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**Research Article**

# Fostering Sustainable Growth: Approaches to Establish India as a Global Centre for Solar Panel Production in the Renewable Energy Revolution

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**ABSTRACT**

The Paper highlights the rapid evolution of Renewable Energy Technologies – particularly Solar Energy – simultaneously underscoring the obsolescence of carbon-dependent energy generation and the need for sustainable alternatives. Worldwide for the last decade plus, Solar Energy has emerged as the leading alternative to Fossil Fuels, contributing significantly towards reducing the Greenhouse Gas emissions; thus, addressing the ever-increasing global energy demands, as also the climate change concerns.

Use of Renewable Energy (RE) is critical in achieving overall economic and human development goals. The UN's SDG 7 assures worldwide access to clean and affordable energy by 2030. *World Economic Forum projects 20% annual growth for Solar Energy and replacing fossil fuels by 2050*. Since 2009 cost of Solar and Wind Energy has drastically reduced by 78% and 58% respectively, driving further growth and fuelling ever increasing levels of investments and expansions in the RE Sector.

Current geopolitical landscape, especially influenced by Ukraine-Russia Conflict, the consequent uncertainty of non-RE Supply Chains in Europe, and further complications due to President Trump Administration led Tariff Regimes, presents greater challenges and corresponding opportunities for RE growth.

In developing countries like India, continued Policy Support and Financial Mobilization are essential. Despite significant advancements, global progress in sustainable energy sector is insufficient, with significant disparities in access persisting.

To position India as a Global Leader in Solar Energy within five years, the paper calls for leveraging available technology and raw materials. By addressing funding gaps and focusing on policy support, India can enhance its RE capacity, contributing significantly to global climate action efforts and energy security. The paper underscores the potential for substantial growth in the RE Sector, as globally the nations' race to meet SDG targets, thus highlighting the critical role of Solar Energy in this transition.

The paper also discusses the role of Carbon Trading in promoting RE investments and how Renewable Energy Certificates (RECs) serve as market-based instruments certifying clean energy production.

**Keyword**: India, China, Renewable Energy, UN SDG 7, Solar Energy, Greenhouse Gas

## Introduction.

The world of Renewable Energy (RE) Generation is constantly changing, and the currency of the technology in use is getting drastically obsolete each passing day, and the old and traditional ways of energy generation evolving for the better.

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***Fig 1**: This figure was taken from Google Images for visual explanation only.)*

- With the per capita consumption of energy exponentially increasing, the old carbon dependent methods of energy generation are getting redundant in terms of capacity generation to match the ever-increasing demand for energy. Efforts to upgrade to modern carbon free methods have become the mainstay; especially in view of the emergent world order, which stands sharply divided on the Climate Change and the resultant emphasis on decreasing the Carbon Footprint impact of each country.
- Since the advent of mankind, the Sun is the primary source of energy that warms the planet, and the power of the Sun has been well understood and the need to use it to create RE is the new age practice.
- Solar energy has been identified as a promising alternative to fossil fuels in the fight against Climate Change. According to the World Economic Forum, Solar Energy is outpacing all other energy technologies and has the potential to replace fossil fuels globally by 2050. *With an annual growth rate of approximately 20%, the Solar Sector is on track to reach 6 terawatts by 2031*[1].
- Post the Kyoto Protocol, Solar energy has an important role in reducing Greenhouse Gase emissions and mitigating Climate Change, which is critical to protecting humans, wildlife, and ecosystems[2]. *It is a renewable source of power that can help reduce our dependence on fossil fuels and move towards a more sustainable future.*

## Aim.

This research paper aims to explore *all possible measures to make India a worldwide powerhouse in Solar Energy, simultaneously examining what will it take for India to become the world's largest supplier of Solar Panels in less than 5 years*, assuming that India addresses the critical triad of concerns – Urgent Labour Reforms, Fast Paced Tech Development and Uninterrupted Supply Chain Management of Raw Materials, to support the said initiative.

## Part I: Renewable Energy – The alternative to Traditional Energy Generation Means

Shifting geopolitical dynamics and a global energy crisis have underscored the importance of energy security. While Carbon emitting process for Energy Generation has rapidly fallen from favour, the power needs of the world now have invariably gravitated towards renewable sources for energy creation.

Progressively, RE and particularly Solar Energy has been identified as the most critical component contributing to the RE Sector, thus mitigating the energy issues related to climate crisis, while simultaneously reducing the geopolitical compulsions dictated Energy Security risks.

