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Utility Of EV Battery

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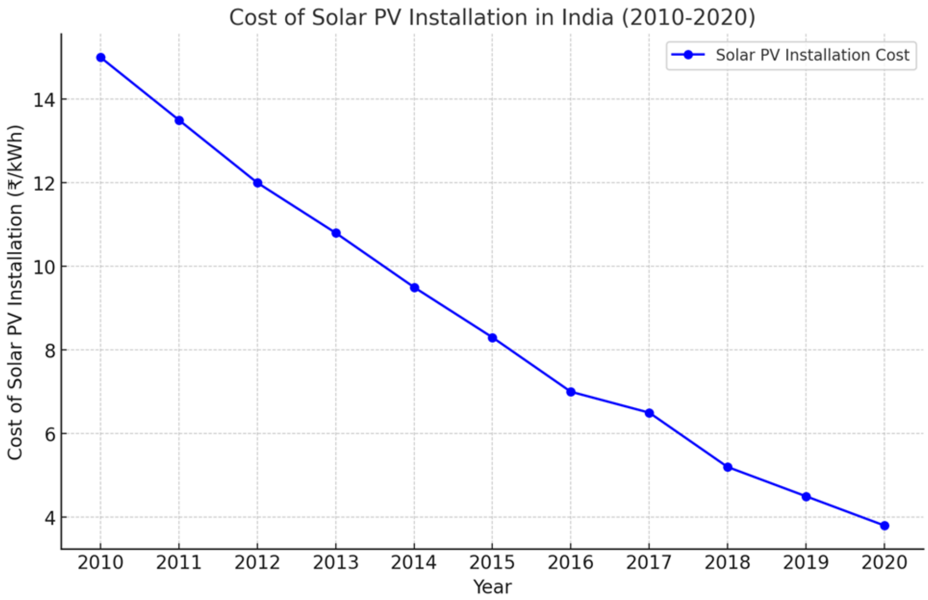
I. Cost-Efficiency

A. Initial Investment

Solar Power: Sensor technology doesn’t really vary a great deal in each cell, so you don't need to purchase a card specifically for each phone. But you do have to learn how to administer multiple cards. Solar photovoltaic (PV) panels costs declined more than 80 percent over the past decade, and are now more affordable for residential and commercial customers. The government of developing countries including India has introduced several subsidies and incentives to mitigate further financial burden of solar installation. Capital subsidies, tax rebates and accelerated depreciation on the other hand are provided through programmes such as the Jawaharlal Nehru National Solar Mission that make solar energy easy to adapt by the individuals and businesses.

Subsidies are supplemented by financial incentives including net metering, which enables solar panel owners to sell excess electricity to the grid, which increases economic viability of solar investment. As a result, even a small scale installations have become economically viable, reducing the financial barriers for residential users, small businesses, and rural communities. In addition, the decentralised nature of solar power in areas does not have traditional energy infrastructure, supports energy access in remote or underserved areas.

Year	Cost of Solar PV Installation (鐶ｹ/kWh)
2010	15
2011	13.5
2012	12
2013	10.8
2014	9.5
2015	8.3
2016	7
2017	6.5
2018	5.2
2019	4.5
2020	3.8



Unlike thermal energy projects, which necessitate large up front capital investments. High cost of land acquisition, plant construction and the installation of the involved complex equipment such as turbines, boilers and cooling systems makes construction of thermal power plants expensive. For example, a coal fired power plant must locate land for the plant and for storing fuel as well as for the disposal of ash or other by products. These facilities need lots of infrastructure stuff such as transportation network to deliver fuel and transmission lines convey electricity.

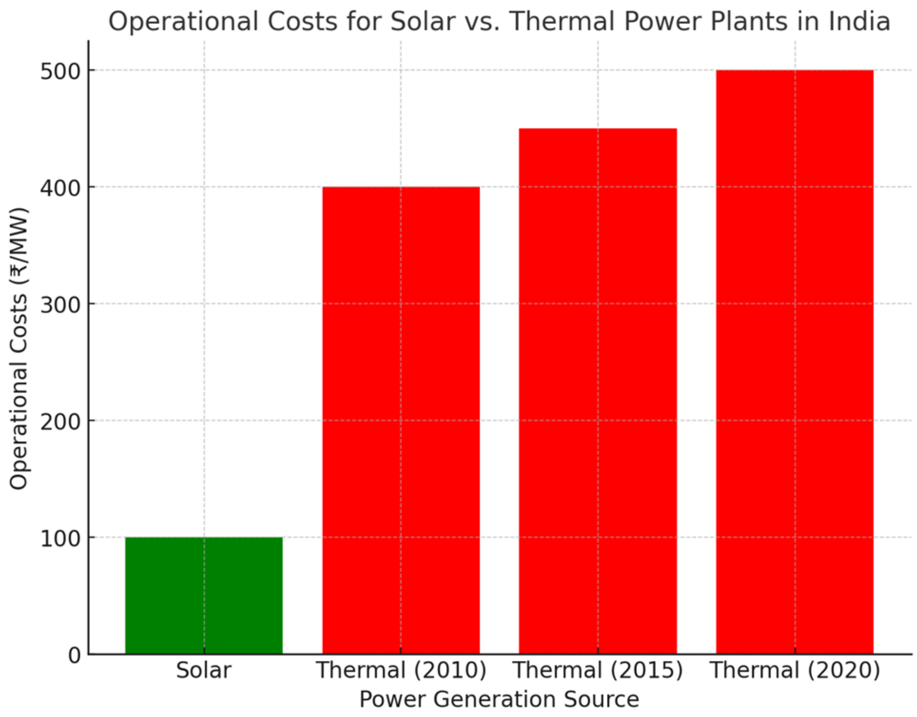
Also, thermal plants are difficult to set for smaller stakeholders or the local community, as due to the high scale of investment, setting them up is very expensive. In addition, large up front cost and longer payback periods from thermal energy projects exposes investors to greater financial risks in a world moving more and more toward cleaner energy alternatives. This is especially applicable in India as thermal plants confront mounting regulatory and environmental pressures that could deter or overburden them from completing, or even complete, the project.

B. Operational Costs

Solar Power: However, once installed solar power systems are very cost efficient to run. Advantages of solar energy, without fuel costs. Without the need for continuous fuel supply to generate electricity, solar panels eliminate the major operational expense associated with fossil fuel based power generation. The advantage of this becomes all the more substantial in a country such as India, where the cost of energy is critical and fossil fuel pricing is governed by the volatility of the global market, as well as the political theatre.

Solar power systems are also very low maintenance costs. Solar PV systems don't have moving parts so wear and tear repair is at a minimum. Routine maintenance usually means periodic cleaning to keep the panels dust or debris free that's what reduces their efficiency slightly. For larger installations automated cleaning technologies or local labour can be used to keep the panels cheap. Solar panels tend to be pretty durable, lasting 25 years and more and seeing only minor degradation of efficiency during their lifespan. For their long operational life, solar's LCOE falls even faster than existing renewable energy sources and is becoming increasingly competitive when that operational life is considered.

Power Generation Source	Operational Costs (竈ケ/MW)
Solar	100
Thermal (2010)	400
Thermal (2015)	450
Thermal (2020)	500



Thermal Energy: On the other hand, the high unburned fuel balance of thermal power plants continues to pose high operational costs, as fuel continuously needs to be supplied. Coal is the most dominant fuel in thermal power in India but coal production in the country is often inadequate to meet domestic demand and coal import becomes a necessity. The global market fluctuates the price of coal and other fossil fuels and so thermal energy operators are exposed to fuel price volatility on top of an increase in their financial risk. This is particularly problematic in an energy hungry economy like India where, with any increase in fuel costs, it directly passes through to electricity tariffs for consumers.

Issues included, apart from fuel expenses, maintenance and operational costs. To guarantee its usual operation, as well as avoid breakdown, the machinery in use is subject to maintenance through, for example, turbines, boilers, or cooling systems. Operational expenses also include: skilled labour; expensive spare parts; plant downtime. Also, plants need to handle the disposal of waste products, such as coal ash, all of which have to have special handling and special disposal to prevent environmental contamination. Another drive, apart from the fuel supply chain itself, is the continuous need to transport coal or gas, further feeding into operational costs that increase at a rate faster than thermal energy.

