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Foreword

As the global community in the 21st Century grapples with the pressing issues of climate change and environmental degradation, the role of energy and its sustainable development has become increasingly crucial. Energy serves as a crucial productivity-enhancing factor in driving economic growth and improving human well-being. However, due to expansion of economies and their population there has been an unprecedented spike in the consumption of fossil fuels leading to an alarming rise in greenhouse gas emissions and natural resource depletion. Many developing nations in the Global South need help with issues such as inadequate access to modern energy services, infrastructure limits, and financial barriers. Sustainable energy technologies, particularly renewable energy sources, have emerged as a promising solution to address these challenges by reducing the environmental impact of energy production and consumption while contributing to economic development, poverty reduction, and social well-being.

The current issue of *Ruminations*, a peer-reviewed e-journal from the Department of Economics, comprises volumes III and IV, which are published together as a single, consolidated edition. It seeks to shed light on the role of energy in attaining sustainable development. The journal discusses the challenges of merging efficient energy use with sustainability concerns.

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Equity in Energy Ecosystem: Implications for Sustainability and Challenges

Ashmita Chatterjee

Energy stands as a cornerstone in propelling economic growth, elevating social well-being, and safeguarding environmental sustainability. In the face of urgent issues like climate change and the depletion of resources, the significance of energy in the realm of sustainable development has reached unparalleled heights. Against the backdrop of urgent challenges like climate change and the depletion of resources, the role of energy in sustainable development has assumed unprecedented importance. This article delves into the profound significance of energy in the pursuit of sustainable development and explores the obstacles that lie on the path ahead. In the global pursuit of reconciling economic prosperity with environmental responsibility, energy finds itself at a pivotal intersection of this delicate equilibrium. Its impact extends across the entire spectrum of human activities, serving as the driving force behind industries that propel economic advancement, while also fulfilling elemental needs for a dignified life, encompassing illumination, heating, and cooking provisions. Access to energy, characterized by both affordability and reliability, emerges as a crucial cornerstone for the ambitions of developing nations. It acts not only as a catalyst for reducing poverty but also as a catalyst for societal progress, facilitating advancements on multiple fronts. This intricate interplay underscores the transformative role of energy as a facilitator of growth and development. The trajectory of human progress has hinged upon the accessibility and utilization of energy, evolving from early applications of fire and animal power that elevated quality of life to the contemporary world reliant on electricity and eco-friendly fuels for myriad purposes. The absence of reliable and clean energy sources poses a significant hurdle to enhancing global human well-being. Approximately 1.6 billion individuals residing in the rural regions of developing nations lack access to electricity, compelling a reliance on fossil fuels. The combustion of fossil fuels contributes substantially to the production of CO₂, a critical greenhouse gas. Recognizing the escalating concerns regarding the impact of anthropogenic greenhouse gases on the planet's climate, international consensus has emerged to mitigate these emissions. Conversely, renewable energy emerges as an underexplored yet profound solution to the dual challenges of poverty and global warming in the coming century. Beyond offering a clean and versatile power source for residences, schools, and medical facilities, renewable energy, especially at the micro-to-medium scale, holds immense potential for generating meaningful and impactful employment opportunities.

In the 21st century, sustainable development has taken centre stage as a global imperative, underscored by the United Nations' Sustainable Development Goals (SDGs), which provide a comprehensive framework for addressing urgent global challenges. These objectives encompass a broad spectrum, from eradicating poverty and ensuring access to clean water to reducing inequality and addressing climate change. A key catalyst for advancing sustainable development is the shift toward renewable energy sources. This article aims to examine the crucial role of renewable energy in the realization of the SDGs, emphasizing its potential to revolutionize economies, alleviate the impacts of climate change, and enhance the quality of life for billions of people worldwide. In this context, technological and policy barriers pose formidable obstacles to the seamless integration of sustainable energy solutions into the global landscape. Advancements in energy technologies demand widespread adoption, and the establishment of effective policies necessitates a delicate balancing act between economic development and environmental preservation. International collaboration and governance mechanisms are pivotal in navigating the complex landscape of global energy challenges, calling for concerted efforts from governments, businesses, and the global community. In the context of economic growth, energy emerges as the lifeblood of progress, fuelling industries, powering transportation, and supporting technological advancements. Access to affordable and reliable energy proves essential for developing countries, acting as a catalyst for economic growth and poverty reduction. Furthermore, energy plays a pivotal role in determining the quality of human life, providing lighting, heating, and cooking facilities fundamental to a decent standard of living. Clean and accessible energy, in particular, contributes to improved health outcomes by addressing issues such as indoor air pollution resulting from traditional cooking methods. However, as the world strives for sustainable development, challenges loom large on the horizon. Disparities in energy access persist, with many developing regions lacking reliable and affordable energy, impeding their economic and social development. Additionally, the global dependence on fossil fuels remains a substantial hurdle, contributing to greenhouse gas emissions and climate change. Transitioning to renewable energy sources demands considerable investments and the navigation of entrenched interests in the fossil fuel industry. The development of necessary infrastructure for renewable energy generation and distribution proves complex and costly, particularly for developing nations facing financial constraints. SDG 7, focusing on securing access to affordable, reliable, sustainable, and modern energy for everyone, emphasizes the critical significance of renewable energy. SDG 7 stands for Sustainable Development Goal 7, which is one of the 17 Sustainable Development Goals set by the United Nations General Assembly in 2015 as part of the 2030 Agenda for Sustainable

Development. SDG 7 aims to "Ensure access to affordable, reliable, sustainable, and modern energy for all." This goal recognizes the crucial role that energy plays in virtually all aspects of modern life, from powering homes and businesses to driving economic growth and combating climate change. Globally, around 789 million (International Energy Agency) individuals lack electricity access, and a greater number depend on polluting and inefficient energy sources like kerosene and biomass. Technologies related to renewable energy, including solar, wind, and hydroelectric power, possess the potential to deliver clean and cost-effective energy to distant and marginalized communities. SDG 13 reflects the global recognition of the urgent need to address climate change, protect the planet, and ensure a sustainable future for all. It calls for collaborative efforts at the international, regional, and national levels to reduce greenhouse gas emissions, enhance resilience to climate-related hazards, and promote sustainable development pathways that are climate-resilient and low-carbon. SDG 13 is dedicated to urgent measures against climate change and its consequences. The combustion of fossil fuels for energy generation stands out as a major contributor to greenhouse gas emissions, the primary driver of global warming and climate change. Renewable energy technologies exhibit minimal to no greenhouse gas emissions during their operation, presenting a cleaner substitute for fossil fuels. Specifically, solar and wind power have the potential to markedly decrease carbon emissions in the energy sector. As nations steer away from coal, oil, and natural gas, opting for investments in renewables, they actively contribute to the global initiative to restrict global warming to levels significantly below 2 degrees Celsius above pre-industrial benchmarks, as stipulated by the Paris Agreement (December, 2015). As the global community strives to fulfill the objectives outlined in SDG 7 and SDG 13, several formidable challenges lie on the path toward sustainable energy. Financial barriers present a significant hurdle, with the initial costs of renewable energy projects often proving substantial, particularly in developing regions. Overcoming this requires securing substantial investments and fostering financial mechanisms that incentivize private involvement. The intricate development of infrastructure for renewable energy production and distribution stands as another complex challenge, necessitating the establishment of robust grid systems and reliable storage solutions. Continued technological innovation is indispensable for enhancing the efficiency and cost-effectiveness of renewable energy sources, with a particular focus on areas such as energy storage, grid management, and emerging technologies. Inconsistent or insufficient policies and regulatory frameworks can impede progress, underscoring the need for clear and supportive government measures, including incentives and regulations. The intermittent nature of renewable sources like solar and wind demands solutions for effective energy storage and grid management to ensure

consistent supply. Public awareness and acceptance play a pivotal role, requiring extensive education efforts to inform communities about the urgency of climate action and the benefits of renewable energy. Achieving global cooperation is crucial, with the lack of consensus among nations posing a threat to coordinated efforts to reduce greenhouse gas emissions. The geopolitics of energy, economic transition, and job displacement in traditional sectors are additional challenges that demand careful consideration and strategic planning to ensure a just and inclusive transition to a sustainable energy future. Energy poverty is a significant barrier to sustainable development. Millions of people worldwide lack access to modern energy services. Bridging this energy gap is crucial for poverty reduction, as access to energy facilitates income-generating activities, improves living conditions, and empowers communities to break the cycle of poverty. Exploration and advancement in energy technologies propel the wheel of innovation. Progress in renewable energy, storage solutions, and efficiency not only paves the way for a sustainable energy landscape but also fuels overarching technological development. Sustainable energy solutions cultivate an environment of creativity that transcends the confines of the energy sector.

In the intricate fabric of our contemporary world, several pressing challenges demand focused attention across economic, social, and environmental spectrums. Climate change, an escalating crisis marked by rising temperatures and intensified weather extremes, calls for immediate and concerted global action. The COVID-19 pandemic, a stark illustration of the vulnerability of global health systems, underscores the imperative of reinforcing healthcare infrastructures and fostering international collaboration in health crises. Lingering disparities in income, education, and access to resources expose the persistent challenge of combating social and economic inequalities that hinder inclusive development. The fight against poverty remains a multifaceted endeavour requiring nuanced solutions encompassing education, healthcare, and economic empowerment. Political instability and conflicts continue to wreak havoc in various regions, resulting in humanitarian crises and mass displacements. The rapid evolution of technology brings both promise and challenges, with issues such as data privacy and the transformative impact of automation on employment requiring vigilant and adaptable governance. Environmental challenges, ranging from biodiversity loss to resource depletion, call for sustainable practices to preserve ecosystems. Forced migration, educational disparities, cybersecurity threats, and food security concerns contribute to the complex tapestry of global challenges. Addressing these issues demands collaborative efforts on local, national, and international scales, reinforcing the urgency of a holistic and inclusive approach to sustainable development. In today's interconnected world, energy security has become a critical concern.