- **United Nations Goals for Sustainable Development linked to RE.** UN has set 17 Sustainable Development Goals (SDGs) to be achieved by 2030.

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- The SDGs listed by UN are the blueprint to achieve a better and more sustainable future for all and play a very crucial part in the ESG Function, and the Foreign Fundings mostly depends on this very parameter. Currently 2030 is the achieving year for these SDGs.

- The SDGs includes universal access to electricity and clean cooking, doubling historic levels of efficiency improvements, and substantially increasing the share of renewables in the global energy mix[3].

- The Goal dealing with Energy is Goal 7 and aims to ensure access to affordable, reliable, sustainable and modern energy[4]. The lack of access to energy hinders Economic and Human Development. Thus, it focusses on ensuring access to clean and affordable energy, which is key to the development of Agriculture, Business, Communications, Education, Healthcare and Transportation.

- **Renewable Energy - A Key Component of SDG 7.** It is essential to achieve the targets set by the UN for sustainable development. The use of RE can help reduce carbon emissions and mitigate Climate Change, and also in achieving energy security and reducing dependence on fossil fuels.

- In the wake of the Russia – Ukraine Conflict[5] and the consequent strain on Energy Security in Europe, traditionally dependent on Russian Gas and Oil, the need for developing RE hubs across Europe has been well understood by all major countries affected by this unprecedented energy crisis in Europe, post WW2. With careful planning, RE and Clean Energy Options to support increased energy efficiency and energy storing for later use will help pave the way.
- According to the estimates of the Investment Firm Lazard, since 2009 the cost of generating electricity from Wind and Solar has declined by 58% and 78%, respectively. As per them, those cost trends are expected to continue and coupled with the recent extension of Tax Credits / Subsidies for Renewable Energy, Wind and Solar Growth is widely expected to accelerate over the next several years, with capacity from 2015 levels having doubled by 2021.
- However, due to factors not foreseen earlier, the cost factor is likely to hit a significant roadblock in the aftermath of President Trump Administration imposing 145% Trade Tariffs on China[6], the world's largest manufacturer of RE Solar Panels and associated ancillaries needed to set up a Solar Power Generating Plant.

- **The Goal 7 Targets are: -**

- **7.1** By 2030, ensure universal access to affordable, reliable and modern energy services.
- **7.2** By 2030, substantially increase the share of Renewable Energy in global energy mix.
- **7.3** By 2030, double the global rate of improvement in energy efficiency.
- **7.A** By 2030, enhance International Cooperation to facilitate access to clean energy research and technology including RE, energy efficiency, advanced & cleaner fossil-fuel technology, promoting investment in energy infrastructure and clean energy technology.
- **7.B** By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support.

- Latest data suggest that the world continues to advance towards sustainable energy targets[7]. Nevertheless, the current pace of progress is insufficient to achieve Goal 7 by 2030.
- Huge disparities in access to modern sustainable energy persist right now. Rising commodity, energy and shipping prices have increased the cost of producing and transporting Solar Photovoltaics Modules, Wind Turbines and Biofuels worldwide, adding uncertainty to a development trajectory that is already far below Goal 7 ambitions.

- Achieving energy and climate goals will require continued policy support and a massive mobilization of public and private capital for clean and Renewable Energy, especially in developing countries.

- The Global Electricity access rate increased from 83% in 2010 to 91% in 2020. Over this period, the number of people without electricity shrank from 1.2 billion to 733 million. At the current pace, only 92% of the world's population would have access to electricity in 2030, still leaving 670 million people unserved.
- This could be an amazing opportunity & era for the Renewable companies to work. To meet energy efficiency target, the annual rate of improvement until 2030 will need to average 3.2% a year. The market

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is giving a huge gap that needs to be filled, the issues faced by the energy sectors are clear now, & during this time of crisis, it could be an arrow shot towards the SDG-7.

- The proper foreign funding would be easy to get in this sector, as the race to SDG-7 is getting faster.

- **Climatic Change.** Increased use of Fossil Fuels without actions to mitigate Greenhouse Gases will have Global Climate Change implications. Energy efficiency and increased use of Renewables contribute to Climate Change mitigation and disaster risk reduction.
  - Maintaining and protecting ecosystems allow using and further developing Hydropower Sources of Electricity and Bioenergy. Renewable Energy is one of the most effective tools we have in the fight against Climate Change, and there is every reason to believe it will succeed.
  - It seems to imply that Renewable Energy investments set back efforts to address Climate Change with minimum monetary investment. *Wind and Solar Energy have experienced remarkable growth and huge cost improvements over the past decade with no signs of slowing down.*

  - Prices are declining rapidly, and Renewable Energy is becoming increasingly competitive with fossil fuels all across India. In some places, new Renewable Energy Plants are already cheaper than continuing to operate old, inefficient, and dirty fossil fuel-fired or Nuclear Power Plants.

