manufacturing facilities, resulting in greater productivity. In the midst of the 21st century, we have witnessed the commencement of Industry 4.0 initiated by the proliferation of cutting-edge technologies, increased connectivity, and the advent of intelligent automation. Kennedy [11] provides a chronology of the four industrial revolutions (see **Fig 2**).

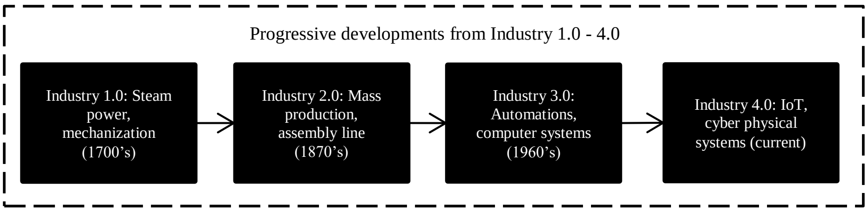

Fig 2. A representation of Industry 4.0 Timeline

Comprehending the transformations ushered in by Industry 4.0 necessitates a quick review of the preceding three industrial revolutions. Another major change in industrial output is happening now. The term "Industry 4.0" was coined to reflect the potential effects of this change on global value chains in Hannover Fair's 2011 in Germany. As part of the fourth industrial revolution, "smart factories" emerged, ushering in a new era in which traditional manufacturing processes could be seamlessly integrated with digital ones. The idea behind this method is that the digitalized world of data technology and the industrial physical world of production will merge in the future. Hence, cyber-physical systems, or digital and networked approaches to manufacturing, will become the norm. These industrial networks are able to coordinate with one another, take initiative, and operate machinery without human intervention. Many areas have given this concept of a digitized and networked industrial sector different label. For instance, the phrase "Industry 4.0" is popular in Germany, whereas the terms "Internet of Things" (IoT) and "digital manufacturing" are more common in the USA.

In the context of the fourth industrial revolution, many gadgets and machines are able to interact with one another, form digital identities, and make choices with the help of intelligence thanks to the availability of sensors and actuators. The algorithms will decide the best route for the products to take as they make their way through the manufacturing process. If anything goes wrong with the system, the gadgets can switch to a backup route so that production doesn't stop. Because of this, factories will be mostly autonomous in their operations, allowing for more product customisation to meet individual needs. Due to its foundation in digital technology, the Fourth Industrial Revolution has also been dubbed the Digital Revolution. Hence, the convergence of physical, biological, and digital worlds may be seen as the driving force behind Industry 4.0. Genetics, robotics,, artificial intelligence, biotechnology, nanotechnologies, and 3D printing are all examples mutually-conditioned and integrated technological advancements. To that end, CPS and IoT are both integral parts of Industry 4.0 that is an industry based on digital technologies, platforms and networks.

Policy Designs and Renewable Energy Market

Both international rivalry and collaboration have the potential to speed up technological progress. Recognizing the usefulness of both and fostering them when appropriate is an essential part of policymaking. Benefits in efficiency may accrue to all nations involved when the innovation cycle of a renewable technology is interconnected across borders. This is especially true when manufacturing is included. It may also help nations without a completely-formed technological chain to effectively stimulate initiatives down the chain. Nonetheless, competition is a fundamental element of global business, and the success of sectors in a single nation could stimulate a doom in that particular industry, thus the globalization of the innovation system can also produce problems. When it comes to improving people's health, quality of life, and access to lucrative work, providing reliable energy access may be a top priority in several nations in the near future. Rather of waiting many decades of technological chain to be established locally, the merits of providing this accessibility as soon as possible could provide a firm basis for the accessibility of global technologies of chains to apply earlier-established intellectual properties and technologies.

On the contrary, the long-term perspective could evaluate industrial and economic policy of a country over a significant timeframe. This point of view might also take into account the fact that in the long run, the economy as a whole stands to gain more from the creation of jobs and accompanying macroeconomic stimulus if more of the innovation supply chain is built up on home soil. Advancements in renewables is highly global, with the stimulators in a single nation having the capacity to make a substantial influence in others, as evident by the significant advancement of solar photovoltaic energy marketplaces.

