

Reviewing the National Solar Mission in India from the lens of Mission Oriented Innovation Policies

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Abstract

Mission Oriented Innovation Policies (MOIP) have historically focused on achieving specific goals and more recently have oriented towards meeting "grand challenges" or "societal challenges" and are being referred to as "big science deployed to meet big problems". Combating climate change is one of such grand challenge and the consequences, Government of India had launched the Jawaharlal Nehru National Solar Mission (JNNSM) as one of the eight missions that make up India's National Action Plan on Climate Change (NAPCC) in 2010 and it is now more than a decade of the mission which had grown significantly over the years. The present paper therefore takes the case of National Solar Mission in India and examines it within the MOIP framework. It analyses the various components of MOIP within the NSM like policies, governance structure, funding mechanisms, human resource development and R&D activities.

Keywords: Solar Energy, Mission-Innovation, Governance, Sectoral Policy, Capacity building

Background

The 21st century is rapidly being demarcated by the necessity to address social, environmental, and economic concerns across the globe, in which innovation has been at the forefront with both a rate and a direction. These issues, sometimes referred to as "grand challenges" or "societal challenges" include the difficulty of generating sustainable and inclusive growth, demographic, health, well-being concerns, food security, and environmental threats like climate change, secure, clean and efficient energy. These issues are "wicked" in the sense that they are urgent, complicated, systemic, linked, and require knowledge

from a wide range of viewpoints. These issues are relevant in both developed and developing nations, with the needs of emerging economies motivating some of the most interesting experiments in sustainability. The report on "Transforming Our World: the 2030 Agenda for Sustainable Development" released by the United Nations on 25 September 2015 mentioned the 17 sustainable development goals (SDGs) which reflect the problems that every society faces worldwide and is bound to be there for some time in the near future. The European Union's Horizon 2020, a research and innovation programme is another example that reflect the policy priorities of the Europe 2020 which addresses major concerns and societal

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challenges shared by citizens in Europe and elsewhere. By coupling research and innovation, Horizon 2020 is helping to achieve this with its emphasis on excellent science, industrial leadership and tackling societal challenges.

When the world is transiting through such challenges, there is much to be learnt from "mission-oriented" policies that have historically been focused on achieving specific goals, whether they be putting a man on the moon or combating climate change, when it comes to turning these challenges into tangible problems that necessitate innovation across several sectors and actors (Ergas, 1987; Mowery 2010; Mazzucato, 2014; Mazzucato 2017). Different actors (both public and private) and various sectors need to innovate for such mission oriented policies to succeed (e.g. going to the moon required innovation in aeronautics, robotics, textiles, and nutrition).

Scope of Mission Oriented Innovation Policies

The third generation of "transformative" innovation policy advocates recognizing the importance of addressing societal issues as well as the challenges of reorienting innovation in path-dependent innovation systems (Schot and Steinmueller, 2018). The paradigm for the first generation of innovation policy was simple: monitor national R&D expenditures and develop measures to boost R&D spending. Second-generation innovation policy became little more complex due to the wide range of options for enhancing the various components of innovation systems. However, it became clear that a key requirement for innovation strategy is to strengthen linkages between participants in innovation networks. Nelson's study on the Moon and the Ghetto (Nelson, 2011) posed the challenging question of why innovation has enabled such challenging accomplishments as sending a man to the moon, but why it has been so terribly disorganised and technologically backward in addressing the more practical issues of poverty, illiteracy, and the emergence of ghettos and slums. While acknowledging that politics played a role, he emphasised that the fundamental issue was the inability of a solely scientific and technological solution to address such

issues. Even at the disciplinary level, there is a greater need to integrate sociological, political, economic, and technological understandings in order to address these issues and to make the deliberate choice to direct innovation in that direction. This is precisely what a carefully thought-out mission can do. A mission-oriented strategy leverages targeted obstacles to promote innovation across industries. Recent years have drawn attention to mission-oriented policies which focus on solving issues in specific ways rather than just investing on them. To understand this, it is important to research how particular mission-driven agencies and organisations have operated, whether in military R&D initiatives or in fields like health (Sampat, 2012), agriculture (Wright, 2012), or energy (Anadon, 2012). Mission-oriented policies are referred to as "big science deployed to meet big problems" or systemic public policies that draw on frontier knowledge to achieve specified aims (Ergas, 1987).