- **Kyoto Protocol**. When the Greenhouse Gases were increasingly threatening life on earth in the 80's, a protocol was adopted in 1997 at Kyoto, Japan to mandate that the Industrialized Nations cut their Greenhouse Gas emissions. The protocol was linked to the United Nations Framework Convention on Climate Change (UNFCCC) seeking to reduce the concentration of GHG emissions in the atmosphere in a cost-effective way. This gave birth to an innovative financing solution that could play a prodigious role.
  - Worldwide, the creation of *Carbon Markets* has provided an additional source of income for Clean Energy Projects. One of the highly valuable avenues for generating capital for climate projects has been the Clean Development Mechanism (CDM). Countries that ratified the Kyoto Protocol were subjected to maximum carbon emission levels for specific periods and participated in Carbon Credit trading.
  - In addition to the climate benefits that they will help deliver, renewables already provide a wide range of market and public health benefits that far outweigh their costs. A recent report from the Department of Energy and Lawrence Berkeley National (LBNL) Laboratory found that Renewable Portfolio Standards—State Policies that mandate that a specific amount of the State's electricity comes from Renewables—provide a wide range of economic, health, and climate benefits.

- **Carbon Trading**. The link between Climatic Change & Renewable Energy is Carbon Trading. The country dependent on Renewable Energy would be *Carbon Negative*, which means more investment can be brought to the Country. Countries with *Carbon Positive* credits will invest in Countries with Carbon Negative Credits. *This buying & selling of Carbon Credits is known as Carbon Trading*.
  - The Foreign Companies too deal with this Carbon Finance; these Foreign Companies invest in Companies that are into Renewable Business. Few of the Organizations have shown interest in investing into technologies catering to these and offset Carbon Credits generated because of their core business.
  - Private Companies are doubly incentivized to reduce the emissions. First, they will be fined if they exceed the cap. Second, they can make money by saving and reselling some of their emissions allowances. ***An active example of this is Total Energies investing Adani Green Energy Ltd.***

- **Renewable Energy Credits**. Another parameter that comes into this picture is Renewable Energy Credits. Formally, ***RECs*** stand for Renewable Energy certificates. *They are Market-Based Instrument that certifies the holder owns a megawatt-hour (MWh) of electricity from a clean energy source*. The green tag represents the energy generated by Renewable sources such as Solar, Wind, and Hydropower facilities.
  - Buying RECs is not the same as buying electricity, but they represent the clean energy attributes of Renewable electricity. Once the power provider has fed the energy into the grid, the corresponding RECs produced can then be sold on the open market as a non-tangible energy commodity.
  - The RECs earned by the Certificate Holder are tradable. In other words, they may be sold to other entities that are polluting as a Carbon Credit to offset their emissions. Businesses can buy Renewable Energy Credits along with their electricity. And the RECs are proof that a certain amount of the electricity was from a renewable source. In a gist, RECs offset kilowatt hours of electricity use instead of carbon emissions.
  - Yet, using Renewables also help cut GHG emissions by favouring energy sources that don't emit carbon. They act as an accounting mechanism for Renewable Energies as they're fed into the power grid. Easy to

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understand statement can be - Carbon Credits cap $CO_2$ emissions while RECs create new energy from Renewable Sources.

- Both Investors and Consumers are after the Green Tag the Renewable Business offers. It means using RECs gives them proof that you are getting your energy from Renewable Sources, and the Organization will get a plus point out of that. Renewable Energy Credits also allow you to invest directly in projects like Solar Farms. This is perfect for the business that has stores or locations in different places.

