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Breaking the Carbon Trap : Path to Achieving Sustainable Development through Rooftop Photovoltaics

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It is often argued that sustainability is a farce dream that good only on papers by particularly an unrealistic dream. Sustainability has often been a top of agenda of many top leaders at the UN who adopted the 17 goals for sustainable development .Many edicational institutions like MIT have also launched competitions to attract talent in he domain. However, the topic is too wide in acope for anybody to fathom a collaborated solution towards solving the problem arising due to modern living. Pollution , climate change , rising ocean levels , equitable living are so intertwined amongst themselves that it is almost impossible to solve, without understanding the basic premise of them .It is often realized through deliberations in the academic circles that energy crisis often foundation for attaining 80% of the SDG goals.

An important contribution to solving the energy crisis happens to tbe the renewable energy and a leader in the same happens to be solar energy . India is fortunate to be in goldilocks location by receieving solar irradiance comparable to the elite group of countries in the equatorial region . As compared to Germany , Japan , India is also witnessing a resurgence in the GDP growth rate with 8.6% growth achieved in the last quarter. The GDP growth is projected to be furthered by the employment of large scale of photovoltaic cells and electric vehicle ecosystem. This paper delves into the hindrances faced by policy makers in attainment independence from fossil based energy system.

Literature Review

My review paper on eco innovation had shed light on the fossile fuel trap that todays generation is embroiled itself into. According to Kemp and Foxen (2007), eco-innovation pertains to the development, implementation, or utilization of a product, service, or process, as well as a business model, organizational structure, or management style that is new to the company or consumer.As per Kemp & Pearson (2007), the eco-industry (also known as the environmental goods and services sector) can be measured in terms of environmental protection measures, sales, or a mix of both.Kemp & Pearson (2007) have classified eco-innovation into four categories: A) Environmental Technologies, B) Organizational Innovation for the Environment, C) Innovative Products and Services, and D) Green System Innovations. The Environmental Technologies category includes pollution control technologies, cleaner process technologies, waste management equipment, environmental monitoring and instrumentation, green energy technologies, water supply technologies, and noise and vibration control technologies. Organizational Innovation for the Environment refers to the usage of organizational methods and management systems for dealing with environmental issues in manufacturing, such as pollution prevention schemes, environmental management and auditing systems, and chain management. The concept of Innovative Products and Services encompasses a range of offerings that provide environmental benefits. These may include the development of new or improved materials that are more environmentally friendly, the creation of financial products that support sustainable practises, the provision of environmental services, and the delivery of services that are designed to minimise pollution and resource consumption. Finally, Green System Innovations include alternative production and consumption systems that are less harmful to the environment than current systems, such as biological agriculture and green energy systems.

Impact of Regulations :

Rennings et al. (2004) argue that environmental regulation can have positive effects on businesses and can align with economic advancement. This idea is referred to as ecological modernisation. According to Kemp & Foxen (2007), the direct benefits for the eco-innovating firm are Cost reductions from increased resource

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productivity and improved logistics are only a few of the operational benefits along with sales from commercialization.Eco-innovators can reap various benefits through their sustainable practises. These benefits include an improved public image, strengthened relationships with suppliers, customers, and authorities, increased innovation capabilities through collaboration with knowledge holders, improved health and safety standards, and higher levels of worker satisfaction.

Unruh's research suggests that high-carbon technologies have become dominant in fossil-fuel-based energy systems due to a co-evolutionary process. This process has led to accumulated knowledge, infrastructure, social norms, regulations, and lifestyles that support these technologies. According to Vincent's (2006) analysis, the development and implementation of novel low-carbon technologies may encounter various obstacles throughout their different stages.

According to Fu and Zhang's (2011) study, the solar photovoltaic industry in China and India was analysed, and it was found that the national innovation systems had a significant impact on the industry's ability to integrate various technology transfer and indigenous innovation mechanisms. According to Watson's (2008) perspective, government technology eco-innovation strategies should encompass more than just financing basic research and taking responsibility for the social costs of carbon emissions. They should also extend support to other phases of the innovation process, including the challenging valley of death. Uncertainty in the low-carbon arena can be attributed to several factors, including the long-term relative costs and feasibility of emerging technologies, the development of entirely new technologies, changes in consumer behaviour and preferences, and geopolitical uncertainty. According to Franco et al. (2021), local government plays a significant role in promoting innovation among local businesses by attracting foreign expertise and technologies. This, in turn, can have an impact on the size of foreign direct investment (FDI) and trade.