The feed-in tariffs that ensure a set price for every power unit issued over an acknowledged term, has been the policy tool most commonly employed to encourage renewable energy. Since renewables are often dominated by large capital costs, this is an appealing type of price support. Feed-in tariffs have helped accelerate the decline in renewable energy prices, especially for onshore wind and solar PV. Many nations have implemented feed-in tariff systems, including the United Kingdom, Portugal, Turkey, the United States, and Kenya. But, the feed-in tariff runs the danger of long-term subsidization of renewables, which might hurt economies if it continues.

For this reason, policy mechanisms like tenders and auctions are increasingly being utilized to determine the cost of renewable energy contracts. The use of feed-in tariffs, which were formerly managed by governments, has given way to auction systems in many nations. Auctions have helped countries like Chile and Mexico reach cheap pricing for solar photovoltaic energy sources, which others such as United Kingdom, Portugal, Japan, and Germany have amended their contractual contributions and tariffs too be auctioned. Auctions are predicted to fuel roughly half of all renewable power capacity expansions over the next five years, up from only twenty percent in 2016.

Governments have a significant role to play in the development and implementation process by, for instance, supporting R&D, increasing demand via changing energy systems, deployment incentives, and establishing standards, and implementing steps to enhance the confidence of investors. For instance, Mexico has established and funded no less than six energy innovation centers dedicated to such areas as geothermal, solar, and wind power; biofuels; ocean energy; and intelligent grids. The Islamic Republic of Iran is a good example of a country where government incentive schemes and procurement regulations have been implemented to promote the use of domestically developed technology and equipment. Generally speaking, governments may play a significant role by establishing a legal and regulatory framework that clarifies the rules and gives private sector actors confidence that they are contributing to society rather than harming it. Renewable energy technology implementation is hindered by a lack of financial support.

Technical Issues in Incorproating Renewables to Electric Grid

More renewable energy sources are being put into use, but there are still technological and financial hurdles to overcome before a significant portion of renewables can be integrated into electrical systems. Smarter power networks, which involve the extensive incorporation of digitalized and futuristic advancements such as AI, are also being developed, as are solutions to enhance the flexibility of energy consumption. To store data is a crucial enabling technology in the year 2023. However, there is a wide range in storage technology's output, charge/discharge rates, and storage duration. It seems improbable that the current state of battery technology will be able to provide enough seasonal storage to allow solar power to be saved in the summer and used to heat buildings in the winter. That's why it's important to develop new methods of storing heat or energy that can keep going for extended stretches of time. Equally, several storage methods are being developed for a wide variety of purposes, from local to grid-wide, from quick discharge to inter-seasonal storage.

The integration of variables and deployable renewable energy relies on the nation’s presence of patterns frameworks and energy resource consumption. In Portugal, for instance, wind energy and hydropower have a vital role to play in power integration in the entire nation. Averagely, renewable energy sources generate more than 60% of its electricity mix per annum. In 2017, there were approximately 6 complete days during which renewable sources generated approximately 100% of the nation’s electricity.

As solar and wind resources are not always concentrated in close proximity to population centers, meeting energy demands may require transporting materials long distances. Thus, it is crucial to invest in the expansion of power system infrastructure. Such infrastructures are costly to build but may significantly restrict and steer a power system's supply and demand over time once they're in place. The placement of power production will significantly change as a result of the shift to a renewables-intensive system, making the future of the electric grid architecture a pressing concern in nations, which have historically immersed in an energy grid, which relies in the supply location, and in schemes that are principally founded on fossil fuels.

In addition to the various renewable energy sources, such as centralized and decentralized, there are varying degrees of infrastructure development that must be addressed. Grid-based centralized power systems need substantial transmission and distribution facilities. Contrarily, decentralized systems are better suited to rural locations that are difficult to access due to their lower size (for example, tiny grids or standalone systems). Comparatively concentrated are huge hydro-powers advancements that are applied in some globe’s greatest energy facilities, while decentralized are solar residential systems. The scale at which renewables are implemented is affected by these elements as well, from small-scale, off-grid deployment (solar household models) to large-scale, grid-scaled energy stations (such as concentrated solar energy plants, hydro-electric power plants, and geothermal energy plants).