Cybersecurity threats targeting energy infrastructure, including power grids and supply chains, pose additional challenges to ensuring a reliable and resilient energy supply. As societies become more interconnected, the potential impact of cyberattacks on energy systems underscores the need for heightened vigilance, secure technological solutions, and international cooperation to safeguard critical energy infrastructure. Amid these challenges, concerted efforts from governments, businesses, and the global community are imperative. Fostering innovation, incentivizing investments in sustainable technologies, and implementing effective policies are pivotal steps toward reconciling the imperatives of economic development with the urgent need for environmental preservation. The dynamic landscape of contemporary challenges requires adaptability, cooperation, and a collective commitment to shaping a sustainable energy future for generations to come.

In conclusion, the role of energy in sustainable development is undeniably paramount, serving as the lifeblood that propels economic growth, enhances human well-being, and steers technological progress. From powering industries to providing essential amenities for a dignified life, energy is intricately woven into the fabric of modern society. However, as we stand at the intersection of unprecedented global challenges and the imperative for sustainable development, formidable obstacles cast shadows on our path forward. Persistent disparities in energy access, especially in developing regions, act as a poignant reminder of the urgent need for inclusive and equitable energy solutions. The world's dependence on fossil fuels not only exacerbates these disparities but also contributes significantly to climate change, necessitating a swift transition to renewable energy sources. This transition, while imperative for environmental sustainability, requires substantial investments, overcoming entrenched interests, and navigating the intricate development of renewable energy infrastructure, particularly in financially constrained nations. Moreover, technological and policy barriers pose significant challenges, requiring a concerted effort to foster widespread adoption of innovative energy technologies and the implementation of robust policy frameworks. As our societies become increasingly interconnected, the growing threat of cybersecurity challenges adds a layer of complexity to ensuring the reliability and resilience of global energy systems. In navigating these challenges, international collaboration emerges as a linchpin, transcending borders to address the shared responsibility of shaping a sustainable energy future. Governments, businesses, and communities must unite to foster innovation, incentivize investments in sustainable technologies, and implement policies that strike a delicate balance between economic development and environmental preservation. The pursuit of a sustainable energy future demands not only a commitment to overcoming obstacles but also a profound

shift in mindset—one that places the well-being of both the present and future generations at its core. As we confront the complexities of the modern world, the role of energy in sustainable development becomes a beacon guiding us toward a future where economic prosperity, social equity, and environmental stewardship coalesce. The challenges ahead are formidable, but they are also an opportunity for collective action, innovation, and the transformative changes needed to secure a sustainable and resilient energy landscape for the generations that follow. In embracing this challenge, we embark on a journey toward a more equitable, sustainable, and harmonious world—one where energy serves as a catalyst for positive change and a legacy for the well-being of the planet and its inhabitants.

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Sustainability of Energy Resources: Challenges and Remedies

Angana Mandal

Energy is the foremost component in sustainable development and is the driving force behind the existence of the whole humankind. All major and minor sectors within our ecosystem are kept alive by harnessing energy from various natural resources. Now coming to preliminary Economics, we find *Lionel Robbins* scarcity definition to be the most appropriate in this case. It states that, "*Economics is the science which studies human behaviour as a relationship between ends and scarce means which have alternative uses*". The statement implies that our resources are limited whereas our wants are unlimited. These limited resources are the medium to satisfy our unlimited wants, which in turn warrants choice-making, given their alternative uses. This definition also opens up a new avenue towards incorporating the environmental effects of consumption and production, into the subject matter of mainstream Economics. Thus, our economic growth rate, the standard of living measures must take into account the quality of environment and efficient use of energy resources to have a more realistic outcome.

The concept of scarcity of resources is what lies at the basis of our day-to-day decision making. A rational human being will always make efficient use of the resources and reap maximum satisfaction for his or her wants. But in reality, not all people think rationally, people are driven by their greed to satisfy their wants which makes them ignore the consequences of their actions. [In *Sapiens : A Brief History of Humankind*, Yuval Noah Harari states that the evidence provided by the past is that the resources are finite only in theory. Counter-intuitively, while mankind's use of energy and raw materials have "mushroomed" in the last few centuries the amounts available for exploitation have only increased. With technological progress and research , we not only produce ways to exploit the existing resources but also new types of energy and materials.] The exploitation and overuse of resources will lead to their rapid decline and if they run out the entire system will collapse and the future generations will suffer immensely. Thus, it became necessary to adopt sustainable development measures to prevent the rampant exploitation of existing as well as new resources. Sustainable development in simpler terms is the development that meets the needs of the present ,without compromising on the ability of the future generations to meet their own needs .In September 2015, United Nations member states adopted a global development agenda known as "Transforming our world : the 2030 Agenda for Sustainable development", the commonly known Sustainable Development Goals(SDGs) .The 17 SDGs cover everything from energy and climate ;to water,

food and ecosystems; to health and poverty; to jobs and innovation; among a number of other objectives. Energy is primarily dealt in Sustainable Development Goal 7 (SDG7) which aims to “*Ensure access to affordable, reliable, sustainable and modern energy for all*”. The three “Targets” pinned under this objective by the United Nations are :-

- Target 7.1: By 2030, ensure universal access to affordable, reliable and modern energy services [The target indicators are Proportion of population with access to electricity and the Proportion of population with primary reliance on clean fuels and technology.]
- Target 7.2: By 2030, increase substantially the share of renewable energy in the global energy mix. [The target indicator is Renewable energy share in the total final energy consumption.]
- Target 7.3: By 2030, double the global rate of improvement in energy efficiency. [The target indicator is Energy intensity measured in terms of primary energy and GDP.]

In accordance with the SDG 7 and its targets the United Nations is set to open a new world of opportunity for billions of people. They believe that by transforming economies and lives of people through sustainable development they can contribute towards safeguarding the planet. So as to fulfil their beliefs and goals they are working alongside the Government to improve energy efficiency and build up infrastructure to harness renewable energy and increase its use. The work of the United Nations in terms of energy focuses on mainly four areas, namely,

- (a) improving the understanding of science and the links between energy and the environment
- (b) providing Government with environmentally sound policy advice ,
- (c) catalysing public and private finance for clean energy ,
- (d) supporting the uptake of clean energy techniques .

The combined efforts of the UN and the Governments of different countries have so far produced the following results. As per the United Nations statistics, the global electricity access rate has increased from 87 percent in 2015 to 91 percent in 2021, serving close to an additional 800 million people. But the pace is lagging for the least developed countries where 675 million people still lack access to electricity in 2021. Between 2015 and 2021, the proportion of people with access to clean cooking fuels and technologies increased only by 7 percentage points and around 29 percent of the global population still rely on inefficient and polluting cooking systems. So at the current pace a quarter of the population will still be using inefficient cooking systems by 2030. The use of renewable sources of energy in the electricity

sector is growing having the largest share of 28.2 percent in total final energy consumption. However the progress in heating and transport sectors has been limited over the past decade. The Global primary energy intensity (the amount of energy used per unit of wealth created) improved by a rate of 1.4 percent between 2015 and 2020 . But due to the COVID-19 crisis the improvement rate slowed down by 0.6 percent .So as to make up for the lost time ,energy intensity improvements must be an average of 3.4 percent until the year 2030.

India has made significant progress in achieving the sustainable development goals. It has been ranked 121 in Sustainable Development Report -2022, with an SDG score of 60.3. In terms of deployment of renewable sources of energy, Government of India has set up various initiatives. It had set a target of achieving 175 GW of renewable energy capacity by 2022 out of which 100 GW of this would be coming from solar energy .As of July 2023, the installed solar capacity stands at 70.10 GW and is ranked 5th in solar PV deployment across the globe at the end of 2022. India has also developed infrastructure to harness wind energy. As of 31stAugust2023, the total installed wind power capacity is 44.089 GW. Thus, the more dependency on renewable sources of energy helps a nation to mitigate its carbon footprint and increase the standard of living in terms of cleaner environment.

The sustainable development, though necessary, is a process facing myriads of challenges. The challenges are recognised worldwide and are uncountable. To provide for the needs of the present without comprising with future generations, requires tailored actions having short, medium and long term implications. These are however are conflicting in nature against each other and hence can pose serious challenges upon implementation. The UN statistics (*Para : 4*) already provide a picture of the lag and inefficiency in various sectors that occur while implementing the SDG goals . There are still millions of people who lack access to modern energy resources. To overcome this deprivation, significant investments and infrastructure are to be made and innovative ways are to be found out to reach remote areas. The transition of energy from fossil fuels to renewable sources, face challenges in terms of intermittency, storage and grid integration. To ensure a successful transition, new technologies must be developed. The developing countries find it difficult to mobilize funds for financing in renewable energy projects. To overcome this difficulty attracting private investments is crucial. At the same time, the energy depletion being a global challenge requires international cooperation. The social and cultural factors may influence and act as a barrier in the adoption of new energy technologies. So countries must collaborate and make diplomatic efforts to ensure fair and equitable distribution of energy resources and share the best practices to accelerate progress towards sustainable energy. Thus, addressing practicability bottlenecks

requires a multidimensional approach involving government, private sector, civil society and international organizations.

The United Nations environment programme has developed a concept of “green economy” based on “low carbon, resource efficient and socially inclusive” model. This green economy brings about growth in employment and income by investing in such economic activities, infrastructure and assets which help in reducing carbon emissions and pollution and thereby enable the conservation of biodiversity and ecosystem services. The Green economy provides a macro-economic approach to sustainable economic growth with a central focus on investments, employment and skills. According to “*Green Future Index 2022*” report countries like Iceland, Denmark and Netherlands were the most prepared for a low- carbon future, with United Kingdom and Norway entering in the top 5 list. In India, the Union Budget 2023 reiterates India’s firm stance on “green growth” by highlighting government’s primacy on sustainable development. Thus, the green economy can be the sole remedy for ecological risk facing the future of sustainable development.