A mission-oriented approach to innovation policy connects it to major scientific initiatives that aspire to provide major technological breakthroughs. According to Ergas 1987, in mission-oriented economies, "few bets are typically placed on a small number of races", with NASA's efforts to land a man on the moon serving as a "archetypical historical mission" (Mazzucato and Semieniuk, 2017). An example of a mission-oriented strategy that failed is the creation (and eventual demise) of Concorde (Mustar and Larédo, 2002). These strategies reflect the ambition of decision-makers to advance radical technology advancement that can address certain issues that are high on the political agenda (Edler and Fagerberg, 2017). Missions engage in tackling particular challenge, like reducing carbon footprint which will necessitate diverse sectors to act collectively in new ways as the issue cannot be tackled by the energy sector only. It calls for transformation in other sectors like transport, nutrition, and many other related sectors. Mission-oriented policies therefore focus on creating system-wide transformation across diverse sectors.

Any new or enhanced technological, social, or organisational solution (product, process, or service) that strives to address one or more of the major societal concerns (missions) and add value to society is considered to be mission-oriented innovation (e.g.,

climate mitigation, clean oceans, sustainable economic growth and well-being etc.). It becomes necessary to frequently implement special governmental measures to support the growth and adoption of such technologies. If we take the case of combating climate change, the economy must decarbonize faster than ever before. In such circumstances, public funding for R&D and institutions are essential components of accelerating the energy innovation process, along with other strategies like deployment policy. Studies have highlighted that the nature of public funding and institutions for energy innovation must change if public energy RD&D is to contribute to the Paris climate targets (Cunliff, & Hart, 2019; Mowery, Nelson, & Martin, 2010). To achieve future energy emission reductions roughly consistent with the 2° Celsius climate goal¹, annual spending for public energy R&D would have needed to at least quadruple between 2010 and 2020. Given the lags between R&D and technology diffusion (Grübler, Nakićenović & Victor, 1999; Eom, et.al., 2015) public institutions for energy innovation need to develop to assist the quick commercialization of technologies. Climate damages and mitigation costs will likely be far greater than they could be in the absence of significantly more rapid energy innovation. Because constant R&D support is more likely to result in the long-term energy innovation required to address the climate problem, understanding volatility among technologies becomes more critical (Chan, et.al., 2017; Guellec & Potterier, 2003).

The present paper therefore takes the case of National Solar Mission in India and examines it within the Mission Oriented Innovation policies framework. India's major contribution to the global effort to combat climate change is the National Solar Mission, which aims to supply all of the country's energy needs using solar energy. As India deals with a growing need for fuel, threats to energy security, and the effects of climate change, solar energy is a must for its economy to grow in a sustainable way. India has a huge potential for solar energy. India's geographical surface receives around 5,000 trillion kWh of incident energy annually, with the majority of areas receiving 4–7 kWh/m² with about 1500–2000 sunshine hours per year, depending upon location resulting in an aggregate incident radiation of about 5000 trillion Kwh/yr (National Solar Mission | Indian Power Sector.

com). On January 11th, 2010, the National Solar Mission (NSM) was launched by the Government of India to promote ecological sustainability and address the country's energy security issues.

National Solar Mission and its imperatives

India as a tropical country, where sunshine is available for longer hours and in great intensity has the most opportune conditions for solar energy. Accordingly the Jawaharlal Nehru National Solar Mission (JNNSM) was planned as one of the eight missions that make up India's National Action Plan on Climate Change (NAPCC). This mission elucidates the country's goal for solar technology: When compared to India's meagre installed solar capacity in 2010, which was only 10.28 MW, setting the target for installation of 40.1 GW of solar capacity by 2022 is a very straightforward endeavour in mission mode. The NSM was expected to develop and deploy solar energy technologies in the country to attain parity with grid power tariff by 2022. It targeted the supply of solar power that is connected to the grid should be increased to 1 GW by 2013, 10 GW by 2017, and 20 GW by 2022 (Shrimali and Rohra, 2012). The Mission was planned in 3-phases, 2012-13 as Phase 1, 2013-17 as Phase 2 and 2017-22 as Phase 3. The mission aimed at developing 20-GW capacity solar grids and 2-GW capacity off-grid solar applications. Besides the energy and ecological security NSM was also conceived to harness the benefit of allowing the decentralized distribution of energy, as a resultant empowering societies at the grassroot level. The total expected investment for upgrading to 100 GW solar power capacity was around \$94 billion (National Solar Mission: Investment Projects under National Solar Mission Scheme | IIG (indiainvestmentgrid.gov.in)). A review mechanism of evaluation of progress at the end of each plan, as well as a review of capacity and targets for succeeding phases, based on developing cost and technological trends, both domestically and globally.