- **Rising Use of Renewable Energy – India and the World**. Presently just 30% of the World's energy needs are dependable on Sustainable Power, and in the wake of the ongoing Ukraine-Russia War and the worldwide stranglehold of China over Rare Earth Metals, the worldwide energy emergency happened triggering unprecedented momentum backing the renewable mode of energy, and the world set out to add as much renewable power in the coming 5 years; as it did in the past 20 years combined.
  - *India has witnessed rapid growth in its Renewable Energy capacity, with solar energy growing about 18 times in the last seven and a half years. The Indian Renewable Sector ranks 4th on the list of the world's most attractive Renewable Energy sectors*[8]. Solar and Wind Energy are the most abundant sources of renewable power in the country.
  - Green Gas emission is a universal problem. Majority of the energy requirement of the Indian economy is accounted for by imported fossil fuel. Contribution of Renewable Energy resources is very less in the total energy requirement. Solar Energy is one of the better alternate energy sources to fulfil the needs of India's energy requirement as geographically it is near the equator.
  - Solar Energy has immense potential in India as an alternative to traditional means of energy generation. It has witnessed rapid growth in the last few years and has the potential to meet India's total energy demands and significantly reduce carbon emissions, according to a study published in the Energies Journal[9].
  - The Indian Government has introduced many schemes and policy initiatives to increase the footprint of solar energy thereby reducing the carbon footprint. This study also investigates the impact of Indian Government policies and initiatives taken to mitigate the green gas emission for a sustainable development in India.
  - This analysis shows that there is a steep increase in production of Solar Energy as a source of Renewable Energy in India, as the impact of solar energy on mitigating Climate Change is significant. For instance, a study published in the IEEE Xplore Digital Library highlights the impact of solar energy in mitigating Climate Change for sustainable development in India[7]. The study also highlights that solar energy can help India achieve its sustainable development goals.
  - To encourage the manufacture of Solar PV Cells and Modules in India, the Indian Government has come up with many policy initiatives. However, the amount of Solar PV Module Manufacturers is negligible, with Adani Group's Mundra Solar Technopark Pvt Ltd being the solo large player. Hence, Government of India needs to initiate concrete steps encourage & popularize the manufacturing of Solar PV Modules to spearhead the creation of an ecosystem of alternate energy sources in the entire sub-continent to reduce the green gases emission for a sustainable development.

## Part II: Renewable Energy – Geopolitical Implications

Renewable Energy is increasingly becoming fundamental to the Geopolitical standpoint. As Nations across the globe seek to drastically reduce their carbon emission footprint and transit to cleaner energy future, traditional RE sources including Solar, Wind, Hydro and Geothermal will play a dominant role.

- One of the key geopolitical implications of Renewable Energy is the potential for it to disrupt traditional energy markets and the geopolitical power structures that are built around them. Many of the world's leading oil-producing countries have built their economies and political systems around their oil exports, and a shift towards Renewable Energy could threaten their dominance and influence.
- At the same time, the transition towards Renewable Energy is creating new opportunities for countries that are rich in Renewable Energy resources. For example, countries with abundant sunshine or windy coastlines are well-positioned to become major players in the global Renewable Energy market.
- In addition, the Geopolitics of Renewable Energy are also shaped by issues such as trade policy, intellectual property rights, and international cooperation. Countries that are leaders in Renewable Energy technology are likely to have an advantage in these areas, while those that lag behind may find themselves at a disadvantage.
- Overall, the shift towards Renewable Energy is likely to have significant Geopolitical implications in the years to come, as countries and regions navigate the opportunities and challenges that come with this transition.

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**The Carbon trading & Carbon Financing have also added a new road to International Relations**.
Both Carbon Trading and Carbon Financing have important Geopolitical implications.

- One key issue is the distribution of benefits and costs between countries. In a global carbon market, countries that are able to reduce their emissions more easily or at lower cost may benefit from selling excess credits to those that have a harder time meeting their targets.
- This can create tensions between developed and developing countries, as the latter may see the former as unfairly profiting from the carbon market. Carbon financing can also have geopolitical implications, particularly in the context of international development. Many developing countries are seeking financial support to transition to cleaner energy sources and reduce their carbon emissions, and carbon financing can be an important tool for achieving this.
- However, the distribution of funding and the conditions attached to it can be contentious, with some countries accusing donors of using carbon financing as a form of Neo-colonialism or imposing conditions that may be harmful to their own development goals.
- Carbon Trading and Carbon Financing are important tools for addressing Climate Change, but they also raise a range of Geopolitical issues that must be carefully managed in order to ensure a fair and effective Global response to this urgent challenge.

**Solar PV Modules have also become a hot issue in International Relations.**

- This is because many countries rely on imports of solar modules to support their own Renewable Energy goals, which can lead to disputes and tensions over trade and intellectual property rights.