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Green Energy and Transitional Economy

Namrata Karia

"Sustainable Development"- a term first coined by Barbara Ward, founder of the International Institute for Environment and Development, is now a catchword in the context of the world economy. 'Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. (Brundtland Report, WCED). This approach of sustainability puts forward a trade-off between future development and higher present consumption of finite resources. It is basically a far-sighted phrase which focuses on the idea of minimizing the 'reckless destruction of the stored-up products of nature' in order to lessen the 'injury done to posterity'(Alfred Russell Wallace,1898). For instance, the escalation of oil prices in the past alarmed the nations regarding the overexploitation and exhaustion of crude oil, posing a threat to the global economic growth in the years to come.

The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by the United Nations in 2015 aiming to reduce inequalities, hunger, poverty; improving health; controlling climatic changes; environmental education, awareness and betterment. The SDG 7 that is "*Ensure access to affordable, reliable, sustainable and modern energy for all*" is about accelerating electrification, increasing investments in renewable energy sources and investing in improving electricity grids which is a key for development in the fields of agriculture, transportation, healthcare etc. It also ensures a transition from the usage of polluting fossil fuels which are limited to diversified and low-carbon energy resources.

Development of countries and depletion of natural resources go hand in hand, unless and until we find alternatives for the latter. The fossil fuels do not replenish themselves as fast as they are consumed. Moreover, these finite resources, when extracted or used for production purposes, release high amounts of greenhouse gases and health-endangering pollutants. This drainage of the exhaustible resources would in turn make our country dependent on foreign imports in future adding to the expenditure and outflow of foreign currency leading to other macroeconomic problems. Thus, increasing eco-anxiety has resulted in a call for economical, social and environmental sustainable practices. Here comes the concept of "green energy", which is nothing but an eco-friendly, quickly restorable and harmless source of energy. It benefits us by reducing carbon footprints and also has a zero-emissions profile. For instance, the energy produced by the sunlight, wind, moving water, organic and waste materials etc. are categorized under the head of green energy as they are non-exhaustible, clean and does not require mining activities, which can damage the ecosystem. The infrastructure required for the

production of green energy would be more flexible due to the surplus nature of the sources. This also implies that the prices would not be affected by the supply chain disruptions or international price hikes. As the concern towards the environment rises among humans, the demand for green jobs is in the limelight. The sector of green energy production has seen a huge creation of job opportunities, mainly in the rural areas, seeking the eradication of poverty. From 2015 to 2021, the proportion of “green talent” rose by 38.5 percent, increasing from 9.6 percent to 13.3 percent (Deloitte, 2023). Globally, the renewable energy sector added 700,000 jobs in 2020 to 2021, reaching 12.7 million, reports International Renewable Energy Agency (IRENA).

We can thus meet the needs of energy for human civilization, while taking good care of sustainable development. Focusing on the recent hike in oil prices and its demand, the immediate transition to an alternative is extremely awaited, the best representative being the biofuels. Biofuels, which are non-toxic and degradable, are derived from the organic waste matter. They can also be obtained by burning or fermenting the plant based by-products and biological feedstock, based on the fact that the energy basically comes from the sun and is stored after photosynthesis. A part of biofuel also comes from algae, which produces a large amount of energy. Being a by-product of renewable feedstock, biofuels can be restored endlessly. This alternative source of energy not only helps to do away with the environmental problems but also reduces the waste products by making good use of it. Biofuels are produced by conversion of the wastes into biogas which is composed of carbon dioxide and methane in particular. This form of biogas can easily replace natural gas, irrespective of the technology or machinery being used, thereby inhibiting the carbon emissions in the air in a cost effective and efficient way. However, the carbon dioxide generated can be liquefied and put into use in the food, chemical and other industries. The introduction of this green resource has witnessed a strong decreasing trend in the use of coal in many European and North American countries and bioenergy occupies almost three-fourths of the total renewable energy used (IEA, 2021).

The very new idea of going green in terms of resources, has led to various economic benefits. In order to adapt to this new form, huge projects need to be undertaken which in turn increases investment by the government as well as the industrialists. Moreover, this means of energy production is incentivized by providing subsidies; quotas etc which encourages interested producers to expand these projects. As new and advanced factories are set up, the economy sees an increase in the demand for laborers; creating jobs and strengthening the rural areas. Increase in employment leads to higher production. These biogas and biomethane plants enable deployment of resources in the fields of agriculture and industry which befits the idea

of circular economy. In most cases, the methane-rich gas produced by the Sewage Treatment Plants (STPs) is converted into electricity to run the factory itself.

Biofuels find a great scope in the field of transportation. Transportation is responsible for approximately 50% of the global oil consumption and 25% of the global carbon dioxide emissions. Thus, taking control over this sector by reducing such emissions and improving the energy production process requires the government to switch to green alternatives to maintain a good air quality. Investments made to bring in Liquefied Petroleum Gas (LPG), Compressed Natural Gas (CNG) and electronic vehicles, have been futile as implementation of such alternatives required modifications in the entire infrastructure. The replacement of transport fuels with biofuels would increase domestic dependence and reduce the import of the same.

The widespread apprehension about the recent climatic changes is also addressed by the biofuels. Being a clean source of energy, they reduce the anthropogenic emissions of harmful substances in the environment as does the fossil fuels. Advancement in technology and research in biofuels might also lead to no harmful emissions in future.

The concept of sustainability draws a relationship between humanity and nature, fulfilling the needs of both simultaneously. The term “Green Economy” is in line with ecological economics, which describes economic growth as environmentally sustainable. The green growth policies improve job opportunities in various sectors like agriculture, industries, commercial sectors and also results in increased labor productivity. Biofuels can result in an increased amount of energy produced per unit of labor (being economically useful) and a reduced amount of waste products per unit of energy produced (being environmentally useful); thus, strengthening the local economy in the long run.

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Energy Policy in the Need of Sustainable development and the Challenges Ahead

Dipanwita Chatterjee

The Nobel Peace Prize-winning Kenyan political activist, Wangari Maathai remarks, “We owe it to ourselves and to the next generation to conserve the environment so that we can bequeath our children a sustainable world that benefits all.”

Energy, which is needed for every aspect of life, plays a significant role in the development of countries. Countries, both developed and developing, need enhancement in technology to be able to use energy efficiently and be in an advantageous position in global competition and thereby ensuring sustainable development. Sustainable development is an organising principle that entails the adoption of production and consumption patterns which meet the needs of the present without jeopardizing the goals of future generations. The World Commission on Environment and Development had originally defined sustainable development in its 1987 Brundtland report as the ability to meet the requirements of the present without compromising the ability of the future generations to meet their own requirement demands. This report had energy as one of its key components. Sustainable development aims at 3 main focal points: economy that helps in attainment of balanced growth, society that ensure equal access to all resources by every human being and finally, environment which aims at preserving the ecosystem. Its foremost aim remains at addressing the growing environmental challenges. The application of sustainability to energy lacks a globally agreed-upon interpretation. Descriptions of sustainable energy frequently encompass diverse elements of sustainability, spanning environmental, economic, and social dimensions. Initially, sustainable energy development primarily concentrated on emissions and energy security. Yet, since the early 1990s, the scope of the concept has widened to encompass more extensive evaluations of social and economic aspects.

Energy is the cornerstone of sustainable development. It involves influencing the economic, social and environmental dimensions. Transitioning of the society to a cleaner and more sustainable energy system is indispensable for addressing the rapid global challenges and for building a future that is economically prosperous, socially equitable and environmentally resilient.

Countries that use energy efficiently succeed economically and have led the field in global competition. The energy crisis is one of the biggest concerns of the modern-day world with the rising demands of industrial society and the depletion of natural energy resources. However, this issue cannot wait to find its solution in the long run but must find an effective

way out in the present times, because these natural resources occurring naturally, can take millions of years to replenish themselves. Again, the problem of environmental pollution crops up with the use of such non-renewable resources, forcing the government and the concerned authorities to look to renewable sources as a solution for their problems.

Since time immemorial, nations had prioritized material production and the economic goal of increasing output and growth. Thus, traditionally, development referred to economic growth associated with important social dimensions. However, no such emphasis was made in the field of sustainable use of energy. By the 1980s, enough evidence had been gathered to prove the detrimental effect of environment degradation on economic growth and development. Thus, new proactive safeguards like environmental assessments were introduced. Strategies for the sustainable energy development are entrenched on the idea of efficiency improvement in existing energy systems and the introduction of renewable energy sources instead of the non-renewable fossil fuels.

Every country's economy can be described as an integrated system that consists of streams of energy-producing and energy-using activities. Energy is crucial for practically all aspects of sustainable development and also for the economy as it is the driving force for all economic activities. This characterization of energy directs our attention to its sources in nature, and the activities that convert this energy, and use it to produce goods, services and household consumption, thereby traditionally being treated as an intermediate input in the production process. This treatment of energy's role understates its importance and contribution to the development of society as a whole. All economic activities and processes require some form of energy effectively making it a critical factor of production. Given the state of technological advancement in the economy, capital and labour perform supporting roles in converting, directing and amplifying energy to produce goods and services that are needed for the growth of an economy. Energy thus plays a critical role in social and economic transformation.

Lack of access to energy imposes severe constraints on national development resulting in adverse sub-optimal outcomes where poor people are often affected miserably. Energy is one of the crucial elements of all four pillars of sustainable development — human, economic, social and environmental. Developed economies have proved that replacing human and animal labour with more convenient and efficient sources of energy and technology leads to gigantic economic growth. At the national level, energy propels economic development by serving as the launch pad for industrial growth via improvement in transport and communications, network facilities and by providing access to international markets and trade. Reliable, efficient

and competitively priced energy supplies also attract foreign direct investment — an influential factor in boosting economic growth in recent times. At the local level, energy facilitates economic development by improving both labour and capital productivity and enabling higher income generation through development in agriculture and other employment generation areas. Renewable sources of energy, directly drawn from the environment, require sound management to be sustainable. Furthermore, energy use affects the environment. Emissions from fossil fuels; a non-renewable energy source reach beyond the local and national levels to affect the global environment causing global warming and climate change. These effects are amplified manifold to create widespread destruction by the melting of ice caps, rise in sea level, and even floods and droughts. The impoverished people often live in the most ecologically sensitive and vulnerable regions that may be the worst affected by the predictable effects of climate change. The risks faced by the impoverished are often increased by the unsustainable use of biomass resources, for example by inhaling the harmful gases released, even when the emission is from industries for commercial purposes.