Thermal plants, too, may become saddled with huge additional financial burdens as a result of environmental compliance. Countries, including India's, are tightening up regulations on carbon emissions, air pollution and waste disposal. As a result, meeting such regulatory standards often necessitates expensive upgrades in the emission control technology, such as adding flue gas desulfurization units, particulate philtre, or carbon capture and storage systems. Thermal power becomes less desirable from an operational cost stand point due to the fact that failure to comply can lead to hefty fines, operational restrictions, or even shutdowns.

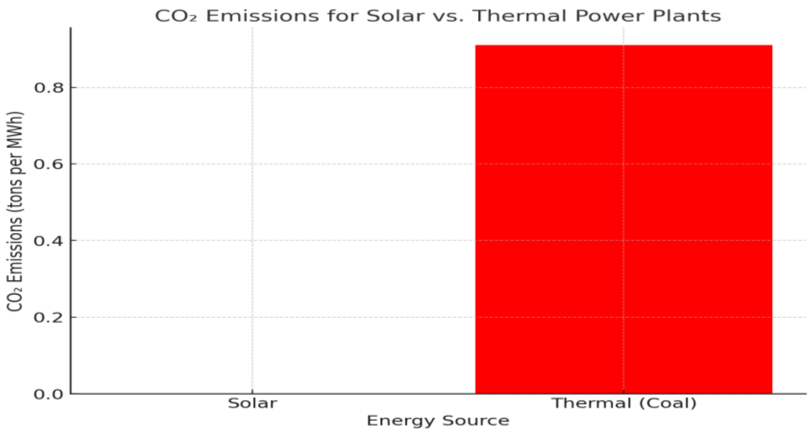
II. Environmental Impact

A. Emissions

Solar Power: Solar power is one of the best environmental things because during operation there are low to no emissions. Solar photovoltaic (PV) systems produce electricity by converting sunlight into energy without combustion and hence have zero or other harmful emissions into the atmosphere (greenhouse gases or other 'pollutants'). The characteristic of it being solar energy makes it an indispensable tool in a credit of reducing carbon footprints, in a country like the India with booming rate of urbanisation and industrialization that has given rise to high rates of air pollution and GHG emissions.

Energy Source	CO_2 Emissions (tons per MWh)
Solar	0

Thermal (Coal)	0.91



Climate Change Mitigation: By adopting solar power, global carbon dioxide (CO_2) emissions which can trigger global warming, are reduced by a huge margin. As an example, India as a signatories to the Paris Agreement is mandated to reduce its carbon intensity and its solar energy growth needs to expand drastically to reach its climate goals.

Air Quality Improvement: Besides reducing CO_2, solar energy acts to reduce the releases of pollutants that thermal generation produces, like sulphur dioxide (SO_2), nitrogen oxides (NO_x), and particulate matter. India can make its air quality better in cities where air pollution has become a big problem for the health, by promoting solar power.

Thermal Energy: On the other hand, most thermal power plants, such as coal fired thermal power plants, are very big causes of greenhouse gas emission and air pollution. But burning fossil fuels, such as coal, oil, or natural gas, releases huge amounts of CO_2 in to the atmosphere and is contributing to climate change.

High CO_2 Emissions: The carbon intensity of coal-fired power plants is high—they produce a lot of CO_2 per unit of electricity produced—and the trend is getting worse. These power plants are big time polluters in India, which is making coal its primary fuel for thermal power.

Other Pollutants: In addition to these [sic], thermal power plants also issue sulfur dioxide (SO_2), nitrogen oxides (NO_x) and particulate matter, contaminants that lead to smog formation, respiratory problems and environmental deterioration. These plants have been linked to increased public health concerns by the air pollution they produce — respiratory diseases and premature deaths.

Contribution to Climate Change: Thermal power's direct and cumulative emissions largely drive global climate change, leading to extreme weather events, altered monsoon patterns and negative impact on agriculture, issues of particular importance for India where many live off agriculture.

B. Resource Depletion

Solar Power: Since sunlight is a renewable and inexhaustible resource, solar energy makes use of it. Solar energy is plentiful, no environmental resources are used up during its generation, and thus solar is a sustainable source of long term energy generation, unlike fossil fuels.

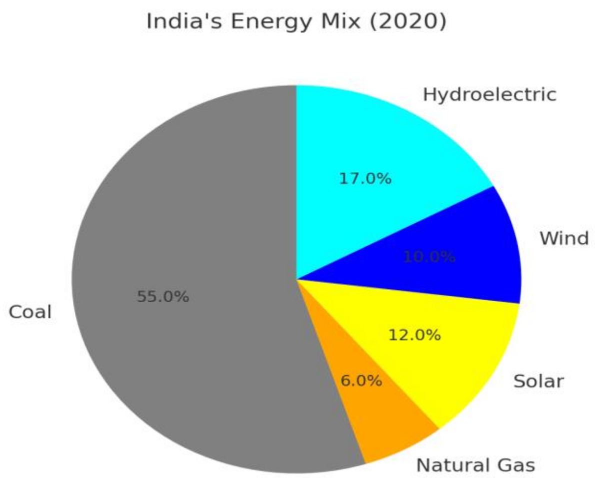
Abundant Resource: With many regions of India having more than 300 sunny days a year, solar power is an ideal renewable resource. More energy is available from the sun in one hour than the whole world consumes in a year — it's an almost unlimited supply of solar energy.

No Resource Extraction: Solar power doesn't need the environmental destructiveness of drilling or mining to provide resource extraction. It acts to minimise ecological footprint of energy production by conserving land, water and natural ecosystems.

Thermal Energy: One of the main sources of thermal energy production, especially coal based, relies heavily on non-renewable, finite and rapidly depleting fossil fuels.

Energy Source	Percentage of Energy Mix (%)
Coal	55
Natural Gas	6

Solar	12
Wind	10
Hydroelectric	17



Depletion of Fossil Fuels: Coal, oil, and natural gas, to generate thermal power, are continuously extracted to accelerate the depletion of natural reserves. India's coal based electricity reliance has a long term resource scarcity challenge given that domestic coal reserves are being depleted.

Environmental Degradation from Mining: Resource intensive and highly damaging to the environment coal mining and fossil fuel extraction. Deforestation, soil erosion, loss of biodiversity and certain kinds of contamination of water sources by mining operations are common. Coal mining in India’s forests has resulted in habitat destruction and the displacement of local communities, exacerbating the already dire environmental impact.

Energy Security Risks: India has to import a large chunk of its fossil fuels in order to meet increasing energy demand. It is vulnerable to the fluctuations of the international market for imported coal or oil, whereby the interruptions of the energy supply, especially from international suppliers would pose a threat to the country's energy security.

C. Land and Water Use

Solar Power: Compared to thermal energy, solar energy systems, especially PV panels, have a very small land and water use environmental footprint.

Flexible Installation: Solar panels can be installed on any surfaces from rooftops to barren land to deserts. The flexible installation also avoids competing for agricultural or forested land, giving developers the option to and place solar systems in land that would otherwise lie idle. Where underutilised land, such as deserts or dry, barren fields, is available, they use it for India’s solar parks.

Minimal Water Usage: Generation of electricity by Solar PV systems requires very little to no water. Cleaning of panels is usually only needed on occasion and this quantity as well as the process of cleaning the panels can be minimised using dry cleaning or an automated cleaning system. This is particularly important in India, where water resources may be scarce, and particularly in arid regions. However, thermal power generation demands substantial use of large amounts of water putting a strain on the water supply at local levels.

Land Efficiency of Solar Farms: Obviously large solar farms can also be built alongside agricultural activities. Specific examples include agrivoltaics, producing solar panels on the land with crops under the shade of the panels, thereby maximising the use of land and improving sustainability.

Thermal Energy: Extensive land use is dictated by the need for fuel sources mining and waste product disposal, as much as by the requirements of the power plants themselves.

Large Land Footprint: The thermal power plants take large land area for the plant infrastructure, fuel storage, disposal of ash and waste. The land needed for coal mines, ash ponds and transportation infrastructure adds additional land use woes, for instance, in encroaching on agricultural or forested land. In India mining here has caused land degradation and displacement of indigenous population in over mining areas.