- One example of this is the ongoing trade dispute between the United States and China over Solar Panels. In 2012, the US accused China of providing illegal subsidies to its Solar Panel Manufacturers, which led to a series of trade disputes and tariffs being imposed on Chinese Solar Panels.
- Another example is the dispute between India and the US over India's domestic content requirements for Solar Panels. India had implemented policies that required a certain percentage of Solar Panels used in the Country to be produced domestically, which the US argued was discriminatory against American Solar Manufacturers. ***Intellectual Property Rights are also a key issue in the International Relations of Solar Modules.***
- Many of the leading Solar Panel Manufacturers are based in developed Countries such as the US, Japan, and Germany, which has led to concerns over technology transfer and intellectual property theft by developing Countries seeking to build their own domestic Solar Industries.
- At the same time, the rapid growth of Solar Energy around the world has created new opportunities for international cooperation and partnerships. Many Countries are working together to share knowledge and technology, and to promote the development of a Global Solar Energy Market that benefits everyone.
- As observed, the International Relations of Solar PV Modules are complex and multifaceted, with a range of Economic, Political, and Environmental issues at play. As Solar Energy continues to grow in importance, it is likely that these issues will continue to shape the geopolitics of Renewable Energy.

## Energy Security.

Here is where Geopolitics meets the Energy Sector head on. Energy Security refers to the availability, affordability, reliability, and sustainability of energy resources for a country or a region. It is a critical aspect of national and global security, as energy plays a fundamental role in economic development, social well-being, and military capabilities.

There are several dimensions to Energy Security, including:

- **Availability:** Ensuring a stable and sufficient supply of energy resources to meet the energy demand of a Country or a region. This includes diversifying energy sources to reduce dependence on a single type of energy or a particular Country for energy supply.
- **Affordability:** Ensuring that energy resources are affordable and accessible to all sectors of society, including Households, Businesses, and Industries. This includes managing energy prices, subsidies, and supporting vulnerable populations who may struggle with energy costs.
- **Reliability:** Ensuring that energy resources are reliable and can be accessed consistently without interruptions. This includes investing in robust infrastructure, maintaining a resilient energy grid, and addressing issues such as energy theft, sabotage, and cyber threats.

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- **Sustainability:** Ensuring that energy resources are produced and consumed in an environmentally sustainable manner, with a focus on reducing Greenhouse Gase emissions, mitigating Climate Change, and protecting natural resources. This includes promoting Renewable Energy, energy efficiency, and clean technologies.

Energy Security is closely linked to Geopolitical considerations, as access to energy resources can be a driver of International Relations and Conflicts. Countries and Regions may seek to secure their energy resources through various means, such as diversifying energy sources, building strategic reserves, negotiating energy agreements with other countries, and investing in domestic energy production.

- It is a complex and multifaceted issue that requires careful planning, coordination, and cooperation among governments, international organizations, and stakeholders in the energy sector.
- It involves balancing economic, social, environmental, and security considerations to ensure a stable and sustainable energy supply for the present and future generations

## Part III: A Critical Analysis of Solar PV Manufacturing Capabilities Worldwide

To help this orbital shift in power generation, the World needs more Solar PV Modules than before. Today, China dominates the worldwide Solar PV Module supply chains and is the home to the world's top 10 Manufacturers / Sellers of Solar PV Modules.

- China has been cutting down the overall cost of Solar PV Modules and Government strategies in China have moulded the worldwide stockpile, demand & cost of Solar PV Modules over the course of the past ten years.
- *Chinese Industrial Policies focusing on Solar PV Modules as a Strategic Sector*, riding on growing global as well as domestic demands have enabled economies of scale and supported continuous innovation throughout the supply chain.
- These policies have contributed more than 80%, in cost decline thus helping Solar PV Modules to become the most affordable Electricity Generation Technology globally. China is the most cost-competitive location to manufacture all components of the solar PV supply chain.

- Costs in China are 10% lower than in India, 20% lower than in the United States, and 35% lower than in Europe. Large variations in Energy, Labour, Investment and Overhead Costs explain these differences.
- Although 38 countries have module assembly facilities, China was still responsible for about 70% of production in 2021, up from 50% in 2010.
- Other important manufacturers include Vietnam (5%), Malaysia (4%), Korea (4%) and Thailand (2%), but most manufacturing capacity in these Countries was developed by Chinese Companies focusing on exports to the United States.

- ***Other Countries with high Module Assembly Capacity, such as the United States (4%), Germany (1%) and India (1%), produce mainly for their Domestic Markets, although they often lack adequate manufacturing capacity for PV Cells and Wafers.***
- Because PV Cell Manufacturing is concentrated in the Asia-Pacific Region, large solar PV demand centres in the United States, India and Europe depend strongly on imports for the main solar module components.
- Although Countries in these markets often possess multi-GW module production capability, most of the plants simply assemble modules from parts shipped from manufacturers located primarily in mainland China.

