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Growth of Solar Jobs in India: A Reality Check

Examining the nuances of growth of solar power jobs in India and comparing their nature to coal jobs

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- Ankita Das

"Nature will never confront you with a problem you can't solve. You already have the answer, that is why the question appears before you."

- *S. S. Ravi Shankar*

Abstract

India is the third largest emitter of greenhouse gases in the world, despite having low per capita emissions. A large quantity of these emissions stem from its fossil-fuel reliant energy sector. Renewable energy sources (RES) like solar and wind power show promise in helping the country transition to cleaner forms of energy generation. India currently has ambitious plans of installing 175 GW of energy generation capacity from RES by 2022, 100 GW of which will be from the solar power sector. Apart from having lower life-cycle greenhouse gas emissions, RES also create numerous employment opportunities for local communities. A large number of these directly created jobs are in the construction and operations and management phases of the projects. Existing literature estimates the overall number of jobs the solar power sector will create on a national level in the future.

However, the distribution of these jobs varies greatly at the state and regional levels due to differing geographical and socio-political factors. This thesis attempts to fill this knowledge gap by comparing estimated solar power potential of each of the Indian states, with their job creation potential based on current government plans and policies. Further, media reports can often insinuate that these newly created "green" jobs can act as an offset to any traditional fossil fuel jobs that are lost. However, they lack a comprehensive comparison of the nature of the employment generated by the two sectors. This study compares the two kinds of jobs, based on quantity, skill type and geographical location. Lastly, this study also explores how the number and nature of the jobs in these two energy production sectors can be expected to change in the next few decades.

Keywords: solar power, employment, jobs, renewable energy, India

Executive Summary

Globally, the energy sector today is heavily reliant on fossil fuels and is responsible for 89% of total greenhouse gas (GHG) emissions. While the OECD and Gulf Cooperation Council countries are some of the largest emitters, India is the third largest contributor to global GHG emissions, despite having extremely low per capita emissions. This is primarily because a large amount of the country's current installed energy generation capacity is coal based. India is also one of the world's fastest growing economies, with a population of 1.35 billion people that is fast moving towards having higher purchasing power. Given these conditions, the country's energy demand is projected to grow exponentially.

However, renewable energy sources (RES) are a promising alternative to allow India to transition to cleaner forms of energy generation. Studies have calculated that certain forms of RES emit less than half the amount of life-cycle GHG when compared to fossil fuels. A major hurdle for deployment of RES technologies however is their dependency on geographical and atmospheric conditions and low energy conversion efficiency. However, the past few years have seen promising technological advancements in solar and wind power technologies. The solar industry has seen a dramatic decrease in costs, making large-scale deployment of the technology a feasible option.

Apart from opening new avenues for low-carbon energy generation, the solar industry also creates many employment opportunities. IRENA (2018b) estimates that the solar PV sector created approximately 3.4 million jobs worldwide in 2017. Presently, India has very ambitious solar power deployment plans, with an aim of installing 100 GW by 2022, and having a total installed capacity of 150 GW by 2027 (CEA, 2018). Additionally, the IEA (2018) estimates India's solar power sector to grow to 450 GW by 2040. Consequently, the sector has a lot of job creation potential as it grows and expands rapidly.

Previous studies have already calculated the overall gross number of jobs that would be created on a national scale in India. However, there is a lack of a comprehensive study on how this employment creation potential plays out on the state and regional levels. Studying this is important as India is a large and very diverse country both geographically and demographically. This means that the distribution of the newly created jobs will not be uniform. This thesis primarily aims to fill this knowledge gap of how the nature of these newly created solar jobs is going to differ across the country.

This research study also attempts to answer the question of how these newly created "green" solar jobs compare to pre-existing traditional coal jobs. Media reports often tend to mischaracterize these new jobs as equalizers for any losses in fossil fuel jobs. However, often, the new jobs are different in quantity, located in different areas, require a different skill set and/or are temporary in nature when compared to traditional stable coal jobs. Finally, the question of how employment in both these sectors is going to grow in the future is also explored.

Data collection primarily involved collating information from publicly available government data sets. Calculations to pin-point the number of solar and coal jobs that exist at the present day, as well as by 2022 and 2040 were also done. The data was then analysed using Excel, to reveal data trends and represent the results graphically. Finally, the findings of this research study were compared with projections from pre-existing research studies. In some cases, the results validated previous findings. While, in other cases, the results of this study conflicted with pre-existing findings. This was predominantly due to differences in the methodological approaches of the studies, and the distinctions were appropriately highlighted.

This research study had **four** primary findings:

The first conclusion of this study was that a majority of Indian states that have the highest theoretical estimated solar power generation potential, do not have the highest 2022 installation targets. This is possibly due to a plethora of socio-political and geographical limiting factors that are described in the Chapter 5 in detail.

Secondly, the distribution of jobs across the various divisions – module manufacturing, ground-mounted and rooftop installations – of the solar power sector was calculated. This coupled with a breakdown of employment based on skill type – skilled, semi-skilled or unskilled – was also calculated. These results are significant as these factors can affect the number and nature (temporary/permanent) of jobs created. When more skilled jobs are required, workers who would want to transition between the two energy producing sectors would have to undergo more extensive retraining. It was found that a lot of the new solar jobs that will be created will also be outsourced, this adds an extra degree of uncertainty as they might be temporary in nature. This might jeopardise the access workers have to pension plans and employer provided healthcare services, as these responsibilities are "outsourced" as well.

Thirdly, this research study also found that solar and coal jobs are typically located in different regional locations within the country. This finding is significant as it shows that workers transitioning between the two sectors would potentially have to move to different states or regions, as the majority of jobs will move as well. Moreover, even though currently the proportion of solar jobs is very low compared to coal jobs, the former can be projected to grow exponentially to rival the number of coal jobs by 2040. So, while there is projected growth in both sectors, with solar growing more than coal, the two industries grow independently of each other and do not compete with each other at least until 2040.

Often the onus of climate crisis mitigation and clean energy transition falls on developed countries, as they are perceived to have historically developed by overshooting their carbon budgets. While there might be truth to this, countries like India and China with their vast populations and exponentially increasing economies and energy demands cannot afford to employ the same developmental strategies that the developed countries once did. RES represent an interesting solution to these complex problems, and there is immense value scrutinising how this fast-changing sector develops and the socio-economic consequences it has.

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Abbreviations

CEA – Central Electricity Authority, Government of India

CEEW-NRDC – Council on Energy, Environment and Water - Natural Resources Defense Council

CPI – Climate Policy Initiative

FTE – Full Time Equivalent

GCC – Gulf Cooperation Council

GDP – Gross Domestic Product

GHG – Greenhouse Gas

Gt – Gigatons

GW – Gigawatt (= 1,000 MW)

IEA – International Energy Agency

IRENA – International Renewable Energy Agency

MNRE – Ministry of New and Renewable Energy, Government of India

MoC – Ministry of Coal, Government of India

MT – Million Tons

MW – Megawatt (= 1,000 KW)

NEP – National Electricity Plan

NGO – Non-Governmental Organisation

OECD - Organisation for Economic Co-operation and Development

PV – Photovoltaic

PWh – Petawatt hour

RES – Renewable Energy Sources

TWh – Terawatt hour

UNFCCC – United Nations Framework Convention on Climate Change

UT – Union Territory

1 Introduction

In India, the combination of a large and growing population and the need to establish a modern industrialised economy has required rapid development of the power generation sector. The country currently has a total power generation capacity of 350 GW, out of which renewable energy sources (RES) account for 75 GW of nameplate capacity (MNRE, 2019). There are plans to increase the total installed capacity to 480 GW by 2022 and to 620 GW by 2027, of which RES are expected to constitute 175 GW and 275 GW respectively (CEA, 2018).

In addition, India has ratified the Paris Climate Accord in October 2016 and pledged to reduce CO_2 emissions intensity by 40% by 2030 (Government of India, 2016). This means that a large share of new electricity will need to come from low-carbon sources. In 2017-18, the Government of India released a 5-year National Electricity Plan (NEP) claiming that India can get 50% of its energy needs from non-fossil fuel sources by 2027 (CEA, 2018). The plans are to have an installed energy production capacity of 480 GW by 2022, while simultaneously reducing energy dependency on imports. The NEP states "Coal based power generation is backbone of Indian Power sector and will continue to dominate power generation in the country." However, due to sharply declining costs, renewable energy may start competing with coal power (UNFCCC, 2018). The government has already stopped plans to build nearly 14 GW of coal-fired power stations and intends on installing 100 GW of power from solar energy, 60 GW from wind power, 10 GW from biomass power and 5 GW from small hydropower to achieve it's 2022 goal (Buckley, 2017; CEA, 2018).

The Indian power generation sector employs a large number of people. For instance, Coal India Limited, the world's largest producer of coal, currently employs over 300,000 people (Ministry of Coal, 2018). In total, the coal mining industry employs around 400,000 people (CMPFO, 2015). The planned changes to energy generation and transmission, could lead to some major shifts in the employment sector in the country. The massive deployment of RES is often hailed as the dawn of a new era, with the sector potentially creating many new jobs, thus offsetting potential jobs losses in traditional energy production (Cleantech Canada, 2017; Gray, 2017). A study conducted by the Climate Policy Initiative and Indian School of Business with experts from Jawaharlal Nehru University and the Indian Institute of Technology, Delhi, estimates that nearly 4.5 million domestic jobs in the renewable energy sector could be added to India's economy by 2042 (Mehra, Mukherjee, Bhattacharya, & Azharuddin, 2018).

What will be the relationship of 'new' and 'old' energy jobs? It is inevitable that the nature of the jobs in the renewables sector will be different from the jobs in the traditional energy generation. For example, newly created jobs might not occur in the same geographical regions as traditional jobs (IRENA, 2018b). The new jobs might also require a different kind of training and expertise, a lot of the coal mining jobs for instance tend to require unskilled labour, however, working in the renewable energy sector requires a certain level of knowledge and expertise (Garg & Kandpal, 1996; IRENA, 2018b). Further, a large number of the newly created jobs might be temporary construction jobs, while the existing jobs in the coal sector tend to be permanent positions (U.S. Department of Energy, 2017).

Despite these important nuances, globally, the literature has focused on the overall numbers of fossil fuel jobs versus renewable jobs when comparing these energy technologies (Jairaj, Deka, & Boehm, 2018; Scott, 2018; Sen, Trivedi, & Shrimali, 2018). Although there is some research on the nature of these 'green jobs' in India, a comprehensive breakdown and analysis on the regional and state-levels remains largely unexplored. The nature of employment in the clean energy sector is a factor that will largely determine the political future of this sector.

Employment and economic development of communities tend to remain on the forefront of political agendas, and often are the primary influencers that shape development decisions (CEEW-NRDC, 2017; INC, 2014; Mathew, 2014). It is therefore important to increase our understanding not only of the quantity, but also of the nature of jobs in the newly emerging energy sectors in India, in comparison with employment in the traditional energy sectors. Systematic exploration of this research area can help predict the future drivers, influencers, and incentives, that can assist in better planning and deployment of sustainable energy in the future. This thesis seeks to contribute to this important agenda by investigating the change in the nature and magnitude of employment in the power generation sector in India. The scope of this research work is limited to the consequences of growth of the solar power sector and does not include wind power. This is mainly due to the fact that solar power is estimated to generate the greatest number of jobs when compared to any other RES sector (IRENA, 2018b). Additionally, India has the largest plans for expansion of the solar power sector for the future (CEA, 2018).

Studying the impact and growth prospects of employment generation from the clean energy sector, allows us to obtain actionable information to support and strengthen future national and state-level policy to assist the growth of RES deployment. The thesis aims to support the development of renewable energy in India and elsewhere by analysing the current and potential future impacts of solar power expansion on employment across Indian states.

1.1 Research questions

The primary research questions being explored by this thesis are:

1. **What is the employment potential of the different types of solar PV jobs that can be realistically generated by existing plans, programs and policies as well as by fully utilizing the technical potential of solar power across Indian states?**
2. **How does it compare to existing and potential future employment in the coal sector?**
3. **How is the nature and quantity of all these jobs going to change over time?**

1.2 Audience

The results and analysis obtained from this research might be of interest for a wide array of societal stakeholders such as, policymakers, academics, labour unions, NGOs and governmental organisations. It might also be relevant to project developers, engineering, procurement and construction firms, as well as financial institutions that are looking to participate and build a market presence in the RES sector in India. Further, it might also appeal to anyone who is generally working in the RES sector or is interested in the future outlook of the sector. In addition, the comparative findings of this research project could also be of interest to coal unions, coal unions and companies such as the Coal Miners Provident Fund or Coal India Limited.

1.3 Disposition

Chapter 1 presents the background of the problem addressed in this research topic. The main contributions this thesis aims to make, the research questions and the intended audience are described as well.

Chapter 2 consists of a thorough review of pre-existing literature and official data, which was used to identify the main knowledge gaps in the research field.

In Chapter 3, the primary methodological approach, research design and methods used for data collection and analysis are outlined. The primary theoretical framework that was for analysis of data, along with the scope and limitations of the research are also presented.

Chapter 4 outlines the results and findings, which categorised by the different research questions.

Chapter 5 presents the discussion and an analysis of the primary findings.

Chapter 6 presents the main conclusions of the research project and outlines how the results contribute towards closing the knowledge gap. The final chapter then outlines areas for future research and suggests recommendations for the principal audience.