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Table 1 Targets of the 3 phases of NSM

S.No	Targets / Application Segment	Solar Collectors	Off-grid solar applications	Utility grid power, including rooftop
1	Target for Phase I (2010–13)	7 million sqmt	200MW	1000MW
2	Target for Phase II (2013–17)	15 million sqmt	1000MW	4000–10000MW
3	Target for Phase III (2017–22)	20 million sqmt	2000MW	100000MW

Source: MNRE website

globally.

In its mission mode approach, India recently has achieved 5th global position in solar power deployment by surpassing Italy. Solar power capacity has increased by more than 11 times in the last five years from 2.6 GW in March, 2014 to 30 GW in July, 2019. Presently, solar tariff in India is very competitive and has achieved grid parity (MNRE website). India still lags behind the 100 GW grid-connected solar power plants target which was to be achieved by the year 2022, but has demonstrated unprecedented growth of the solar energy sector and hence prompts to look into the stages of development from the mission oriented innovation policies perspective such that we are able to learn from the experiences undertaken in mission-mode.

3.1 Policies and programs for solar energy in India

The JNNSM is supplemented by a set of guidelines that describe the implementation roadmap and the regulatory architecture for each technology and application type, such as grid-connected power plants, off-grid and decentralised applications, and roof-top installations for solar photovoltaic (PV) and solar thermal. The JNNSM is a comprehensive framework for policy and regulation that addresses the need for an industrial policy, emphasises the need to develop research and development capabilities with a focus on demonstration, acknowledges the need to develop a skilled talent pool, outlines a governance structure, and identifies financial sources.

It is obvious that JNNSM and India's power sector reforms cannot be considered separately. Before the mission was launched the government recognizing the necessity and importance of developing renewable energy, had implemented a number of power policies replacing the legal framework which was put in place 55 years earlier, where the government was in

charge of all facets of the power sector, specifically generation, distribution, and transmission. Table 2 enlists the reforms in the power policies which directly or indirectly had set the platform enabled growth of the solar energy sector in the country.

India, in its federated mode of operation the major policies were taken up by the Central Government and simultaneous State-led initiatives also brought policy reforms at state level. The state of Gujarat had framed its Solar Policy much before the launch of NSM in 2009 followed by Rajasthan, Madhya Pradesh, Uttar Pradesh, Odisha and Andhra Pradesh who announced their state level solar policies in 2013. NSM has formulated favourable policies with a feed-in-tariff regime, viability gap funding mechanisms, capital subsidies, progressive net-metering arrangements and solar specific renewable purchase obligations which have created an enabling situation for growth of solar power in the country. Power Purchase agreements (PPAs) were introduced and a compulsory domestic content requirement (known as a “DCR”) was imposed on Solar Power Developers participating in phase I and phases II under the Guidelines for selection of New Grid Connected Solar Power Projects to encourage solar cells and modules manufacturing in India. Waiver of inter-state power transmission charges by the Government which has abolished the fees associated with interstate energy transmission and damages for solar and wind power producing projects that will be operational by March 2022 has boosted the sector as no additional cost was levied for the transmission of electricity through an interstate transmission system for the distribution and acquisition of electricity.

Corporate Social Responsibility (CSR) was established to encourage the participation of the private sector in national development and the attainment of social goals. Presently, CSR provides funds to account for

2% of the top 500 corporations' investments in off-grid activities.

The Government of India has made efforts through its policies to expand the nation's capacity to meet its energy demands in a socially, economically, and environmentally responsible manner. In addition to this, it has enacted a number of programmes to promote the country's general development. It has introduced a number of programmes to promote the production of solar power in the nation in order to meet the set goal which includes the Solar Park

Program, Viability Gap Funding (VGF) Programs, Central Public Sector Undertaking (CPSU) Program, Defence Program, Canal Bank & Canal Top Program, Bundling Program, and Grid Connected Solar Rooftop Program. Table 3 summaries some of the recent programs with its deliverables. Besides the programs which are directly linked to solar energy installations, there are several other initiatives which are connected to the sectoral development. Some of them are:

