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Solar Energy in India and China: A Comparative Analysis

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ABSTRACT

One of the great benefits of solar energy is that humans are never going to run out of it as it is available and will be available in abundance beyond human existence. That is not something one can say for fossil fuels like coal, petroleum, etc. that humans have been dependent on for thousands of years. If humans want to prevent the Earth from raising carbon-emission, pollution of water, depletion of air quality, and other factors of global warming and climate change they will have to change the energy sources they use today. Turning to alternative energy source like "Solar Energy" has huge potential for the preservence of the environment which we are living in and, simultaneously substantially lower our electric bills for long run. In this paper, we are going to study about the solar energy's potential in the two most densely populated countries in the world, i.e., India and China. In this paper we will also study, the facts and figures for implementation of solar energy and its usage in both the countries. Also, we will try to rectify on the basis of analyzation of facts to prove that solar energy, is both sustainable and an economically efficient alternative to fulfill both, need and demand of energy consumption in India and China.

Keywords: *Sustainable energy, Solar Power, Availability, Alternate resource.*

I. INTRODUCTION

In present day, the solar energy technologies has experienced exceptional growth. The achievement of technological improvements, growing public awareness of environmental issues, the economic climate and number of policy instruments have enabled and sustained this strong interest in these technologies.

In today's environment, where all-natural resources are declining drastically; power, gas, water, forests, etc. The significant factor responsible for this impact on the availability of resources and atmospheric conditions is primarily shared by the high rate of worldwide growth in the number of populations. It has increased in the numbers which are considerably countable in millions, in the last decade. This not only has increased the rate for the

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exhaustion of such resources but has also taken a huge toll on the atmosphere in terms of pollution: increased use of plastic, less knowledge of recycling and reusing resources, whereas regulated use of such resources is also not visible.

Presently, "the term climate change has gained much importance in the world at large, scientific as well as political discussions. Climate has been changing since the beginning of creation, but what is eye-opening, is the speed of change in recent years and it may be one of the threats facing the earth. The increase in rate of emissions was still relatively slow until the mid-20th century. In the year 1950 the world emitted just over 5 billion tonnes of (CO2). By the year1990, this had quadrupled to 22 billion tonnes. Emissions have continued to increase drastically; we now emit over 36 billion tonnes each year. It is estimated that in order to limit global CO2 emissions from human activity to 15 Giga tonnes per year by 2050, the maximum level to limit global warming to two degrees Celsius above pre-industrial levels, will require an investment of $2 trillion per year". This would approximately halve current CO2 emissions and would require all countries to make the transition to low carbon societies. (Shah, 2013)

However, global energy patterns are complex and concern relating to the security and sustainability of energy supply will require rigorous efforts to resolve. As such, there is a fundamental need for sustained political efforts to change energy trends. Action from well-informed policy-makers, industry and other stakeholders are essential to attempt to change global energy trends and ameliorate sustainability and energy security concerns. (IEA, 2014) Furthermore, unsustainable production and consumptions systems limit future development and prosperity of humanity by gradually increasing the amount of irreversible damage on the environment must be reduced.

Renewable technologies like Solar Energy, is considered as clean sources of energy and optimum use of such resources reduce the environmental impacts, produce the minimum secondary waste and are sustainable based on the current and future economic and social demand. Renewable energy technologies provide an excellent opportunity for mitigation of greenhouse gas emission and lessen the impact of global warming through substituting conventional energy sources (fossil fuel based).

Solar energy is the most abundant form of energy available on the planet which is easy to access and nothing other than equipment required for electricity production through sunlight which is a 'Solar Panel' is required in order to access it. Solar technologies convert sunlight into electrical energy either through photovoltaic (PV) panels or through mirrors that

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concentrate solar radiation. This energy can be harnessed to generate electricity or be stored in batteries or thermal storage.

India and China have been selected for analysis for a variety of reasons. There are numerous similarities between the two countries, including: that both are most densely populated country in the world, each has experienced dramatic economic growth in recent decades and has plagued by widespread poverty. Perhaps the most noteworthy similarity relevant to this research is that the two countries are responsible for the biggest growth in carbon emissions in the last few years. (Rapier,2019) The substantial impact that India and China could have on global climate change if persistent is devastating, especially considering that both countries are still developing and account for one third of the world's population between them.

(A) Review of Literature

Lee Phillips (2019) states that Solar power, despite its recent rapid growth in adoption, and the enthusiastic support it receives both from the scientific establishment and energy investors, remains a very small proportion of total energy consumption. Its potential to drive a crucial reduction in the emissions of greenhouse gasses lies in a potential future. If the exponential trend of the last decade continues, solar power will replace a sufficient quantity of fossil-fuel combustion to play a large role in reaching humanity's climate goals.

Suyash (2017) highlights that rapidly developing countries like India face numerous challenges related to social and environmental sustainability, which are associated with their fast economic growth and rising energy demand. For this, the initiative of off-grid PV solar energy in India, specifically homing in on the innovative business models are evolving. This is found to be quite successful, but have difficulty in terms of reaching the poorest of the poor.

Ahteshamul Haque (2016) mentions **"**human beings have tried to utilise solar energy in the past for their convenience. In the fifth century BC, passive solar systems were designed by the Greeks to utilize solar energy for heating their houses during the winter season. Currently, global demand for electricity is increasing. The limited reservoirs of fossil fuels and emission of greenhouse gases have led to serious concerns regarding energy crises and climate threats. These concerns led researchers to look for alternative sources of energy, and solar energy is considered as the most acceptable source among all renewable energy sources. Solar energy is available in abundance and free of cost all across the globe". Studies reveal that Earth receives energy from the Sun, which is 10,000 times more than the total energy demand of

the planet.

The Intergovernmental Panel on Climate Change (IPCC) (2015) highlights that, "acting on raising carbon-emission levels and Climate Change is "possible, beneficial and affordable." If countries with well-developed economies accept strong regulations, which include a lot more investments in solar energy, and other alternative energy sources, that will dramatically reduce the emissions".