**Companies in Several Countries & Regions are contemplating significant expansions** to their manufacturing capacity in upcoming years, notably in India, Vietnam, Thailand, the United States and the European Union. *However, with over 300 GW of new assembly plants under consideration in China, its market share is expected to remain high.*

- Organizations in a few Nations and Regions are planning huge extensions to their assembling units in impending years, eminently in India, Vietnam, Thailand, the US & the European Association. Be that as it may, with more than 300 GW of New Assembly Plants under consideration in China, its piece of the pie is supposed to stay high.
- The Important part in this game is always the presence of Natural resource and Energy Consumption Ratio. This ratio decides how your Energy future would be.
- A major geographical shift has occurred in solar PV manufacturing capacity and production over the last decade. People's Republic of China further fortified its driving situation as a producer of wafers, cells &

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modules somewhere in the range of 2010 and 2021, while its portion of worldwide Polysilicon production capacity significantly increased.

- Today, the Nation's share in all assembling stages surpasses 80%, more than double its 36% offer in worldwide PV Deployment. China is ahead in solar module assembling due to having more Rare Earth metal, the Solar PV Supply Chain Expansion has outpaced rapid demand growth in the last decade, with Crystalline Silicon Technology dominating the market at over 95% of installed capacity in the last five years, *and this is one of the main reasons of China being ahead in the game.*

## Part IV: Solar PV Manufacturing Strategy – The Chinese Dominance vs Rest of the World

The World currently needs more Solar PV Manufacturing Units. Based on the manufacturing projects currently under construction, Polysilicon Production Capacity will be reaching around 400 GW by the end of this year. However, considering production times and maintenance schedules, only a part of this new capacity will be available throughout 2023 and as a result, Polysilicon Supply Chain could remain tight as current market scenario.

- In all Countries except China, demand for Solar PV *exceeds manufacturing capacity*, from Polysilicon to Modules are increasing. In the last five years, only the Asia-Pacific region outside of China has become capable of manufacturing its share of its needs, with manufacturing located mostly in ASEAN nations.
- Although Countries in North America and Europe have great module-manufacturing capability, they depend almost entirely on China and Southeast Asia for Solar Cells, except for manufacturing capacity linked to Thin-Film Technology, which relies less on the Chinese Supply Chain. In addition, ***China is also the main manufacturer of Module Components including Glass, EVA, Back Sheet and Junction Box.***
- Material requirements for Renewable Electricity Technologies differ significantly from those of Fossil Fuel and Nuclear Power Plants. Global acceleration in Renewable Electricity deployment in the past two decades has elicited concern about rising new material requirements for the energy sector, including for Solar PV.
- The estimates suggest that ***raw materials make up 35-50% of the total cost of a Solar PV module at 2021 prices.***

### Chinese Solar PV Manufacturing Dynamics.

It requires Metals, Metalloids, Non-Metallic Minerals and Polymers, with material needs differing across technologies and segments.

- Solar-Grade Glass (for covering), Aluminium (for the frame and structure) and Polymers (particularly EVA and Polyolefin for Encapsulation, Barrier Films such as PVDF, PVF or PET for Back Sheets, and PET for Junction Boxes) constitute most of the weight of a solar PV module.
- Despite rapid demand growth through 2020, the overcapacity situation persisted as Chinese Manufacturers further invested in new production facilities. ***Meanwhile, low prices have led producers in Japan, Korea and the United States to downsize or close their Polysilicon Plants***.
- In the United States, low prices combined with import tariffs limiting exports to China have reduced PV-grade Polysilicon production since 2015.
- In the Second half of 2020, supply chain disruptions due to the Covid-19 pandemic, fires in large Manufacturing Plants in China, shuttering of Plants in Korea and a step increase in global PV Installations transformed the previous supply glut into tightness with Polysilicon prices quadrupling to around USD 35/kg in the last Quarter of 2021.
- As of June 2022, Polysilicon Prices remained high (monthly average USD 35/kg) even though 60 GW of additional Polysilicon capacity was commissioned in China last year.
- While the commissioning of new plants is expected to increase global Polysilicon capacity from around 220 GW in 2021 to almost 400 GW in 2022, rapidly growing global PV Demand, fires and maintenance in existing plants in China, and slow ramp-up period for new plants, kept the Polysilicon market tight.
- In addition, 350 GW of manufacturing capacity is to be commissioned in upcoming years. Considering demand projections through 2025, another Polysilicon supply glut cycle is possible if this additional capacity is completed in the coming years.
- China added almost 115 GW of new manufacturing capability in 2021, and another 300 GW was announced in 2022, thus making China even more dominant in Global Wafer Production.