High Water Consumption: Vast quantities of water are consumed by thermal power plants, mainly for cooling and steam making. The World Resources Institute states that thermal power plants consume a huge share of India's industrial water. If water is withdrawn from rivers or groundwater sources, they can be depleted leading to resource depletion over agriculture, drinking water availability and local ecosystems.

Thermal Pollution: Thermal plants typically discharge the water used for cooling back into near water bodies at elevated temperatures, sometimes causing thermal pollution which damages aquatic ecosystem and reduces biodiversity.

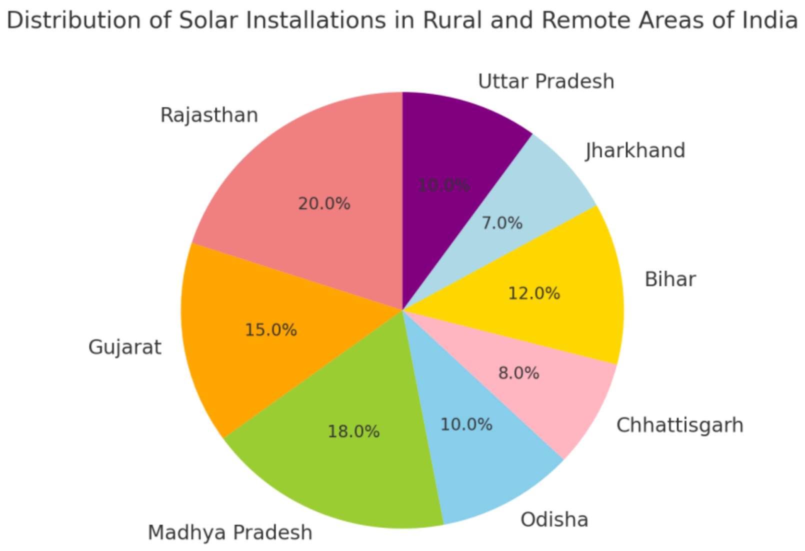
Soil and Water Contamination: Coal ash can then contaminate soil and water sources with everything from heavy metals to toxins, all of which are extremely dangerous to human health and to the environment. These by products can contaminate local communities and agricultural productivity if disposed off in an improper fashion.

III. Energy Accessibility

A. Grid Infrastructure

Solar Power: Considering the fact that decentralised power generation bears the key aspect for improving energy access in developing countries, solar energy systems have a unique advantage for this purpose. Decentralised energy is the generation of electricity near to where it is used rather than relying exclusively upon large centralised power plants as almost every other form of electricity generation. Solaren in particular can provide electricity directly to households and local businesses as direct solar power through rooftop solar panels programmes and community solar projects, largely sparing the necessity for extensive transmission and distribution infrastructure.

Location	Latitude	Longitude
Rajasthan	27.0238	74.2179
Gujarat	22.2587	71.1924
Madhya Pradesh	22.9734	78.6569
Odisha	20.9517	85.0985
Chhattisgarh	21.2787	81.8661
Bihar	25.0961	85.3131
Jharkhand	23.6102	85.2799
Uttar Pradesh	26.8467	80.9462



Ideal for Remote and Rural Areas: There is vast rural parts of India which can't or won't support an extension of the national grid. These areas can be used to instal solar power that would provide off grid or micro grid systems that bring electricity to communities that would otherwise be disconnected. This flexibility to address changes to energy demand makes solar power the ideal solution to address energy access in India's remote, underserved regions.

Reduces Transmission Losses: In a traditional centralise grid, electricity produced at a faraway generating plant has to traverse long distances to reach consumers, while considerable transmission and distribution losses are inevitable. By reducing the distance between generation and consumption, the local generation of solar power minimises these losses. It is particularly critical in a country like India where there is wastage of a large chunk of electricity generated during transmission resulting in inefficiency and belies the cost of generation.

Thermal Energy: Thermal energy is powered by centralised power generator. Transmission of electricity usually occurs from large scale power plant far from consumption centre, thus calls for construction of grid networks of very extensive to transmit electricity across long distance.

Extensive Grid Networks Required: Thermal power, because it must be centrally generated, is dependent on a highly developed grid infrastructure for transportation of electricity to off site consumers. This is a big challenge in India — especially in rural or remote regions where building and maintaining grid networks is expensive and logistically hard. This leaves many isolated communities with little or no electricity.

Less Accessible to Isolated Communities: Usually thermal power plants are situated near the fuel sources or large water bodies (fresh water bodies) for cooling and generally located far from rural or isolated areas. It's far too expensive and takes years to extend the national grid to these areas. This leads to less thermal energy available for the rural population of India fuelling energy inequality.

B. Scalability

Solar Power: Another advantage of solar energy is that it can scale. Solar power systems can be easily scaled up or down and can be matched to the particular energy requirements of any region or business or household. The flexibility of solar power makes it ideally suited to targeting a wide variety of applications in India.

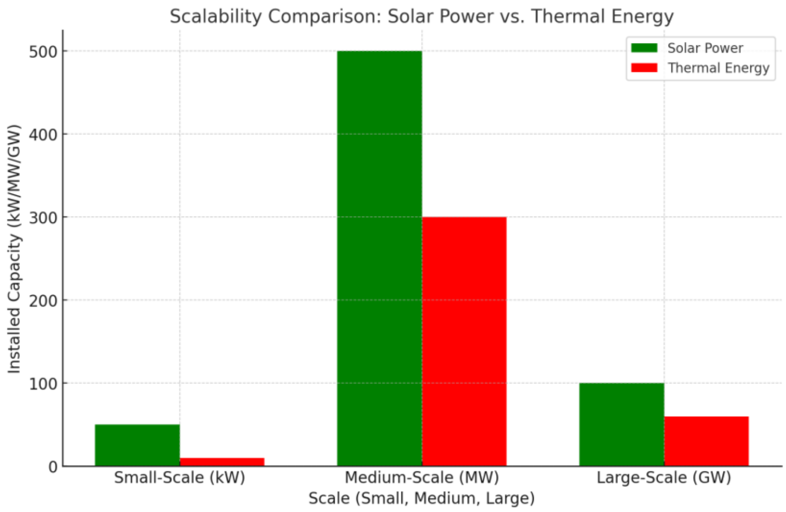
Easily Scalable from Small to Large Systems: Solar energy systems can range from a small residential rooftop system to large, solar power generating farms that can generate enough power for an entire city. Due to this scalability, solar power is an attractive form of energy that can fulfil different energy demand fluctuations with ease both at the residential as well as commercial level.

Customizable Based on Energy Needs: Solar power systems are tailor made to the unique energy needs of a community or individual. Small rooftop systems can be installed by rural households to run basic appliances, or in urban areas where demand is higher, grid scale solar farms can be invested in. Tailoring of solar energy systems to meet local needs allows the technology to be deployed across diverse settings in India with greater efficiency in energy accessibility.

Thermal Energy: Thermal power generation, however, is not scalable, and is economical only when it is implemented on a large scale.

Economical Only at Large Scales: Thermal power plants are capital intensive, and need huge infrastructure to generate electricity at an optimum level. The high operational costs for fuel procurement, maintenance, and environmental compliance makes these [smaller] thermal plants not economic. Thermal energy therefore is less adaptable to small scale or localised services and hence is less appropriate for satisfying the energy requirements of smaller communities or rural areas in India.

Scale	Solar Power	Thermal Energy
Small-Scale (kW)	50	10
Medium-Scale (MW)	500	300
Large-Scale (GW)	100	60



Lack of Customization: Moreover, thermal energy systems are not flexible enough to be customised on a small scale. A large, consistent demand of electricity is needed for building, operating and servicing of a thermal power plant because of the high capital and operation cost of fuel. The technology can only serve these populations coupled with little if any outside assistance.

C. Reliability

Solar Power: Solar power has numerous benefits, which is itself reason for joy, but one of its main hurdles is its inherent intermittent nature – it relies on weather conditions and daylight hours.

Intermittent Due to Weather Dependence: Solar energy production is, as you might expect, much less reliable in more cloudy regions, during the rainy season or when the daylight hours are short. For India, for instance, the monsoon season can leave some solar areas less productive, maybe affecting reliability of energy.