Table 2 Policies for Power sector reforms in India before and just after the NSM

Year	Policies	Component enabling development of Solar Energy
2003	Electricity Act	Main goal was to move the industry toward the development of electricity markets that would be dominated by private firms; provided the foundation for the entire growth of India's energy market. Created provisions for favoured tariffs and alternative renewable energy quotas, mandatory renewable energy procurement for circulation permits and improved grid connectivity.
2005	National Electricity Policy	The goal of the policy is to ensure that everyone has access to energy and to increase the minimum availability per capita to 1,000 kWh per year by 2012, enables preferential tariffs for green energy.
2006	National Tariff Policy	Renewable Purchase Obligation (RPO) mechanism for establishing a minimum share of the states' electricity purchases from renewable electricity sources; a specific rate for solar power was also offered.
2006	Integrated Energy Policy	Emphasised on the development of renewable energies and outlined specific capability objectives.
2006	National Policies Rural Electrification (NREP)	Providing all homes with access to electricity by the end of 2009, ensuring an efficient and steady electricity supply at reasonable pricing, and reducing lifeline usage to a daily average of one unit per household by 2012 Off-grid solutions based on independent renewable energy systems, such as solar photovoltaic, can be utilised for electricity delivery in villages/houses where grid connection is impractical or prohibitively expensive
2007	Semiconductor Policy	Aimed to improve the production of semiconductors and ecosystems, of which solar photovoltaics are an element. It provides a 20% financial subsidy for SEZ manufacturing facilities and a 25% subsidy for plants manufactured outside of Special Economic Zones
2008	NAPCC	To tackle climate change, a project-based action approach for sustainable growth in which one of the primary objective was to accelerate solar energy generation.
2008	Solar PV generation-based financial incentive scheme	MNRE established a strategy for production-based incentives for both solar thermal and solar photovoltaic grid-connected systems. The programme has been expanded to include all currently approved enterprises for state and central electricity generation, as well as private and public PV producers.
2010	Clean Energy Cess	Levied a 50 INR tax on every tonne of coal consumed in the region. The cessation acknowledged the National Clean Energy Fund (NCEF) to assist ideas for sustainable energy.
2011	Renewable Energy Certificates (RECs)	RECs are based on a market structure designed to maximise the potential of renewable energy sources. It reduces interstate differences in the production of renewable energy and the obligation of relevant institutions to comply with their RPOs at a solar and non-solar price differential.
2011	Generation Based Incentives (GBIs) for Solar Power	Provided to support small grid solar power projects connected to the distribution grid (below 33 KV) to the state utilities. GBIs aim to close the difference between the CERC tariff for 2010-11 (Rs. 17.91 per kWh) and a reference tariff of Rs. 5.5 per kWh

Source: Compiled by authors from different sources

Table 3 Brief description of select recent programs to promote solar energy in India

Programme	Brief
Faster Adoption and Manufacturing of Electric Vehicles in India (FAME) programme	Launched in 2015 by Ministry of Heavy Industries. In this programme the Indian government is offering funding to smart cities for the purchase of electric vehicles to be used for public transportation. This phase aims to generate demand by way of supporting 7000 e-Buses, 5 lakh e-3 Wheelers, 55000 e-4 Wheeler Passenger Cars (including Strong Hybrid) and 10 lakh e-2 Wheelers. The program is connected to the solar sector as the charging stations for such vehicles are envisaged to be driven by solar power.
Solar Parks	In 2014 to expedite installation of grid connected solar power projects for electricity generation on a large scale, the scheme aimed to create required infrastructure for setting up of Solar Power Projects. It was planned to set up at least 25 Solar Parks and Ultra Mega Solar Power Projects targeting over 20,000 MW of solar power installed capacity within a span of 5 years.
Pradhan Mantri Sahaj Bijli har Ghar (PM-SAUBHAGVA) Yojna	Launched in 2017 by the Ministry of Power is to provide energy access to all by last mile connectivity and electricity connections to all remaining un-electrified households in rural as well as urban areas.
Kisan Urja Suraksha Evam Utthaan Mahabhiyan (KUSUM) yojna	Launched in 2018 with the objective of giving financial assistance and water security to farmers, it involves the construction of solar pumps, the solarisation of currently grid-connected farm pumps, and the installation of renewable energy facilities that are grid-connected. The farmer will be able to use the generated energy to satisfy irrigation needs, and the surplus energy might be sold to DISCOM.
Sun One World One Grid plan (OSOWOG), 2020	Aims to connect solar energy supplies across international borders. Government intends to bring together over 140 countries from the regions of the far east and far west in order to establish agreement, launch energy policy imperatives, and provide the groundwork for global cooperation of this nature. This will contribute to the creation of a network of integrated clean energy services that can be smoothly transferred for mutual benefit and global sustainability. An interconnected grid would pool the renewable energy resources of all countries to meet their electrical demand, particularly peak demand, and rationalise their rates (Arora, et.al, 2010). This will attract developers from all over the world, aid in addressing socioeconomic issues, and lead to reduced project costs, increased productivity, and enhanced capacity utilisation for all participating agencies.