Research Methodology:

The study employs longitudiunal study covering the regional and global trends in solar photovoltaic installations .

Findings:

According to the International Renewable Energy Agency (IRENA), accelerated solar PV deployment alone is predicted to result in considerable emissions reductions of 4.9 gigatonnes of carbon dioxide (Gt CO) by 2050. This alone accounts for 21% of the whole energy sector's emission mitigation potential. By the same year, solar PV is projected to replace wind power as the second-largest power-generating source, ushering in a paradigm shift in the global electrical sector. The modular and dispersed nature of Solar Photovoltaic technology has made it a popular choice for a variety of off-grid and local applications. The capacity of off-grid solar PV has experienced a significant increase of over ten times its size since 2008, reaching approximately 3 GW in 2018 from an initial capacity of around 0.25 GW. The implementation of solar PV off-grid technology is considered crucial in attaining complete energy access and meeting the Sustainable Development Goals.

The Agency predicts that Asia, specifically China, will maintain its position as the leader in solar PV power with over 50% of the total installed capacity. North America and Europe are expected to follow with 20% and 10% shares, respectively. The user has provided a numerical value of 10 percent.

- In the next three decades, the overall installation cost of solar PV installations will continue to fall around the world. As a result, solar PV would become very competitive in many areas, with average prices dropping to USD 340 to 834 per kilowatt (kW) by 2030 and USD 165 to 481/kW by 2050 from USD 1210/kW in 2018.

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- Solar PV's levelized cost of electricity (LCOE) is comparable with all fossil fuel generation options and is predicted to fall as installation costs and performance improve. According to projections, the levelized cost of energy (LCOE) for solar photovoltaic (PV) technology is expected to decrease over time. In 2018, the average LCOE for solar PV was USD 0.085 per kilowatt-hour (kWh). By 2030, it is estimated that the LCOE will range between USD 0.02 and 0.08/kWh. Further into the future, by 2050, the LCOE for solar PV is projected to be between USD 0.014 and 0.05/kWh..
- First-generation technologies continue to be the primary driver of solar industry growth, accounting for the vast majority of market value.

- Higher efficiency levels have been made possible by the advent of improved cell architectures. The recent market shift in cell architecture can be attributed to the increased use of advanced designs like passive emitter and rear cell (PERC), which are now compatible with other emerging innovations like half-cut cells. This has led to the development of bifacial cells and modules. BIPV solar panels are an advanced design example. Multifunctionality (they can be applied to a range of surfaces), cost-efficiency (savings on roofing material, labor/construction, refurbishment and maintenance expenses), versatility and design flexibility in size, shape, and colour are all advantages of BIPV solutions.

- The deployment of rooftop solar PV systems has experienced a notable increase in recent times. The reason for this can be traced back to the adoption of favourable measures such as net metering and financial rewards. The economic feasibility of PV has been enhanced in specific markets due to the execution of particular initiatives. The process of obtaining electricity from the grid can be accomplished through different methods, including PV-hybrid minigrids, virtual power plants, and utility PPAs. Consumers have the option to store power generated by rooftop solar PV for future use or sell it to the grid using behind-the-meter storage business models. The International Energy Agency (IEA) report from 2018 states that there was an increase of approximately 43 GW in distributed-scale solar PV capacity during that year. Distributed solar power has a clear comparative advantage in significant markets such as Brazil, China, Germany, and Mexico. The existence of significant variations among countries suggests that there is potential for further improvement.

- With dispersed plants accounting for 47 percent of the capacity added in 2018, China is the world's largest solar market, not just in Asia. In India, distributed solar has been rising as well, with installed rooftop capacity reaching 6 GW in 2018, up over 2.5 GW from the previous year . In India, the majority of installed capacity comes from utility-scale installations, which make up 82% of the total. In contrast, distributed installations only account for 10% of the total installed capacity. (SolarPower Europe, 2019a).