Mitigated by Energy Storage Solutions: Nevertheless, technology of energy storage, say batteries are more and more mitigating the intermittency of the solar power. Solar systems can store extra energy produced during sunny times so that electricity can be drawn from it when the sun isn't shining. The use of solar-plus-storage systems is being adopted rapidly in India, helped by the fact that it provides a more secure and steady stream of electricity in off grid or rural areas.

Hybrid Solar Systems: Improving solar power reliability can be accomplished by hybridizing solar power with other energy sources (e.g. wind, hydropower, or diesel generators). Hybrid systems allow more even energy generation and provide a steady flow of electricity even in times of low solar currents.

Thermal Energy: The main distinction between thermal (steam) power plants and conventional power plants is that the former are capable of powering generating a constant and reliable energy output as long as a constant fuel supply is maintained.

Consistent Energy Output: Unlike solar power, solar thermal is not weather or daylight dependent. Thermal power plants can run continuously (in other words, their output is not a function of varying demand) as long as fuel (coal, natural gas, etc.) supply does not dry up.

Dependent on Steady Fuel Supply: Relevant to the availability and cost of fuel, the reliability of thermal energy is however closely tied. Thermal power plants in India can be affected by disruptions in coal or natural gas supply, either due to domestic shortage or to global market fluctuation. In addition, energy security is threatened by geopolitical factors, for instance high import prices or conflicts in the producing fuel countries. Thermal power's vulnerability to external market forces and supply chain disruptions, especially for fuel imports for coal, derives from its dependency on foreign markets.

IV. Socio-Economic Factors

A. Job Creation

Solar Power: As the solar energy industry grows the opportunities for job creation are wide ranging, from the manufacturer through to the installation and on-going maintenance of the equipment. Solar power projects have already created thousands of new jobs in India, especially in rural and semi urban areas, with expansion.

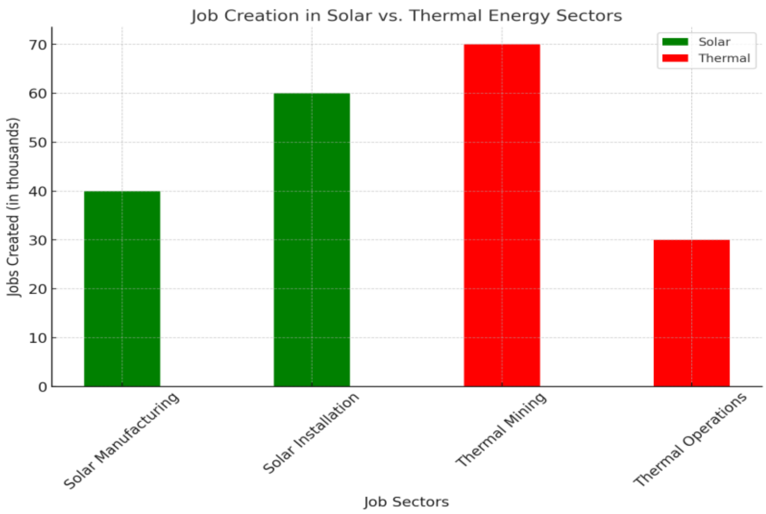
Employment in Manufacturing: Manufacturing sectors are created with the production of solar panels, inverters and other related components. India has been in a race to achieve increased domestic solar production through initiatives including the Production Linked Incentive (PLI) scheme to foster local manufacturing of solar equipment, also creating jobs.

Jobs in Installation and Maintenance: First of all, solar PV system installation requires labour ranging from skilled to unskilled, and these jobs could be found in both urban and rural areas. Each includes rooftop solar for homes, businesses and industrial facilities, as well as big solar farms. These systems need regular maintenance and will create long term employment opportunities for local communities after they are installed.

Skill Development in Renewable Technologies: With the growing demand in renewable energy there is a need for experts in solar technology, electrical engineering and system design. This trend enhances the development of training programs and educational initiatives to support workers to develop necessary skills for the locality, and raising local employment and technological advancement.

Thermal Energy: In coal dependent countries like India, thermal energy has historically played a major role in employment generation. Many depend on jobs in the mining, transportation and operation of power plants.

Job Sector	Jobs Created (Solar)	Jobs Created (Thermal)
Solar Manufacturing	40	0
Solar Installation	60	0
Thermal Mining	0	70
Thermal Operations	0	30



Jobs in Mining and Transportation: Coal mining has a lot of people working in it, but especially in the coal rich Jharkhand, Chhattisgarh, Odisha areas. Also, transportation industries are created and coal has to be moved from the mines to power plants sometimes over long distances. However, these jobs are usually laborious and dangerous.

Plant Operation: The machinery on a thermal power plant has to be operated and maintained, fuel has to be managed, waste products like coal ash must be handled, and a team must work to run the place. But some plant operations are now automated, putting jobs at risk in the future as the industry becomes more mechanised.

Hazardous Working Conditions: Jobs in coal mining and in operations of power plants often require hazardous conditions and put workers at health risks, among them lung diseases, accidents, and the effects of long term exposure to pollutants. These risks put workers at risk in the thermal energy sector.

B. Health Impacts

Solar Power: Not only is solar power environmentally friendly, it only has virtually no negative impacts to human health and promotes better quality of life in the communities where it is scattered.

Minimal Health Risks: Solar energy systems unlike thermal power however, are not associated with harmful emissions including sulphur dioxide, nitrogen oxides and particulate matter, which are known to aggravate respiratory problems. Solar installations don’t burn fuel, reducing the chance of exposure to hazardous air pollutants.

Improvement in Air Quality: Replacing fossil fuel based electricity generation with solar power is a great way for India to reduce air pollution, a major health problem facing the country. Outdoor air pollution kills millions of premature deaths worldwide, and is a cause of respiratory and cardiovascular diseases, according to the World Health Organisation (WHO). Solar energy can help mitigate these risks by lowering the public health burden and health care associated with pollution related illnesses.

Rural Health Benefits: Solar energy systems are used in remote and rural areas where a large number of communities depend on kerosene or biomass for lighting and cooking. Solar power also reduces indoor air pollution from burning fossil fuels, and thus reduces the number of people that become sick from inhaling the pollutants at home.

Thermal Energy: Both thermal power plants (especially coal fired power stations) as well as solar projects are detrimental to public health due to pollutants emissions.

Air Pollution and Respiratory Diseases: Coal and other fossil fuel combustion in thermal plants cause the release of very significant quantities of harmful pollutants such as sulphur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter and heavy metals. Particulate pollutants also cause smog and acid rain, both of which have been associated with respiratory illness like asthma, chronic bronchitis and lung cancer.

Water Pollution and Health Issues: Thermal power plants also displace pollutants into water bodies that can pollute local water supply. To give one example, coal ash is full of toxic substances like mercury and arsenic and lead, that can leach into groundwater and cause very real health risks to the communities living nearest to it.

Higher Healthcare Costs: Thermal energy production air and water pollution health effects increase in population affected healthcare costs. In India where air pollution levels are some of the highest in the world, there is a large economic cost of pollution related health problems threatening to be both a drain on health care expenditures and reduce productivity due to illness.

Year	Incidence of Respiratory Diseases (per 1000 people)
2010	50
2011	55
2012	60
2013	65
2014	68
2015	70
2016	72
2017	75
2018	78
2019	82
2020	85

C. Energy Independence

Solar Power: Reduced dependence on imported fuels is the key contribution of solar energy towards national energy independence. Solar power is a renewable and domestic energy source, which can help India become meaningfully self sufficient in its energy needs.

Reduced Dependence on Imported Fuels: Feeding India's growing energy demand also requires heavy dependence on imports of fossil fuels such as coal and oil. India however can reduce its dependency on imported fuels for solar power generation by increasing the generation by expanding it.

Enhancing National Energy Security: Diversification of the energy mix and reduction in the risks related to fuel supply disruption enhance solar energy's role in improving energy security. Because solar power doesn't require a continuous fuel supply, it is a stable, secure form of an electricity supply when there is fuel scarcity or when fuel costs are volatile. Especially for India, since in this programme like Atmanirbhar Bharat, the goal of national policy is energy independence.

Thermal Energy: Coal based thermal energy production, particularly as India imports coal to meet their domestic demand, is sensitive to international fuel price fluctuations and supply chain disruption.