The Objective of Renewable Energy in Diversifying Accessibility to Electricity

There are still over 1 billion people who still face issues accessing reliable energy. Broadening access to electricity has been linked to several positive outcomes for a country's social and economic growth. Electrifying rural regions, particularly in poor nations, via off-grid and mini-grid solutions is a possibility because to the rapid technical advancements in renewables and cost reductions. UNCTAD found that an energy-transformation nexus is the best way to incorporate energy access goals and associated income-generation possibilities into a country's overall development strategy. 28 In this view, addressing energy supply and demand as a whole helps to diversify the economy and create new jobs. Grid expansion has traditionally been the primary method of increasing access to renewable power sources, whereas off-grid methods have been used less often. Solutions based on a centralized network, or "grid," often have the initial costs of infrastructure covered by the government or a utility corporation, with the cost passed on to consumers via higher rates.

Any consumer who is interested and able to pay the minor connection fee and ongoing charges may do so with little outlay. It may take some time for a top-down strategy to permeate the whole population. Off-grid renewables have the potential to meet the electrical needs of communities far more quickly in such cases than grid electrification can. Off-grid options, especially solar photovoltaic technology, have been proposed as the most cost-effective methods of achieving universal electricity throughout sub-Saharan Africa by the International Energy Agency (IEA29) [12]. The cost of employing renewable energy sources to widen people's access to the grid is a crucial 37th factor to think about. Because of the low population density creating an unclear return on investment, low-income societies could not be able to pay for essential investments in advance, and potential stakeholders may be hesitant to take the risk.

By the use of microfinance or pay-as-you-go agreements, for example, these expenditures may be spread out over time, making the venture financially feasible and fostering its development. The nonprofit group Solar Sister, which helps women set up solar microbusinesses, has successfully implemented the pay-as-you-go system. New renewable energy technologies may be compensated in a manner that makes them competitive with the price of the energy source they displace, such as kerosene. Often private investors aren't enthusiastic about working on off-grid solutions for rural locations. Clustering and combining initiatives to reach scale might be one answer to this problem. Structuring a firm governmental structure with straightforward supporting and regulatory policy models, standardized off-grid rates, licensing processes, and handling upfront costs through low-interest micro-financing and lending are all potential solutions to the problem of the private sector's reluctance to engage in renewable energy projects of any size.

Applying Renewables in Household Cooking

Almost half of the world's renewable energy comes from conventional biomass sources. 30 Traditional biomass (wood, animal dung, agricultural waste), and coal are still used by about 2.7 billion people to head and cook in their homes. This has devastating effects for people's health, the environment, and society as a whole. 40th Sustainable Development Goal 7 addresses a critical challenge in many developing countries: how to get rid of conventional, polluting biomass while simultaneously increasing the proportion of renewables in an energy mix.

As a result, it is critical to rapidly implement replacements for the conventional use of bioenergy in the kitchen and for other energy services. The problem can be solved in two ways: either by encouraging homes to change to modern technologies of cooking, or by promoting effective and long-lasting biomass application (distributing and producing bio-methane using wastes that are biodegradable and syngas off from biomass that is lignocellulosic in nature and localized). Making headway in expanding people's access to clean cooking has been hampered by issues of cost (solid biomass is principally free, while modern cooking stoves as well as other fuels are not) and cultural opposition (preferences for food tastes done traditionally).

It has now become clear that, to mitigate this issue, programs and policies should be embedded in the cultural and social setting of the society they serve and considering the communities' preexisting energy habits, expectations, and potential productive applications. Women's participation is especially important since they often shoulder the most of the load when it comes to tasks like fuel collecting and meal preparation that are connected to the usage of energy in the home. Women have shown to be excellent communicators and trainers for new community energy projects. Although there may be some overlap between the goals of expanding access to clean cooking facilities and expanding the use of renewable energy sources, these two goals are not always congruent.