The use of renewable natural resources combined with efficient supply and the use of fossil fuels with cleaner technologies can help reduce the environmental effects of energy use. It can further go on and help the developing countries grow their economies while also replacing existing, inefficient polluting fossil fuel technologies that pollute environment with cleaner sustainable technologies that benefit society as a whole. For example, even though the cost of constructing hydel power stations is high, with increased chances of flood, it is pertinent to note that there are no standby losses and abundant resources. Solar energy, even though the manufacturing of photovoltaic panels is high, one must look at the infinite potential of energy and the fact that it causes no pollution. Again, with wind energy multiple problems crop up with the requirement of large space and appropriate landscape, however, it is to be noted that in the long run wind farms are relatively inexpensive.

Even though the concept of cleaner and sustainable energy may seem alluring, the issue of the unaffordability of the poor cannot be taken as granted. Thus, as a precautionary measure, careful management of energy resources is extremely essential to promote rapid economic growth, protect ecosystems and provide sustainable natural resources at the same time. Furthermore, a continued investment in research is of paramount importance to overcome the challenges in the future. Adding to this improvisation of existing technology and invention of new technology which improves efficiency is vital for the growth of renewable energy sources. For such innovation a collaboration of the industry, academia and the government stand crucial. Imposition of numerous environmental regulations since the 1970s has been able to promote

sustainable usage of energy resources of which the most important one is the development of performance requirements. All pieces of equipment are to meet the emission standards before they can be bought and sold in the market henceforth.

Government policies play a crucial role in transforming energy systems, offering benefits like reduced greenhouse gas emissions, improved air quality, enhanced energy security, and reduced financial burdens. Renewable portfolio standards mandate increased use of renewable sources, while infrastructure development aims to boost efficiency and decrease energy consumption. Government support for research and invention of clean energy technologies, along with carbon pricing mechanisms, contributes to emission reduction. However, despite efforts, policy reforms as of 2023 fall way short of the goals as they are broadly geared towards conserving the resources and environmental issues [like Water Laws and Wildlife Protection Law(China), Biological Diversity Act, Hazardous Waste Handling and Management Rules and Noise Pollution rule(India)]as separate identities without considering their interconnectivity and their long-term effects. Current global policies also fail to give due importance to the rights of various indigenous communities and their roles in preserving the environment. International cooperation is vital for innovation and assisting poorer countries in achieving sustainable energy access.

With the development of Artificial Intelligence (AI) and machine learning (ML), and the help of programming it is easier to optimise the use of renewable energy based on huge data samples. AI and ML can predict and analyse parameters like weather, optimum energy distribution and its efficient storage, methods to improve load forecasting, etc.

Enhancing energy accessibility in the least developed nations and transitioning to cleaner energy sources are crucial for realizing a majority of the United Nations' 2030 Sustainable Development Goals. These goals encompass a wide array of issues, from climate action to gender equality. Sustainable Development Goal 7 specifically advocates for "ensuring access to affordable, dependable, sustainable, and modern energy for all," aiming for universal electricity access and clean cooking facilities by 2030.

With these measures we find some countries have already achieved their goal of switching over to renewable sources of energy of which some examples are noteworthy. Where Denmark shows its achievement in successful integration of wind power by utilizing flexible electricity markets and its interconnections with the neighbouring countries, Germany has made significant stride in solar power development and its use via favourable policies and incentives. Costa Rica even after being a developing country it has shown remarkable progress in its renewable energy adoptions so much so that nearly 98% of its electricity finds its sources

in renewable resources. In India with the setting up of Ministry of New and Renewable Energy one finds considerable progress in sustainable energy development, and today India stands 4th globally in terms of renewable energy production. Development and research institutes like National Institute of Solar Energy (Gurgaon), National Institute of Wind Energy (Chennai), Sardar Swaran Singh National Institute of Bio Energy (Kapurthala) have been set up for the improvement and development of renewable energy.

In conclusion the relationship between sustainable development and the role of energy is intricate and pivotal in shaping the future of our global society. They are interlinked pillars that support the encompassing goal of creating a balanced and resilient society. Sustainable development with its emphasis on meeting current needs without compromising the ability of the future generations to meet their own needs, requires a thoughtful and integrated approach for both energy production and consumption. Renewable energy sources once developed can be a veritable tool for sustainable development and overcome the problem of energy crisis in the world. Even though it promises a sustainable pathway for the future, it is not without its challenges. For this objective to be realised in the near future, the government and the technology-developing authorities must harness the potential of renewable energy resources that are available abundantly throughout the world. The path to a sustainable future lies in the collective commitment of all to address these challenges whilst embracing the transformative power of the renewable sources.

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Sustainable Development and Clean Energy: an outlook for 21st Century

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In this 21st century, there's hardly anyone who is alien to the concept of sustainable development. According to the definition adopted by United Nations (UN) conference on the environment and development held in Rio de Janeiro in 1992 sustainable development stands for "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The idea is to create a world in which everyone has access to the resources they need to live a decent life, without harming the planet. In the name of development local communities have been displaced, land deforested for urbanization and inefficient resource use are all common practices. As a result, the world is now facing several issues with no immediate solution like poor air quality, degraded land and climate change. The most important cause of all these impacts is the emission of fossil fuels. Over time we remain predominantly dependent on fossil fuels like kerosene, petrol, diesel, on lieu more and more emission of harmful greenhouse gases in the environment. Due to an increase in the greenhouse gases the average temperature of earth is mounting fast leading to intensification of global warming problem. CFCs (Chlorofluorocarbons) used in refrigerators and air conditioners deplete the ozone layer when they reach the stratosphere allowing inroads for harmful UV rays to the earth's atmosphere to the detriment of sustainability of life.

Sustainable development and economic growth of a country works hand in hand. With an increased amount of production although the GDP of the country increases but the growth in economic welfare remains really questionable. Now one might wonder why so. It is because with an increase in production, the environment is impacted adversely. To avoid this over the past decade, the green economy has emerged as an important policy framework for sustainable development in both developed and developing countries. A green economy is an economy that aims at reducing environmental risks and ecological scarcities, and that aims for sustainable development without degrading the environment. It presents an attractive framework to deliver more resource efficient, lower carbon, less environmentally damaging, more socially inclusive societies. The idea behind the foundation of green economy recognizes the fact that separation of economic development and environmental policies is artificial. The first step of moving towards a green economy is reducing dependence on non-renewable sources of energy by exploring ways to tap renewable energy viz. solar energy, wind energy, geothermal energy, biomass energy, tidal energy. Economic growth increases the level of energy use, especially the

need for fossil fuels. Renewable sources are environmentally friendly low-carbon energy sources which can be replenished once exhausted unlike non-renewable sources. They do not produce greenhouse gases (GHGs) like carbon. For instance, when compared to coal-fired power plants, electricity from renewable energy sources emits between 90 and 99% less greenhouse gases (GHGs) and produces 70 to 90% less pollutants. These technologies also create jobs and stimulate economic growth, which is essential for sustainable development. Renewable energy technologies have become increasingly important as the world faces the challenge of mitigating the negative impacts of climate change and reducing the dependence on finite and polluting fossil fuels. Additionally in several other factors such as energy supply security, energy dependency, climate change, energy price volatility, health issues, and environmental disasters, encouraged the consumption of renewable energy sources by emerging economies. Many countries are moving towards renewable sources of energy. India's need for energy is constantly surging to quench the country's current economic growth initiatives. A vital pre-requisite for a nation's economy to grow is the availability of growing amounts of energy. With the aim of providing energy across the nation, the National Electricity Plan [NEP] defined by the Ministry of Power (MoP) has created a thorough 10-year action plan. The use of renewable energy sources has been recognized as a key factor in promoting sustainable development.

Renewable energy resources thus reduce the dependence on fossil fuel and decrease the amount of harmful pollutants like carbon dioxide that are emitted into the atmosphere. These will never run out. Not only that we can now reduce our dependence on foreign energy sources and become more selfsufficient as we are now focusing on locally available energy sources like solar power and wind power. Besides this it can also be used to provide access in the rural areas where it was previously not possible. This will improve the quality of lifestyle of rural people as energy is required for several things like lighting, cooking etc. Rural people mostly depend on firewood which is obtained by cutting down of trees. If these are substituted with renewable resources it would also reduce deforestation. The maintenance requirements of renewable energy is also lower. Renewable energy technologies can create jobs and stimulate economic growth, particularly in the manufacturing and installation of renewable energy systems. For example the growth of the solar power industry has created a large number of jobs in the production of solar panels and the installation of solar systems.

Although the renewable sources are more environment friendly than the non-renewable sources but their initial cost of installation is very high. A high upfront capital outlay is needed for renewable energy. Wind turbines, solar panels, hydroelectricity plants all require a substantially huge financial outlay. With most of the plants being installed in rural areas there

will be additional cost of power lines to get electricity generated to towns and cities. Thus, renewable sources of energy are expensive. It is also total dependent on weather. Wind and solar energy can be better investments when lifespan costs are considered. Lack of infrastructure is a barrier to renewable energy development. The present infrastructure is mainly built for fossil fuel plants and nuclear plants. Infrastructure is needed to build the facilities. These often use non-renewable energy during their construction phase. It takes many years of renewable energy generation to offset carbon emission.

Any natural calamities or even night time, calm weather will disrupt the production of these energies. We need the wind to blow for the wind turbines to move. We need clear skies in the daylight to produce solar energy. Thus, an electricity grid that is too heavily reliant on renewable energy is vulnerable to extreme weather conditions. Now as these sources of energy are not reliable, we need a backup. Storage technologies are available but they are costly. They also take up a lot of space. Although we are aware of the necessity to substitute the non-renewable sources with the renewable sources but it remains a difficult aim.

Despite of all the obstacles we must embrace sustainable development to preserve the environment, protect biodiversity, mitigate climate change and foster long-term economic growth. The earth is a storehouse of resources enough to sustain both the present and future generations but only if we use them carefully otherwise it would soon turn into a barren land.