Vulnerability to Global Price Fluctuations: Despite its large endowment of coal, domestic production has not been able to meet the country's spiralling demand for electricity. This is why India has to import most of its coal from countries such as Indonesia, Australia and South Africa. India's reliance on imported coal makes it susceptible to global price fluctuations as well as supply disruptions. An increase in international coal prices, for example, could push up electricity prices that would affect consumers and businesses.

Impact on Trade Balance: High energy import bill results from need to import large quantities of fossil fuels, which puts a strain on India's trade balance. It can make the economy more dependent on foreign energy sources that can weaken the economy especially during high international fuel prices or periods of geopolitical instability. Solar energy, on the other hand, is locally produced, which decreases our fuel imports, favours a more balanced trade position.

V. Government Incentives And Policies

A. Solar Power

Tax Benefits and Subsidies for Solar Installations: To achieve the Indian renewable energy targets, the Indian government has instituted a host of tax benefits and subsidies to encourage spread of solar energy.

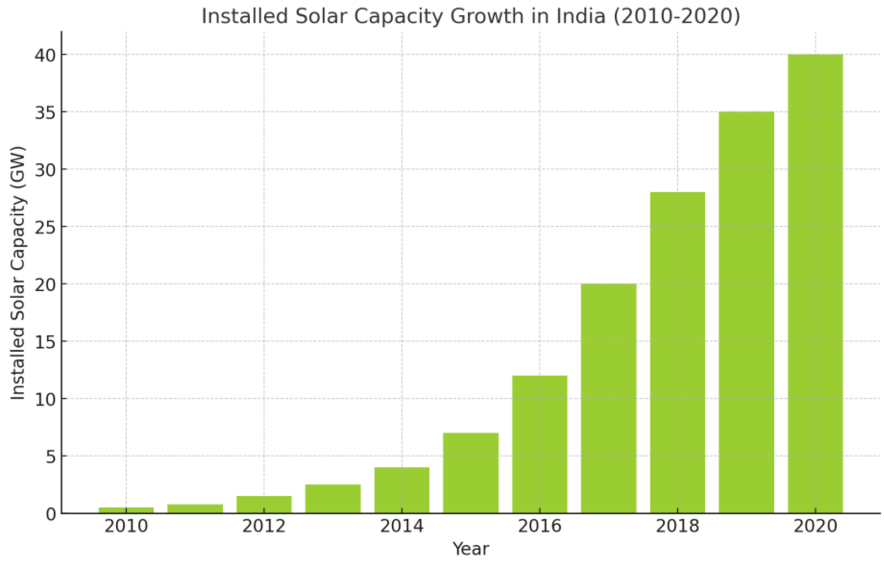
Capital Subsidies: Indian government are promoting adoption of solar power by offering capital subsidy for installation of solar photovoltaic (PV) systems, which is mostly used in residential, commercial or industrial sectors. For example, under the Ministry of New and Renewable Energy (MNRE), homeowners can claim a subsidy of up to 40 percent of the rooftop solar systems installation costs up to 3 kW.

Tax Exemptions: Several tax benefits can be deferred toward solar energy investments, including accelerated depreciation. The ability to claim up to 40% accelerated depreciation in the first year reduces the cost of a project, adding to the financial viability of solar projects and reducing a developer's tax liability. In addition, tax exemptions are applied to most taxes, including customs duties, for the purchase of solar power equipment and components, with result in more economic solar projects.

GST Reduction: This reduction in GST on Solar energy equipment has made solar installations affordable at any level of the economy. For example, the GST on solar panels has been set at a lower rate to further reduce the upfront cost to consumers and businesses.

National Missions Promoting Solar Energy: India is global leader in renewable energy due to its government's national missions and initiatives aimed to promote adoption of solar energy across the country.

Year	Installed Solar Capacity (GW)
2010	0.5
2011	0.8
2012	1.5
2013	2.5
2014	4
2015	7
2016	12
2017	20
2018	28
2019	35
2020	40



Jawaharlal Nehru National Solar Mission (JNNSM): The JNNSM, launched in 2010, is one of India's flagship initiatives to pave the way for solar energy to become one of its most visible sources of energy. It was already ambitious — its mission called for installing 100 GW of solar power by 2022 (and now aims for 300 GW by 2030) — and it is one of the largest renewable energy programmes in the world. The government in JNNSM has both grid connected and off grid solar applications which have financial incentives and enabling policies to develop solar projects. The solar sector was largely boosted through this initiative, and India has rapidly raised its installed solar capacity.

Kisan Urja Suraksha evam Utthaan Mahabhiyan (KUSUM): One noteworthy scheme is KUSUM that encourages solar energy in agriculture. Farmers get subsidies to instal solar powered pumps and panels on their farmland to power by electricity, and can then sell excess to the grid. It also provides an alternative source of income for rural communities and goes some way towards reducing redundancy on diesel and grid electricity.

Net Metering Policies Encouraging Grid-Connected Solar Systems: Solar adoption is especially encouraged in Indian urban and semi urban areas due to India's net metering policies.

Net Metering Mechanism: Net metering regulations allow individuals and businesses to feed in the surplus electricity generated by grid connected solar systems into the grid. In exchange for them supplying excess power they get charged credits on their electricity bills. It incentivizes consumers adopting of rooftop solar systems, as consumers are able to cut down on energy cost while at the same time, they also reduces energy grid.

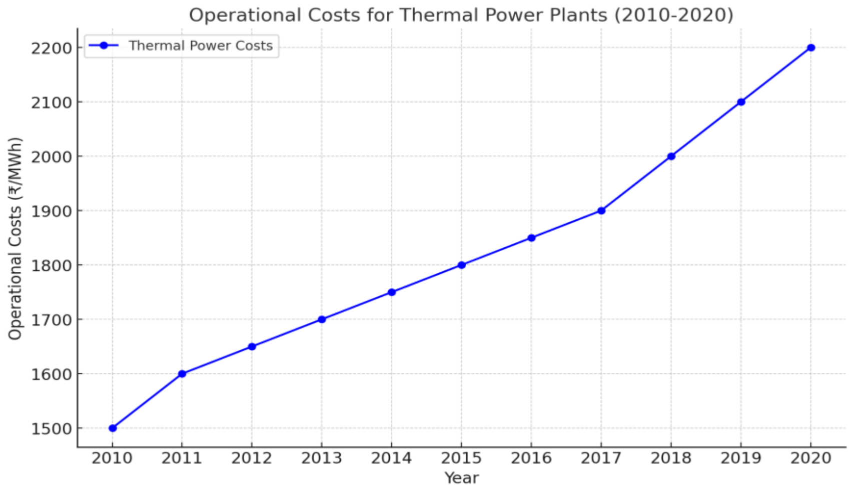
Grid Stability and Financial Savings: This allows for the growth of distributed solar power, and that can reduce transmission losses and free up capacity on the national grid during peak demand periods. Also, this policy helps the consumers save the money on electricity bill and hence makes the solar power economical from perspective in terms of environment as well as economically.

B. Thermal Energy

Stricter Environmental Regulations Increasing Operational Costs: Facing global efforts to combat climate change, the Indian government has been pushing more stringent environmental regulations on the thermal power sector especially coal fired power, considered one of the largest sources of green house gas emissions in India.

Year	Operational Costs (竄ｹ/MWh)
2010	1500
2011	1600
2012	1650
2013	1700
2014	1750

2015	1800
2016	1850
2017	1900
2018	2000
2019	2100
2020	2200



Emission Control Mandates: Under the Environmental Protection Act the government has set new emission norms and now the thermal power plants are supposed to instal pollution control technology such as flue gas desulfurization (FGD) unit and the electro static precipitators to reduce sulphur dioxide (SO_2), nitrogen oxides (NO_x)and particulates. Thermal power plant has to spend more due to these regulations as they have to much more investment in new equipment and structure in order to comply with these regulations.

Carbon Penalties: In India, industries that don't meet their emission reduction targets have been penalised or taxed. These include carbon price mechanisms that increase the cost of operating on fossil fuel based power plants, which creates further incentive for moving away from cleaner power sources such as solar and wind. With it being less economically viable, so have the additional compliance costs from emissions control tied to thermal power plants.

Reduction of Subsidies for Fossil Fuels: In the past decade, the Indian government has cut its subsidies to coal, but also fossil fuels generally, reducing them in line with its aim of cleaning up its energy system.