2 Literature Review and Analysis

This literature review covers multiple bodies of literature and seeks to explain the interlinkages between the rising deployment of RES to meet energy demand, and the resultant changing nature of energy jobs. This review attempts to draw a red thread from the macro-scale of global energy demand, narrowing down to the micro-level of India's renewable energy mix. Section 2.1 puts into perspective the perils of the increasing emissions from growing global energy demand, and how RES like solar power can be a feasible alternative. Section 2.2 introduces the case study of India's energy challenges. This section goes on to describe the changes that India's energy mix can be expected to undergo, based on the government's development plans and the IEA projections for future growth in its energy production capacities. Section 2.3 scrutinizes India's solar power sector, subsection 2.3.1 first discusses the key driving factors that affect the development of the solar power sector. This is followed by an analysis of the different growth stages of India's solar power sector in subsection 2.3.2. Section 2.4 delves into the current state of employment in India's energy production industry. Subsections 2.4.1 and 2.4.2 talk about the current state of employment in India, in the solar power and the traditional coal sectors. Section 2.5 discusses the future employment potential in the solar power sector and further reiterates the knowledge gap.

2.1 The role of solar power in meeting global energy demand

The gross domestic product (GDP) of the world economy is projected to grow from the current 81 trillion USD (World Bank, 2019c) to 175 trillion USD (OECD, 2018) by 2040. This will lead to an increase in the global energy demand, which the International Energy Agency (IEA) (2018) estimates to be around 27% or 3,743 million tons oil equivalent (mtoe) by 2040 as compared to 2017. Most of this growth will happen in the developing countries. As of 2018, the energy sector is responsible for 89% of global greenhouse gas (GHG) emissions and annually adds 33.1 Gt CO_2 to the Earth's atmosphere (IEA, 2019). This number could potentially increase to 42.5 Gt CO_2 by 2040 if the world economies continue to operate with present day fossil-fuel reliant energy generation policies in the future (IEA, 2019).

While, the OECD and the countries of the Gulf Cooperation Council (GCC) have some of the highest per capita emissions in the world (World Bank, 2019b), in recent years, emissions reduction has been documented in countries like the United States, Japan, U.K., Germany and France (IEA, 2019). However, developing countries like India and China are fast growing to make up the difference in reduced global GHG emissions, despite their per capita emissions remaining comparatively low (Chakrabarty, 2018; IEA, 2019). Fuelled by the need to provide energy access to their large and growing populations, while maintaining sustained economic growth, their energy consumption and resulting emissions are predicted to exponentially increase in the coming decades (Dubash, Khosla, Rao, & Bhardwaj, 2018; IEA, 2017; Thambi, Bhatacharya, & Fricko, 2018). India is currently home to 18% of the world population (United Nations, 2017), out of which an estimated 200 million still lack access to electricity (World Bank, 2019a). The country projected to be the most populous country in the world, becoming home to 1.6 billion people by 2040 (United Nations, 2017). This coupled with the ambition to become one of the prime manufacturing and developmental hubs of Asia and the world (GoI, 2013; PTI, 2017), the energy demand and production can be expected to soar (IEA, 2018).

Renewable energy sources, together with energy efficiency can be a solution for expanding electricity production while limiting GHG emissions (Amin, 2018; EEA, 2015). At present, one-third of total global power capacity is sourced from RES (IRENA, 2019), with its share in the energy mix slowly growing in the major world economies (IRENA, 2017). Investments in RES tend to act as critical growth drivers for the economy by adding new jobs and providing livelihoods for millions (IRENA, 2018b; Lehr, Lutz, & Edler, 2012). Previous research has estimated that the world has a technical RES generation potential of 975 PWh/year (Hoogwijk & Crijns-Graus, 2008).

Solar PV represents the highest share of this potential, with a capacity to generate up to 613 PWh/year (Korfiati et al., 2016). This is several times larger than the current world energy consumption of 175 PWh/year (EIA, 2017). Even though it is unlikely that the entire technical potential will be utilized owing to socio-economic and political constraints (Ansari, Kharb, Luthra, Shimmi, & Chatterji, 2013; Karakaya & Sriwannawit, 2015), solar PV still remains a major energy solution to the growing global energy demand and climate problem. That apart, the solar PV industry has the potential to create numerous new employment opportunities, giving a boost to the economy (IRENA, 2017, 2018b; Okoro & Madueme, 2006) and thus its future is worthy of further scrutiny.

2.2 Energy challenges in India and India's changing energy mix

India has one of the lowest per capita emissions and energy use (7 MWh, World Bank, 2014b); its 1.35 billion people only account for 6% of the global energy demand (Mehra & Mukherjee, 2018). However, it is also one of the fastest growing economies in the world, with a projected GDP growth rate of 7.8% by the year 2024 (IMF, 2019). At its current GDP of 2.65 trillion USD (World Bank, 2019c), India contributes 2.23 $GtCO_2$/year in carbon emissions, which is roughly 6% of global emissions (World Bank, 2014a). With significant policy initiatives in place to promote faster growth, India's contribution to global carbon emissions will be significant and increasing. The IEA (2018) projects that India will share 10% of the world's electricity demand in 2040 and will need to produce 3,700 TWh of electricity to meet its needs. To put this into perspective, this is equivalent to the current electricity consumption of all of Europe and Africa combined (Enerdata, 2018; IEA, 2019).

Most of this projected growth in electricity demand is expected to be from the buildings sector, overtaking industry as the largest energy use sector (IEA, 2018). The slow but steady progress towards electrifying the homes of 200 million people, coupled with rising purchasing power of the population are also adding to the increasing energy demand. Higher income levels have allowed for higher consumption of electronic appliances (ASSOCHAM & NEC, 2017; IBEF, 2019). Electricity demand for space cooling with the utilization of air conditioners or ACs is predicted to account for a large share of demand as well (IEA, 2018). More households are able to own ACs to regulate internal room temperatures during the country's long summer months, which are only predicted to get hotter as a consequence of climate change (IEA, 2018; Jacob & Dutta, 2018). Rapid expansion of power production in India might lead to a massive increase in GHG emissions. India's emissions are set to double by 2030, even under optimistic estimates (Dubash, Khosla, Rao, & Bhardwaj, 2018; Timpereley, 2019). This is one reason why India aims to change its energy mix towards low-carbon renewables. Another reason is high and growing dependence of India on imported fossil fuels (PPAC, 2019). Thus, India's energy needs are significant and growing, and their consequences are worth analysing.

At present, India has a total installed energy generation capacity of approximately 350 GW, out of which, non-hydro[1] RES account for 70-80 GW (MNRE, 2019). The highest RES generation capacity is in wind power, 35 GW, followed by solar power, 26 GW (MNRE, 2019). The 2018 National Electricity Plan released by the government sets out a target of achieving a total RES installed capacity of 175 GW by 2022, and 275 GW by 2027 (CEA, 2018). Around 100 GW of this capacity addition for 2022 is going to stem from solar, which will have an expected generation of 162 TWh/year (CEA, 2018). For 2027, the projected target for solar power installed capacity is 150 GW which will lead to an expected capacity generation of 243 TWh (CEA, 2018). This means that between now and 2022, around 100 GW of RES should be added to the energy generation mix.

[1] This includes small hydro power plants (≤25 MW) of the total capacity of some 4 GW (MNRE, 2019)

Achievement of this target will require addition of 80 GW of solar power generation capacity by 2022 and another 50 GW by 2027. Of the 2022 solar installation target, 60% is planned to be in the form of ground-mounted projects while the remaining 40% is meant to be from roof-top installations (CEA, 2018).

The ground-mounted projects (Figure 2-1) will be in the form of utility-scale large and medium sized power plants. While the roof-top power plants (Figure 2-2) can be expected to be more decentralised installations (CEA, 2018). Ground-mounted and roof-top solar power installations are not inherently different in terms of the way the generate energy. The primary difference is in the way the generated energy is used. Ground-mounted solar farms tend to have higher energy generation capacities – for e.g. 1-100 MW or more – and are a more centralised form of power generation like thermal or nuclear power plants. The energy generated is usually transmitted to various places through the electricity grid and not used on-site. While in the case of roof-top solar power generation, the solar panels are installed on individual households or businesses and the energy generated is used locally. In certain cases, there might be a feed-in tariff mechanism in place where, any surplus energy is sold back to the local electricity utility to be utilized elsewhere in the grid. The utility-scale plants are operated and maintained by the government and/or a large power generation company. Whereas, the operational and maintenance responsibilities of roof-top solar installations generally fall on the owner of the building on whose rooftop the panels are installed. The key differences between the two kinds of installations are summarised in Table 2-1.

Table 2-1: Differences between ground-mounted and roof-top solar installations

Ground-Mounted Installation (Figure 2-1)	**Rooftop Installation (Figure 2-2)**
Centralised form of energy generation.	Distributed form of energy generation.
Energy generation capacity is 1-100 MW or more.	Energy generation capacity is 5-100 KW.
Energy generated is transmitted through the electricity grid for use elsewhere.	Energy generated is used on-site, with the option of a feed-in tariff mechanism for surplus energy existing in some cases.
Operated and maintained by government and/or utility company.	Operation and maintenance responsibilities fall on the owner of the building.

Figure 2-1: Ground-mounted solar plant

Source: https://www.pexels.com/photo/black-and-silver-solar-panels-159397/

Figure 2-2: Rooftop solar installation

Source: http://pxhere.com/en/photo/864008

While, conventional sources of energy such as thermal power plants continue to be the primary backbone and fallback of the energy generation system in India (Chandra, 2019; CEA, 2018), there is a fair amount of evidence to suggest that solar PV sector is going to be a major player sooner or later (IRENA, 2017; UNFCCC, 2018). If only 3% of the wasteland in India was made available for solar power installations, the country would have an estimated solar generation capacity of 750 GW (MNRE, 2016). Solar power offers high flexibility and adaptability to varying climates and terrains (IRENA, 2018a; Wentworth, 2018). In addition, solar power has 10 times lower life-cycle GHG emissions as compared to fossil-fuel based energy generation (Pehl et al., 2017). This further boosts the interest in solar power development in the country.

2.3 India's solar power sector

2.3.1 Drivers influencing development of the solar power sector

Political support for solar power comes from its positive socio-economic effects, including effects on employment (Rennkamp, Haunss, Wongsa, Ortega, & Casamadrid, 2017). Employment effects of solar power can be significant, especially at the stage of construction, where most capital investment occurs (Chen, 2018). They can also depend on how much the sector expands as well as how big it is (IRENA, 2018b; TSF, 2018). Expansion of the solar sector primarily occurs as a result of supportive government policies (Kilinc-Ata, 2015; Röttgers, 2017), so it is reasonable to predict future expansion of the sector in India based on the current government plans (CEA, 2018). However, growth of the solar sector also depends on many non-policy factors such as geography and economics that can show a high degree of variation across a country (**Error! Reference source not found.**; Karakaya & Sriwannawit, 2015; McEwan, 2017; World Bank, 2010). That apart, new technological developments leading to increased efficiency and reduction in costs of panels can also contribute to heightened interest in development of the sector (IRENA, 2017; Srivastava, 2019; UNFCCC, 2018). Lastly, increased social acceptability of deployment of the technology can also act as a positive driver by paving the way for faster and more efficient distribution of the technology (Brinkman & Hirsh, 2017; Cass, Walker, & Devine-Wright, 2010). Figure 2-3 succintly depicts the various drivers and factors that influence the expansion and growth of the solar power sector.

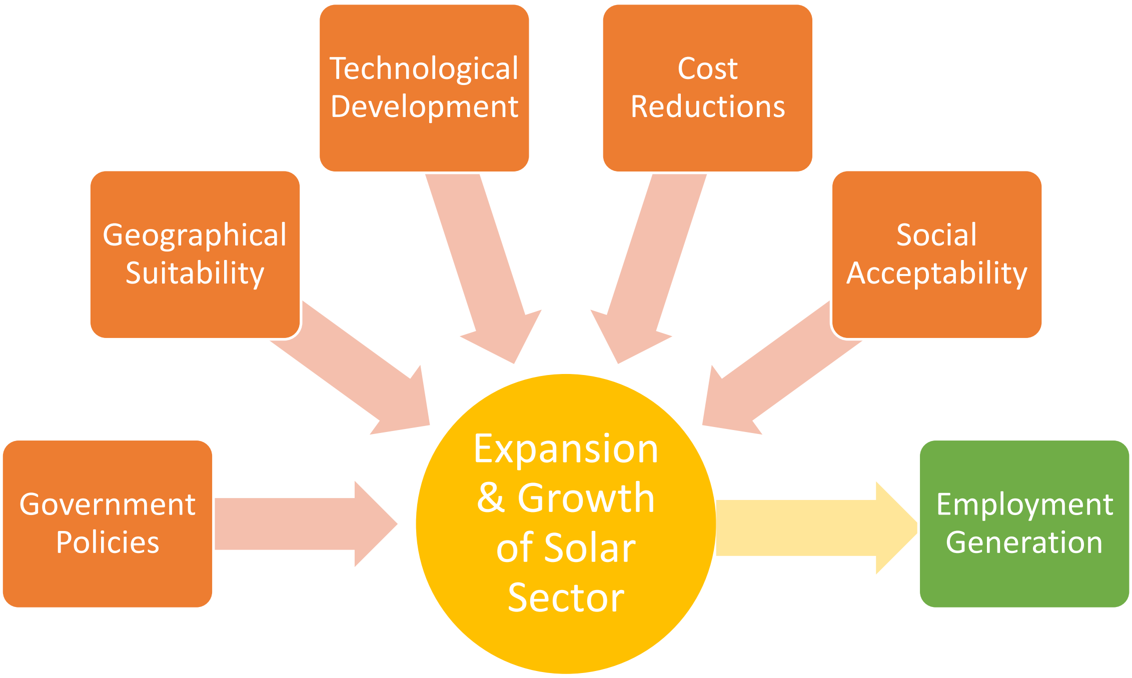


Figure 2-3: Drivers of growth of solar PV sector

Source: Author's illustrations

2.3.2 Differentiation of growth stages of solar power in India

In India, solar power is a new RES technology, and its expansion is expected to follow a "S-curve" (Figure 2-4), when after the initial stage there is an exponential growth when the rate of expansion is proportional to the rate of deployment (Vinichenko, 2013). Therefore, to calculate the future impact of solar power on employment we need to study government policies and targets for expansion and understand the relationship between growth and installed capacity.