Source: Compiled by authors from different sources

State governments encourage solar energy independently, in addition to the efforts of the federal government, through initiatives in which residential sectors would receive central financial aid. The emphasis was given on increasing participation of Distribution Companies and a subsidy of up to 40% was provided for the installation of 3kW to 10kW rooftop solar systems. Such companies were encouraged with performance-based incentives based on total capacity in excess of base capacity reached throughout the fiscal year. Creation of Joint Liability Group (JLG), a group of four to ten entrepreneurs formed locally for off-grid installations combining market and collective capacity to make financing accessible for non-agricultural companies that are essential to micro grid networks was also taken up at state level.

3.2 Governance structure

The key to mission-oriented innovation is the exploration of the characteristics of innovation agencies that must be in place so that they can welcome uncertainty and build explorative capacity (Mazzucato, 2018). What unlocks a mission mode operation is the dissemination of knowledge and network connections among individuals, businesses, and institutions. It details the interactions between the various players involved in developing an idea into a marketable method, item or service. The many actors serve as the links and networks in the innovation ecosystem for the advancement and expansion of the sector. In NSM, the Ministry of New and Renewable Energy (MNRE), the Indian Renewable Energy Development Agency (IREDA), State Nodal Agencies, the Central Electricity Regulatory Commission

(CERC), and the State Electricity Regulatory Commission (SERC) have all been established by the Government of India to ensure that the ecosystem operates in a cohesive manner. The interactive model of policy serves as the foundation for the development of the JNNSM (Grindle & Thomas, 1991). Diverse institutional agents have created action plans to speed up the adoption of solar technologies. Pressures to change policy rise from many sources and groups that have emerged, such as the solar versus the anti-solar cohort, the concentrated solar power (CSP) versus the PV lobby, and indigenous against international cell and module manufacturers. MNRE and the Central Electricity Regulatory Commission (CERC) is in charge of designing policies and the State Electricity Regulatory Commissions (SERC) are in charge of carrying them out; the Forum of Regulators (FOR), which, given India's federal structure, is the body through which the CERC influences the SERCs; and NTPC VidyutVyapar Nigam Ltd. (NVV). Fig 1 gives a broad overview of the governance structure of NSM in India at various levels. Private sector participation is gradually increasing in the sector but still remains fragmented. Few prominent players include Adani

Enterprises Ltd, Emmvee Photovoltaic Power Private Limited, Azure Power Global Limited, JinkoSolar Holdings Co. Ltd, Acme Solar, Renew Power, Softbank Energy, Tata Power, Avaada, Greenko, Engie and Ayaana. Understanding the market prospects Shell Energy Solutions took a 20% stake in Indian solar firm Orb Energy Pvt Ltd. as part of a drive to deliver a reliable source of electricity to 100 million people in the developing world by 2030.

Electricity Boards of several states of India and relevant state-level government bodies for renewable energy are essential to the implementation of state-level policies. Fig 2 shows the status of installed solar energy capacity across states in India in which Rajasthan, Gujarat, Karnataka, Tamil Nadu, Andhra Pradesh, Telangana and Madhya Pradesh are the leading states. Similarly Fig 3 also reflects Andhra Pradesh, Rajasthan, Karnataka, Gujarat, Madhya Pradesh are the progressive states where the solar parks are installed with cumulative capacities ranging from 3000 – 1000 MW. Owing to the steady growth MNRE has now revised its guidelines on targeting of solar power installed capacity in such parks from 20,000 MW to 40000 MW.

Figure 1 Governance structure of NSM in India.