- The Republic of Korea has set a policy goal of expanding distributed power production as part of its energy policy, positioning itself as a significant player in the region. This is to address challenges associated to the country's hilly geography, which makes major utility-scale PV plant development problematic. By 2030, the national energy strategy plans to grow distributed power generation to 18.4 percent of overall generation, up from 11.2 percent now (SolarPower Europe, 2019a). Mexico has experienced a notable rise in installed solar capacity in Latin America. This can be attributed to a surge in distributed solar, which has resulted in over 100,000 solar roofs being installed on various structures such as homes and businesses in the country. SolarPower Europe (2019a) highlights that the low installation costs and potential for significant monthly power cost savings of up to 95% are key factors contributing to the competitiveness of distributed solar. In Brazil, the adoption of distributed solar PV has increased significantly, resulting in the addition of 390 MW of new capacity in 2018. This growth can be attributed to the country's net-metering regulations becoming more competitive, making solar PV a more attractive option for consumers. According to the Brazilian Solar Energy Association (ABSOLAR) as reported by SolarPower Europe in 2019, there is a prediction that the growth will more than double in 2019. According to data from 2018, there was a decrease of 15% in global investment in small-scale distributed solar PV systems (less than 1 megawatt [MW]) compared to the

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previous year, with a total investment of USD 36.3 billion. In 2018, the global investment in small-scale distributed solar PV systems (less than 1 MW) decreased by 15% compared to the previous year, as per the available data. The total investment made in this sector during the year was USD 36.3 billion. REN21's report in 2019 reveals that small-scale solar has proven to be a lucrative market for various countries such as Germany, Australia, India, Japan, and the Netherlands, with each generating over USD 1 billion in sales. The small-scale solar market in the United States, which is the largest market for this type of energy, saw a decrease of 15% in sales, resulting in a total loss of $8.9 billion. The increased usage of Distributed Energy Resources (DER) is a clear indication of its global adoption. The Sonnen Community is a German platform that aggregates data from around 10,000 users who have solar PV generation, battery storage, or both. In 2015, the aggregator was initially introduced as a virtual power plant (VPP) for peer-to-peer trading purposes. However, in 2017, it was expanded to include the provision of grid functions, such as frequency regulation, to the electricity grid. The distributed "virtual" storage resource is a highly responsive option for primary frequency services when compared to alternatives such as pumped hydro storage. The sub-second reaction time of this technology makes it a favourable option for grid operators. The German electricity grid has a limited storage capacity. The statement suggests that by minimising the variability of renewable energy, it is possible to reduce the need for costly grid expansion. (IRENA, 2019d).

- The IRENA's REmap Case predicts that solar PV will have a significant role in global power generation, with an estimated 13% share by 2030 and 25% by 2050. The data suggests that by 2030, Japan and South Africa are projected to have the largest proportion of solar power in their electricity mix, estimated at 26%. The United States is expected to follow with 18%, while India and China are projected to have 15%. According to projections, the distribution of solar power production is expected to shift significantly by the year 2050. Australia is predicted to have the highest proportion of solar power generation, accounting for approximately 40% of the total share. The United States is expected to follow with a 33% share, while South Africa and Japan are projected to have a 32% and 30% share, respectively.

Conclusion:

It is clear from the above findings that the government policies and market conditions play an important role in influencing the adoption of rooftop PV amongst the residents. It is important for the countries to have a national strategic development plan to aid the diffusion of rooftop PV amongst the residents. The scale of industry development, proactive consumers and institutional suppliers play an important role in determining the competitiveness of PV industry in a market. During the development, construction, and operation stages, key stakeholders face several risks, including:

a) Institutional Risk: This arises from changes in a country's policy regarding permits, regulations, legal aspects, and fiscal matters related to investments.
b) Economic Risk: This type of risk involves pricing and volume risks associated with contracts.
c) Technical Risk: This includes risks related to construction, operation, maintenance, and the availability of raw materials.
d) Environmental & Social Risk: This type of risk covers issues related to public acceptance, labor, safety, and the environment.

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