Dincer I, Ezzat M. (2018) says that the source of Photovoltaic (PV) solar energy is obtained through photovoltaic panels; being an abundant and sustainable source of energy, that is highly promoted for its environmental privileges because it does not emit harmful gases, such as carbon dioxides, contributing to the slowing of global warming and to meet global energy demand in a sustainable way. The research, development and continuous improvement of this solar technology is essential with the view to increase the energy efficiency for beneficial use in all consumer segments.

Bardi U (2013) states that the modern agriculture is heavily dependent on the energy supply obtained mainly from fossil fuels. It is a natural response that PV technology is applied to agriculture sector, called PV agriculture, that is, solar PV power generation is utilized to supply the green and sustainable electricity for agricultural production activities such as planting, breeding, irrigating, etc.

(B) Central Question

Will India and China be able to fully transform from carbon intensive resource utilization to clean energy resource utilization?

(C) Related Questions

1. Does India have more solar power potential than China?
2. Would solar power be developed to such an extent that it can fulfil the high electricity demands of each sector?
3. How fast the use of renewable and clean energy technologies can scale?
4. What is the global status of India and China in producing solar power?
5. Solar power requires large open area to operate. Can it be implemented in every developed area?
6. What are the employment opportunities for people in solar power?

(D) Hypothesis

China is the worst polluter in the world however, it is also the greatest investor in renewable

energy. Similarly, India is amongst the top polluter, but experienced its highest growth rate in renewable energy. So yes, Solar power has huge potential to replace power generation through electrical grids and other techniques currently being used. Both the countries have great potential to sustainably transform the foundation of energy systems from fossil fuels to renewable sources.

(E) Objectives of the Study of 'Solar Energy'

- Promote the use of sustainable, economic and least cost decentralised electrification solutions for areas not feasible for grid connection/extension in partnership with the local government units, semi-private and private sectors.
- Plan and execute an integrated programme on development and implementation of renewable energy projects.
- Apply solar energy technology as the enabling technology for sustainable development.

(F) Methodology

In the following project, the knowledge and facts are gathered from newsletters and reports published in newspapers and online on blogs and journals written by various environmental activists which are working and promoting solar energy as a most valuable source of renewable energy. We take into consideration the unique nature of solar power generation in which systems produce electricity on peak, produce power at the location of use, do not require continuous fuel purchases, and have significant security and environmental advantages over fossil fuels. These characteristics generally increase the value of solar electricity as they allow utilities to evade the costs of fuel, plant, reserve capacity, transmission, and distribution in their centralized assets.

II. SOLAR ENERGY IN INDIA

(A) Geographic Sketch of India

India is the seventh largest country by area and ranks second in terms of most populated country in the world with over 1.38 billion people. (Statista, 2021) "India lies in the northern part of Indo-Australian plate and north of the equator between 8°4′ and 37°6′ north latitude and 68°7′ and 97°25' east longitude. The country is divided into almost two equal halves by the Tropic of Cancer (23°30′N)". The southern half which coincides with peninsular India lies in the tropical zone, while the northern half belongs to the subtropical zone. **Due to its locational advantage, on average, the country experiences 250 to 300 sunny days per**

year and receives an average hourly radiation of 200 MW/km2. "The country is bounded by water bodies in three sides, Indian Ocean in the south, Arabian Sea in the south-west, and Bay-of Bengal in the south-east. It shares maritime borders with Indonesia and Thailand and land borders with Pakistan in the west, Burma and Bangladesh in the east and China, Nepal, Bhutan in the north-east. India, the populous democratic country in the world consists of 28 states and 8 union territories. The Indian rivers mostly originate from three watersheds: Himalaya and Karakoram Ranges in the north; Vindhya, Satpura and Chota Nagpur Plateaus in the central India and Western Ghats in the western India".

(B) Need For Environmental Law

According to the Brundtland commission- earth is one but world is not. We all depend on one biosphere for sustaining our lives. Yet each community each country strives for survival and prosperity with little regard for its impact on others. Some consume the earth's resources at a rate that would leave little for future generations. Others, many more in number, consume far too little and live with the prospects of hunger and disease. (Shastri, Satish C, 2012)

Several committees were set up in India in 1980s, to suggest administrative and legislative measure that ought to be taken to preserve the environment. As a result, the environment department was set up at both the levels- center and state level and an independent ministry and department came into existence in 1981.

The first UN conference on human environment that was held in June 1972 in Stockholm created an awareness for environmental protection in which India participated to take steps for the protection and improvement of human environment. Also, the concept of sustainable development was introduced for the first time by Stockholm conference.

(C) The Indian Constitution and Environment Protection

"India was the first country in the world to have provisions on the environment in the constitution. The Indian parliament passed the 42nd amendment to the constitution in 1976 and incorporated specially two articles relating to protection and improvement of the environment". (Shastri, Satish C, 2012)

"The Ministry of New and Renewable Energy serves as the primary source of funds for the expansion of solar power generation and the policy of developing solar energy. The purpose of the ministry is to develop a grid-based energy network to increase private sector investment in renewable energy and research on renewable energy policy. The agency responsible for solar energy research and development under the Ministry is the National Institute of Solar energy which is an autonomous organization. This ministry plays an

important role in the overall design, promotion, and development of renewable energy systems in the country, including solar energy". (Ebinger,2011) In addition to this ministry, which is responsible for setting the policy framework for solar power, there are other organisations involved in policy design to drive this energy, such as the Ministry of Power and NITI Aayog.

"There are three main policies for policy promotion and development of solar power in India, which is, The National Solar Mission (the Ministry of New and Renewable Energy), National Energy Policy (NITI Aayog) and the National Electricity Plan (the Ministry of Power)". These policies have a similar goal and mission for renewable energy and solar energy, which is to expand the production of solar electricity to promote access to electricity. Another interesting feature is that these policies are similar in defining the organisation that drives the policy, concentrating on the state and sub-sectors of the organisation that design the policy, except NITI Aayog. "The National Solar Mission is the clearest policy in the solar energy and has set a clear goal to achieve. The other two policies are similar in many respects, but the National Energy Policy targets a broad spectrum of energy, including electricity, transportation, etc., while the National Electricity Plan focuses solely on electricity".