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Clean Energy and Road Map for Sustainable Development: A Critical Perspective

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In the present century, world is at the cusp of trade –off between economic growth and inter-generational equity. During the United Nations Summit in September 2015, world leaders adopted the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development. In official capacity, the SDGs went into effect on January 1, 2016. Countries are expected to mobilise efforts by 2030 to combat poverty, inequality, and climate change while making sure that no one is left behind, while keeping these Goals in mind.

The success of the Millennium Development Goals (MDGs) served as the foundation for the SDGs. The Sustainable Development Goals (SDGs) urge all nations, rich or poor, to take action to safeguard the environment and advance prosperity. They recognize that ending poverty must go hand-in-hand with strategies for addressing a variety of social needs, such as health, education, social protection, climate change, environmental protection and economic growth. Although governments are expected to set up national frameworks for the accomplishment of the 17 Goals, the SDGs are not legally binding.

Reviewing the progress made in implementing the Goals is the primary responsibility of all countries, and this will necessitate the timely, accessible, and high-quality collection of data. Based on analyses conducted at the national level, regional follow-up and review will support global follow-up and review.

Energy is at the core of many of these Sustainable Development Goals. Increased access to electricity, providing clean cooking fuels, reducing wastage of energy, curbing air pollution that kills millions around the world are some of the energy-related issues mentioned in the SDGs. One of these Goals – commonly known as SDG 7 – aims to “ensure access to affordable, reliable, sustainable and modern energy for all” by 2030. SDG 7 is about ensuring access to clean and affordable energy, which is essential to the growth of business, communications, agriculture, healthcare, education, and transportation.

Targets of SDG 7 are as follows:

- Ensure that everyone has access to modern, dependable, and reasonably priced energy services by 2030.
- By 2030, double the rate of improvement in energy efficiency worldwide.
- Significantly raise the proportion of renewable energy in the world's energy mix.

- Strengthen international collaboration by 2030 to make it easier for people to access clean energy research and technology and to encourage investment in clean energy technology and energy infrastructure.
- By 2030, to provide modern, sustainable energy services to all developing nations, especially least developed nations, small island developing states, and land-locked nations.

Affordable and dependable energy is essential to our daily existence. Energy consumption, however, is the primary cause of climate change, contributing to almost 60% of all greenhouse gas emissions worldwide.

About 30% of the energy used in the electricity sector comes from renewable sources, but there are still issues with the heating and transportation industries. According to UNDP Sustainable Energy Hub bulletin, renewable energy installations in developing nations are growing by 9.6% annually, but despite their huge need, foreign financial flows for clean energy are still declining.

Investing in clean energy sources like solar, wind, and thermal energy is necessary to guarantee that everyone has access to reasonably priced electricity by 2030. A critical goal that can promote growth and benefit the environment is for all developing nations to upgrade their infrastructure and technology in order to provide clean energy. Every industry is supported by a robust energy system, including commerce, healthcare, education, infrastructure, agriculture, communications, and advanced technology. Poorer nations' access to electricity has started to pick up speed, energy efficiency keeps getting better, and renewable energy is progressing remarkably.

However, there are numerous obstacles in the way of achieving SDG 7 targets, particularly for countries where people at large are to depend on hazardous and environmentally harmful fuels for cooking, better access to clean and safe cooking fuels is required. Fossil fuels, like coal, oil, and gas, have been important sources of electricity production for many years. However, burning fossil fuels releases a lot of greenhouse gases, which contribute to climate change and have negative effects on the environment and the health of people. Not only a few, but everyone is impacted by this. The world's consumption of electricity is also growing quickly. Simply put, nations cannot run their economies without a consistent source of electricity.

Without electricity, many schoolchildren are unable to complete their homework at night, women and girls must spend hours fetching water, clinics are unable to store vaccines for

children, and people are unable to operate profitable businesses. Around a third of the world's population, primarily women and children, will continue to be exposed to dangerous household air pollution if we do not reach our target by 2030. The slow progress towards clean cooking solutions is a serious global concern because it affects both human health and the environment. 675 million people, mostly in LDCs and sub-Saharan Africa, lack access to electricity. That equates to around one in ten people globally. According to estimates published by UNDP Sustainable Energy Hub, between \$35 billion and \$40 billion worth of investment will be required yearly between 2021 and 2030 to achieve universal access to electricity. Sub-Saharan Africa has the lowest rates of access to clean cooking technologies and fuels, with 0.9 billion people lacking access to clean cooking in 2021. This is because progress in clean cooking fuels did not keep up with population growth.

From powering healthcare facilities and providing clean water for essential hygiene to enabling communications and IT services that connect people while maintaining social distancing, energy services are essential to preventing disease and fighting pandemics. By putting an emphasis on energy-efficient practices, investing in renewable energy resources and implementing clean energy technologies and infrastructure, nations can accelerate the transition to an inexpensive, dependable, and sustainable energy system.

Companies can pledge to source all of their operational electricity needs from renewable sources and preserve and safeguard ecosystems. By giving telecommunications top priority and encouraging less energy-intensive modes of transportation like train travel over automobile and air travel, employers can lower the internal demand for transportation. By increasing their investment in sustainable energy services, investors can hasten the introduction of new technologies from a wide range of suppliers. When not in use, turn off all appliances, including your computer, and save electricity. You can cut your carbon emissions by walking, biking, or using public transportation. By 2030, we must ensure that everyone has access to energy. To do this, we must expedite electrification, boost renewable energy investments, increase energy efficiency, and create supportive legislative and regulatory frameworks.

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Energy and Holistic Sustainable Development: A Quintessential Nexus

Purvi Gupta

“A transition to clean energy is about making an investment in our future”. The poignant reliance on coal and petroleum to cater energy needs at large is indispensable, especially for the less-developed countries, yet alarming for the world as a whole .This narrative is testified in as much as these fuel sources are non-renewable in nature and emit pollution into our physical environment and the atmosphere. As such, these sources, namely fossil fuels, have limited availability, henceforth would eventually get exhausted. In what is more dismaying, the unrestrained use of fossil fuels can take sustainability of life on this earth to an acute crisis by causing permanent damage to environment and its ecological balance, more than any else. Combustion of conventional sources of energy fuels global warming. Coal and oil pour toxic gases into the environment, impacting general health, causing respiratory issues, and reducing live expectancies. Simple extraction of oil and coal can affect the environment of an area, pose a threat to the livelihoods of some, or take a more serious form of devastating oil spills. Energy is critical to economic and social development, but depending on the way it is produced, transported and used, it can contribute to both local environmental degradation, such as air pollution, and global environmental problems, principally climate change. The energy forms, if utilised in a cleaner, economical and better manner will lead not only to an economic growth but also an increase in the development of a nation .This development should be taken into analysis keeping a record of the long term sustainability. Cleaner energy can certainly help us mitigate and sidestep at least some of these issues, and bring about a better tomorrow. In this regard, it is most worth a while to consider ‘Holistic Sustainable Development’- a concept entrenched in the interconnectedness of various aspects of the environment and society and seeks to balance economic, social, and environmental well-being.

The challenge before the global energy sector is twofold: first, to dramatically increase access to affordable, modern energy services in the countries that lack them, especially for poor communities; and, secondly, to find the mix of energy sources, technologies, policies, and behavioural changes that will reduce the adverse environmental impacts of providing necessary energy services. Energy was one of the key themes in the World Summit on Sustainable Development, and this was an opportunity to take stock of international accomplishments and identify specific national and international action plans for moving forward. With the Summit now past, it is time to reflect on whether the outcomes match the challenges, and what actions are required to implement the energy aspects of the Johannesburg Plan of Implementation.

Providing affordable, adequate, and reliable modern energy supplies to the vast majority of the world's population remains a major challenge: these supplies are still beyond the reach of some two billion people. . At the same time, current methods of producing and using energy have environmental and health impacts that are increasingly endangering the welfare of communities and biodiversity world-wide, while problems of oil supply security are linked to increasing regional political instability. To this effect, there should be a safer method which ensures the health safety of the workers in the working environment. In this regard, comes the concept called Ethical Sourcing, which refers to ensuring that workers are globally protected from unsafe, unhygienic or working conditions which are polluted and exploitative. A large share of the population in both rural and urban areas in these countries does not have access to safe, affordable fuels to provide cooking, lighting, or heating.

Furthermore, wide disparities exist within and among developing countries, which in certain cases contribute to social instability and affects basic human development. The fact that two billion people live in energy poverty, despite the implementation of a wide range of grant- and loan-based programmes in the developing world, is the most compelling evidence that a new approach is needed—one that can mobilise significantly more financial resources and direct them in a way that will have the greatest effect on development. Key areas that must be addressed include the impact of energy reform programmes (including private sector investment) on the poor, the excessive focus on upstream investment and large-scale fossil energy supply projects, the lack of appropriate institutional structures to support international energy and development programmes, research and development not being sufficiently relevant to policy, and the lack of funding to support major infrastructure investments).

As one major research stride, between 1974 and 1998, International Energy Agency (IEA) member countries spent 8% of their research and development budgets on renewable energy, 7% on energy efficiency, 14% on fossil fuels, and 59% on nuclear technologies. Sustainable production technology plays a pivotal role in addressing environmental challenges and fostering long-term viability. It is to be noted that the environmental impact that has received the most attention in the 10 years since the United Nations Conference on Environment and Development (UNCED) is climate change, and this problem cannot be addressed without major changes in the energy sector. Thus, it is perhaps by integrating eco-friendly practices into manufacturing processes, companies can minimize resource depletion, reduce waste, and mitigate their ecological footprint. This approach emphasizes the efficient use of raw materials, energy conservation, and the incorporation of renewable resources. One

key aspect of sustainable production technology involves the adoption of cleaner and more energy-efficient manufacturing methods. This not only reduces greenhouse gas emissions but also lowers operational costs for businesses. Additionally, the implementation of circular economy principles, such as recycling and reusing materials, promotes a closed-loop system that minimizes waste and contributes to a more sustainable supply chain.