Phasing Out Fossil Fuel Subsidies: India heavily subsidised coal and other fossil fuels, to make electricity affordable for its population. But now the government is phasing out these subsidies, diverting money instead to building renewable energy. The government has signalled its departure from fossil fuels by cutting coal subsidies while raising thermal power costs vis-a-vis renewable energy sources.

Impact on Electricity Pricing: When fossil fuel subsidies are cut, the cost of coal and natural gas fuelled electricity production has increased, which could increase electricity prices for consumers. Given that costs of solar power are dropping, this makes solar power an even more attractive alternative for businesses and households to generate their energy.

Policies Aimed at Reducing Carbon Emissions: India has in place policies to curb its carbon emissions from its energy sector, a focus particularly on its thermal power plants in line with the country's commitment to the Paris agreement.

National Action Plan on Climate Change (NAPCC): An action plan of action on climate change is set up by India, which describes India's approach for reducing greenhouse gas emissions and mitigates any effects associated with the change in the climate. One of its biggest components is to encourage renewable energy sources such as solar and wind and decrease the country's dependence on coal fired power plants.

India's Nationally Determined Contributions (NDCs): Its Nationally Determined Contributions (NDCs) for reducing the emission intensity of the GDP by 33–35% by 2030 against 2005 levels. Such commitment has encouraged the adoption of policies designed to reduce carbon emissions of thermal power plants, limiting the use of coal through the stricter regulation of coal use, investment in cleaner coal technologies and insistence on reliance on renewable energy to replace.

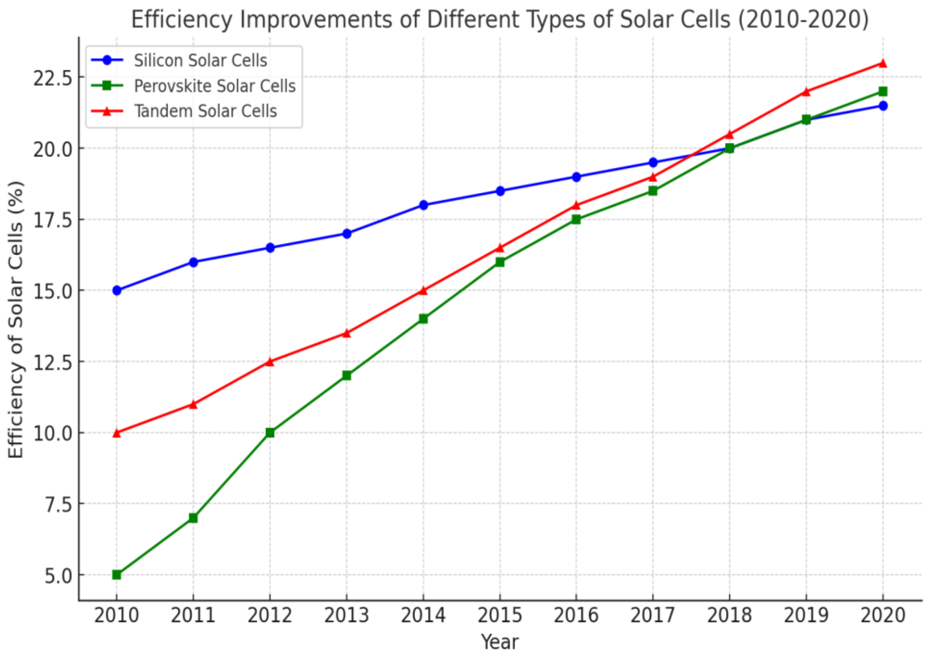
Carbon Trading and Cap-and-Trade Schemes: To limit the total emissions produced by thermal power plants, the government is looking at carbon trading schemes and cap and trade programmes. These market based mechanisms allow companies to trade carbon credits, creating both financial incentive to reduce emissions as well as attract investment for cleaner technology.

VI. Technological Advancements

A. Solar Power

Improvements in Photovoltaic Cell Efficiency: Over the past decades there have been great progress in the efficiency of photovoltaic (PV) cells leading to the rise of solar energy in India and across the globe. Solar cells convert sunlight into usable electricity, so they are called solar cells. As continuous research and innovation they have led to generation of newer solar cells of higher efficiency and made the solar power more cost effective and easily available.

Year	Silicon Solar Cells (%)	Perovskite Solar Cells (%)	Tandem Solar Cells (%)
2010	15	5	10
2011	16	7	11
2012	16.5	10	12.5
2013	17	12	13.5
2014	18	14	15
2015	18.5	16	16.5
2016	19	17.5	18
2017	19.5	18.5	19
2018	20	20	20.5
2019	21	21	22
2020	21.5	22	23



Silicon Solar Cells: The traditional silicon based solar cells that have been used are carrying on their steady improvements in their efficiency, up to 22-24 % in commercial applications. These advancements have brought about increased generation from the same amount of solar panels to make large scale solar farms smaller in land and material requirements.

Perovskite and Tandem Solar Cells: Perovskite solar cells and tandem cells are emerging technologies that are already pushing the limits with solar cell efficiency. For example, perovskite solar cells have been shown to operate with efficiencies over 25 percent in lab. The best efficiency for tandem cells, which combine different materials to capture wider parts of the solar spectrum, has reached 29% — and could reach 30% in the future. Hopefully in the near future, these advancements will seal the deal by making solar power ever more competitive and widespread.

Development of Affordable Energy Storage Systems: Its intermittent nature is one of the major stumbling blocks with solar energy: energy generation depends on sunlight, which fluctuates on a day to day and seasonal basis. However, solar power has been constrained by this issue, but developments in solar power energy storage technology in recent years has helped to make solar power a more reliable, stable energy source.

Lithium-Ion Batteries: Lithium ion battery technology has been developed and scaled at prices sufficiently low for energy storage systems. Such batteries can store excess solar electricity generated during sun hours of the day and release it at other times of the day, like night or cloudy days. While grid scale storage projects and smaller India decentralised solar installations use lithium ion batteries, they offer more consistent and reliable solar power.

Next-Generation Energy Storage Technologies: Next-generation storage technologies include, in addition to lithium ion batteries, solid state batteries, flow batteries and hydrogen storage. These technologies promise even more efficient, durable, and cost effective energy storage solutions. Growing affordability of storage systems will make them a key enabler in the Indian solar energy world, supplying power on the grid round the clock and contributing to the energy security offered by the renewable energy sector.

Innovations in Solar Panel Manufacturing Reducing Costs: Advances in production techniques and materials have drastically reduced the cost of manufacturing solar panels, thereby making solar energy cheaper to an individual consumer, as well as for large scale projects.

Automated Manufacturing: High production efficiency has been achieved in manufacturing of solar panels by automation, which has consequently resulted in cheaper solar panels. In the race to grow its domestic solar manufacturing prowess, government incentives such as the PLI (Production Linked Incentive) scheme are fueling the growth of automated solar factories.

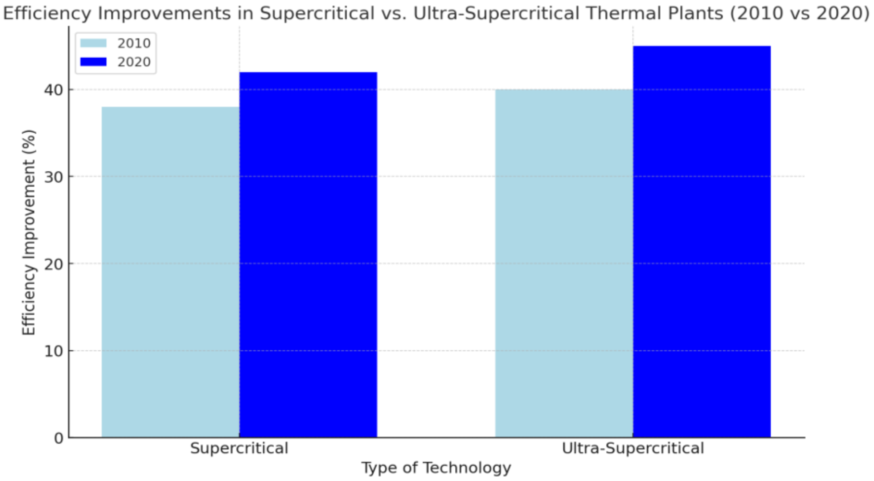
Thin-Film Solar Panels: Cost reduction also has been aided by advances in thin film solar panels. Less material is used than traditional silicon based panels, so the process in which they are produced is more resource efficient and less expensive. This type of panel is flexible in use from rooftops to buildings where conventional panels may be difficult to instal.