1. **Electricity Act, 2003**

The Electricity Act 2003 promotes electricity generation from co-generation and renewable energy sources. The Act accelerated the process of renewable energy development in the country. (Anoop, 2011)

- "Section 3(1) of the Act provides that the National Electricity Policy (NEP) to be formulated by the central government, in consultation with the state governments for development of the power system based on optimal utilization of resources including renewable sources of energy".
- "Section 4 of the Act provides that the Central Government to prepare a national policy, in consultation with the state governments, permitting stand-alone systems (including those based on renewable sources of energy and other non- conventional sources of energy) for rural areas".
- "Section 61 (h) stipulated that the terms and conditions for the determination of tariff to be prescribed by the SERCs to promote co- generation and generation of electricity renewable sources of energy".
- "Section 86(1) (e) empower the SERC"s to specify, for purchase of electricity from such sources, a percentage of the total consumption of electricity in the area of

distribution licensee. The aforesaid section of the Act also empowers the SERCs to promote co-generation and generation of electricity through renewable sources of energy by providing suitable measures for connectivity with the grid and sale of electricity to any persons".

- SERCs have specified a Renewable Purchase Obligation (RPO) and have specified feed-in tariff and other terms and conditions to promote cogeneration and generation of electricity from renewable energy sources.

(D) Potential for Solar Energy

The Indian power sector is primarily based on fossil fuels, with India being fifth largest coal reserve in the world and the second largest coal producer. But in few last decades Indian government has taken several steps to reduce the use of fossil fuels-based energy while promoting renewable generation. Solar energy constitutes the most abundant renewable energy resource available and in most regions of the world even its technically available potential is far in excess of the current total primary energy supply. As such solar energy technologies are a key tool to lower worldwide carbon emissions.

(G Balachandar, 2021) At present, India is the third largest producer and consumer of electricity in the world. The national electric grid in India has an installed capacity of 375.32 GW as of 31 December 2020. Renewable power plants, which also include large hydroelectric plants, constitute 36.17% of India's total installed capacity. As of 31 December 2019, the installed solar power plants capacity was 33.73 GW, or 2% of utility electricity generation.

Initially, "Indian Government had a target of achieving 20 GW capacity by year 2022 but, it was achieved four years before the schedule. In the year 2015, the target was upraised up to 100GW of solar capacity to be achieved by the year 2022. At present, India has established around 42 solar parks for establishing solar power plants. As of November 2020, India has installed 36,910 MW Solar PVs including both ground and roof mounted plants".

(E) Major Photovoltaic Power Stations and Solar Energy Application in Major States

According to the IEA report of 2011, India is one of the favored nations of the Sun as it receives 5,000 trillion kWh of insolation yearly, which is greater than the annual consumption and a daily global radiation of around 4–7 kW h/m2/day. (IEA, 2011)

Bhadla Solar Park: located in Rajasthan, until March 2020, it is the World's biggest solar Park in terms of generation and second largest in terms of areas. The park has a capacity of 2245MW.

Pavagada Solar Park: located in Tumkur district of Karnataka, the park covers total area of 13000 acres in Pavagada taluk and has a capacity of 2050 MW. This makes it the World's second largest photovoltaic solar park in terms of area.

"India is the **third leading solar power producer in the world** after China and United States respectively. Karnataka and Andhra Pradesh are leading the country in producing the solar power". India's top five solar power producing states are set to lead the nation in reaching its 450GW renewable energy target by the year 2030: (NS Energy,2021)

i. **Karnataka: "**the south-western state of India is heading its way in producing solar energy. So far 7100MW solar power capacity has been installed. The state is home to World's second largest Solar Park- Pavagada Solar Park in Tumakuru district" and the government is planning to set three more mega solar parks in districts of Bidar, Koppal and Gadag. (Bosky Khanna, 2020) As the state generates 39.97 percent of solar energy, the state energy department plans to sell excessive solar energy to the other deficit states in India and also have a proposal to collaborate with the government of California where the latter will purchase renewable energy in order to meet its demands.

ii. **Telangana: "**the southern state in India comes second in terms of solar power capacity reaching about 5000MW including rooftop solar units and grid connected ones". The state is also planning to set up Floating Solar Photo Voltaic (FSPV) based power generation units on its reservoirs as according to the government the state doesn't have suitable waste lands for setting up ground mounted solar power plants and such lands could be used by them for other purpose. (Telangana State Renewable Energy Development Corporation, 2020)

iii. **Rajasthan:** home to World's largest fully operational Solar Park, Badhla Solar Park in Jodhpur and having the high potential for solar power generation than any other region in the country, the state ranks third after Karnataka and Telangana. "The state has reached the capacity of 4,400MW of solar energy and intent to reach the target of 30,000MW by the year 2025. Due to scarcity of water in the desert region, the Central Arid Zone Research Institute has developed the unique rain water harvesting system for cleaning the solar panels which are placed between the rows of plantations in agriculture fields". (Dr. Priyabrata Santra, 2020)

iv. **Andhra Pradesh: "**the state ranks fourth with the total capacity of 3,470MW solar energy in India. The state has a goal to generate up to 10,000MW of solar power to meet the energy requirements of the agriculture sector". (Economic Times, 2020) The government promises to provide free power supply to the agriculture sector and lift the irrigation schemes, the state energy department recognize solar energy as the best alternative to provide quality

power and nine-hour day time free power supply to farmers. This way the state can control the increasing agriculture subsidy.