Technological innovations, such as 3D printing and smart manufacturing, play a crucial role in enhancing sustainability. These advancements enable precision in production, minimizing material wastage and optimizing resource use. Moreover, the integration of IOT (Internet of Things) devices facilitates real-time monitoring of energy consumption, allowing companies to identify areas for improvement and optimize their processes for sustainability. Furthermore, sustainable production technology embraces the use of alternative and eco-friendly materials. From biodegradable plastics to plant-based alternatives, these innovations contribute to reducing the environmental impact of manufacturing. Eco-friendly practices not only appeal to environmentally conscious consumers but also contribute to building a positive corporate image, fostering brand loyalty, and attracting socially responsible investors.

Over the past two decades sustainable development has increasingly become accepted as an important objective for governments and societies. It is about reforming institutions and social practices to ensure a more environmentally sound and equitable development trajectory. Sustainable development is best understood as an emergent international norm that denotes a specific kind of development trajectory. It is associated with important values such as the promotion of human welfare, the preservation of ecosystems, inter- and intra-generational equity, and public participation in development decision making. First, sustainable development emerged because of concern that existing development pathways are not sustainable. Secondly, sustainable development implies change in practices of societal governance. Sustainable development is not a spontaneous societal product. Thirdly, sustainable development requires a measure of “societal self-steering”. To put it in other words, society as a collective considers what types of a future are more desirable, and what pathways are to be avoided. Fourth, in developed countries such as Canada the environmental dimension of sustainable development is particularly critical. This is because it is with respect to the environment that governance practices have most clearly failed to deliver. Finally, sustainable development requires active governments.

In the context of sustainable development, Green Energy has a wide scope. It is the form of energy that causes less or negligible harm to the natural environment. Green energy is

a solution to greater sustainability in our power grid, and a more efficient utilization of available resources. However, the term is met with confusion by some, and commonly used to refer to renewable by many. In the context of sustainable development, Green Energy has a wide scope. The recent years have received considerable attention from environmental research organizations, environmentalists, and policy makers as their concern for the present climate crises intensifies. Noticeably, one of the key objectives of sustainable development is to secure the supply of energy resources for all generations, and that must be least costly and release minimal emission. Therefore, green energy, which are less costly, efficient needs to be explored for improving the sustainability of a country's productive sector, people's standard of living and environment, are necessary. Green energy stands as a beacon of hope in the intricate landscape of sustainable development, weaving a tapestry of positive contributions that resonate far beyond the present. In the intricate dance of progress, green energy emerges as a vital partner, choreographing a symphony of benefits. Foremost, its environmentally benign nature mitigates the perilous dance with climate change, curbing carbon emissions and fostering a harmonious coexistence with our planet. Moreover, the intricate web of sustainable development finds strength in the decentralized nature of green energy solutions, empowering communities to be architects of their energy destiny. As the intricate gears of economic growth turn, green energy becomes the linchpin, fostering job creation and economic resilience. The tapestry extends to social realms, as access to clean energy becomes a linchpin in empowering marginalized communities. In this complex narrative, green energy stands as a catalyst for a brighter future, intertwining economic, environmental, and social threads to craft a sustainable legacy for generations to come. Affordability of clean energy is essential in this context. The energy forms must be economical and feasible in the long run too. Affordable and Clean Energy is also one of the 17 Sustainable Development Goals (SDGs) established by the United Nations in 2015. It aims to ensure universal access to reliable, affordable, and modern energy services while promoting the use of renewable energy sources and enhancing energy efficiency.

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Harnessing Sustainable Sources of Energy: The road-bumps ahead

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From the rubbing of 2 stones to lighting a fire to soften the meat to processing the decomposed crude of the carcass of that animal and stone, energy sources have always evolved throughout the history of humankind. The mid-19th Century saw the use of primitive sources like wood and charcoal - biomass. The needs were simple until the Industrial Revolution which brought coal into the picture. The use of the two was about half and half by the time the 20th century came around.

The 20th Century had a basket of sources. First, the world had petroleum and hydropower. The '60s saw the presence of nuclear energy, with the more staple renewables- wind and solar showing up by the 80s. This evidently shows how the switch and emergence of energy sources sped up from taking centuries to decades.

In 1987, the Brundtland Commission highlighted some key factors that need to be kept in mind while talking about Sustainable Energy. It stated that we need an energy source that is safe, environmentally sound, and economically viable. Not only this but it should also sustain human progress in the long term.

The renewable sources of energy that are more prevalent hold several pros and cons in this respect. All sources of energy, no matter it is renewable or non-renewable emit greenhouse gases. It is the amount which ghastly differs. According to the World Resource Institute, renewable sources of energy emit about 50 g of carbon dioxide per 1000 kWh with continued use, while fossil fuels emit 1000 g of carbon dioxide per 100 kWh with perpetual use.

Geothermal energy is a prime example of the problem of economic viability and environmental soundness. This energy source requires tapping into the molten rocks near the earth's surface. It involves drilling and digging of ground to access the geothermal energy, hence due to high installation and infrastructure costs, it's only available to areas that have hot molten rocks, close to the earth's surface. Further, the drilling, as well as the cooling process, causes water and air pollution. Yet, according US Energy Information Association, it produces 97% less acid rain-causing sulphur compounds and about 99% less carbon dioxide than fossil fuel power plants of similar size.

Another controversial energy source is Nuclear energy. The Nuclear source requires Uranium which needs to be mined and extracted. This process is more hazardous and energy-consuming than the mining of a non-radioactive material like coal. Additionally, the nuclear wastes generated need proper disposal. Radioactive pollutants in the nuclear power plant plume

can settle and contaminate individuals outside, as well as buildings, food, water, and livestock. Inhaling radioactive elements or consuming contaminated food or drink can also introduce these substances into the body.

Residents who live near a nuclear power station and are exposed to radiation run the risk of developing long-term health problems including cancer. The world has seen some huge disasters due to nuclear power plants. The Fukushima Daiichi nuclear catastrophe, which led to plant meltdowns and radiation releases in Japan, was sparked by an earthquake and tsunami in 2011. Massive radiation leaks were the consequence of a disastrous catastrophe that happened in 1986 at the Chornobyl nuclear power plant in Ukraine. A partial meltdown at Pennsylvania's Three Mile Island in 1979 sparked concerns about public safety in the US. In 1961, a criticality accident at an experimental reactor in Idaho led to three fatalities and reinforced safety measures.

When associating controversies with energy sources, one can never not include all the controversies and headlines hydropower projects create in India. Be it the Dibang Dam displacing the tribal community of Idu Mishmi and harming the biological diversity of Himalayan biodiversity, or the Tapovan Vishnugad project that allegedly led to the ultimate sinking of the entire town of Joshimath, these hydro-power projects generally are built upon the land of tribal communities or forested areas. This can also be seen in the case of the infamous hydropower project- the Sardar Sarovar Hydro Electric Project.

Moving away from the water and jumping into the Sunlight, the manufacturing process of a Solar power plant produces a significant amount of carbon emissions. The process requires materials like quartz which need to be mined, cleaned and further processed at a significantly high temperature. It also involves the use of hazardous chemicals, the disposal means of which can be questionable. Furthermore, currently faulty solar panels that are no longer in use are treated exactly like regular e-waste. This means that the efficient recycling process of these panels is solely dependent on the country.

Speaking of recycling, according to The University of Cambridge estimates, 43 million tons of used wind turbine blades will need to be disposed of by 2050. This is because the blades are designed to be durable, and the materials used to build them can't currently be recycled. Biomass, which can be adopted over a wide range of geographies poses a key challenge with its energy generating process. It burns the wastes collected in a boiler to produce high-pressure steam which rotates turbine blades to generate electricity. This although is a lot less harmful than a thermal power plant, does not seem like the best solution.

When it comes to adopting an energy resource, analysing the resource is simply not enough. A country can only implement this switch if it is stable. India both in the G20 summit as the leader and in COP'28 pushed the wealthy nations to adopt the net zero emission, while did not sign this pact along with China. India stressed the idea wherein the Wealthy nations must take charge of Climate Action due to historical abuse of the environment to get the very developed status.

This developed status had been used by India as both a shield and sword. Union Environment Minister Bhupender Yadav has commented that until India reaches the developed country status, it will not attempt to reduce coal power and efforts are being made to increase the coal-based power generation capacity by 17 gigawatts. Amidst all this, India pushed for developed countries to aim for Net negative emissions and not just Net Zero.

India's aim is to reach the status of a developed country by 2047 but its decision to withhold much progress in the Energy sector might prove detrimental to this goal. There are 3 major organizations that classify a country- UNDP, the World Bank and IMF's World Economic Outlook. The UNDP classifies a country based on its Human Development Index (HDI) which factors in longevity, Education, and Income. The developed countries are in the top Quartile of the HDI Distribution. The World Bank classification uses per capita income while the IMF classifies countries as Advanced Economies and Emerging markets and developing countries. Hence, if India does not expand on renewable resources, and instead continues to expand coal-based power plants, the quality of living will be affected. Hence the longevity factor for India will take the brunt. On the other hand, data will definitely improve for other countries, creating a gap between India and the rest of the Developed countries, failing India to reach the top quartile for UNDP. Furthermore, the IMF's warning that India would be frowned in debt of 100% of its GDP by 2028 makes it seem impossible for it to fall under the category of the World Bank which expects those countries to lend out loans to others.

Yet we cannot deny the fact that right now India is not in a situation to take on the Net Zero Emission pledge. India needs additional financing of USD 101 billion to further expand its renewable energy capacity and align with the IEA's proposed net-zero scenario alone. Estimates show that to have a net zero emission i.e. to not produce more GHG than it reduces, India would need to generate around 32 per cent of its energy from solar and 12 per cent from wind by 2030. This amount far surpasses the current investment and funding capacities available in India. This shows that however relieving green energy sources are for the environment, their implementation requires a heavy green load of notes as well.