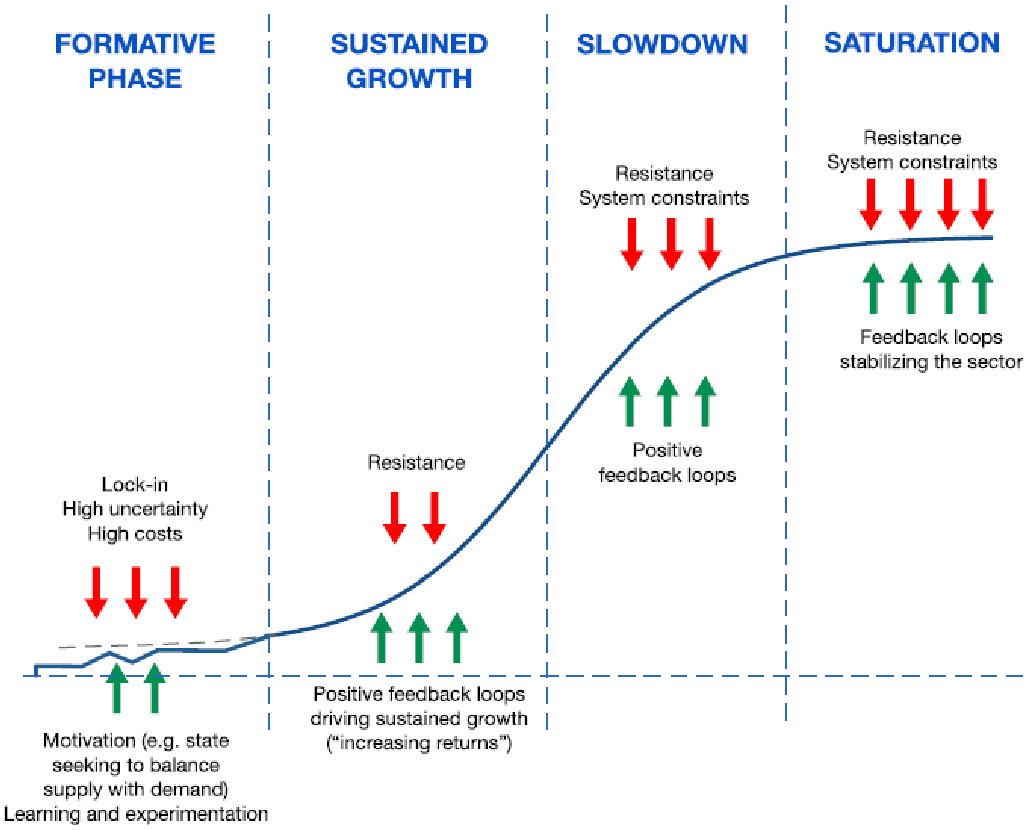


Figure 2-4: Stages and mechanisms affecting the RES deployment process

Source: Vinichenko, 2013

The Indian solar market can be argued to have been in the 'Formative Phase' from 2009 to 2017, when the solar generation capacity increased from 6 MW to 9,500 MW (Mercom India, 2017). Presently, with the dropping costs of solar (Srivastava, 2019; UNFCCC, 2018), conducive government policies (CEA, 2018; ISA, 2019; MNRE, 2016) and the increase in deployment of installations by 15,000 MW bringing the total installed capacity to around 26,000 MW (MNRE, 2019). The market can be postulated to have entered the 'Sustained Growth Phase'. While it is inevitable that growth in the sector will slow down eventually, as market saturation is reached, it is highly unlikely that this will happen in the near future. With the extensive capacity addition plans set out for the future (CEA, 2018; MNRE, 2016), the solar power sector can be expected to only reach the 'Slowdown Phase' after the years 2040-50.

India has already overtaken Japan's to become the third largest solar power market worldwide in 2017 and is on a trajectory to move up to the second spot overtaking the United States (SPE, 2018). The sector is expected to overtake coal power in terms of installed capacity by 2040 (IEA, 2018). Further, the solar power sector has also most ambitious deployment plans of all renewables (CEA, 2018), with there currently being significant solar power development plans underway in 13 of the 39 states and territories of India (BTI, 2017). Anticipating this future growth, India initiated the launch of the International Solar Alliance in 2015 (Neslen, 2015). The treaty-based intergovernmental organisation is currently an alliance of 122 countries and has the primary aim of researching the best possible ways of utilisation of solar energy and its subsequent applications in the world (Chaudhury, 2016; ISA, 2019). Apart from helping meet the energy needs of the country's entire population, solar power has the potential to create millions of direct and indirect jobs and positively impact the development of the local communities in India (Mehra, Mukherjee, Bhattacharya, & Azharuddin, 2018).

2.4 Current state of employment in India's energy sectors

2.4.1 Employment in the solar sector

A comprehensive 2017 study by CEEW-NRDC surveyed and analysed employment data from 45 solar companies from different parts of the country and categorized solar PV jobs based on their nature. The companies were engaged in a diverse group of activities ranging from module manufacturing, project deployment, construction and power production. The study found that the nature and quantity of jobs created can vary significantly based on the type of solar PV installation – ground-mounted or rooftop – that is being deployed.

Employment in any industry can be broadly placed into three distinct categories: direct, indirect and induced (Mutton, 2016). In the case of the solar PV sector, direct jobs are associated with the design, development, management, construction and maintenance of the project (CEEW-NRDC, 2017). While indirect jobs are associated with the manufacturing of equipment used for the facility, along with those involved in the supply chain, providing the raw materials and services to the manufacturers. Finance and banking jobs created by the sector to provide services for the construction and operation of the facility are also considered indirect jobs (CEEW-NRDC, 2017). Induced jobs are those that are created due to the spending of the earnings by employees directly or indirectly involved with the project. Optimistic estimates predict the solar PV sector could provide employment to close to 4.5 million people in India by 2040 (Mehra, Mukherjee, Bhattacharya, & Azharuddin, 2018).

However, current literature only analyzes and predicts employment generation based on national solar power targets. A comprehensive differentiation of employment potential at the state-level is lacking. The comparison of the differences between the estimated solar power potential of each of the states to their planned targets remains largely unexplored. Attention to state-level solar development policies and plans is important as the distribution of solar power generation potential varies greatly in each of the states depending on geographical parameters (CEA, 2018). This has direct effects on the where these newly created jobs are going to be located. Lastly, there is no examination of how these new solar power jobs compare with jobs in the traditional energy generation sector like coal. Often, phrasing of reports and news articles can give the impression that the large number of newly created "green jobs" by the RES sector, can act as an offset to the job losses incurred by the fossil fuel industry (Holcombe, 2019; ILO, 2018; Marcacci, 2019). It is inevitable that the two sectors will require a markedly different skill-set of jobs. Further, the duration these new jobs exist for when compared coal jobs might vary as well. Primary findings of the studies mentioned previously indicate that many of these new solar jobs might be temporary in nature.

2.4.2 Employment in the coal sector

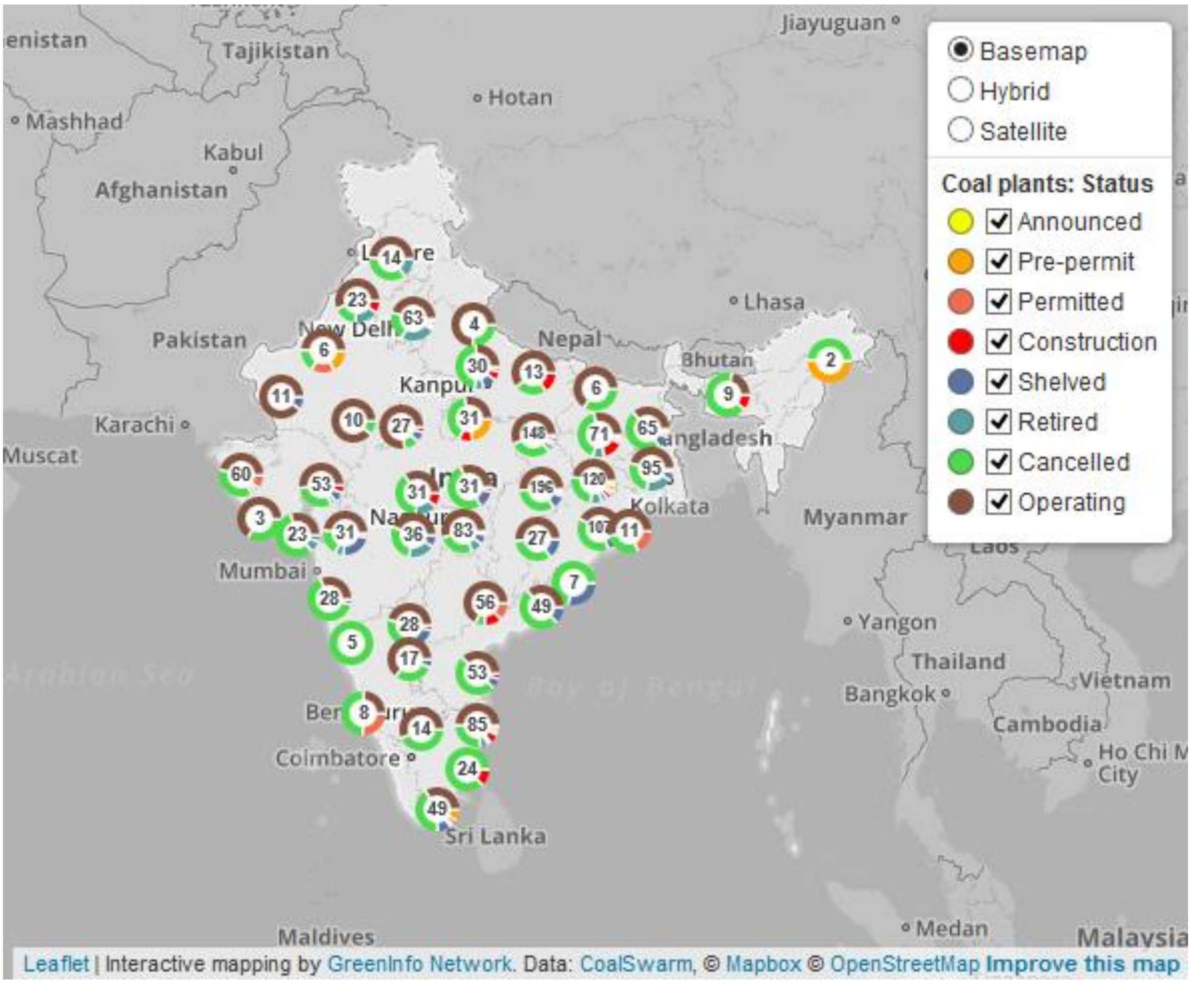


Figure 2-5: Locations of coal power plants in various stages of operation in India.

Source: https://endcoal.org/tracker/

While there are currently no plans of commissioning new coal capacity, apart from what is already under construction until 2027 (CEA, 2018), India still relies heavily on coal power to meet its energy needs (Chandra, 2019). Around 579 GW of previously planned coal plants have been shelved or cancelled so far due to a variety of reasons (Figure 2-5; GCPT, 2019). But the net thermal power production is expected to rise since the current plants have been running at sub-optimal capacities (Sengupta, 2018; Thakkar, 2014). With future plans for improvement of transmission infrastructure (CEA, 2018), productivity of the power plants can be expected to go up leading to a consequent increase in coal mining and imports (Vishwanathan, Garg, & Tiwari, 2018).

Further, thermal power plants tend to have an average lifespan of up to 40-50 years, which puts most developed nations in an advantageous place to phase them out (BC, 2018; EIA, 2018a). However, 80% of Indian coal power plants were constructed in the past two decades (Bhushan et al., 2015). This means, that they can be operational for the next 20-30 years to ensure a profitable return on the investments that were made. So, although, their share in electricity generation falls to 48% in 2040 from today's 74%, the actual production capacity almost doubles (IEA, 2018). Thus, despite it currently being more expensive to produce coal-based power as compared to RES (UNFCCC, 2018), coal still remains as a major player in the Indian energy mix.

Currently, the coal power and mining sectors employ more than half a million people, with most of the jobs being permanent and stable in nature (CMPFO, 2015; Ministry of Coal, 2018). This is evidenced by the added security of all workers being registered with a centrally managed Coal Miners Provident Fund, and the existence of a Coal Mines Pension Fund. As of the writing of this thesis, no such centrally managed provision exists for solar power workers.