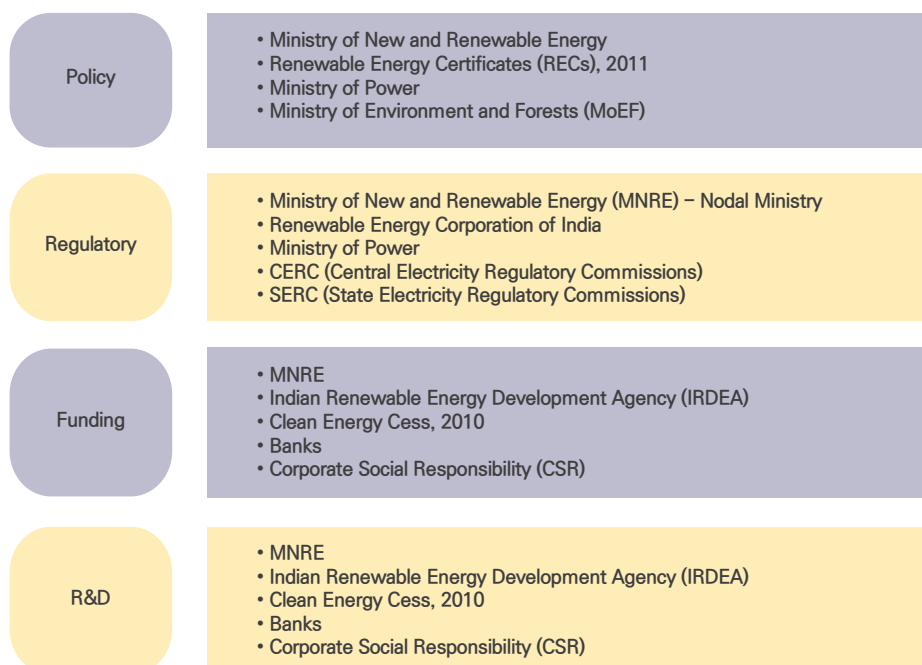
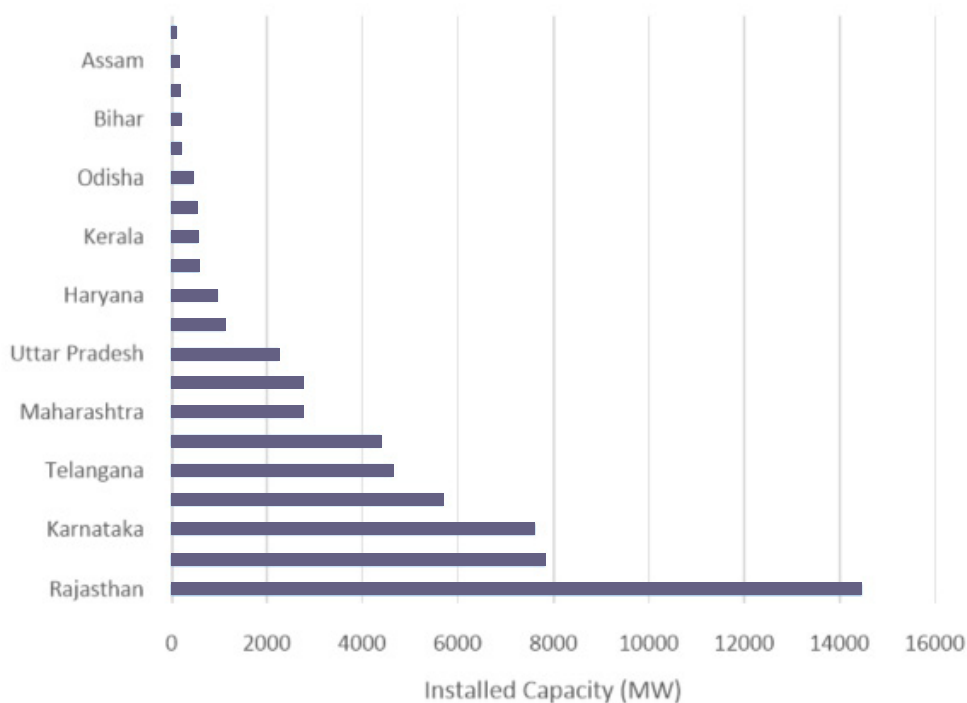
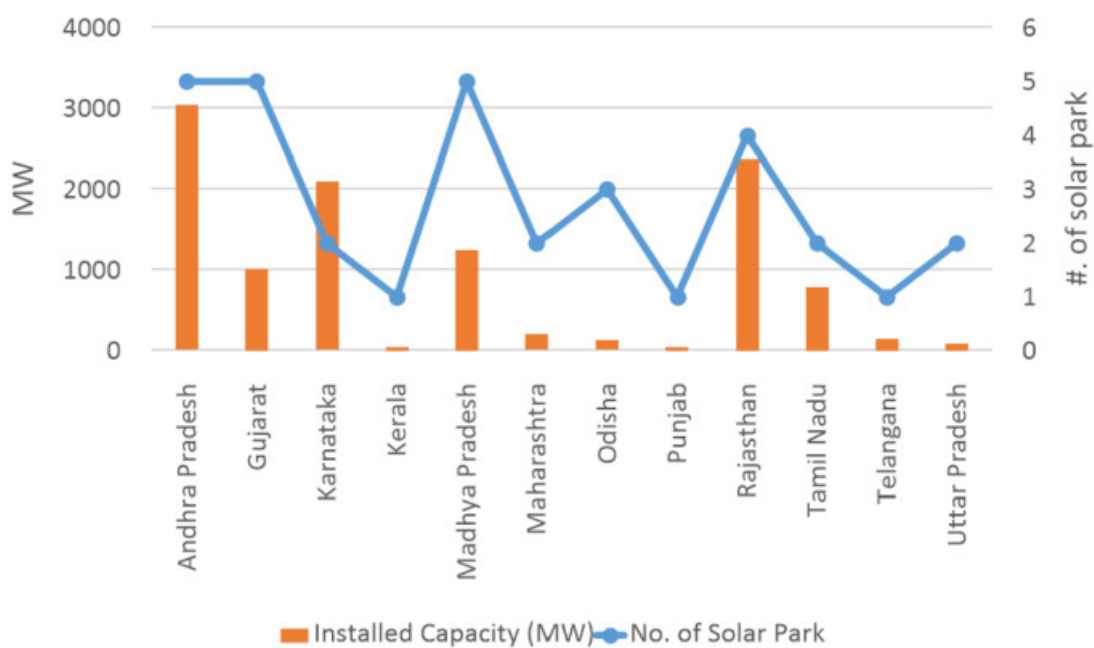