In the case of China, it is undergoing, what experts call its biggest economic experiments since economic liberalisation in the 1980s. The Housing Market is facing a huge oversupply of unaffordable houses. Evergrande, a company deemed to never fail has accumulated a debt amounting to \$300 billion. A substantial household income of Chinese households is tied up in the housing market, and the economy needs the household to spend. Hence, renewable energy seems the last thing on their mind.

The Brundtland report also mentioned energy sources have to meet the needs of the people. The energy source should be abundant enough to meet the needs of the entire population. This poses several challenges. The growing population has imposed serious pressure on energy demand. With time, the individual energy “need” has vastly evolved. The future does not seem to curb it with even earphones now requiring to be charged. This also defies the other suggestion by the report that encourages a society with reduced energy demand. The global fertility rate has dropped from 4.7 in 1970 to 2.4 in 2020. This creates an issue of an ageing population around the world, India, previously known for its youth-driven population, is now entering the ageing bracket, with estimates showing that by 2030, 1 out of every 8 people would be senior citizens. This creates additional liabilities for the economies as an aged population is seen as equivalent to a health hazard-prone population, with a reduced share of the working force.

On the energy front, the older generations tend to be less susceptible to the use of renewable sources and prefer fossil fuels over wind or solar energy. Hence if the major chunk of the population in the coming years has a preference for say- petrol over battery-operated cars which wind power plants recharge, This makes a rapid change seem difficult.

The other key point of the report is the involvement of the government in moving towards sustainability. This has not occupied a very considerable space in the report, yet the challenge it imposes is great. World leaders almost always tend to over-exaggerate all the achievements and promises. Over the last 56 years, the share of fossil fuels has reduced from about 93% to 82%. If the change is not accelerated, sustainable development seems impossible.

A major challenge to sustainable energy is the changing of ecosystems due to climate change. This can be evidently seen in the past few weeks when the highest temperature to be ever recorded in Kolkata in 43.9 Celsius, yet the city had crossed the 42 mark in the first two weeks of April- the start of summer. This has very much increased the energy consumption of the city as the people are not adapted to the weather conditions. Every ecosystem has its own suitable renewable energy source based on its general climate. If Climate Change continues to

affect the ecosystem similarly, we will face difficulty in understanding the appropriate energy source for that region.

Sustainable development is only possible if the entire world comes together in its common interests. It cannot happen if only a handful of economies like Denmark completely switch to a renewable source of energy. World leaders instead of single-handedly favouring the individual interest of the giant conglomerates of their countries need to frame and enforce appropriate laws and policies to influence the change. This is because even after 43 years of one of the biggest successful climate actions, the hole in the ozone still exists with a prediction that it does not go anywhere even till 2050.

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Navigating Global Energy Transition: Challenges, Innovations, and India's Stewardship

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In the expansive realm of global progress, few elements are as pivotal as energy. Serving as the cornerstone of urban functionality, economic vitality, and societal cohesion, it occupies a central role in our collective narrative (Sheth, 2023). However, the conventional energy sources that have historically propelled our advancement exact a heavy toll on our environment, resulting in negative externalities such as pollution and climate change. Thus, in the crucible of global evolution, the pursuit of sustainable energy emerges as an imperative of unparalleled significance (Sridhar, 2023).

This article delves into a detailed exploration of renewable energy's complex landscape, analyzing the various challenges and opportunities that influence our path toward a more environmentally sustainable and economically resilient future. Within this discussion, we carefully examine India's distinctive position in this global journey, where developmental complexities intersect with innovative potential. Using India's National Electricity Plan as our analytical framework, we explore the intricate relationship between energy consumption, economic productivity, and ecological preservation, providing nuanced insights into the road toward a sustainable and prosperous future (Kumar & Majid, 2020).

Amidst the global endeavour towards sustainable energy, significant challenges emerge, hindering its smooth transition. Particularly in developing economies, the high initial costs pose a major obstacle, limiting widespread implementation and perpetuating reliance on conventional, albeit environmentally harmful, energy sources. For instance, in 2022, the global average cost of electricity for utility-scale solar PV projects was USD 0.049/kWh, while for onshore wind projects, it was USD 0.033/kWh (IRENA, 2023). This financial burden slows down the adoption of renewable technologies in many African nations facing fiscal limitations, thus prolonging their dependence on fossil fuels (Kumar & Majid, 2020).

Compounding these challenges is the unsettling spectre of policy uncertainty and reliance on government subsidies, creating a dilemma for investors hesitant to commit capital to renewable energy projects due to uncertain returns caused by shifting government policies. According to a recent study by the International Energy Agency, policy uncertainty has been cited as a significant deterrent to renewable energy investment (IEA, 2014). Abrupt policy shifts in the solar industry, as seen in Spain, have led to a 45% decline in renewable energy investments following the changes (Sendstad, L. H., et al., 2022) (Sridhar, 2023).

Moreover, access disparities pose a significant impediment, particularly prevalent in developing regions where marginalized communities face barriers to accessing sustainable energy solutions. According to the World Bank, approximately 733 million people worldwide lack access to electricity, with the majority residing in Sub-Saharan Africa (World Bank, 2022) (Kumar & Majid, 2020).

Furthermore, the large-scale deployment of renewable infrastructure introduces intricate environmental challenges, ranging from land use conflicts to concerns about resource scarcity. Hydroelectric projects in the Amazon rainforest, while contributing to clean energy, have led to the loss of forest cover annually, exacerbating biodiversity loss and habitat destruction (University of East Anglia, 2022) (Yadav, Davies, & Sarkodie, 2019).

To surmount the challenges facing renewable energy adoption, technological advancements play a pivotal role. Ongoing research focuses on developing energy storage systems, particularly breakthroughs in battery technology, to mitigate solar and wind source intermittency (Sheth, 2023). Innovations also target environmental concerns linked with renewable projects, from turbine design enhancements to grid management. For instance, in 2023, wind energy in Germany accounted for about 32% of total electricity production, contributing to a 31% reduction in greenhouse gas emissions compared to 1990 levels (German Wind Energy Association, 2024; IEA, 2020).

Notwithstanding the challenges, a vista of opportunities emerges for the advancement of sustainable energy transition. Effective policies and community engagement strategies are vital for overcoming resistance and ensuring equitable benefits from renewable energy projects. Denmark's community wind projects exemplify tailored approaches, with the country generating over 47% of its electricity from wind power by 2019 (Murray, J., 2020) (Sheth, 2023).

Moreover, the pressing need to address cyber security risks becomes increasingly evident as renewable energy systems rely more on digital infrastructure. Proactive measures, akin to the United States' emphasis on cyber security in smart grid technologies, are essential for ensuring the secure and reliable operation of renewable energy systems (Sheth, 2023). Recent data shows a 39% increase in cyber attacks targeting renewable energy infrastructure, with a particular emphasis on sophisticated hacking attempts aimed at smart grid technologies (Security Magazine, 2023).

Responsible resource management is crucial for addressing environmental challenges in large-scale renewable projects, especially in the domain of biomass energy. Countries in Southeast Asia are leading efforts to implement strict regulations to ensure responsible resource

management, thereby enhancing the overall sustainability of renewable energy initiatives (Kumar & Majid, 2020). However, despite these efforts, research indicates that only a portion of biomass energy production meets sustainability standards due to inadequately stringent regulations for responsible resource management (Mai-Moulin, T., et al., 2021).

Finally, international cooperation and financial assistance emerge as indispensable pillars for surmounting challenges in sustainable energy transition (Kumar & Majid, 2020). The European Union's commitment to energy independence and renewable investments fosters a resilient global energy landscape. The approval of 171 new projects under the LIFE Programme by the European Commission, valued at €396 million, signals a 28.5% surge compared to the previous year, facilitating a total investment of €722 million and emphasizing collaborative efforts in innovation and climate resilience (European Commission, 2023).

India's trajectory towards sustainable energy adoption is shaped by its diverse topography, socio-economic dynamics, and expansive populace. Despite commendable commitments outlined in the National Electricity Plan (NEP), the nation grapples with formidable impediments on its path to a seamless transition. Aligned with the struggles of many developing nations, India faces the daunting challenge of initial costs associated with sustainable energy technologies, particularly evident in ambitious solar power projects across the expansive Thar Desert. Reports indicate that in 2021, India added approximately 15.4 GW of renewable power capacity, ranking third globally after China and the United States (Nandi, J., 2022). Strategic fiscal investments and robust international collaborations emerge as imperative strategies to mitigate these economic hurdles and make clean energy more economically accessible on a broader scale (Kumar & Majid, 2020).

Significant progress has been made in rural electrification, yet persistent challenges persist, especially in remote regions like Jharkhand, where last-mile connectivity issues and financial constraints hinder the effective deployment of decentralized energy solutions. While initiatives like the Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) and the Rural Electrification Corporation (REC) show promise, sustained efforts are essential to address lingering concerns about affordability and maintenance. The Saubhagya scheme, launched in 2017, aimed to provide electricity connections to all rural households, with over 28 million connections established by 2022 (Ministry of Power, Government of India, 2023). However, affordability and maintenance remain obstacles, calling for further innovation in decentralized energy solutions. The Jawaharlal Nehru National Solar Mission, with its target of deploying 100 GW of solar power capacity by 2022 (IEA, 2021), highlights the urgency of comprehensive strategies to tackle economic challenges, access disparities, and environmental concerns.

Despite progress, energy access disparities persist, requiring innovative solutions like micro-grids and off-grid solar-powered initiatives, particularly in regions like Jharkhand (Kumar & Majid, 2020).

India's considerable reliance on coal, notably evident in regions such as Singrauli, creates urgent environmental challenges. Striking a balance between economic growth, energy security, and environmental preservation requires nuanced approaches. According to the IEA 2022 report, India ranks second globally in coal consumption, following only China. Integrating renewable energy initiatives with responsible resource management is crucial to address environmental concerns and smoothly transition to cleaner energy paradigms (Sheth, 2023).