2.5 Future employment potential in the solar PV sector and the knowledge gap

The deployment of solar power installations not only creates employment opportunities, but also have other direct and indirect impacts on the economic activities of the local communities. For instance, in previously unelectrified areas, a stable and reliable supply of electricity can allow businesses, educational and healthcare facilities to operate for longer hours (Winther, 2015). These changes have indirect effects by increasing the overall well-being of the communities (Yoo, 2006). In addition, there is also significant potential in the distributed applications for solar water pumps and space heating services in the residential, commercial and industrial sectors (MNRE, 2014a, 2014b). Solar power can play an active role in ushering in universal access to energy, as it has a high degree of flexibility to adapt to the socio-economic and geographical factors in question (Samad, Khandker, Asaduzzaman, & Yunus, 2013; Thompson & Duggirala, 2009). They can be decentralized or stand-alone facilities, and represent a scalable, viable solution for providing power access to un-electrified power deficient villages and towns in remote areas of the country where the transmission grid has yet to reach (Baurzhan & Jenkins, 2016; Urpelainen, 2014). Further, they can be crucial in providing much-needed energy security to the country which currently relies heavily on foreign fossil fuel imports to meet its energy needs (Russell, 2018; Varadhan, 2019; Vishwanathan, Garg, & Tiwari, 2018).

While there have been extensive scientific studies and reports on the job creation potential of the solar power sector on a national scale, a more nuanced analysis of the employment opportunities on the state-level is lacking. Since the distribution of natural resources among the states and territories is not geographically homogenous, the potential extent of existence of solar PV installations in traditional coal states is not uniform and/or proportional. That apart, India has demonstrated bullish stance towards increasing the share of solar power generation in its energy generation mix. Thus, a detailed analysis of the economic consequences of these changing energy choices is necessary.

The findings of this thesis could be of value to both various actors, such as policy-makers at different levels of governance, as well as researchers interested in conducting similar studies both in and outside India. It is anticipated that the thesis will reveal the state-level correlations between the solar power targets and the nature of the employment generated. Further, a comprehensive mapping of when the solar power jobs would start competing, if at all, with the traditional coal power generation sector is also expected. Lastly, the study also aims to map changes in the job creation numbers from the present day until 2040 for all these sectors.

In summary, this literature review has investigated the multiple relevant aspects of India's changing energy mix, solar power, coal power and the resulting affect they have on employment opportunities. Connections and interlinkages of these micro-level processes with macro-scale issues have been identified wherever possible. However, this review has also revealed that there is a lack of adequate academic literature investigating how the nature of solar power jobs in India is going to change in the future, and how they will compare to traditional coal jobs.

3 Methodology

In this chapter, the base analytical framework initially utilised by this study is described in Section 3.1. Section 3.2 defines the research design and the modified analytical framework developed by this study. Section 3.3 describes the primary data collection sources and methods. Section 3.4 illustrates the data analysis procedures undertaken by this study. Lastly, the primary limitations of this study are listed out in Section 3.5.

3.1 Analytical framework

The CEEW-NRDC study (2017) developed four primary categories for grouping direct jobs in the grid-connected solar installation market. The categories were developed based on the nature of the predominant tasks assigned to the jobs and do not include module manufacturing jobs. The results of the survey were also used to calculate coefficients for 'job-years/MW' or 'full time equivalent (FTE)/MW' for each of the categories. An FTE coefficient is defined as the time spent by an employee working on a particular task in a given year, divided by the standard total working hours in that specific year (OECD, 2015). The survey results also revealed information about the skilled/unskilled nature of the jobs that were created. A summary of the four primary categories that were created are:

- Business Development – Involves all actions taken to develop a specific project, as well ongoing efforts to promote the business. The typically types of jobs include sales, marketing, legal, financial and regulatory affairs. Employees are typically skilled or semi-skilled in nature.

- Design & Preconstruction – Jobs involved in the primary design of the project, including individuals who are designers, planners, architects, engineers, resource analysts, legal personnel and financial staff. The majority of employees are skilled in nature.

- Construction & Commissioning – The actual engineers, planners and contract labourers deployed for the construction of the entire plant. An equal number of skilled and unskilled labour is employed.

- Operations & Maintenance – One of the only phases that requires full-time permanent employees to facilitate continuous operation of the utility-scale power plant. In the case of rooftop installations, this responsibility is often outsourced or undertaken by the person whose rooftop the panels are installed on. Most of the jobs are semi-skilled or unskilled in nature.

The four categories with their varying skill-set requirements lead to the inference that not all the solar PV jobs that are created, are going to be permanent in nature. Literature analysis showed that the jobs grouped in the first three categories tended to be temporary in nature. That is, they do not exist once the construction phase of a solar power project had concluded. These 'construction jobs' often tend to be contractual and would only exist if the solar energy sector were to show continuous addition of installed capacity. Jobs related to operations and maintenance can be considered more permanent since they will have to exist as long as the project is functional.

The CEEW-NRDC (2017) analysis found that the quantity of jobs created by the two types of projects is not uniform, with rooftop solar employing a larger share of people owing to the comparative complexity, and labour-intensive nature of the installation process. However, the number of jobs created can be vastly different from the actual workforce needed. To put this in context, one employee can perform multiple 'jobs' in a year as some of the tasks might exist for a short-term. Thus, accurate quantification of not only the **number of** jobs, but also the **kinds of jobs** created is important to ensure development of appropriate policies and provision of suitable skill-training.

This study uses this theoretical framework created by CEEW-NRDC as an initial starting point to group the different types of jobs created in the solar power sector. This thesis also primarily uses the FTE/MW coefficients created by this study. However, it goes further to develop its own analytical framework to regroup the types of solar jobs, and to create a way of comparing them at an equal level to coal jobs. This is done with the aim of simplifying an analysis that already has multiple complex variables, without compromising the quality of the research. This is described in detail in the research design and data analysis sections (Section 3.2 and Section 3.4).

3.2 Research design

This thesis examines two primary types of solar PV installation plans being deployed in India – ground-mounted and rooftop, and the resulting direct jobs that are created. Additionally, jobs created by the domestic module manufacturing industry are also included in the calculations. An inductive research approach is employed. The coefficients (Table 3-1) calculated by the CEEW-NRDC (2017) study were primarily used for data analysis. However, the first three job categories of business development, design & preconstruction and construction & commissioning were grouped together into a broader category of "Total Construction Jobs". This was done to simplify the calculation of the overall number of temporary and permanent jobs that were created.

Table 3-1: Job-years/MW or FTE/MW coefficients

Job Categories	Ground-Mounted Solar Project	Rooftop Solar Project
Business Development	0.05	1.53
Design & Preconstruction	0.2	8.85
Construction & Commissioning	2.7	13.84
Total Construction Jobs	2.95	24.22
Operations & Maintenance	0.5	0.5

Source: CEEW-NRDC (2017)

Calculation of the percentage of skilled, semi-skilled and unskilled jobs that are created by the projects however used separate ratios for each of the four job categories identified by the study (Table 3-2).

Table 3-2: Employment by skill type

Job Categories	Ground-Mounted Solar Project	Rooftop Solar Project
Business Development	~100% Skilled/Semi-skilled	Uncategorized
Design & Preconstruction	60% Skilled	72% Skilled + 20% Semi-skilled
Construction & Commissioning	50% Unskilled	Uncategorized (Outsourced)
Operations & Maintenance	~100% Unskilled/Semi-skilled	Uncategorized (Outsourced)

Source: CEEW-NRDC (2017)

3.3 Data sources & collection

The first step was to look for data and literature on the number of jobs that RES, and specifically the solar power sector is projected to create. This information was obtained through reviewing research done by various domestic and international organisations. However, most studies limited their research to national projections and did not delve deeper into regional analysis. Initial organisation and categorization of literature was done with the help of a Synthesis Matrix. Information processing for the literature review was primarily done using the coding and annotation functions of the NVivo software.

The primary mode of data collection involved searching online for data on RES development strategies and policies on both national and state-levels. Most of the primary data that was analysed was procured from publicly available monthly and annual reports published by the Ministry of New & Renewable Energy of the Government of India. These reports yielded information on the:

i. Estimated solar power potential,
ii. The current installed capacities of the energy generation mix in the country, and,
iii. The target installed capacity for 2022 for each of the 39 states and union territories (UTs) of the country.

Data regarding the current installed thermal power capacity in each of the states and UTs was sourced from the databases of the Ministry of Coal of the Government of India. Data on employment in coal mining was derived from data on current total memberships in the centrally managed Coal Miners Provident Fund.

The aforementioned sources succeeded in providing data on current installed capacity in the solar and coal power generation sectors. In the case of solar, data on expansion targets for 2022 were also found. However, to ensure that the findings of the study had a more long-term perspective, IEA (2018) growth projections for both the sectors for the year 2040 were also used to calculate future employment generation potential.

3.4 Data Analysis

Data processing was predominantly conducted using MS Excel. At first, the capacity additions that would need to be achieved in each of the states to reach the 2022 installed capacity target set by the government was calculated. A cursory glance of the data revealed discrepancies between the data on the estimated solar power potential and the 2022 targets. The percentage of the estimated natural solar potential that the 2022 installation target was going to achieve was calculated. The states and UTs with targets that were exceeding 80% and those below 5% of the estimated potential were identified. It was deemed important to flag percentages higher than 80% as it is practically very difficult for a region to reach an installed capacity that is so close to the estimated potential, due to various socio-economic and political barriers (Ansari, Kharb, Luthra, Shimmi, & Chatterji, 2013). Similarly, when an installation target is extremely low in comparison to estimated potential, then the contribution of that region to overall job creation numbers can be expected to be minor. Thus, regions who's targets fell into three of the following categories were flagged:

i. Too close to the estimated total potential of the State (≥80%)
ii. Too low when compared to the estimated potential (≤5%)
iii. Above the estimated potential (>100% - possibly due to some sort of calculation or reporting error)

The data obtained on the projected 2022 capacity additions was then used to calculate the actual number and types of jobs that would be added in the various divisions of the solar power sector. The FTE/MW coefficients used for this calculation were previously listed in Table 3-1. The number of jobs created were initially calculated for three separate divisions involved in solar power production i.e. module manufacturing, ground-mounted and rooftop power (Table 3-3). The present market and future market share projections of domestic module manufacturing companies was taken into consideration during the calculations.

The primary mathematical formula used to quantify the number of jobs created was:

$$Total\ number\ of\ jobs\ created = Power\ capacity\ (MW) \times Job - years/MW\ or\ FTE/MW\ coefficient$$

(Equation 1)

When calculating future construction jobs that would be created, this equation was modified to reflect the number of temporary jobs created per year:

$$Total\ number\ of\ construction\ jobs\ created = Power\ capacity\ added\ in\ that\ year (MW) \times FTE/MW\ coefficient$$

(Equation 2)

The results for ground-mounted and rooftop sectors were further broken-down based on the total construction jobs (Equation 1) and the operations and maintenance jobs created (Equation 2). The number of construction jobs were calculated on an annual basis. It was assumed that these jobs were going to be temporary and would cease to exist once the planned capacity target had been installed in a particular year. Meanwhile, operations and maintenance jobs were calculated based on cumulative installed capacity, as it was assumed that the jobs will permanently exist once the planned power capacity is deployed. Additionally, the ground-mounted and rooftop jobs created were also divided by the skill type employed i.e. skilled, semi-skilled and unskilled. The number of jobs currently existing in the solar power sector were also calculated.

Table 3-3: FTE/MW coefficients for different solar power sectors

Sectors	Coefficient (job-years/MW or FTE)
Solar PV Module Manufacturing	2.6
Rooftop solar	24.72
Ground-Mounted Solar	3.45

Source: CEEW-NRDC (2017)

A similar approach was employed for calculation of the number of jobs currently existing in thermal power plants. However, the job-years/MW coefficient of 0.11 that was used, was based on surveys of U.S. companies (Wei, Patadia, & Kammen, 2010), unlike the CEEW-NRDC (2017) study which was based on surveys of Indian companies. While utilisation of a U.S. based coefficient might not be accurate, this was done as a last resort as data on FTE/MW coefficient for coal power plant jobs in India was unavailable. As a result, an assumption about the operational efficiency of Indian thermal power plants had to be made. It was assumed that the energy generation facilities were going to be operating round the clock for 365 days in the year. The total number of coal miners presently working in the country was procured using information on the total number of active memberships in the Coal Miners Provident Fund. Finally, the number of thermal power plant jobs and coal mining jobs were added to give the total number of people currently employed by the coal industry.

The final step in the analysis involved using the IEA World Energy Outlook model projections for energy demand trends in India up to 2040, to study how the installed capacities for coal and solar power are expected to increase in the future. The consequent number of jobs that would be created in each sector was calculated. A comparative timeline of the number of jobs existing in both sectors, currently, by 2022 and by 2040 was created. Lastly, an analysis of the year at which solar jobs would start competing, if at all, with traditional coal jobs was done. All of the results obtained regarding the three research questions were mapped graphically.

Thus, in conclusion, a timeline for employment creation potential in both the solar and coal sectors was created. Firstly, the number of jobs existing at the present day was calculated. Then in the case of solar power, government installed capacity targets for 2022 were used to calculate the number of jobs that will be created by 2022. Finally, IEA installed capacity projections for 2040 for both the sectors were used to estimate the number of jobs that will exist in both the sectors by that year.