v. **Gujarat:** being the first state to adopt solar energy in the county, "the state ranks fifth with the total capacity of 2,654MW of solar energy. As of March 2020, the state was leading the country for installing 50,915 domestic rooftop solar plants". As per the state's new solar power policy, the state government will now purchase the surplus energy from the residential, micro, small and medium enterprises consumers after setting off against their consumption. The state also allows the consumers to lease their premises/roof to third parties to help them generate and consume solar power in the same premises. (Aarushi Koundal, 2020)

(F) Solar Energy in Indian Agriculture

India is an agrarian economy and its demand for electricity is one of the hurdles on India's power sector as irrigation system are largely underdeveloped and farmers depend on electricity to power their pumps. India has around 18 million grid-connected and 7 million diesel pump sets for irrigation and other purposes and electricity produced through solar panel has a potential to replace them with solar power plants and grids along with pump sets used for irrigation running on electric motors powered by electricity produced through solar energy. (Goerdeler, 2014) Solar Water pumps are ecofriendly and are an economical solution as compared to the conventional water pumps and also lowers the electricity bills to its minimum. If one replaces 1 million diesel pumps with solar pumps it will result in reducing carbon dioxide (C02) emission by 25.30 million tons.

Large piece of agricultural land is irrigated through pumps powered by electricity and it takes a toll on distribution companies (DISCOMs) to provide continuous power supply even for few hours as the company is already under debt. Here, solar power becomes the most versatile forms of energy and can be game changer for the agriculture sector, saving water resources, reducing the dependency on grids and has the potential to become additional revenue for farmers, if used wisely.

"The Ministry of New and Renewable Energy (MNRE) provides 30 percent subsidy with loans at low interested rates to people interested in installing solar water pumps. Certain States like, Rajasthan, Tamil Nadu and Panjab provides higher subsidies 86 percent, 80 percent and 70 percent respectively as compared to subsidies given by MNRE". (Goerdeler. 2014)

Solar Energy can also be used to dry crops and grains. Significant proportion of agriculture produce is ruined during the traditional open air-drying method. Perishable crops are difficult

to dry and major portion of it ends up spoiled. By using solar drying method, it is fast to dry crops and at an even rate than leaving them out open in the field. This will also help in protecting the crops from birds, insects and decrease the portion of spoiled crops and contribute to increase the farmer's income.

A solar drying apparatus consists of a shed, a drying rack and a solar collector. The shed traps the solar heat coming from the south-facing window and natural convection or a solar fan propels the heat. There are different types of solar dryers available in the Indian market like, direct drying (solar box dryer), indirect drying (solar cabinet drying), mixed mode drying (solar tunnel dryer) etc. (Amit Bajpaye, 2019)

Livestock and diary operations often have considerable air and water heating requirements. Modern pig and poultry farms raise animals in enclosed buildings, where it becomes essential to carefully control the temperature and air quality in order to maximize the health and growth of the animals. These facilities require replacing the indoor air regularly to remove moisture, toxic gases, odours, and dust. Heating this air, when necessary, requires huge amount of energy. With proper planning and design solar air/space heaters can be integrated into farm buildings to preheat incoming fresh air. These systems can also be used to supplement natural ventilation levels during summer months depending on the region and weather. Water heating accounts for as much as 25 percent of a typical family's energy costs and up to 40 percent of the energy used in a typical dairy operation. If used wisely, solar water heating system could cut those costs in half.

There is need for improved energy sources in agriculture that are affordable, clean, risk free and constitute no harm to man and environment.

III. SOLAR ENERGY IN CHINA

(A) Geographic Sketch of China

"People's Republic of China is located in Southeast Asia along the coastline of Pacific Ocean. It is the world's most populated country with total population of 1.44 billion people. It is also the third largest country by area". The vast land of china is two-third occupied by plateaus, plains, basins, foothills and mountains. The highest peak in the world, Mount Qomolangma is located on the border between China and Nepal. "The country is divided into four regions, i.e., North, South, Northwest and the Qinghai-Tibetan areas. The ninety-five percent of Chinese population are settled in the North and South regions which lies in the Eastern monsoon area that is further divided by the Qinling Mountains- Huai River. The other fifty-five percent of the land is occupied by the Northwest and Qinghai-Tibetan regions

where most of ethinic groups live. There are 30 first level administrative units (provinces, autonomous regions, and national municipalities) in China and three municipalities directly under the Central Government, namely Beijing, Tianjin and Shanghai. Also, there are 22 provinces and five autonomous regions for minority nationalities. The longest river in Asia and third longest river in the world flows in China- the Yangtze River. Other major rivers include the Yellow River, the Yarlung Zangbo River, Pearl River etc".

(B) The People's Republic of China in Promoting Solar Energy

Renewable energy law of China came into effect on 26 December 2009. It was formulated to elevate the development and utilization of renewable energy (including wind energy, solar energy, hydro energy etc), raise the supply of energy and to protect the environment in order to achieve sustainable development. The law describes that the development and utilization of renewable energy should be done on priority basis. (MINISTRY OF COMMERCE PEOPLE'S REPUBLIC OF CHINA, 2013)

"The National Development and Reform Commission (NDRC) is one of the organizations that plays a significant role in designing and identifying policies related to promoting and improving solar energy in China. There is an important organization specifically responsible for renewable energy under this board". It is China National Renewable Energy Centre (CNREC) which functions as a key facilitator of the commission through renewable energy research involving policy, standards, governance, strategy, trends, technology, etc.

Even though the National Energy Commission (NEC) is a sub-commission of the main commission, it is responsible for developing new proposals and strategies for national energy production. Besides, the NEC also has one agency responsible for promoting and coordinating information for the country's solar policy, known as the National Energy Administration (NEA). "The National Energy Administration (NEA) is another critical research organisation that studies and analyses the formulation and execution of energy production and industrial policy strategies, providing advice on energy structure improvement, managing the energy market, and so on". Thus, the structure of China in terms of renewable energy policy, including solar power, is centralized under the management of the NDRC.