Figure 2 State-wise installed capacity of solar energy in top-20 installed state



Source: compiled from MNRE report and PIB report

Figure 3 State wise solar parks with their installed capacities in India



3.3 Solar energy generating equipment manufacturing in India

NSM in its set objectives had envisaged to attain global leadership in solar manufacturing (across the value chain) of leading edge solar technologies and had aimed for a 4-5 GW equivalent of installed capacity by 2020, alongwith establishing dedicated manufacturing capacities for poly silicon material manufacture about 2 GW capacity of solar cells annually. The Indian solar manufacturing sector comprises of both crystalline silicon and thin films in PV technologies and thermal technologies. The indigenous capacity to manufacture silicon material was very low during the launch of NSM and there were no indigenous capacity/capability for solar thermal power projects. Since the 1970s, BHEL and CEL have been engaged in making solar panels and other equipment, but were later joined by other companies that began small-scale manufacturing of modules which are limited to off-grid applications (Akoiyam, & Krishna, 2017). It was therefore conceived that to achieve the target of NSM, new facilities will be required to manufacture concentrator collectors, receivers and other components to meet the local demand. Therefore incentives for solar generation coupled with large government pilot/demonstration programs was thought will make the Indian market attractive for solar manufacturers and several incentives like Special Economic Zones to the manufacturing parks, Zero import duty on capital equipment, raw materials and excise duty exemption, Low interest rate loans, priority sector lending were devised. Incentives for establishing integrated manufacturing plants; (i) from poly silicon material to solar modules; and (ii) thin film based module manufacturing plants were provisioned under the Special Incentive Package (SIPs) scheme of the Department of Information Technology. Solar components was proposed to be considered for the Bureau of Energy Efficiency's star rating programme to ensure high standards. Creation of a single window clearance mechanism for all business related permissions for ease of doing business was considered. By the beginning of the national solar mission's second phase, about 1500 MW of cell manufacturing capability and around 2000 MW of domestic module manufacturing capability existed in India as compared with only 15 MW of ingots and

wafers manufacturing (MNRE 2015).