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- Low solar cell prices, the possibility of sourcing several panel components locally (Frame, glass, wiring and packaging), trade restrictions and government support have encouraged many companies around the world to invest in module assembly lines.

### Rest of the World Capabilities.

38 Countries had Module Assembly Capabilities in 2021, by far the highest of all steps of the PV Manufacturing process. In many cases, however, investments were relatively small or stopped at the pilot stage, with just 19 Countries having assembly capacity of at least 1 GW.

### Part V: The Indian Scenario – Capabilities & Possibilities

In comparison, ***the new Policies of Indian Government aims to make India a hub for Solar Manufacturing as well as wants to consume more of Renewable Energy***.

- In wake of the supply chain issues during COVID pandemic and increased tensions related to border dispute between the two Countries, the Indian Government decided to launch a subsidy scheme for Solar Module Manufacturing Sector.
- From then, till now India's Solar Photovoltaic (PV) Module Manufacturing capacity exceeded 39 GW at the end of September 2022 and is expected to reach ~95 GW by the end of the Calendar Year 2025[10].
- The Government's Production Linked Incentives Program is an added push to enhance vertical integration of new capacity additions and technology used.
- In September 2022, the Indian Cabinet approved a Rs 19,500 Crore production linked incentive (PLI) scheme on ***'national programme on high efficiency solar PV modules'*** with an aim to attract Rs 94,000 Crore investment in the sector.

Gujarat housed the majority of Solar Module and Cell Manufacturers. It is expected that the State will remain the major producer of PV Products for the next 2-3 years as it accounts for nearly 57% of all the upcoming PV Manufacturing Capacity.

- Some major reasons manufacturers chose Gujarat for setting up their PV fabrication facilities include cheaper industrial electricity prices and easy access to ports for imports and exports.
- This is a huge jump in a countries Energy dependency. According to the Institute for Energy Economics and Financial Analysis (IEEFA) report, India could become the world's second-largest solar photovoltaic manufacturer by 2026, if continues in this direction with this fast pace.

### But still, what is China doing differently compared to India to be at the top?

China has already achieved economies of scale given the huge PV manufacturing capacity that they have. Also, to bring this market to this huge scale, the Chinese Government has offered cheap credit, free land, cheap loans, research funds, tax rebates, and sometimes even cash to support its manufacturing sector.

- Because of their Large-Scale Integrated Facilities and Government support, Chinese Manufacturers are able to absorb larger shares of the profit of their operational revenues.

- Thus, they are always able to invest significantly in a robust R&D Infrastructure, hence always staying ahead of the curve than the rest of the world.

In comparison, the Indian Government recently opened bids for 39.6 GW of Solar Module Manufacturing Capacity, for Companies looking to set up Solar Module Manufacturing facilities. These Companies will be eligible for Rs 140 billion in subsidies over a period of five years after they start production.

- **India's Production-Linked Incentive** (PLI) Programme for Solar PV provides grants to Companies manufacturing high-efficiency cells from locally produced supply chain components, from Polysilicon to Modules.
- As the Government received significant interest from Companies in the first phase of this Scheme owing to the level of incentives and rising domestic demand, in 2022 it announced additional funding that could increase local manufacturing capacity by four times.

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**Thus, India has a bright future in Solar Module Manufacturing due to several factors: -**

- **Favourable Government Policies.** The Indian Government has introduced several policies to promote Renewable Energy, including Solar Power. ***These Policies include Subsidies, Tax Incentives, and Favourable Regulations***, which have encouraged the growth of the Solar Industry in the Country.
- **Abundance of Natural Resources.** India is blessed with abundant Sunshine, making it an ideal location for Solar Power Generation. With the decreasing cost of Solar Cells and Modules, it is becoming increasingly cost-effective to harness Solar Power in the Country.
- **Increasing Demand for Clean Energy.** With increasing awareness about the impact of Climate Change and the need to transition to cleaner sources of energy, the demand for Solar Power is growing rapidly in India. This has created a huge market for Solar Module Manufacturing in the Country.
- **Skilled Workforce.** India has a large pool of Skilled Workers and Engineers who are capable of designing, developing, and manufacturing high-quality Solar Modules.
- **Attractive Investment Opportunities.** The Indian Solar Industry has attracted significant investment from both Domestic and International Investors. This has led to the development of World-Class Manufacturing Facilities and the adoption of Cutting-Edge Technology in the Industry.

Overall, India has all the necessary ingredients to become a major player in the Global Solar Module Manufacturing Industry.