In ecologically sensitive areas like the Sundarbans, ongoing infrastructure maintenance challenges create significant obstacles for the effectiveness of decentralized energy solutions. In such complex ecosystems, customized innovative strategies are crucial to guarantee reliable, sustainable, and inclusive energy access. The economic impact of infrastructure maintenance challenges in ecologically sensitive areas is highlighted by the reported environmental loss in the Sundarbans worth Rs 1290 crore, as documented by the World Bank (Economic Times, 2015).

Continual policy innovation is indispensable to navigate emerging challenges adeptly. Flexibility in policy frameworks, regular stakeholder consultations, and periodic reviews are critical for ensuring adaptability to the evolving energy landscape. Drawing insights from global best practices and tailoring policies to suit India's unique needs will bolster efforts to construct a more resilient and adaptive energy terrain (Kumar & Majid, 2020).

India ranked fourth globally in 2022 for its renewable energy installed capacity, boasting a total of 172.72 GW from non-fossil fuel sources, highlighting its potential in this sector (MNRE, 2022). Integrating mechanisms such as feed-in tariffs, tax incentives, and fostering supportive regulatory frameworks for decentralized energy solutions emerges as indispensable imperatives to foster an environment conducive to sustainable growth (Kumar & Majid, 2020). For instance, India's solar feed-in tariff policy, overseen by the Ministry of New and Renewable Energy, has spurred significant growth in solar installations, leading to a cumulative capacity of over 70 GW by 2023 (MNRE, 2023). Additionally, government-provided tax incentives and subsidies, including the accelerated depreciation benefit, have played a pivotal role in driving renewable energy adoption. Furthermore, supportive regulatory frameworks such as net metering, introduced by state electricity regulatory commissions, have encouraged rooftop solar installations by enabling consumers to sell excess electricity

generated from their solar panels back to the grid at a predetermined rate. This initiative has resulted in a substantial increase in rooftop solar capacity across the country.

India's rapid urbanization presents both challenges and opportunities for sustainable energy adoption. Balancing the growing energy needs of urban areas with sustainable practices is crucial for long-term environmental and economic sustainability (Kumar & Majid, 2020). Innovative urban planning, incorporating green spaces, energy-efficient infrastructure, and robust public transportation networks, is pivotal for India's sustainable urban development. Initiatives like the Smart Cities Mission (Ministry of Urban Development, Government of India, 2015) and promotion of energy-efficient building practices by the Bureau of Energy Efficiency (BEE) underscore India's commitment to sustainability. Leveraging data on energy savings, emissions reduction, and urban green cover can inform policies, ensuring urban areas become models of sustainability while curbing their carbon footprint (Kumar & Majid, 2020). According to MNRE 2023, installed renewable energy capacity surged from 76.37 GW in March 2014 to 178.98 GW in October 2023, a 2.34-fold increase, highlighting India's progress in renewable energy deployment. This underscores the country's commitment to transitioning towards cleaner energy sources.

In conclusion, achieving sustainable development and responsible energy practices demands a holistic and inclusive approach. Navigating the transition to sustainable energy sources requires innovative strategies, adherence to circular economy principles, and mobilization of green finance, along with active engagement of multinational corporations (Sheth, 2023). India's pivotal role in this endeavour is evident through its steadfast commitment, strategic investments, and robust policy frameworks (Kumar & Majid, 2020), which have significantly contributed to job creation, energy security, and economic stability. Looking forward, widespread adoption of clean energy offers opportunities to foster environmental stewardship, drive economic prosperity, and promote social equity on a global scale (Sridhar, 2023). Achieving collective resolution demands shared responsibility and resolute commitment across national, corporate, community, and individual spheres, with India's journey serving as an inspiring example of transformative potential and collaborative spirit (Yadav et al., 2019). By transcending energy resource challenges through comprehensive, collaborative, and innovative approaches, we can transform hurdles into stepping stones for global progress, laying the foundation for a harmonious, inclusive, and prosperous future for generations to come.

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Resolving Unsustainable Practices: A Holistic Approach

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Sustainable development and green energy have emerged as crucial components in addressing the pressing challenges of our time. As the global population continues to grow, so does the demand for energy, putting a strain on traditional resources and exacerbating environmental degradation. In response, the concept of sustainable development has gained prominence, emphasizing the need to meet present needs without compromising the ability of future generations to meet their own. This essay explores the intertwined relationship between sustainable development and green energy, examining the importance of transitioning towards environmentally friendly practices to ensure a resilient and harmonious future for our planet. Sustainable development is a holistic approach that seeks to balance economic, social, and environmental considerations. It aims to foster progress that meets the needs of the present without jeopardizing the well-being of future generations. Key pillars of sustainable development include economic prosperity, social equity, and environmental responsibility.

The world has witnessed the adverse effects of unsustainable practices, including deforestation, pollution, and overexploitation of natural resources. Climate change, driven by the accumulation of greenhouse gases, has become a global crisis with far-reaching consequences. According to the World Resource Institute Report 2017, India is responsible for nearly 6.65% of total global carbon emissions, ranked fourth next to China (26.83%), the USA (14.36%), and the EU (9.66%). According to a World Energy Council prediction, global electricity demand will peak in 2030. India is one of the largest coal consumers in the world and imports costly fossil fuel. Close to 74% of the energy demand is supplied by coal and oil. According to a report from the Centre for monitoring Indian economy, the country imported 171 million tons of coal in 2013–2014, 215 million tons in 2014–2015, 207 million tons in 2015–2016, 195 million tons in 2016–2017, and 213 million tons in 2017–2018. Therefore, there is an urgent need to find alternate sources for generating electricity. Some of the recent threatening news include, The Arctic experiencing the warmest summer on record this year, contributing to extraordinary wildfires and melting glaciers while threatening the rest of the world with problems including higher sea levels. These only indicate towards an extremely threatening situation which requires immediate attention.

Embracing renewable energy sources like solar energy, wind, geothermal energy as well as biogas and algae based biofuels are essential for achieving sustainable development goals by mitigating climate change and reducing dependence on finite resources. Green energy offers

numerous advantages, including reduced greenhouse gas emissions which act like a blanket, trapping heat and creating significant harmful impact from stronger, more frequent storms, to drought, sea level rise, and extinction of flora and fauna, renewable energy improves air and water quality, as a result improving public health, and decreased reliance on non-renewable resources helps increase employment and stimulate technological innovation. Moreover, the decentralized nature of many renewable energy sources empowers local communities, fostering economic development and energy independence.

Ongoing advancements in technology are driving the efficiency and affordability of green energy solutions. Use of green technology help decrease the adverse impact of human activities and tends to cover a vast area of production and consumption technologies. Adoption of Green building or sustainable design, is the practice of rising the efficiency which buildings and their sites utilize energy, water and materials and their decreasing impacts on human health and the environment for the whole lifecycle of a building. The concepts of green building expand beyond the walls of buildings and involve site planning, community and land-use planning issues as well. Breakthroughs in energy storage, green nanotechnology; smart grids, and sustainable transportation contribute to a more comprehensive and accessible green energy infrastructure. Closed loop supply chains with usage lean manufacturing methods are a way to a healthier future. A green supply chain with forward and reverse logistic consideration is designed and queuing system is used to optimize the transportation and waiting time of transportation fleets' network. This optimization model will lead to the reduction in adverse environmental impacts. Governments, businesses, and individuals alike are increasingly investing in these innovations to accelerate the transition towards a sustainable energy future. Governments worldwide are recognizing the urgency of adopting green energy solutions and implementing policies to promote their widespread adoption. Incentives, subsidies, and regulatory frameworks are being established to encourage the development and utilization of renewable energy sources. International collaborations and agreements, such as the Paris Agreement, exemplify global efforts to address climate change through sustainable development. Close to 40% of the population of the developing world was living in extreme poverty only two decades ago. Since then, the world has halved extreme poverty. Recognizing the success of MDGs, and the need to complete the job of eradicating poverty, the UN adopted the ambitious 2030 Agenda for Sustainable Development, which includes ending poverty; zero hunger; good health and wellbeing; quality education; gender equality etc. India backs UAE's transition agreement at COP 28(conference of the parties of the UNFCCC) and has called for

delivery of means of implementation to ensure COP28's consensus on moving away from fossil fuels can be implied in developing countries.

Achieving sustainable development requires addressing disparities in energy access, this can be looked after by including social equity in sustainable development it involves ensuring fairness, justice, and inclusivity in the distribution of resources, opportunities, and benefits across all segments of society. By tackling disparities in education, healthcare, income, and participation in governance, social equity enhances the overall effectiveness and longevity of sustainable development initiatives, fostering a more balanced and just society for present and future generations.

Building a sustainable future necessitates the active participation of communities. Education and awareness campaigns are vital in fostering a collective understanding of importance of sustainable development and the role individuals can play. Empowering communities to embrace renewable energy sources is key to achieving widespread and a lasting change. Some of the famous sustainability campaigns initiated by global brands include the campaign initiated by IKEA "Climate Action starts at Home". The advertisement aims to encourage individuals to take responsibility for their carbon footprint and adopt more sustainable habits in their daily lives. Dove joined the campaign by making their iconic Beauty Bar packaging Plastic-Free and launching new 100% plastic free bottles. Such steps would help increase public awareness and make consumers more inclined towards consuming sustainable products.

Hence to overcome the challenges in the role of energy in sustainable development, a multifaceted approach is required. Firstly, governments and policymakers must establish clear and ambitious targets for transitioning to renewable energy, accompanied by supportive regulatory frameworks. Investments in research and development should focus on improving the efficiency and affordability of renewable technologies, as well as addressing energy storage and transmission challenges.

Economic instruments, such as subsidies and tax incentives, can be leveraged to make renewable energy more competitive with conventional sources. International collaboration is crucial for sharing knowledge, technology, and financial resources to support developing nations in their transition to sustainable energy.

Additionally, fostering a culture of innovation and entrepreneurship in the energy sector can spur the development of ground-breaking solutions. Governments, businesses, and educational institutions should collaborate to create an environment that encourages research and the implementation of cutting-edge technologies. By overcoming technological, economic,

and social barriers, we can pave the way for a more resilient, equitable, and sustainable future—one where energy is harnessed responsibly to meet the needs of the present without compromising the ability of future generations to thrive.

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