3.5 Limitations

One of the primary limitations of this study was that there was no data on FTE/MW for thermal power plants in India, and so U.S. coefficients had to be extrapolated to calculate the approximate number of jobs. It was unfortunately beyond the timeframe and scope of this thesis to conduct market research to identify the exact coefficient.

Next, domestic solar module manufacturers currently have a very small market share. This share was hypothesized to increase based on the introduction of new government policies and trade tariffs on imported solar modules. This increase in market share was an estimate and was used to project future job creation numbers in India.

Finally, while rooftop solar projects theoretically create the greatest number of jobs, the skill type requirement for three out of the four job categories is ambiguous. This lack of data stems from the fact that a large number of these jobs seem to have been outsourced to third-party companies which were not included in the CEEW-NRDC survey. The lack of this information hinders exact calculation of how many jobs will fall in each of the categories and divisions.

4 Results

This chapter illustrates the primary findings and results of the thesis project. Section 4.1 showcases the state-wise employment potential of the solar power sector based on existing government plans. The subsections graphically depict the resulting changing distribution and nature of solar power jobs. In doing so, this section explores the first research question. Section 4.2 addresses the second and third research questions, and compares the employment generated by India's solar power sector to the coal sector, at both the present day as well as in 2040 levels.

4.1 State-wise employment potential based on existing government policies for solar power

4.1.1 Correlation between solar power potential and future installation targets

The 2018 National Electricity Plan released by the Central Electricity Authority reports the estimated solar power generation potential, for all 39 states and UTs in India. The report also describes the 2022 installed capacity addition targets for each of the regions. A cursory glance of the reported numbers revealed that not all the states with highest geographical solar power potential have the largest 2022 deployment targets (Figure 4-1 & Figure 4-2).

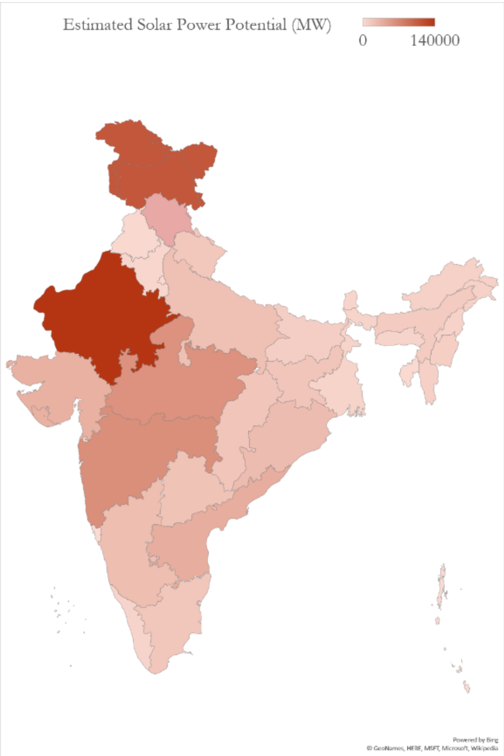


Figure 4-1

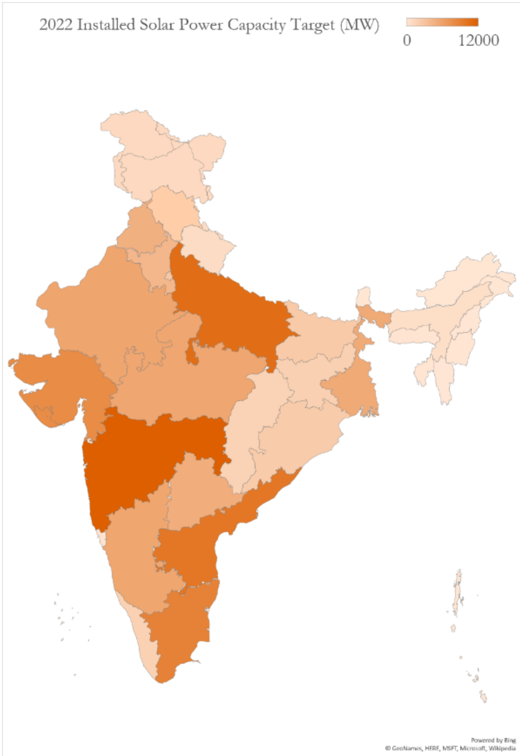


Figure 4-2

Figure 4-1: Estimated solar power potential of each of the Indian states

Figure 4-2: 2022 Installed Solar Power Capacity Target for each of the Indian states

Source: Author's calculations based on CEA (2018) data

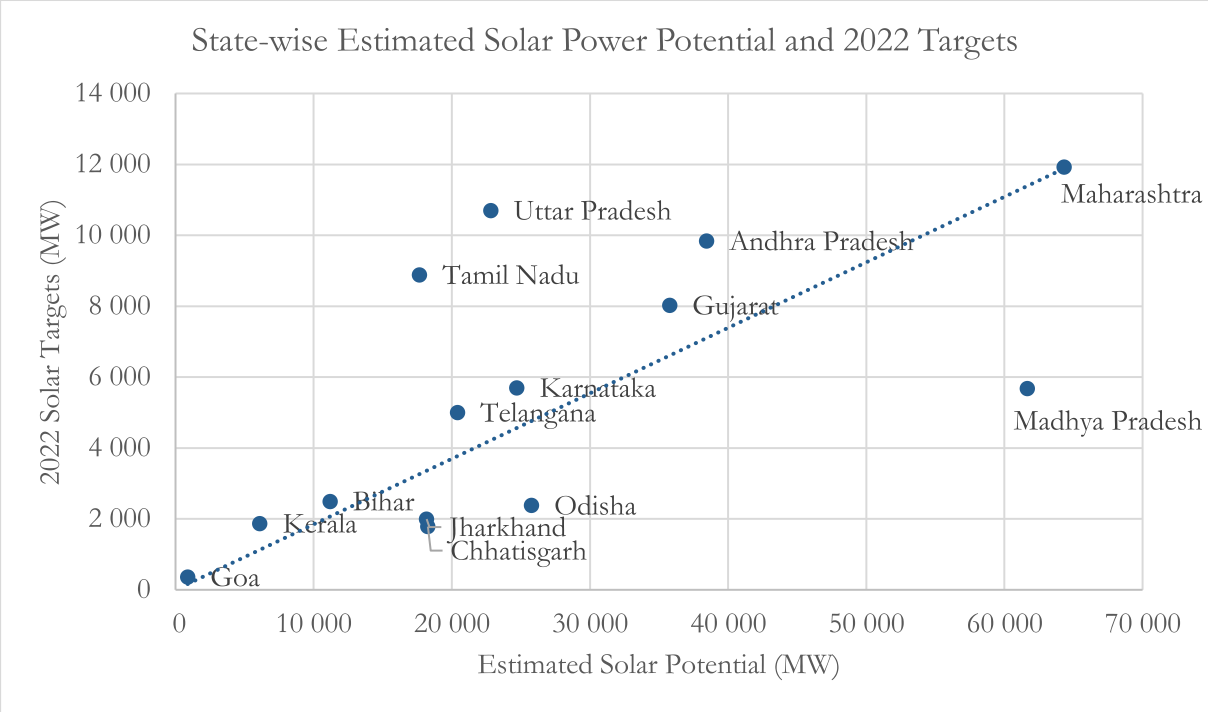


Figure 4-3: The estimated solar potentials and 2022 solar power targets of Indian states

Source: Author's calculations based on CEA (2018) data

Comparative analysis of the 2022 target numbers with those of the estimated solar power potential for the respective states revealed that the targets for only 14 out 39 could be considered realistic (Figure 4-3 and Table 4-1). The remainder were flagged as unrealistic as their 2022 targets were either too high, too low or erroneous, as described in Section 3.4. Thus, while they are 3rd and 10th respectively in terms of estimated generation potential, the states with the highest 2022 installed capacity targets and consequent job creation potentials are Maharashtra and Uttar Pradesh (Table 4-1).

Table 4-1: Comparison of estimated solar power potential and 2022 installed capacity targets of the 14 states with realistic solar power targets

S. No.	States/UTs	Estimated solar power potential (MW)	2022 solar power targets (MW)	% of estimated potential, 2022 target is
1.	Tamil Nadu	17 670	8 884	50%
2.	Uttar Pradesh	22 830	10 697	47%
3.	Goa	880	358	41%
4.	Kerala	6 110	1 870	31%
5.	Andhra Pradesh	38 440	9 834	26%
6.	Telangana	20 410	5 000	24%
7.	Karnataka	24 700	5 697	23%
8.	Gujarat	35 770	8 020	22%
9.	Bihar	11 200	2 493	22%
10.	Maharashtra	64 320	11 926	19%
11.	Jharkhand	18 180	1 995	11%
12.	Chhatisgarh	18 270	1 783	10%
13.	Odisha	25 780	2 377	9%
14.	Madhya Pradesh	61 660	5 675	9%

Source: Author's calculations based on CEA (2018) data

4.1.2 Nature of current jobs in the Indian solar power sector

Using job-years per MW coefficients (Table 3-1 and Table 3-3) calculated by the CEEW-NRDC (2017) survey and report, the total number of jobs currently existing in the solar power industry, was calculated to be 17,749. This includes jobs created in domestic Module Manufacturing, and both the Construction and Operations & Management phases of Ground-mounted & Rooftop solar power installations. The job creation numbers calculated for module manufacturing took into consideration the fact that domestic manufacturers currently only have a 7% market share in India, with the majority of installed solar panels being imported from China (IRENA, 2018b).

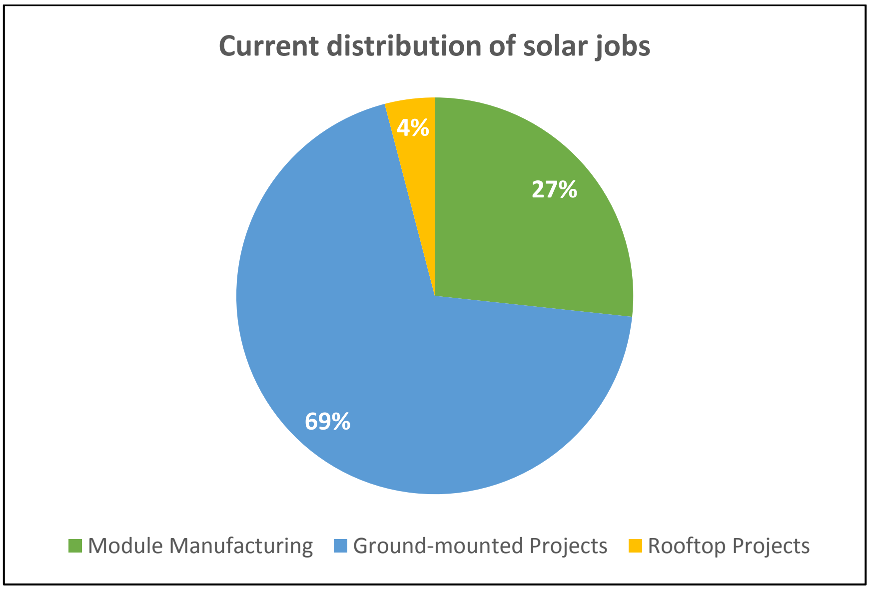


Figure 4-4: Current sectoral distribution of solar power jobs

Source: Author's calculations based on MNRE (2019) data

Presently, ground-mounted projects seem to employ the maximum number of people i.e. 12,291, as shown by Figure 4-4. However, by 2022, the rooftop solar projects can be estimated to take over as the highest employing sector at 205,848 jobs (Figure 4-5). This change can be attributed to the fact that currently there is only 1.5 GW of rooftop installed capacity as opposed to 24 GW of ground-mounted capacity. This can be predicted to change drastically thanks to the aggressive government deployment plans to increase rooftop installations to 40 GW in the future (CEA, 2018). It is important to also note that only operations and management jobs were considered when calculating current employment numbers for both ground-mounted and rooftop solar projects. Construction jobs were excluded from the total calculations as it was hypothesized that these jobs did not exist once the project has been successfully built.

Table 4-2 depicts the current distribution of solar power jobs across different sectors in each of the Indian states.