Recycling and Sustainability in Production: Solar panel recycling and sustainable manufacturing processes innovations are also happening. As the industry for solar panels matures, it is important to make sure they can be recycled when the day comes that the panels finally come to an end. Although the costs of solar have decreased over time, solar panel production remains relatively expensive and requires considerable resources, consuming both energy and materials. Efforts are underway to develop eco-friendly materials and methods to mitigate the environmental impact of solar panel production and bring down the price and improve the sustainability of the solar supply chain.

B. Thermal Energy

Limited Advancements in Efficiency: Solar power, however, is currently undergoing far more significant technological progress than the highly inefficient thermal energy sector. Coal fired power plants are a traditional mainstay in electricity production in many countries including India. In fact, thermal energy technology has remained fairly static in the past few decades.

Technology	Efficiency Improvement (%) in 2010	Efficiency Improvement (%) in 2020
Supercritical	38	42
Ultra-Supercritical	40	45



Supercritical and Ultra-Supercritical Technologies: A number of thermal power plants in India have opted for supercritical and ultra-supercritical technologies, used in conjunction with high temperature and pressure, to expand the efficiency of power generation. Fuel efficient and lower emissions than conventional coal plants, these technologies are. Though these improvements are a step in the right direction, in terms of environmental and economic challenges presented by thermal energy, they do not constitute fundamental improvements.

Cogeneration: Some thermal plants have used cogenration or combined heat and power (CHP) systems to burn the same fuel to generate electricity and useful heat simultaneously. The power plant system that these systems are in, boosts the overall efficiency of the power plant by capturing and using waste heat which otherwise would be lost. Cogeneration improves fuel utilisation and may be advantageous, but has not been widely adopted in large scale power plants because of economic and operational constraints.

Carbon Capture and Storage (CCS) Still Not Widely Implemented Due to High Costs: Carbon dioxide (CO_2) emissions from coal fired and gas fired thermal power plants are mitigated by carbon capture and storage (CCS) technology: the emissions are 'captured' (separated from the flue gases) and stored underground. However, CCS is a valuable way to reduce dramatically the carbon footprint of thermal energy but has not been widely deployed due to high costs and technical difficulties.

High Costs of CCS Implementation: The cost for installation and operation of CCS systems is high such that many thermal power plants, particularly of the order of development countries like India, become financially nonviable. CO_2 capture, transportation and storage is prohibitively expensive in particular when coal remains cheap compared to energy sources. In many cases additional costs associated with CCS technology do not pay for themselves economically in emissions reduction terms thus CCS technology is less attractive than alternative options to power producers.

Energy Penalties: As well as being costly, CCS technology may lower the efficiency of thermal power plants. The energy penalty associated with lowering the efficiency of the plant to capture and compress CO_2 for storage is lower when the CO_2 is captured in the oil stream. However, this further diminishes the economic viability of CCS because it increases fuel consumption to overcome the loss of efficiency.

Limited Infrastructure for CO_2 Storage: The main challenge with CCS is that there is no infrastructure for long term CO_2 storage. However, not all thermal power plants are sited near suitable geological formations for storage of the captured carbon — such as in deep saline aquifers or depleted oil and gas fields. The overall cost and complexity of CCS implementation on a large scale increases as transport infrastructure is also built for CO_2 to storage sites.

Research to reduce the cost of CCS and improve its efficiency is ongoing, but the technology is not yet a mature enough and economically attractive enough so that it can be deployed widely across the thermal energy sector. Thermal energy thus remains a highly challenged area when it comes to lowering its environmental footprint.

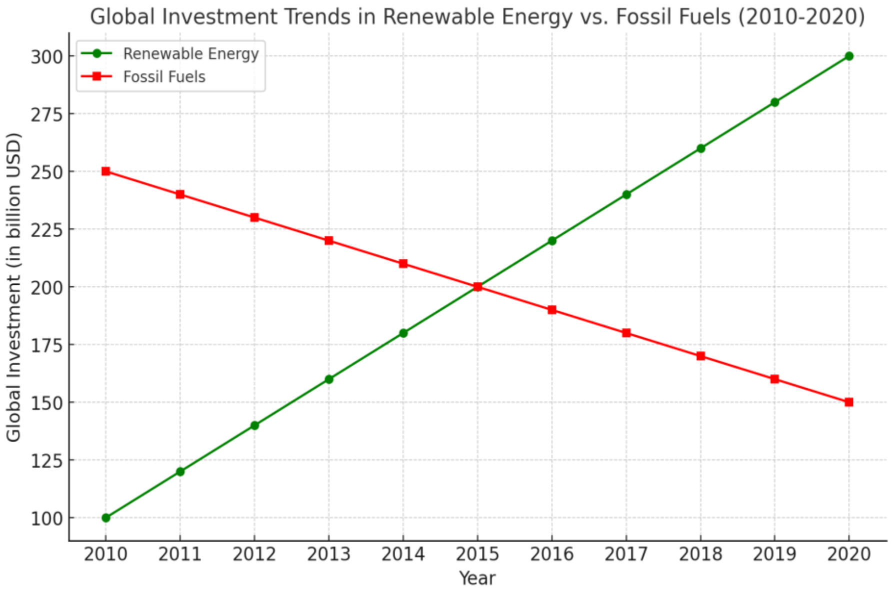
VII. Global Trends

A. Slipping into Renewable Energy Status

International Agreements (e.g., Paris Agreement) Pushing for Renewable Adoption: International agreements to reduce the effect of climate change — the most notable of which is the Paris Agreement — are leading the global switch to renewable energy. The Paris Agreement — signed in 2015 by nearly 200 countries including India — aims to keep increases of global temperatures to 1.5°C to prevent the worst temperature rises.

These targets are only achievable by a substantial reduction in greenhouse gas (GHG) emission and therefore require a substantial shift away from fossil fuel based energy systems towards renewable sources of energy such as solar, wind and hydropower.

Year	Renewable Energy Investment (Solar & Wind, billion USD)	Fossil Fuels Investment (Coal & Gas, billion USD)
2010	100	250
2011	120	240
2012	140	230
2013	160	220
2014	180	210
2015	200	200
2016	220	190
2017	240	180
2018	260	170
2019	280	160
2020	300	150



Nationally Determined Contributions (NDCs): Nationally Determined Contributions (NDCs), under the Paris Agreement describe the country specific plans and targets for emission reductions and the adoption of cleaner energy technologie. The NDCs of India include a commitment to reduce the emission intensity of India's GDP by 33–35 percent by 2030 compared to the emission intensity of 2005 and to increase share of non fossil fuel energy in its electricity mix by 40 percent by 2030. It is through solar energy that India is fulfilling this goal, and the International Solar Alliance (ISA) launched by India and France is an affirmation of India's leading role in the global solar movement.

Commitment to Renewable Energy Financing: At the same time, the international community has been bolstering financial support to renewable energy projects. Large scale solar projects are being funded by institutions such as the World Bank, International Monetary Fund (IMF) and Green Climate Fund in the developing countries. Combining our experience with these mechanisms reduces upfront costs of renewable energy infrastructure and the resulting financing makes solar and wind energy more accessible (even if only after subsidies are withdrawn) for countries such as India that are rapidly scaling their energy systems.

Global Investment Trends Favoring Renewable Energy Projects: Renewable technologies have seen declining costs and the investment trend towards them has accelerated, motivated in part by policy directives and in part by technological progress. Organisations such as the International Renewable Energy Agency (IRENA), International Energy Agency (IEA), all report that investment in renewables is increasingly outpacing investment in new fossil fuel projects over the last decade.

Cost Competitiveness of Solar and Wind: Safeguarding the future of India is no longer a slogan but a fact. Pioneer Indian organisations have proven that technological advancements and economies of scale have made solar and wind power cheaper than fossil fuel based energy in various parts of the world including India. The levelized cost of electricity (LCOE) for solar power has fallen by more than 85 percent since 2010, according to Bloomberg New Energy Finance (BNEF). A drop in price, alongside booming interest from investors in sustainable, climate-friendly assets, has meant a global boom in investments in renewable energy projects.