IV. KEY POLICY CONSIDERATIONS

Nations have Distinct Pathways for Local Renewable Energy

As various variables, including scale economies, sunk expenditures, learning implications, user lifestyles, and behaviors, could amount to lock-in for decade or years, a country's renewable energy route is a crucial issue. In other cases, the inflexibility of these routes might be locked in permanently. Due to their strategic relevance, national development policies should provide renewable energy routes and associated income-generation prospects a prominent position. When considering the deployment of systems for developing new forms of renewable energy, it is important to do so in the context of both individual countries and regions. Conditions such as location, weather, GDP growth, social and economic development objectives, institutional make-up, and policy and regulation all have a role. Therefore, the percentage of renewables in each country's energy mix varies widely. In Colombia, for instance, hydropower, a significant source of renewable electricity in America, accounts for the vast majority (82 percent) of the country's main energy supply. In

Ethiopia, over 93% comes mostly from biomass. In the Philippines, renewable sources including geothermal, solar, wind and biomass account for 36% of the total energy used.

Governments should strike a balance between competing objectives and goals while planning for the widespread use of renewable energy. Jobs in the industrial, manufacturing, and commercial sectors involved in renewable energy generation and deployment may be created as a consequence of renewable energy expansion, which can contribute to regional or national objectives. Communities whose access to electricity has been spotty or nonexistent may find new sources of revenue via the widespread use of renewable energy. Reducing the time women and girls spend collecting fuel, boosting their access to school, and enhancing their health by lowering indoor pollution levels are all ways that this technology may help advance gender equality. Additionally, renewable energy may help boost agricultural output by powering technologies like pumped irrigation. So, the implementation of renewables may take place along any number of different routes. Consequently, a deployment strategy requires an in-depth comprehension of specific elements and priorities in each setting.

Policy Mix is Fundamental in Supporting the Deployment of Renewable Energy

As a means of bolstering renewable energy, national, regional, and sectoral innovation systems should all be included in the development of innovation, science and technology policy. Due to the systemic nature of renewables innovation, it is necessary to create a distinct market demand for distinct sources of renewable energy and a diversity of enabling standards to commence research efforts, manage infrastructures, produce local skills, align incentives and rules, and mobilize funds.

Innovations in renewable energy sources may range in size and complexity. Accelerating the offshore wind turbine size is one example of an incremental innovation that has the potential to enhance an existing technology. Meanwhile, disruptive innovations provide novel products and/or production processes, such as the creation of smarter, more flexible power networks that may enable the integration of variable renewable advancements in large-scale shares or at low-cost compared to how it was previously conceivable. When it comes to renewable energy technology, regulations may foster both incremental and dramatic innovation. Implementing policy mixtures calls for an intricate network of interventions, actors, and processes that must co-evolve through time and space.

Based on particular priorities, challenges, and varying technological development phases in each country, effective policy mixes will employ a wide range of instruments, from international standards, and feeds-in tariffs to the actions on the demand sides, like publicized incentives and procurement like bottom-up funding strategies and mission-innovative programs. It is crucial to strengthen capacities in order to raise people's understanding of renewable energy technology and train them in their installation and upkeep. Training and capacity-building in rural energy applications might benefit from taking into account social and economic concerns, such as gender difficulties. Several studies conducted by UNCTAD have highlighted the significance of developing locally inventive skills, such as the capacity to create and design technologies tailored to certain regions' requirements.

Local inventive capacities may be bolstered by investments in science, technology, and policy measures like funding for research centers and universities that specialize in technologies of renewable energy or offering financial incentives to businesses that invest in R&D and demonstration. The right policy procedures and governance structures are also essential for maximizing the impact of policy combinations. Coordination, coherence, policy learning, and cooperation are all examples.

Regional and Global Cooperation Have a Major Obligation

Due to the global character of the components that make up the renewable energy supply chain, international collaboration is crucial to the development of this sector. When countries work together, they may pool their resources and take advantage of synergies in the supply chain. Governments have to be informed of their obligation as a broker could enhance the functionality of supply chain or initiate effective accessibility to shared assets, be they knowledge assets, infrastructure, or natural assets, including creating marketplaces in which the private industries can effectively provide feedback promptly to the competitive marketplace. Because neighboring nations have vastly varied renewable energy potential owing to geographical factors, it is extremely crucial for them to work together across regions to find solutions.