Table 4-2: Total number of solar jobs currently present in each of the Indian states

S. No.	STATES / Uts	No. of Current Solar Jobs			Total Current Solar Jobs
		Module Manufacturing	Ground - Mounted Projects	Rooftop Projects	
1	Andhra Pradesh	526	1 420	24	1 970
2	Arunachal Pradesh	1	1	2	4
3	Assam	3	5	4	13
4	Bihar	26	69	2	97
5	Chhatisgarh	42	108	8	158
6	Goa	0	0	0	1
7	Gujarat	365	918	83	1 366
8	Haryana	40	65	44	150
9	Himachal Pradesh	1	0	2	3
10	Jammu & Kashmir	3	4	3	10
11	Jharkhand	6	10	7	22
12	Karnataka	970	2 588	77	3 634
13	Kerala	25	50	19	94
14	Madhya Pradesh	300	810	15	1 125
15	Maharashtra	295	724	86	1 105
16	Manipur	1	0	2	2
17	Meghalaya	0	0	0	0
18	Mizoram	0	0	0	0
19	Nagaland	0	0	1	1
20	Odisha	71	192	3	266
21	Punjab	165	414	39	618
22	Rajasthan	572	1 523	48	2 143
23	Sikkim	0	0	0	0
24	Tamil Nadu	406	1 049	68	1 523
25	Telangana	652	1 760	32	2 444
26	Tripura	1	3	0	3
27	Uttar Pradesh	164	417	34	615
28	Uttarakhand	55	120	32	208
29	West Bengal	13	25	10	47
30	Andaman & Nicobar	1	3	1	4
31	Chandigarh	6	3	13	22
32	Dadar & Nagar Haveli	1	1	1	4
33	Daman & Diu	3	5	2	10
34	Delhi	23	4	58	85
35	Lakshwadeep	0	0	0	1
36	Pondicherry	0	0	1	1
	Total	**4 737**	**12 291**	**722**	**17 749**

Source: Author's calculations based on MNRE (2019) data

4.1.3 Distribution of solar power power jobs by 2022

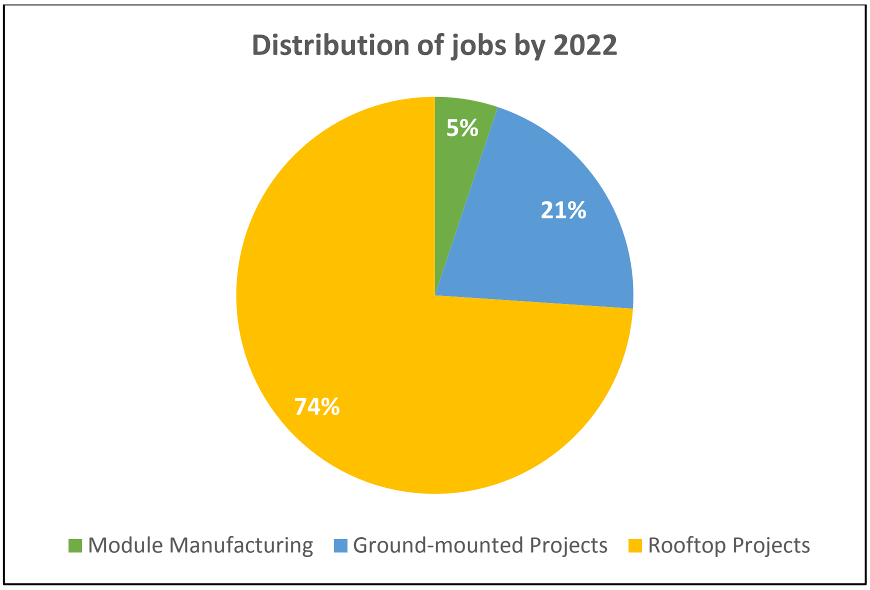


Figure 4-5: Sectoral distribution of solar power jobs by 2022

Source: Author's calculations based on CEA (2018) data

The calculations employed by this study showed that the solar power sector will likely grow to employ a total of 278,428 people by 2022. Most of these newly created jobs will be in the rooftop deployment sector (205,848), owing to the high labour-intensive installation process. The 2022 job number calculations for ground-mounted and rooftop solar projects include employment generated in both construction and operations and management of the projects. The construction jobs are calculated on a yearly basis, i.e. they are considered to be temporary, thus ceasing to exist once the capacity addition is complete. The MW capacity that would be installed in a year was estimated, and then used to calculate the number of construction jobs that would be created in that particular year. Whereas, the operations and management jobs are calculated as a cumulative, since the jobs will continue to exist once a certain capacity is added and will not reduce with time.

Table 4-3 depicts the projected distribution of jobs among the three divisions of the solar power sector, in all the Indian states in the year 2022. Figure 4-5 showcases a visual representation of the sectoral distribution of solar power jobs by 2022.

Table 4-3: Distribution of jobs in the solar power sector in the year 2022

S. No.	States & UTs	Solar jobs to be created by 2022			Total Solar Jobs created by 2022
		Module Manufacturing	**Ground – Mounted Projects**	**Rooftop Projects**	
1	Andhra Pradesh	1 264	5 156	18 209	24 629
2	Arunachal Pradesh	6	25	88	119
3	Assam	117	478	1 689	2 285
4	Bihar	428	1 745	6 163	8 336
5	Chhatisgarh	282	1 152	4 068	5 503
6	Goa	65	265	934	1 264
7	Gujarat	1 095	4 468	15 776	21 339
8	Haryana	714	2 912	10 285	13 911
9	Himachal Pradesh	140	573	2 023	2 736
10	Jammu & Kashmir	208	847	2 991	4 045
11	Jharkhand	357	1 457	5 146	6 960
12	Karnataka	67	273	965	1 306
13	Kerala	315	1 286	4 540	6 141
14	Madhya Pradesh	733	2 989	10 554	14 275
15	Maharashtra	1 876	7 653	27 023	36 552
16	Manipur	19	76	267	361
17	Meghalaya	29	119	422	571
18	Mizoram	13	53	187	254
19	Nagaland	11	45	157	213
20	Odisha	362	1 475	5 209	7 046
21	Punjab	704	2 871	10 138	13 712
22	Rajasthan	477	1 945	6 870	9 292
23	Sikkim	7	27	94	128
24	Tamil Nadu	1 210	4 938	17 438	23 587
25	Telangana	258	1 052	3 714	5 023
26	Tripura	18	74	262	354
27	Uttar Pradesh	1 783	7 273	25 682	34 737
28	Uttarakhand	108	442	1 562	2 113
29	West Bengal	958	3 910	13 809	18 677
30	Andaman & Nicobar	4	15	54	72
31	Chandigarh	22	90	316	428
32	Dadar & Nagar Haveli	81	329	1 163	1 573
33	Daman & Diu	34	137	484	654
34	Delhi	480	1 959	6 916	9 355
35	Lakshwadeep	1	2	9	12
36	Pondicherry	44	181	640	866
	Total	**14 288**	**58 292**	**205 848**	**278 429**

Source: Author's calculations based on CEA (2018) data

4.1.4 Employment differentiation based on skill type by 2022

The CEEW-NRDC (2017) study also categorized the employment in the different kinds of solar power installation jobs based on three different skill types: skilled, semi-skilled & unskilled (Table 3-2). However, the study also categorized certain proportions of the jobs types as uncategorized, as these jobs were outsourced. Figure 4-6 is a graphical representation of the division of the solar power jobs based on these different skill types. Research analysis showed that the majority of the jobs created by 2022 fell into the 'uncategorized/outsourced' category. Most of these will be created in the rooftop installations sector and they will be contractual or outsourced jobs. This is a significant finding as it might represent uncertainty for employment in the sector, as contractual jobs are often temporary. Further, it is likely that it will be hard to guarantee for instance healthcare and pension benefits for workers employed in these jobs.

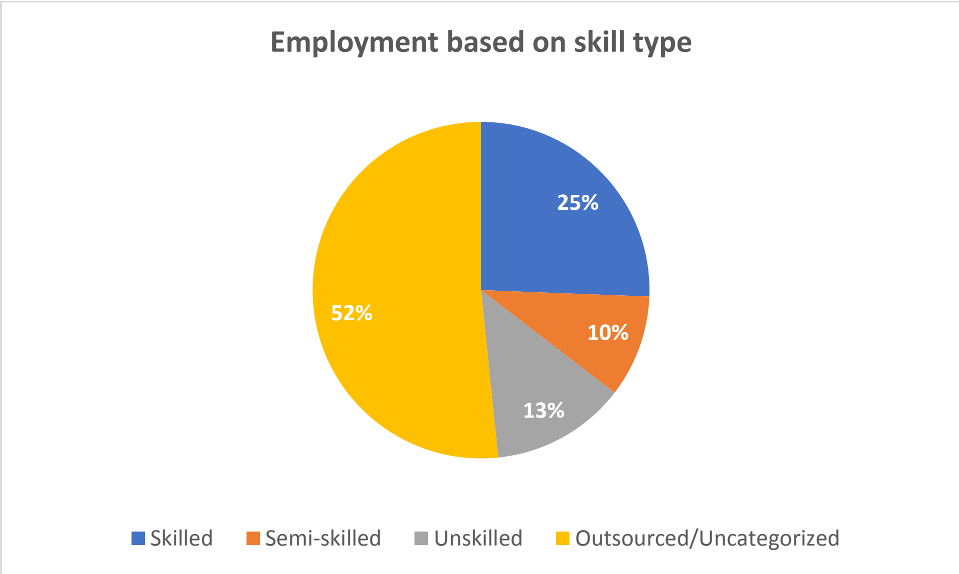
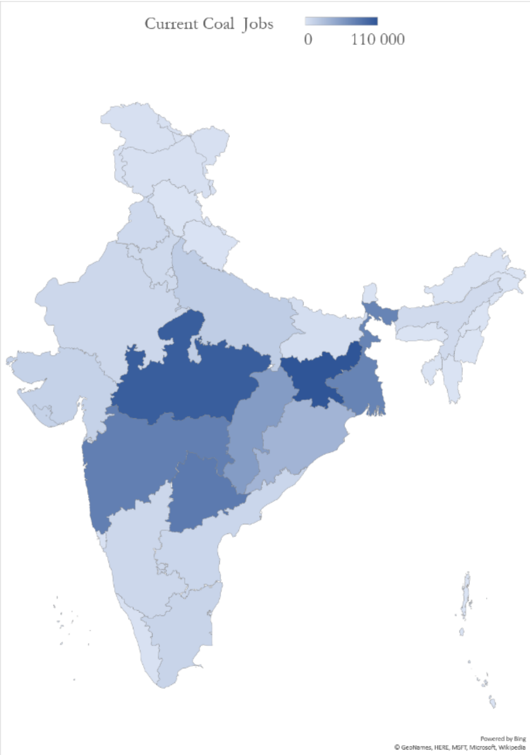


Figure 4-6: Division of 2022 solar power jobs based on skill type

Source: Author's Calculations based on CEA (2018) data

4.2 Comparison with employment in the coal sector

4.2.1 Nature and location of current coal and solar power jobs



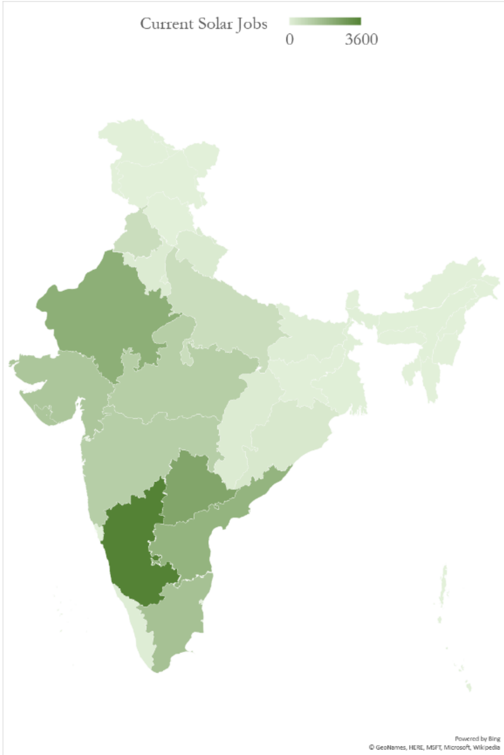


Figure 4-7

Figure 4-8

Figure 4-7: Distribution of current coal jobs (mining and thermal power plant) in Indian states

Source: Author's Calculations based on CMPFO (2015) data

Figure 4-8: Distribution of current solar power jobs (module manufacturing, ground-mounted and rooftop projects) in Indian states

Source: Author's Calculations based on MNRE (2019) data

The coal industry in India currently employs a total of 657,850 people. The coal mining sector currently has a productivity of 676 MT (MoC, 2019), and employs 473,713 (MoC, 2017) people. While there are some contract workers that are employed by the mining industry, 94% of employees in coal mining are registered with a centrally managed provident fund and also have access to pension services. An additional 184,137 individuals employed are also estimated to be employed in operating and maintaining thermal power plants in the country. In contrast, the solar power sector currently employs 17,750 people.

Table 4-4 shows the geographical distribution of current coal and solar power jobs across each of the Indian states. Figure 4-7 and Figure 4-8 showcase a visual representation of the distribution of present-day coal and solar power jobs in the different Indian states.