The purpose of solar policy is not only a responsibility for the central government, but it is also a vital role for local governments. To implement solar policy in China, the government gives the authority to local government to design their own guidelines for achieving policy goals. Therefore, the central government sets the contract with local government in different

ways so that when all the local states reach their respective goals, they will together promote National goals along the way. (Smil, 2010)

(C) Solar Energy Potential in China

Energy demand has risen swiftly and reached an unprecedented level due to the high-speed economic growth and modern development in China. This increasing demand for energy encouraged China to add an average of 53GW of electric capacity each year over the past ten years to its power generation needs. China is also the world's second largest producer of coal but, that doesn't stop the country to lead in the manufacturing of clean energy.

Charlotte Edmond (2019) China has a huge potential for solar energy than any other country in the world and the country's rapidly developing population makes it the biggest energy growth market globally.

It was in the1970s when the country started to use solar energy and achieved good results in the beacon lights. The solar photovoltaic (PV) technology began to be used in road lighting and signals in 1990s and by the support of China government the solar water heating systems entered the rural residential areas by the late 20th century. In the 21st century, solar photovoltaic technology has been greatly encouraged by the growing attention of government and the improvement of solar cell production technology, meanwhile solar energy applications field also expanded gradually. Today, china is leading the world market of solar energy. In the year 2015, the country's solar power capacity was 43GW and reached to total installed solar capacity of 240GW in the year 2020. The country's capacity has increased more than fivefold since 2015 and has an aim to double the capacity by the next five years. (China PV Industry Association, 2020)

"According to the International Energy Agency (IEA), China manufactures more than 60 percent of the world's solar panels which makes it the world's largest manufacture and exporter of solar panel technology". Besides, the cost of photovoltaic technology remains low in China and between the year 2008 to 2013, China's emerging solar electric panel industry dropped the world prices by 80 percent which is the huge achievement in high- tech market.

According to some veterans in the U.S. solar industry, China bought solar companies and invited others to move to China, where they found cheap, skilled labor. Instead of paying taxes, they received tax credits. (Fialka, 2016)

The country's 14th Five-Year Plan covering the period 2021-2025 was revealed in the October 2020 where the government has an aim to make the country carbon-neutral by the year 2060 and it will increase its annual solar power generation capacity to 85GW which is

two-fold the country's current rate.

1. Major Solar PV Plants

Five largest solar power plants in China are listed below: (Murray, 2021)

i. **Huanghe Hydropower Hainan Solar Park**: the park is located in the China's rural Qinghai province, "is the country's largest and the world's second largest solar farm. It has a 2.2GW installed capacity". The site is linked to an ultra-high voltage power line being constructed to connect the country's far northwestern regions to the more highly populated eastern provinces.

ii. **Tengger Desert Solar Park**: located in Ningxia, it is the country's second largest solar power plant and the world's fifth largest. "It is often labeled as the "Great Wall of Solar" with the capacity of 1.55GW which covers the 1200Km of the 36700km Tengger Desert. It supplies clean energy to more than 600,000 homes in China".

iii. **Datong Solar Power Top Runner Base**: "located in Datong city, Shanxi Province, with the capacity of 1.1GW it is the country's third largest solar plant". It is one the plan of country's National Energy Administration to develop solar projects in the region.

iv. **Yanchi Ningxia Solar Park**: situated in Yanchi district, Ningxia, with the installed capacity of 1GW, is the fourth largest solar park. "The central operation of the power plants is handled by the Fusion Solar Smart O&M cloud Centre, which uses cloud infrastructure and big data to run the plant efficiently. It has a life expectancy of 25 years".

v. **Longyangxia Dam Solar Park**: located high on the Tibetan Plateau in the northwestern Chinese province of Qinghai. "It is the fifth-largest solar site in the region, with an installed capacity of 850MW, and was previously the world's largest when it first went online in 2013. The power plant is connected to the nearby 1.28GW Longyangxia hydroelectric power station which can power up to 200,000 homes in China".

(D) Application of Solar Energy in Agriculture

China is constantly confronted with extreme electricity shortages as a result of very high energy demand for rapid economic development, as well as serious environmental pollution due to the production and consumption of non-renewable energy. Green and sustainable solar energy has developed as a natural choice, because of the increase in demand for energy in agriculture and the adverse environmental impacts and limited sources for fossil fuels. The use of Photovoltaic (PV) technology in agriculture have unparalleled benefits for the country.

One of the motives of PV agricultural greenhouse is to obtain higher agricultural income by flexibly creating a suitable environment for crops growth. For example, farmers can plant

high value-added crops such as organic agricultural products and rare and expensive seedlings. The anti-season planting is achieved because greenhouse can be heated in winters. According to transparent and semi-transparent PV panels, it can boost the amount of sunlight to enter the greenhouse and by using selective plastic films, it can provide corresponding wavelengths of light absorption for growth of different plants. It can also combine the natural radiation with supplementary lighting powered by PV energy, or it can provide light for plant growth in night with LED lamp using PV power generation in the daytime. (Reda, 2016)

PV agricultural greenhouse power generation system can alleviate the contradiction between more population and less availability of land which is the major issue in China considering it is the highly populated country. (Dupraz,2011) The PV system can install on or above the roof of agricultural greenhouse and can save land resources because it does not occupy land and change the nature of land usage. This system can play an active and effective role in the relative reduction of arable land with the increasing population.

Considering the rise in sewage problem in rural areas of China where agriculture production takes place and the excessive emissions of agriculture pollutants such as COD have done a lot of damage to the water in those areas, the government focuses on the use of solar PV wastewater purification system with no battery and no storage system which can utilize solar PV electricity generation into the wastewater treatment process with no extra pollution and energy transferring. Without the battery installed inside, the system works during the daytime and stop wording after sun goes down, which is an ideal condition for nitrogen and phosphate to release from the wastewater. (Han C, 2013) It is indicated that the system can achieve average removal of 88% COD, 98% NH4+-N, 70% TN and 84% TP. Nowadays, more and more such PV wastewater purification system have been established in China such as Yangzhou 9.7MW PV wastewater treatment project and Taizhou 5 MW PV wastewater treatment project.