## Probable Markets Outside India.

Post the Russia Ukraine War, Europe has developed into a major market for Solar Energy, with Middle East and Africa being good locations to establish Solar & Wind Plants.

- Currently, we also see Small Island Countries and Africa a good market for Renewable Energy and the Energy made in Africa can be easily transmitted to Europe through Strait of Gibraltar.
- Germany recently shut down its last Nuclear Powerplant to go nuclear free, and rather than depending on Coal, it sees Renewable Energy as the future.

Additionally, the Module Manufacturing Firms should focus also on Individual selling of the PV Modules to Customers. ***A B2C Model is required currently, which will focus on: -***

- **Developing Countries** have limited access to reliable electricity, with millions of people relying on traditional fuels such as Wood, Coal, and Kerosene for cooking and heating. Solar Energy can provide a clean, affordable, and reliable source of electricity to these communities, & thus making them a good market for Solar module.
- **Remote Areas**, as it is not feasible & easy to connect to them to grid, making solar energy an attractive option for providing electricity. Solar panels can be installed in these areas to provide a reliable source of power for homes, businesses, and public services.
- **Disaster Prone Areas** can also be good market ahead. In the aftermath of natural disasters such as Hurricanes, Earthquakes, and Floods, Electricity Grids are often damaged, leaving Communities without power. Solar panels can be used to provide emergency power to these areas, allowing people to access critical services such as healthcare and communication.
- **Urban Areas**, where electricity prices are high, making it difficult for low-income households to afford electricity. Solar Energy can provide an affordable and clean source of electricity for these communities, reducing their energy costs and improving their quality of life.

## Part VI: Environmental Impact of Renewable Energy.

Renewable Energy has been the focus to reduce carbon footprints & gain Carbon Credits. At first, it seems to be a clean, non-environmentally damaging solution. *But most of the upstream activity to set up the infrastructure is actually nefarious, and sketched out as under: -*

- Renewable Energy is generated from PV Solar Modules, which uses raw elements to make solar cells. These raw elements come through Mines, these mine & mining tunnels degrade the soil and environment around them which can cause soil compaction, erosion, and alteration of drainage channels, as well as create negative effects on local wildlife.
- Furthermore, Solar Energy Systems can impact the land in the process of materials extraction, exploration, manufacturing, and disposal. Also, during this process they forget to eliminate plastic waste. Silica exposure

also is quite prone to the workers. On addition to this, Module manufacturing, has high energy consumption and hardware use, which bring it equal to any other manufacturing facility.

- To understand this better, Solar Energy could be a perfect example. To build Solar Power Facilities, large pieces of land are needed. According to the National Renewable Energy Laboratory (NREL), for a solar power plant to provide electricity for 1,000 homes, it would require 32 acres of land. With the NREL's estimate, all the United States' energy requirements could be met where 18,734,500 acres were used for solar plants, which is equivalent to 0.8% of the entire area of the United States.
- Thus, the environmental impacts of solar panels include habitat loss first, but also water use in the case of concentrating solar thermal plants, along with the use of hazardous materials that can be dangerous if not disposed of correctly.
- On the other hand, wind energy can also be taken for better example. If observed properly, Wind turbines are lethal to birds and bats according to data from 16 and 12 Countries respectively. It was found that a total of 362 bird and 31 Bat Species were affected by turbines.
- A greater number of Small Turbines (Lower Turbine Capacity) resulted in higher predicted mortality rates than a Smaller Number of Large Turbines (Higher Turbine Capacity).

## Conclusion.

Current geopolitical landscape, especially influenced by Ukraine-Russia Conflict, the consequent uncertainty of non-RE Supply Chains in Europe, and further complications due to President Trump Administration led Tariff Regimes, presents greater challenges and corresponding opportunities for RE growth.

- In developing countries like India, continued Policy Support and Financial Mobilization are essential. Despite significant advancements, global progress in sustainable energy sector is insufficient, with significant disparities in access persisting.
- To position India as a Global Leader in Solar Energy within five years, the paper calls for leveraging available technology and raw materials. By addressing funding gaps and focusing on policy support, India can enhance its RE capacity, contributing significantly to global climate action efforts and energy security.
- The paper underscores the potential for substantial growth in the RE Sector, as globally the nations' race to meet SDG targets, thus highlighting the critical role of Solar Energy in this transition.

The paper above also discusses the role of Carbon Trading in promoting RE investments and how Renewable Energy Certificates (RECs) serve as market-based instruments certifying clean energy production.

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