Table 4-4: Current locations and distribution of coal and solar power jobs in India

S. No.	States & UTs	Current Coal Jobs	Current Solar Jobs
1	Andhra Pradesh	10 051	1 970
2	Arunachal Pradesh	24	4
3	Assam	6 625	13
4	Bihar	3 763	97
5	Chhatisgarh	55 111	158
6	Goa	438	1
7	Gujarat	13 554	1 366
8	Haryana	7 801	150
9	Himachal Pradesh	177	3
10	Jammu & Kashmir	2 208	10
11	Jharkhand	112 773	22
12	Karnataka	9 064	3 634
13	Kerala	1 423	94
14	Madhya Pradesh	103 320	1 125
15	Maharashtra	77 479	1 105
16	Manipur	30	2
17	Meghalaya	29	0
18	Mizoram	20	0
19	Nagaland	21	1
20	Odisha	36 172	266
21	Punjab	7 449	618
22	Rajasthan	9 018	2 143
23	Sikkim	84	0
24	Tamil Nadu	11 499	1 523
25	Telangana	81 084	2 444
26	Tripura	36	3
27	Uttar Pradesh	17 325	615
28	Uttarakhand	426	208
29	West Bengal	73 801	47
30	Andaman & Nicobar	0	4
31	Chandigarh	37	22
32	Dadar & Nagar Haveli	168	4
33	Daman & Diu	122	10
34	Delhi	4 102	85
35	Lakshwadeep	0	1
36	Pondicherry	136	1
37	Others	12 480	0
	Total	**657 850**	**17 750**

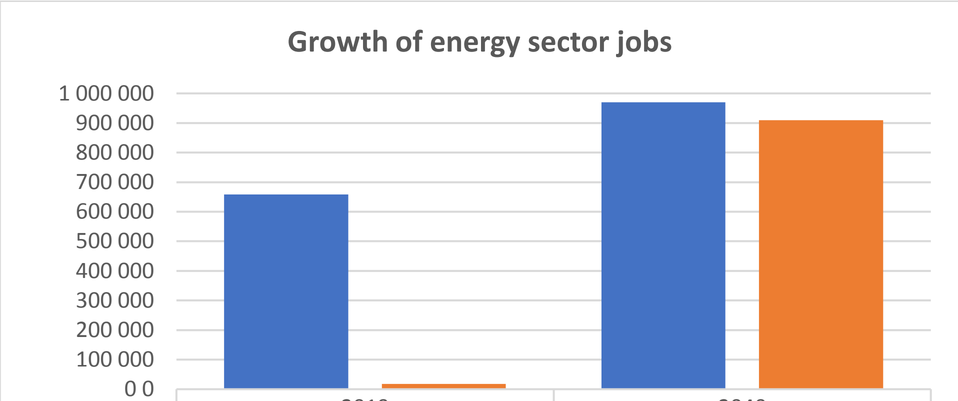
Source: Author's calculations based on data from CMPFO (2015) and MNRE (2019)

4.2.2 2040 employment outlook for coal and solar power sectors

According to IEA (2018) projections, installed solar power capacity is expected to reach 450 GW by 2040. Assuming that the ground-mounted and rooftop solar power installation proportions remain the same i.e. 60:40; and a uniform rate of capacity addition in maintained through the years, the total employment generated will by 2040 was calculated to be 909,469. This projection also includes the assumption that the market share of domestic module manufacturers will grow in the future.

Parallelly, the coal power sector is expected to grow to approximately 410 GW (IEA, 2018) from the current installed capacity of 191 GW (MNRE, 2019). This installed capacity increase will be achieved by the addition of thermal power projects that are already in the announced, pre-permit and permit stages of operation (GCPT, 2019). India has not announced any new additions of thermal power plants since 2016 (CEA, 2018). Assuming all other conditions remain the same, the thermal power plants can be expected to employ 395,268 people by 2040. Meanwhile, coal mining productivity is expected to increase to 820 MT by 2040 (Vishwanathan, Garg, & Tiwari, 2018) and can be estimated to employ 574,215 people. Thus, the coal industry will cumulatively employ 969,482 people by 2040.

Figure 4-9 visualises the change in the employment generation trends of the coal and solar power sectors by 2040 from the present day.



	2019	2040
Coal Jobs	657 850	969 482
Solar Jobs	17 750	909 469

Figure 4-9: Growth of jobs in the coal and solar power sectors from present-day until 2040

Source: Author's calculations based on data from IEA (2018) and Vishwanathan, Garg, & Tiwari (2018)

5 Discussion & Analysis

This discussion follows up on the findings presented in Chapter 4 and objectively discusses the methods, results and epistemological implications of the findings of this study.

Estimated solar power potential and future installation targets: Correlation analysis between these two parameters for each of the Indian states revealed multiple discrepancies. In certain cases, they could be attributed to geographical and political limitations. For instance, the states with the highest solar power generation potential are Rajasthan and Jammu & Kashmir. However, their 2022 installed capacity targets are fairly low (Table 5-1). Large portions of Rajasthan are covered by the Thar desert; thus, the region technically receives a lot of solar irradiance and has a high potential. However, lack of adequate water resources to cool and clean the solar panels once they are coated with dust, to ensure that they operate at optimum efficiency, could be major limitations affecting expansion of solar power in the region (Al-hasan & Ghoneim, 2005; Levitan, 2013). In the case of Jammu & Kashmir, the issue might be due to the fact that large portions of the state are disputed territories with Pakistan and China. However, the Government of India still chooses to report the regions administered by the other two countries as its own territory, so in reality the area available for solar power development is much smaller (Easen, 2002; Zutshi, 2019). Further, a significant portion of the Himalayan mountain range also falls within the state boundaries. So, while the region might receive high amounts solar irradiance, geographical and political barriers might limit the actual installed capacity target of the state.

Table 5-1: Solar power potential and target numbers for 2 Indian states.

Solar Power (MW)	Rajasthan	Jammu & Kashmir
Estimated Potential	142,310	111,050
2022 Installed Capacity Target	5,762	1,155

Source: MNRE, 2019

Further, comparative analysis of the two parameters also revealed multiple cases where the 2022 reported targets were inaccurate. In the case of the state of Punjab for example, the 2022 target installed capacity is 70% higher than the total estimated solar power potential of the state. It is hypothesized that this is due to some form of reporting error generated by using differing geographical boundaries during calculation. Meanwhile, in the cases of states and UTs like Chandigarh and Pondicherry, there are plans to achieve certain solar power installed capacity, but there is no reported data on the estimated solar power potential of these states.

Nature of current and future jobs in the Indian solar power sector: Data analysis showed that presently, maximum number of jobs exist in the ground-mounted project sector as it has the largest share of deployment. However, by 2022, the rooftop project sector will employ the greatest number of people.

Module manufacturing jobs on the other hand are, at present, very few in number. This is primarily due to the small market share (7%) of domestic manufacturers, with the majority of equipment being imported from China. However, this market share can be expected to increase owing to the push for increase in domestic manufacturing. The government recently introduced an increase in trade tariffs on imported modules to achieve this goal (Seetharaman, 2018; Thomas, 2018). For the purposes of this research study, an increase of domestic market share of up to 40% by 2040 was assumed while calculating employment potential. However, there is inevitably a margin of uncertainty regarding this increase in job numbers owing to the fact that it depends on political forces, and thus can change if political agendas were to alter. Further, there might also be other unforeseen barriers resulting from the trade tariffs such as reported drop in installed capacity additions due to short-term increase in module prices (Singh, 2019; Upadhyay, 2019).

Employment differentiation based on skill type by 2022: Figure 4-6 clearly shows that the maximum number of jobs in the solar power sector will fall in the 'Uncategorized/Outsourced" section. While there is nothing inherently wrong with solar power developers and installers outsourcing certain tasks, it raises questions about the uncertainty of the nature of these jobs. It also represents a significant hurdle in mapping the exact number of jobs that will be created, as "outsourcing" brings in another new variable of service provider companies. These companies would provide contract workers to the solar developer clients. This might also complicate availability of adequate worker's rights, such as pension and healthcare benefits, as this responsibility is "outsourced" as well.

Nature and location of current coal and solar power jobs: Graphical analysis of the current geographical distribution of coal and solar power jobs showed that not all of the new "green jobs" are located in the same states as the existing coal jobs (Figure 4-7 and Figure 4-8). While the phrasing of news articles and reports can lead one to believe that the RES industry jobs can act as an offset to the fossil-fuel jobs (Holcombe, 2019; Marcacci, 2019). This is often not representative of the ground reality. Solar PV jobs for example, typically require a varied skill set than traditional fossil-fuel jobs. This means that workers transitioning between the two sectors would have to undergo extensive re-training. Further, the new solar jobs might not always occur in the same geographical regions as the previous coal jobs. This might mean that workers that want to switch between the energy sectors would not only have to relocate their lives, but also invest significant time and money in learning a new set of skills.

2040 employment outlook for coal and solar power sectors: Another important finding of this study was that while the costs of solar power are showing a historic decline, the growth of solar and coal power sectors in India are not competing with each other until at least 2040. Both sectors are essentially growing independent of each other, in different geographical locations. Consequently, as demonstrated by the research findings (Figure 4-9), employment generated in both the sectors is projected to grow without having any influence on each other. This finding is further validated by India's NEP which showcases policy plans for continued growth in both sectors.

However, the solar power industry which only started picking up pace in 2011 (Mercom India, 2019), will by 2022, already be employing as many people as 43% of the coal industry currently does. Moreover, in 2040, the number of solar power jobs will almost rival the number of jobs in the coal sector. These statistics demonstrate the expanding future of the solar power and consequently the RES sector as a whole in India. Especially when one considers how new the solar industry is when compared to the coal industry which has been around since the 1960s.

The research conducted by this thesis is also significant when put into context with pre-existing literature. A 2018 study by the Climate Policy Initiative (CPI) reported that the RES sector in India would create 4.5 million jobs by 2040 under an optimistic scenario. 2.8 million of these RES jobs are expected to arise from the solar power sector. In contrast, the findings of this study estimate that the solar power sector will only generate employment for 909,469 people by 2040. This difference can be attributed to the fact that the CPI study calculates the total number of construction and operations and management jobs that are created, in a cumulative fashion. Whereas, in reality construction jobs typically tend to be contractual and temporary in nature. This means that they cease to exist once the capacity addition has been built in a particular year. This puts the actual number of construction jobs present in a particular year as much lower than portrayed. A similar methodology seems to be adopted by the IRENA (2018b) report, which estimates that the solar power sector to have created 164,000 jobs in India so far.

This distinction is significant as the CPI numbers are widely quoted in news reports (Kenning, 2018; Tanwar, 2018; The Economic Times, 2018) and can be misleading as they do not accurately represent reality. In contrast, the methodology employed by this research study considers the temporary nature of construction jobs. The fact that the construction jobs will not exist once the desired installed capacity is added, is taken into account, instead of making a projection based on cumulative installed capacity estimates. Construction workers who are employed in Year 1 can be expected to work the newly created jobs in Year 2, once the jobs created in the 1st year cease to exist after completion of capacity addition. The only way the absolute total number of construction jobs will increase is if the annual solar power capacity additions increase as well. This is portrayed through a hypothetical situation depicted in Figure 5-1.

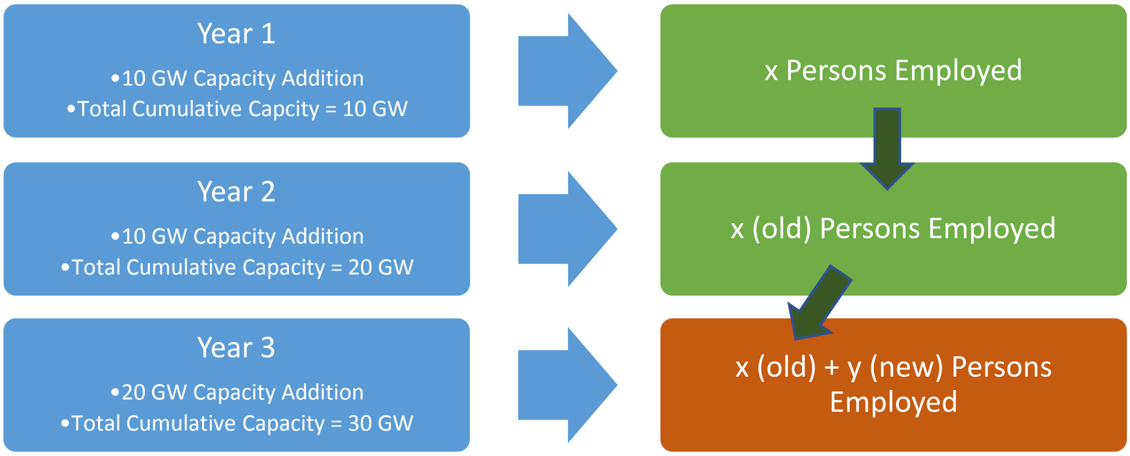


Figure 5-1: Change in employment numbers with progressing capacity additions every year.

Source: Author's illustration

Pre-existing literature also projects the solar power sector to employ around 290,000 people by 2022 (CEEW-NRDC, 2017). The research done by this thesis not only validates the research done by these previous studies, but also provides a comprehensive breakdown of the current nature and future outlook of the sector on the individual state-levels. That apart, it also fills the knowledge gap of how employment in the solar power sector compares with the same in the coal sector, in the present day as well as in the future. A comprehensive comparison of the two sectors does not yet exist in literature. Finally, the research also identifies discrepancies in previously reported government data and provides clarification of the methodology employed by previous reports to estimate future employment projections.

6 Conclusion

The aim thesis was driven by the idea of adding pertinent useful information to the broader discourse on the potential addition of large numbers of renewable energy jobs to India's economy. This conclusion starts with explaining how the primary aims and objectives of this study were achieved. Then it outlines the contributions of this thesis to the filling the identified knowledge gap. Finally, it describes pathways that may be undertaken for future research and recommendations for reporting and portrayal of data.

6.1 Central findings

The primary aim of this thesis was to shed light on the nature and quantity of jobs that are being generated in India by the two divisions of the solar power sector, based on existing government plans and policies. While existing studies have already analysed data regarding this and produced job creation estimates, they tend to only focus on the national scale. However, it is important to showcase the regional breakdown of how and what kinds of jobs are created and correlate it to the geographical and demographical complexity of the country. Further, the RES sector is often compared and treated as a competitor to the fossil fuels sector. Thus, this thesis also attempts to showcase how employment generation capacities of the solar power and coal sectors compare. Finally, this study has attempted to create a timeline of how the number and nature of jobs in these two sectors are going to change in the upcoming decades.