A scientist from the University of Arizona states that the crops growing under the shade of solar panels can help produce to two or three times more fruit and vegetables than conventional agriculture setups. Crops like chiltepin peppers, jalapenos and cherry tomato plants are being grown in the shade of PV panels in a dry location in China.

“The solar park with the capacity of 640 MW in the Binhe New District on the eastern banks of the Yellow River in the Ningxia Province of China is expanding up to 1 GW”. In this giant project, the country is combining PV power generation with the production of goji berries, which are an ingredient in traditional Chinese, Korean, Vietnamese and Japanese medicine.

IV. COMPARATIVE ANALYSIS

(A) Contribution in Development of Solar Energy in India and China

"India and China both, have the largest economies in the world and their economic development has primarily been fuelled by coal". China burns out the most coal in the world with its consumption level at 49 percent and its production level at 46 percent, followed by India, who comes second in the list by producing 783 million tons. Both of these countries are racing to produce and develop other types of energy resources. India currently has installed 42.9GW capacity of solar power and reached 9 percent share of the global PV market of the year in 2019. However, China has total installed capacity of 205.2GW of solar power as of 2019 which makes the country stand far ahead of its neighbors. The country represents 29 percent of total global installation in the market.

"Of the five leading solar power plants in the World, three belongs to India, having World's largest solar park in terms of generation- "Badhla Solar Park" and two of them belong to China".

In the late 19th and 20th century, electricity has become the symbol of modernity. Access to electricity has become a means of measuring the economic viability of people. Those who have access to electricity are considered to be urban dwellers, while those who don't have access to electricity are defined as rural. (Hezri, 2012) The economic development in urban societies is driven by the service sector and industry while the agriculture production happens in rural areas. With the different economic structure there is inconsistent supply of electricity between urban and rural areas. The power generation by non- renewable energy contributes to environmental problems and studies found out that the rural areas are adversely affected by it. With the use of electricity in urban areas combined with issues of climate change, it is revealed that the rural areas are significantly affected in terms of opportunities, access to electricity and climate change. (International Bank for Reconstruction and Development, 2017) "India ranked first in the year 2014 where people do not have access to electricity. Besides, India's electricity shortage accounted for one-third of global electricity shortages, where more than 270 million people in the country do not have household electricity". However, In China, since 1997, over 95 percent of the people have access to electricity and the country was able to succeed in expanding its electricity network where 99 percent of the total population was covered in the year 2009.

Solar energy has become an imperative alternative to renewable energy to address the crisis in access to electricity and mitigate future climate change. It has the potential to generate

energy more than global energy consumption requirements. Solar energy also contributes in the economic development of the country by providing employment opportunities. (International Renewable Energy Agency, 2017) the study done by the IRENA suggest that the renewable energy industry is the most active sector and employed more than 9.8 million people in the year 2016. Most of employment in the photovoltaic sector took place in the developing countries like India and China, where many are unemployed. More than half of the employment occurred in China including the manufacturing and installation sectors. The data also suggested that more than 60 percent of solar cell production occurred in China in the year 2017. The growth of employment in the solar industry raises the employment system of developing countries from the labor-intensive industry to technology-based industry.

(B) Different Pathways of India and China in Promoting Solar Energy

India and China have a similar development goal which focuses on the expansion of solar power. China's development growth is very different from India. China developed solar power not only to meet business and energy needs but also to provide energy to the people. "According to the goal of renewable energy development 2009, The Renewable Energy Law of the People's Republic of China, the government must support the development of electricity generating sources from renewable energy, especially solar energy at the local and community levels to support the lives of the people". (People's Republic of China, 2009) On the contrary, Indian government gave prior importance to increase the access of electricity of the private sector in order to strengthen the country's economic growth. Second priority was given to upgrade the access to electricity to the people of the country. "The Jawaharlal Nehru National Solar Mission which was parted into three phases clearly mentioned that the production of electricity from solar power is to meet the energy demands of industrial and big cities in the first phase. Later, in second and third phase, the plan mentioned about the access to electricity to people". (Ministry of New and Renewable Energy, 2012) Therefore, this change in preference resulted in differences in the outcomes of both the countries regarding the role of solar power.

China focuses on the research and development of solar energy as the country invests large amount of money in this sector that resulted in technical reduction in cost of solar energy. That is why, China is able to export their products to other countries so that they can fulfil their requirements. On the other side, India invests not enough amount in research and development and imports much material like PV panels from China.

China is also trying to eradicated poverty by using innovative methods such as photovoltaic

poverty relief program which will promote not only local social and economic development, but also facilitate ecological restoration. “In the Talatan area of Gonghe Country, Qinghai Province of China, a subsidiary company of the state power investment corporation planted seed of grass under the solar panels as the area was facing desertification due to overgrazing of grass by sheep”. The water was also recycled which was used to clean the solar panels for irrigation. When the grass started to grow higher and higher, it started blocking the solar panels affecting the power generation. To solve this issue, farmers were called to bring their sheep to gaze under the PV panels and thus “photovoltaic sheep” was born. Now the farmers are likely to earn and this model also created jobs of security, maintenance, cargo handling and other opportunities for the surrounding villages.

(C) Organisational Structure in Promoting Solar Power

The organizational structure of India and China in fostering solar policy is also an important factor resulting in different development outcomes. “India has many central government organisations that are responsible for driving solar policy like Ministry of New and Renewable Energy, Ministry of Power and NITI Aayog”. The three authorities are responsible for solar development at the state level and also play a fundamental role in driving all the solar policies. But, the lack of linkage of work among the three organisations and their independent efforts in solar energy policy creates a conflicting organizational structure. Whereas, China has the single body in managing and promoting solar energy. “The National Development and Reform Commission (NDRC) is the only national organisation in the country who is in charge of promoting solar energy through the support of other lower-level organisations”. Besides, the single structure makes it easy to monitor and track the progress of the projects. This results in having greater efficiency in the use of human resource.