Divestment from Fossil Fuels: With climate risks growing as awareness of them becomes more global, investors are more and more failing to invest in fossil fuel projects. A growing number of institutional investors, including pension funds, banks, insurance companies and so on, have been adopting Environmental, Social, and Governance (ESG) criteria, in which sustainable investments are prioritised. Therefore, capital is being reallocated to rennables instead of coal, oil and gas. One of the largest emerging markets of renewable energy is India, and with the involvement of this country, many foreign direct investment (FDI) have been made in solar and wind power projects.

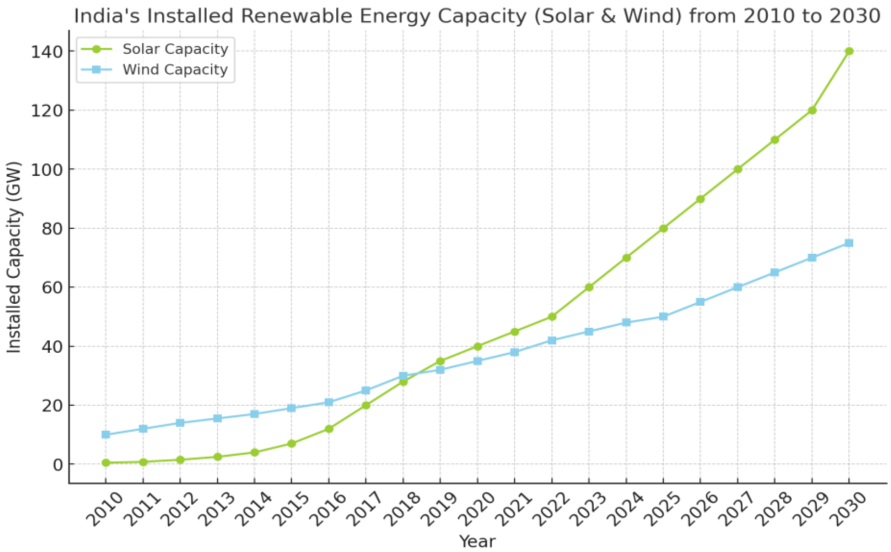
Renewable Energy as an Economic Growth Engine: Renewable energy is also perceived as a force driving economic growth and job creation. Currently, the renewable energy sector employed 12 million people globally in 2021, and that number is expected to rise as counties ramp up green energy capacities. India, with its ambitious solar targets, is well positioned to reap the benefits from these global trends—both by creating new industry and jobs in renewable energy.

B. Environmental Commitments

India's Commitment to Increasing Renewable Energy Capacity: India has also pledged renewable energy capacity, making it a leader in renewable energy transition in the global order. National Indian policies, global pacts, and strategic alliances to enhance the use of renewables, especially solar power, are replete with India's environmental obligations.

Year	Installed Solar Capacity (GW)	Installed Wind Capacity (GW)
2010	0.5	10
2011	0.8	12
2012	1.5	14
2013	2.5	15.5
2014	4	17
2015	7	19
2016	12	21
2017	20	25
2018	28	30
2019	35	32
2020	40	35
2021	45	38
2022	50	42
2023	60	45

2024	70	48
2025	80	50
2026	90	55
2027	100	60
2028	110	65
2029	120	70
2030	140	75



Ambitious Renewable Energy Targets: India has set ambitious renewable energy targets as part of its overall effort to fight climate change and lessen its reliance on fossil fuels. At first, the country sought to instal 175 GW of renewable capacity by 2022, which would include 100 GW of solar power alone. In 2021 India crossed the 100 GW mark of installed renewable energy capacity, and is aiming towards 500 GW of renewable energy (solar, wind, hydropower and biomass) by 2030. India is one of the fastest growing markets for renewable energy in the world due to this.

Solar Power as a Pillar of India's Strategy: India's renewable energy plans revolve around solar. Jawaharlal Nehru National Solar Mission (JNNSM) started in 2010, and has been advocating for scaling up generation of solar power across the country. In addition, solar parks on a large scale, rooftop solar projects, and solar irrigation projects under KUSUM (Kisan Urja Suraksha Evam Utthaan Mahabhiyan) can promote the emergence of solar energy as accessible to both rural and urban areas, and for environmental sustenance as well as energy security.

International Solar Alliance (ISA): India's leadership role for the International Solar Alliance, a coalition of 121 solar rich countries, shows its willingness to push global solar energy capacity. The ISA seeks to create opportunities for member countries to work together to achieve higher solar energy deployment, at the lowest possible cost in solar technology. India's proactive engagement at the level of the ISA is particularly related to its interest in making solar energy production and innovation a global hub.

Global Pressure to Reduce Carbon Emissions Influencing National Energy Policies: The national energy policies in India are also affected largely by the global push to reduce carbon emissions. The policies of India's energy are driven by international pressure to comply with climate commitments and decarbonization strategies to steer the country toward renewable energy.

Decarbonization of Energy Systems: Having global institutions such as United Nations Framework Convention on Climate Change (UNFCCC), Intergovernmental Panel on Climate Change (IPCC) and many climate conferences (e.g, COP 26), all highlight the need for rapid decarbonization of the energy system to prevent the worst impacts of climate change. With India playing a key role in these international talks regarding energy, it has been updating its energy policies to slash its carbon footprint, making renewable energy particularly solar a centrepiece of its energy transition.

Carbon Pricing and Emission Regulations: Global trends like carbon pricing and promotion of emission regulations are increasingly bearing influence on energy policies of India. The strategy of India on environment has aimed at reducing its carbon intensity of the energy sector, which includes setting an emission cap on its coal fired power plants, the promotion of cleaner energy sources and the phasing out of thermal power plants with low efficiencies. These policies are consonant with wider India's global climate stratagems, and fit in with the growing international momentum to displace coal and other carbon intensive fuels.

Corporate and Investor Pressure: Energy policies in India are also being influenced by global corporate commitments to reach net-zero emissions by mid century. Indian policymakers, spurred to create an enabling environment for renewable energy investments, have taken a lead from large multinational companies operating in India, such as Google, Microsoft, and Amazon that have promised to transition to 100% renewable energy. Yet, India is also becoming attractive to international investors, underpinned by ESG criteria, which are driving India's renewable energy sector to grow, and solar and wind projects are more attractive, from the financial and environmental standpoints.

VIII. Conclusion

It turns out that solar power can become a more effective and sustainable electricity option for India, compared to other supply options that are available. Solar energy, provided at lower long term costs by falling prices of photovoltaic cells and reductions in storage costs, is economically viable versus thermal energy. Further helping to sweeten its financial appeal, government policies like subsidies, tax breaks and supportive regulations also make solar available to urban as well as rural communities.

In contrast to the thermal energy, solar power has very limited environmental impact. It creates zero greenhouse gas emissions during operation and is based on an abundant renewable resource, sunlight, which significantly lowers India's carbon footprint and reduces public health damage from air and water pollution.

Additionally, the decentralised availability of solar energy guarantees more people have greater access, especially in rural and under development areas. Large enough to be generative and small enough to be round trip loss free, both rooftop panels and off grid systems offer flexible installation options, allowing solar power to be a practical and effective solution for electrifying rural areas where servicing the national grid is expensive and difficult.

Last but not least, as solar energy nicely aligns with global and national sustainability goals, such as India's commitments under the Paris Agreement as well as the ambitious targets for renewable energy, the deployment of solar technologies has tremendous potential. By supporting the transition to a cleaner and sustainable energy future of India, solar power helps India's national energy security by reducing dependence on imported fuels and fossil resources.

On the other hand, thermal energy confronts increasing obstacles. These include higher operation costs from the need for continuous fuel and environmental compliance costs; and resource restrictions owing to the depletion of non renewable fuels like coal. Also, thermal power's high emissions of carbon and pollution are less in keeping with the country's environmental commitments and global trends to reduce carbon dioxide emissions.

Finally, in light of India's attempts to arrive at a balanced choice amongst economic growth, energy security and environmental sustainability, solar power provides a cleaner, clean, available alternative to power the country in the next generations, whereas thermal energy faces the increasing constraint in its capacity to make an optimum contribution in a sustainable future.

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