A region's potential for renewables may be so great that it is capable of meeting or even exceeding the needs of the nation in which it is situated if only the region's full potential were used. In addition, if the renewable outputs of various areas were connected together in a unified transnational network, they might effectively complement one other by mitigating the diurnal and seasonal timing differences between their respective outputs. Many efforts and strategies have been developed to address this issue; one such plan is the Nordic Grid Development Plan, which is exploring the possibility of constructing additional interregional transmission lines to carry energy excess from one region to population hubs.

The International Renewable Energy Agency's Africa Clean Energy Corridor (ACEC) program [13] is another good example; it intends to facilitate the trading activities of renewables (that are cross-border) in the energy pool of southern and eastern Africa to accelerate the development of renewable energy. In order to hasten the growth of renewables cross-border trading and potentials of renewable electricity with the SAPP (Southern Africa Power Pool) [14], and EAPP (Eastern Africa Power Pool) [15], the ACEC (Africa Clean Energy Corridor) was established as a regional project. Being a continent with a large potential for renewables and the pressing necessity to meet the high demands, Africa stands to benefit greatly from recent developments in the affordability and performance of renewables. Nations such as Tanzania, South Africa, Lesotho, Zambia, Mozambique, Zimbabwe, Sudan, Namibia, Malawi, Kenya, Ethiopia, Egypt, Djibouti, Democratic Republic of Congo, Burundi, Botswana, and Angola all signed a communiqué of the 4th assembly of IRENA (International Renewable Energy Agency) in January 2014 to provide guidance to the development of ACEC. Since then, more than 30 nations, development partners, financial institutions, and regional organizations have joined the effort.

Technology transfer is a possible aspect of cooperation. To provide just one example, China is helping Argentina and Pakistan build wind farms, while India is helping Mozambique in the transfer of renewable energy technologies and expertise. The most pressing difficulty is developing regulations and methods for collaboration that encourage the sharing of technological know-how among businesses, particularly in developing nations with budding renewable energy industries. Consequently, indigenous capacity-building activities should not be supplanted by technology transfer but rather complemented by them. North-South and South-South collaboration, as well as other forms of international cooperation, have numerous potential applications. These include the sharing of knowledge and the creation of new policies, the advancement of technology, the betterment of cross-border grid connectivity, the creation of new industrial capacities, and the provision of financial contributions. For the latter, consider the solar photovoltaic energy plant sponsored almost equally by the Bolivian regional electricity firm and Denmark and located in Cobija, Plurinational State of Bolivia. During daylight hours, the facility produces enough solar power to meet around half of Cobija's energy consumption, which results in significant fuel savings and lowers emissions.

V. CONCLUSION AND RECOMMENDATION

The availability of renewable energy services is a critical factor in meeting the Sustainable Development Goals. The pace of deployment of renewable sources of energy has a significant effect on the increment of income, including developmental goals including climate change, health, and gender equality. This article shows that different countries adopt various ways to developing renewable energy due to variables including location, culture, institutions, and policy and regulation. Due to their importance in guaranteeing the long-term sustainability of economies, policies supporting the use of renewable energy sources are gaining prominence in debates about national development plans. The article also draws the conclusion that a combination of legislative tools and a methodical model to technological advancement are essential to enhance the shares of renewables in local and international mix of energy. With the objective of satisfying both the growing demand and the expanding supply of renewable energy, this would need a range of policies to initiate incentives for Research and Development (R&D), cultivate local talents, provide supportive regulatory models, and guarantee affordability.

Globally, enhancing the considerable share of different sources of renewables by 2030 would need substantial North-South and South-South cooperation. Among the numerous potential gains from international cooperation are the development of connected grid infrastructures, which in turn necessitates the exchange of knowledge, the study of policy, the strengthening of institutional capacities, and the invention of new technologies. In all, 58 suggestions are presented below for review by Member States: Expand national funding for R&D efforts in supporting technologies for renewables, from fundamental research to practical application. (a) Enhance policy coherence and policy coordination with sectoral policies like technology and science. (b) Support the development and implementation of renewable energy sources by adopting policy combinations that allow for some leeway. (c) Check that a country's growth strategy and its policy on renewable energy are congruent.

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No data was used to support this study.

Conflicts of Interests

The author(s) declare(s) that they have no conflicts of interest.

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