Since 2007, “the Indian Ministry of Power publishes a five-year National Electricity plan. The third draft was published in December 2016, and made number of suggestions and forecasted how India could meet its electricity demands during its current 13th five-year plan (2017-2022). The plans aim at having 175GW of renewable capacity installed by the year 2022 where nine major states will contribute to almost 77 percent of Renewable energy capacity”. The country has a target to increase the solar capacity by 10 times in coming 5 years and at the same time plans at weakening the position of coal in the market by reducing to only 44GW of coal capacity to meet its electricity demands between 2022 to 2027. Whereas, “China also announced its 14th five-year plan (2021-2025) electricity and energy, which aims in increasing its solar power capacity by 75-85GW annually”.

V. CONCLUSION AND RECOMMENDATIONS

With the rapid economic growth, both India and China's demand and usage for electricity are increasing. While fossil-fuel-based electricity is still the primary source of power in both countries, the governments of both countries acknowledge the advantages of a sustainable energy transition. India and China have both made commitments towards low-carbon technologies and have improved their efforts to promote these technologies. Solar energy is a foremost component in the strategy of both countries to achieve sustainable energy production. Solar energy will continue to grow in popularity as the alternatives have significant downsides as technological innovation continues to improve the efficiency and cost effectiveness of solar.

Both the countries have been ambitious with policies to increase distribution and this is set to continue into the future, with both countries setting ambitious targets for the future of solar energy. "India has installed 36,910 MW Solar PVs including both ground and roof mounted plants as of November 2020. Similarly, China, the world's biggest carbon emitter, intends to speed up solar power deployment and set a target of 85GW of solar installed capacity by the year 2025 to cut its reliance on coal". Thus, so far, China has a greater cumulative installed solar capacity than India, however, the reasons for this are not limited to those examined in the analysis. The global financial crisis, the anti-dumping, anti-subsidy and countervailing investigations against Chinese solar panel manufacturers, excess solar manufacturing panel capacity and global pressure to transition to low carbon have all impacted the decision-making process to increase solar deployment in China.

India is enriched with abundant solar energy source. The foremost application of solar energy in Indian soil is water heaters, which is at the beginning of growth phase of PV industry in India. "The Indian share of solar water heaters in global market is only 1.20% where as China, also a developing country, ranks first in the world with 10% share". For agricultural use, farmers are using PV technology in farming tools, pumping various water resources, mowers, tractors etc by utilizing 70–80% subsidies provided by various state governments. Moreover, solar lantern is used in indoor and outdoor applications in Indian houses and stand-alone and hybrid solar lighting systems are used in most of the streets of Indian cities. With the aim of achieving the solar distributed power generation, the goal is challenging, but for a sustainable market growth, steps have to be taken to release it for commercial purpose. As the solar resource is massive, it has the highest potential to play a remarkable role in India's energy scenario.

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Furthermore, the IRENA report framework for assessing the long-term sustainability of renewable energy policies: "Evaluating Renewable Energy Policy: A review of Criteria and Indicators for Assessment", has been used to assess both the countries. When it comes to the sustainability of overall solar energy policy, the outcomes suggest that China is stronger than India. However, at the individual policy level, specifically solar energy auctions, the results of the analysis suggest that India's solar energy policy is stronger than China's. The solar energy auction scheme in India was implemented based on previous domestic and international experience. This suggests that India has given serious consideration to previous renewable energy sector experience and the sustainability of policies when developing the solar auction policy. Whereas, the solar energy auction scheme in China made many of the same mistakes that the first wind power auctions did, suggesting that experience and sustainability were not given reasonable consideration. In China the policy and procedure has developed for wind power auctions, these lessons were mostly ignored by the solar energy auction scheme. (Wang, 2014).

The investment in solar power in both India and China is primarily aimed at promoting energy security to reduce dependence on foreign energy and push to use new technologies to promote and develop a society that has access to electricity to increase equality between cities and rural areas. This is a significant benefit to solar power, which is very different from other renewable energy. The above information reflects us that both China and India have achieved great success in pushing the solar power policy. China can produce electricity from solar energy up to 130.2 GW, while India can produce up to 23 GW. Although the amount of electricity produced by the solar power of India is much lower than China, the proportion of expansion is similar. There are a variety of factors that result in the production of electricity from solar energy in India and China are different. First of all, it is the policy of India and China for solar power. According to analytical studies, data indicate that the Chinese government's policy on solar electricity management is clear and has only one policy. On the other hand, the Government of India has a variety of policies for managing solar power, which makes it difficult to implement policies. For the second factor is the agency responsible for overseeing the solar power policy. The Chinese government has only one agency, which is responsible for formulating policies to pass on to local governments to implement. On the other hand, the Government of India has a variety of agencies to set policies. In addition, the agency responsible for implementing those policies also includes local and Union governments. The diversity of agencies involved in the policy has resulted in the overall work of the solar power policy moving slowly. Finally, India and China want to

increase the domestic energy mixture by using solar energy. However, this policy push has a different goal. China wants to expand the development of solar power to promote public access to electricity and reduce the import of fossil fuels from abroad. On the other hand, India wants to promote the expansion of solar energy to reduce the import of fuel from abroad and increase the stability of the electricity use of the business sector. Therefore, the Chinese government has made significant progress in increasing access to electricity by 99%. In contrast, India has a growing number that is slow, not progressing as it should.

The endowment in solar power in both India and China is primarily intended at promoting energy security to decrease dependence on foreign energy and stressed to use new technologies to promote and develop a society that has access to electricity to increase equality between cities and rural areas. This is a substantial aid to solar power, which is very different from other renewable energy. The study reflects that, "both India and China have achieved great success in pushing the solar power policy. China has a capacity to produce 253GW electricity from solar energy, while India has a capacity to produce 100 GW of solar power by the year 2022". Although the sum of electricity produced by the solar power of India is much less than China, the proportion of expansion is similar. There are a variety of factors that result in the production of electricity from solar energy in India and China are different. Firstly, it is the policy of India and China for solar power, according to analytical studies, it is indicated that the Chinese government's policy on solar electricity management is clear and has only one policy. On the contrary, the Government of India has a variety of policies for managing solar power, which makes it difficult to implement policies.