The study found that not all the estimated solar power potentials of the various Indian states coincide with their installed capacity deployment targets. Certain states need to revise their datasets to reflect more accurate, and feasible target numbers. The results also showcased the distribution of future jobs based on skill-type among the different divisions of the solar power sector. Building further research on this is crucial to allow for organization of well-informed job training programmes. These results also revealed the proportions of jobs that each of the divisions of the solar power sector currently have, and how these proportions can be expected to change by 2022.

Secondly, the findings revealed that majority of the current solar jobs exist in entirely different geographical locations than traditional coal jobs. Consequently, any transition of workers between the two sectors will require extensive retraining programmes. Therefore, there is value in researching this further to allow for better planning of policy and strategies for potential job transitions between the two sectors.

Finally, the number of coal jobs was found to currently grossly outnumbers the number of solar power jobs, possibly due to the solar sector having just moved to the "Sustained Growth" phase (Figure 2-4). However, with India's aggressive solar deployment strategies in play, this status quo can be expected to change drastically within the next two decades. Calculated estimates showed that the employment potential of the solar power sector can be expected to grow exponentially to rival the number of jobs in the coal industry. But, the two industries will not compete and can be expected to grow almost independently of each other. This is partly because installed capacity in both sectors is projected to increase with increase in energy demand in the country. Another reason for this prediction is the fact that the states with high solar power potential are different from the ones with current coal mining and/or power capacities. As a result, the two sectors have less avenues for competition.

6.2 Future research and recommendations

There is immense potential for future research in this area as a lot of knowledge gaps still exist. Based on the research findings, the primary recommendations of this thesis for future research in this area are:

- Improving reporting and accuracy of power potential and installed capacity target data.
- Developing better projections of number of module manufacturing jobs that will be created in the future. This could be based on more informed and accurate information on the growth of the market share of the module manufacturing sector.
- Better reporting of the number and nature of jobs that are outsourced by the different divisions of the solar power sector.
- Conducting surveys similar to those conducted by CEE-NRDC (2017) for other power production sectors in the country. This would produce accurate job-years/MW coefficients specifically geared towards the Indian context.
- Communicating findings related to creation of RES jobs in a more practical manner. This can be done by clearly accounting for the temporary or permanent nature of the jobs, such that the overall findings are not misinterpreted to be greater than what is actually true.

89% of global GHG emissions stem from the power sector, which puts 33.1 Gt CO_2 into the atmosphere annually. The responsibility of climate change mitigation and clean energy development is often put on the developed world, since they are perceived to have reached their levels of development by overshooting their carbon budgets. Planning and investing in transition to clean energy is perceived as too costly and difficult a task for poor countries which are themselves trying to raise their populations out of poverty. However, the reality is that this characterization is not true for all developing countries uniformly. While their per capita emissions remain at historic lows, manufacturing giants like India are China are fast becoming powerhouses of production and consumption, with exponentially growing energy demands (Ummel, 2010). Thus, it is not possible for such countries to "develop" with the same carbon budget as the developed countries once did. It is important to ask; how much longer will these per capita emissions remain so low as the purchasing power of the population grows?

RES show promise as the pathway that can lead these countries into cleaner modes of development. This is a realization that their governments are very aware of, as evidenced by the numerous utility-scale RES plants that have been commissioned and are operating within only the past few years (Al Jazeera, 2016; Bengali, 2018; Kumar, 2018; TFE, 2017). Moreover, both India and China have exceeded the U.S. and the developed world in the share of their national income devoted to subsidizing clean energy for a number of years (Al Jazeera, 2016; IISD, 2017; Xu & Stanway, 2019). Further, the falling price of solar tariffs in India have made the technology cost-competitive, and for the first time lower than the price of energy generated from traditional fossil-fuel sources like coal (Srivastava, 2019; UNFCCC, 2018). Further studies have the potential to showcase and characterize more accurately how the energy production industry can be expected to change, and what would be the consequent socio-economic effects of this change on the nature of jobs.

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Appendices

Appendix A shows the correlation between estimated solar power potential and the 2022 installed capacity targets of each of the Indian states. This was the complete dataset that was used to create the maps in Figure 4-1 and Figure 4-2.

Appendix B presents the present day and future (2022) geographical distribution of jobs created by the solar power sector.

Appendix C depicts the present-day geographical distribution of coal jobs, separately calculated for mining and thermal power plant jobs, in each of the Indian states.

Appendix D presents the scenario modelling that was used to predict the 2040 job creation potential for solar power. This was is part used to create the graphical representation seen in Figure 4-9.

Appendix A

In Table A-1, the 2022 state installed capacity targets that are greater than 80% of their estimated solar power generation potential are highlighted in orange. Similarly, those targets that are less than 5% of the estimated potential are highlighted in yellow.

Table A- 1: Correlation between estimated solar power potential and the 2022 installed capacity targets in each of the Indian states

S. No.	States & UTs	Estimated Solar Power Potential (MW)	2022 Installed Solar Power Capacity Target (MW)	% of Estimated Natural Potential, 2022 Target is
1	Punjab	2 810	4 772	170%
2	Delhi	2 050	2 762	135%
3	Haryana	4 560	4 142	91%
4	West Bengal	6 260	5 336	85%
5	Tamil Nadu	17 670	8 884	50%
6	Uttar Pradesh	22 830	10 697	47%
7	Goa	880	358	41%
8	Kerala	6 110	1 870	31%
9	Andhra Pradesh	38 440	9 834	26%
10	Telangana	20 410	5 000	24%
11	Karnataka	24 700	5 697	23%
12	Gujarat	35 770	8 020	22%
13	Bihar	11 200	2 493	22%
14	Maharashtra	64 320	11 926	19%
15	Jharkhand	18 180	1 995	11%
16	Chhatisgarh	18 270	1 783	10%
17	Odisha	25 780	2 377	9%
18	Madhya Pradesh	61 660	5 675	9%
19	Uttarakhand	16 800	900	5%
20	Tripura	2 080	105	5%
21	Assam	13 760	663	5%
22	Rajasthan	142 310	5 762	4%
23	Meghalaya	5 860	161	3%
24	Himachal Pradesh	33 840	776	2%
25	Jammu & Kashmir	111 050	1 155	1%
26	Manipur	10 630	105	1%
27	Nagaland	7 290	61	1%
28	Mizoram	9 090	72	1%
29	Sikkim	4 940	36	1%
30	Arunachal Pradesh	8 650	39	0%
31	Andaman & Nicobar	0	27	
32	Chandigarh	0	153	
33	Dadar & Nagar Haveli	0	449	
34	Daman & Diu	0	199	
35	Lakshwadeep	0	4	

36	Pondicherry	0	246	
	Total (MW)	**748 990**	**104 534**	

Source: Author's calculations based on CEA (2018) data

Appendix B

Table A- 2: Present and future geographical distribution of solar power jobs

S. No.	States & UTs	Current Installed Solar Power Capacity (MW)			Solar Power Capacity to be added by 2022 (MW)		
		Ground – Mounted Projects	Rooftop Projects	Total	Ground – Mounted Projects	Rooftop Projects	Total
1	Andhra Pradesh	2 841	49	2 889	4 167	2 778	6 945
2	Arunachal Pradesh	1	4	5	20	13	34
3	Assam	11	8	19	387	258	644
4	Bihar	139	4	142	1 410	940	2 351
5	Chhatisgarh	216	16	231	931	621	1 552
6	Goa	1	1	2	214	143	356
7	Gujarat	1 836	167	2 003	3 610	2 407	6 017
8	Haryana	131	89	220	2 353	1 569	3 922
9	Himachal Pradesh	0	5	5	463	309	772
10	Jammu & Kashmir	8	6	14	684	456	1 141
11	Jharkhand	19	13	32	1 178	785	1 963
12	Karnataka	5 175	154	5 329	221	147	368
13	Kerala	100	38	138	1 039	693	1 732
14	Madhya Pradesh	1 619	31	1 650	2 415	1 610	4 025
15	Maharashtra	1 447	172	1 620	6 184	4 123	10 306
16	Manipur	0	3	3	61	41	102
17	Meghalaya	0	0	0	97	64	161
18	Mizoram	0	0	1	43	29	72
19	Nagaland	0	1	1	36	24	60
20	Odisha	384	7	390	1 192	795	1 987
21	Punjab	828	78	906	2 320	1 547	3 866
22	Rajasthan	3 046	96	3 142	1 572	1 048	2 620
23	Sikkim	0	0	0	22	14	36
24	Tamil Nadu	2 098	135	2 233	3 990	2 660	6 651
25	Telangana	3 519	64	3 584	850	567	1 416
26	Tripura	5	0	5	60	40	100
27	Uttar Pradesh	834	68	902	5 877	3 918	9 795
28	Uttarakhand	240	64	304	357	238	596
29	West Bengal	50	20	70	3 160	2 107	5 266
30	Andaman & Nicobar	5	1	7	12	8	20
31	Chandigarh	6	26	32	72	48	121
32	Dadar & Nagar Haveli	2	3	5	266	177	444
33	Daman & Diu	10	4	14	111	74	185
34	Delhi	9	115	124	1 583	1 055	2 638
35	Lakshwadeep	1	0	1	2	1	3
36	Pondicherry	0	2	2	147	98	244
	Total	**24 582**	**1 444**	**26 026**	**47 105**	**31 403**	**78 508**

Source: Author's calculations based on CEA (2018) data

Appendix C

Table A- 3: Present-day distribution of coal power jobs in all Indian states

S. No.	States & UTs	Current Installed Coal Power Capacity (MW)	No. of Jobs Currently in Coal Power Plants	No. of People Employed by Coal Mining Industry
1	Andhra Pradesh	10 431	10 051	0
2	Arunachal Pradesh	25	24	0
3	Assam	279	269	6 356
4	Bihar	3 905	3 763	0
5	Chhatisgarh	12 723	12 260	42 851
6	Goa	455	438	0
7	Gujarat	14 066	13 554	0
8	Haryana	8 096	7 801	0
9	Himachal Pradesh	183	177	0
10	Jammu & Kashmir	506	488	1 720
11	Jharkhand	1 544	1 488	111 285
12	Karnataka	9 406	9 064	0
13	Kerala	1 476	1 423	0
14	Madhya Pradesh	13 708	13 209	90 111
15	Maharashtra	26 961	25 979	51 500
16	Manipur	31	30	0
17	Meghalaya	30	29	0
18	Mizoram	21	20	0
19	Nagaland	21	21	0
20	Odisha	4 993	4 811	31 361
21	Punjab	7 730	7 449	0
22	Rajasthan	9 358	9 018	0
23	Sikkim	87	84	0
24	Tamil Nadu	11 933	11 499	0
25	Telangana	8 529	8 218	72 866
26	Tripura	37	36	0
27	Uttar Pradesh	17 980	17 325	0
28	Uttarakhand	442	426	0
29	West Bengal	8 586	8 273	65 528
30	Andaman & Nicobar	0	0	0
31	Chandigarh	38	37	0
32	Dadar & Nagar Haveli	174	168	0
33	Daman & Diu	127	122	0
34	Delhi	4 117	3 967	135
35	Lakshwadeep	0	0	0
36	Pondicherry	141	136	0
	Total	**178 141**	**171 657**	**473 713**

Source: Author's calculations based on data from CMPFO (2015) and MNRE (2019)

Appendix D

For the calculation of 2040 job creation potential of the solar power sector, a scenario where the amount of annual added installed capacity remains uniform was assumed.

Table A- 4: 2040 job creation projections for solar power

Year	Ground-Mounted Projects				Rooftop Projects				Total No. of Solar Jobs Generated
	Added capacity (GW)	Total Capacity (GW)	Construction Jobs Generated Per year	Total Operations & Maintenance	Added Capacity (GW)	Cumulative (GW)	Construction Jobs Generated Per year	Total O&M	
2019	11	11	32 450	5 500	8	8	193 760	4 000	235 710
2020	11	22	32 450	11 000	8	16	193 760	8 000	245 210
2021	11	33	32 450	16 500	8	24	193 760	12 000	254 710
2022	11	44	32 450	22 000	8	32	193 760	16 000	264 210
2023	11	55	32 450	27 500	8	40	193 760	20 000	273 710
2024	11	66	32 450	33 000	8	48	193 760	24 000	283 210
2025	11	77	32 450	38 500	8	56	193 760	28 000	292 710
2026	11	88	32 450	44 000	8	64	193 760	32 000	302 210
2027	11	99	32 450	49 500	8	72	193 760	36 000	311 710
2028	11	110	32 450	55 000	8	80	193 760	40 000	321 210
2029	11	121	32 450	60 500	8	88	193 760	44 000	330 710
2030	11	132	32 450	66 000	8	96	193 760	48 000	340 210
2031	11	143	32 450	71 500	8	104	193 760	52 000	349 710
2032	11	154	32 450	77 000	8	112	193 760	56 000	359 210
2033	11	165	32 450	82 500	8	120	193 760	60 000	368 710
2034	11	176	32 450	88 000	8	128	193 760	64 000	378 210

2035	11	187	32 450	93 500	8	136	193 760	68 000	387 710
2036	11	198	32 450	99 000	8	144	193 760	72 000	397 210
2037	11	209	32 450	104 500	8	152	193 760	76 000	406 710
2038	11	220	32 450	110 000	8	160	193 760	80 000	416 210
2039	11	231	32 450	115 500	8	168	193 760	84 000	425 710
2040	11	242	32 450	121 000	8	176	193 760	88 000	435 210

Source: Author's calculations based on IEA (2018b) data