Secondly, it is the agency responsible for supervising the solar power policy. "China has only one agency, which is responsible for formulating policies to pass on to local governments to implement. Instead, Indian government has a variety of agencies to set policies". Besides, the agency responsible for implementing those policies also includes local and Union governments. The multiplicity of agencies involved in the policy has resulted in the overall work of the solar power policy moving slowly.

Finally, India and China plan to increase the domestic energy mixture by using solar energy. Yet, this policy push has a different goal. "China aims to expand the development of solar power to promote public access to electricity and reduce the import of fossil fuels from abroad. On the other hand, India objects to promote the expansion of solar energy to reduce the import of fuel from abroad and increase the stability of the electricity use of the business sector. Thus, China has made significant progress in increasing access to electricity by 99%. While, India is slowly progressing and not the pace as it should".

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Recommendations

The Indian government should invest in PV research and development to accelerate high potential technologies in solar industry. To address the obstacles that the PV industry is facing, the federal and state governments must provide appropriate financial assistance as well as guidelines. Certain recommendations to promote solar energy are as follows:

- Certain initiatives must be launched by the government in order to promote the advantages of clean energy to the population, especially the youth. Universities, educational centers, and colleges should have energy-related courses in their education systems so that young people can pursue advanced degrees in these fields.
- The government should provide funds to initiate research work for the advancement of clean energy and enable students to pursue energy-related courses by waiving tuition fees. To gain access to climate-friendly technologies, governments must facilitate technology transfer among developing countries.
- The solar power market of India has the potential to play a significant role in global market, if the government adopts proper project planning, efficient execution, adequate financing and localization with satisfactory design and engineering. Upgrading technologies in the PV industry must be agreed upon between ministries and industries. "In order to maintain global competition, incentives for upgrading existing infrastructure must be implemented. Long-term loans with lower interest rates must be made available in order to increase the availability and demand of raw materials used in the solar industry".
- While India leads globally in the green energy field, intelligent and supportive government policy in the form of incentives, tax policies, and incentive schemes for green energy development are needed to accelerate the growth of the PV industry in India.

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VI. REFERENCES

Books:

- Shah, N. (2013). Halving Global CO2 by 2050: Technologies and Costs, London: Imperial College London
- Lee Phillips (2019). Managing Global Warming, London, Academic Press

- Ahteshamul Haque (2016). Electric Renewable Energy Systems. University of West Florida, USA. Academic press
- Shastri, Satish C (2012). "Need for Environmental Law- Indian Perspective", Environmental Law, Lucknow: Eastern book company
- Ebinger, C.K. (2011). Energy and Security in South Asia Cooperation or Conflict? Cambridge University Press India, New Delhi
- Smil, V. (2010). "Energy Myths and Realities: Bringing Science to the Energy Policy Debate". The AEI Press, Washington.
- Wang, X., Barroso, L. & Elizondo, G., (2014). Promoting Renewable Energy through Auctions: The Case of China. Washington, DC: World Bank
- Ibrahim Dincer, Ezzat M. (2018). Comprehensive Energy Systems. Elsevier.

Newspaper Articles

- Rapier Robert. The World's Top 10 Carbon Dioxide Emitters. Forbes. December 4, 2019.
- Aaron o'Neill. Total Population of India.Statistics.com. March 31, 2021
- G Balachandar. Solar Outshines Wind Power in Total Capacity. The Hindu. 21 FEB 2021.
- NS Energy. Profiling the Top Five States for Solar Power Production in India. NS Energy. 26 MARCH 2021
- Bosky Khanna. With Excess Renewable Energy, Karnataka Plans to Sell Power to Other States. The New Indian Express. 25 September 2020
- Energy World. Andhra Pradesh Govt Proposes to Set Up Solar Plants to Produce 10,000 Mw. The Economic Times. 20 February, 2020
- Aarushi Koundal. Gujarat Announces New Solar Power Policy 2021. Energy world from The Economic Times. 29 December 2020
- Charlotte Edmond. China's Lead in The Global Solar Race- At A Glance. World Economic Forum. 19 June 2019.
- James Murray. Profiling the Five Largest Solar Power in China. NS Energy. 12 March, 2021

Journal Articles

- Suyansh Jolly (2017). Sustainability Sciences. Volume (7) Issue 2, pp, 199-212.
- Bardi U. (2013). "Turning Electricity into Food: The Role of Renewable Energy in the Future of Agriculture". *J clean prod*. 53: 224-31.

- Anoop Singh (2009). "A market for Renewable Energy credits in the Indian Power Sector". *Science Direct Renewable and Sustainable Energy.* Pp, 643-652.

Blog Post

- Amit Bajpaye. The Application of Solar Energy in Powering Agriculture. 28 February 2019.

Web Sources

- Telangana State Renewable Energy Development Corporation Ltd. (2020). Status of solar energy in Telangana. www.tsredco.telangana.gov.in.
- International Energy Agency. (2014). World Energy Outlook. www.iea.org
- The Intergovernmental Panel on climate change. (2015). Issues on climate change. www.ipcc.ch
- Shakti Sustainable Energy Foundation. (2014). Feasibility Analysis for Solar Agriculture Water Pumps in India. www.shaktifoundation.in
- Ministry of Commerce People's Republic of China. (2013). Renewable Energy Law of the People's Republic of China. www.mofcom.gov.cn
- China Photovoltaic Industry Association. (2020). China leading in PV Industry. www.chinapv.org.cn
- International Bank for Reconstruction and Development. (2017). India transforms market for rooftop solar. www.worldbank.org

*****