3.4 Funding for the solar energy Project:

Mission-oriented investments are proposed to be 'direct'. Government of India is boosting adoption of solar energy and both public sector banks & private banks have been given statutory instructions by Ministry of Finance to offer loan at reasonable cost. In this context, according to a study by Ernst & Young India was ranked as the most attractive destination for solar PV investment and deployment in its latest Renewable Energy Country Attractiveness Index. India scored 62.7 in solar attractiveness, with the sector expected to grow significantly and with generation from solar PV set to surpass coal before 2040. The country rose to rank third in the overall renewables rankings as the most appealing renewable energy market in the world (Ernst & Young ranks India as world's most attractive solar market – pv magazine International (pv-magazine.com)). Besides the public and private sector banks, Indian Renewable Energy Development Agency (IREDA) is a Non-Banking Financial Institution (NBFC) under MNRE providing finance upto 75% of the cost of the solar project venture for renewal energy and thermal energy efficiency projects. Other major Solar Project Financing Institutes in India are International Finance Corporation (IFC), a financing division of the World Bank, Asian Development Bank (ADB), Rural Electrification Corporation (REC) and Germany's Kreditanstalt fuer Wiederaufbau (KfW) bank. Data from the Department for Promotion of Industry and Internal Trade (DPIIT) shows that between April 2000 and December 2020, FDI inflow into the Indian in the sector was \$9.83 billion. In 2018, the nation's fresh renewable energy investment was \$11.1 billion. In terms of its investments and intentions for renewable energy in 2020, India was placed third globally, according to the analytics company British Business Energy. Even during the COVID-19 pandemic, India added 2,320 MW of solar capacity between January and September 2020. The table 4 gives a glimpse of some of the recent significant investments and developments in India's solar energy sector which throws light on the catching up phase of the NSM.

Table 4 Indicative select investment in Solar Energy sector in India

Period	Agency	Brief
April – December 2019	Various private companies	Invested over Rs. 36,729.49 crore (US\$ 5.26 billion) in renewable energy
April 2020	Vikram Solar	Won a 300 megawatt (MW) solar plant project from National Thermal Power Corporation Ltd (NTPC) under the CPSU-II scheme for Rs. 1,750 crore (US\$ 250.39 million)
October 2020	Tata power	100 MW solar plant in Gujarat's Dholera Solar Park
November, 2020	Airports Authority of India (AAI) and NTPC VidyutVyapar Nigam, a subsidiary of NTPC	Memorandum of agreement to encourage the use of electric vehicles and install solar power plants at its airports
November, 2020	Sun Source Energy in a tender bid with the Solar Energy Corporation of India (SECI)	Announced construction of 4 MW grid-connected floating solar PV power plant and a 2 MW Battery Energy Storage System (BESS) in the Andaman and Nicobar Islands.
December, 2020	SJVN Limited, a PSU under the Ministry of Power and Indian Renewable Energy Development Agency Ltd. (IREDA), a PSU under the Ministry of New & Renewable Energy	signed a Memorandum of Understanding in December 2020 to collaborate on green energy projects
December, 2020	Gujarat UrjaVikas Nigam Ltd. (GUVNL)	Organized auction for projects with a 500 MW capacity, bringing the price of solar energy to an all-time low of Rs. 1.99 per unit
FY 2020	ReNew Power and Shapoorji Pallonji	Will collectively invest nearly Rs 750 crore in a 150 megawatt (mw) floating solar power project in Uttar Pradesh.
2025 and 2030	Adani Group	Intended to be the largest renewable energy company in the world
2032	NTPC	NTPC hopes to generate 31%, or 39 GW, of its total power capacity using renewable energy.

Source: Compiled by authors from different sources

3.5 Human resource development (HRD) in solar energy sector

India has put more effort than ever before into building solar power capacity in the last few years recognizing that innovative clean energy solutions, like large solar parks and rooftop solar plants in dense urban areas, can help solve these difficult problems while also making energy more accessible, creating jobs, and reducing carbon footprint. In its stride, the country has faced several challenges and one of them is lack of with the right skills to install and maintain solar energy systems resulting in an imbalance between supply and demand, which can also be linked to the fast growth of solar installations.

According to a report by the Council on Energy, Environment, and Water (CEEW) and the National Research Development Corporation (NRDC), India would need about 210,800 skilled solar plant designers and site engineers and about 624,600 semi-

skilled or low-skilled technicians to carry out solar EPC projects. On top of that, about 81,000 highly skilled people would be needed to monitor the performance of 100 GW of solar projects and analyse the data. Also, about 182,400 people would be needed by 2022 to do low-skilled operation and maintenance work. This is mostly because solar rooftop and utility scale projects are growing quickly. Realizing the importance of availability of skilled manpower for the uninterrupted growth of the sector the following initiatives were taken up.

Way back in 1999-2000, the MNRE made a coordinated effort to train people in project planning, system design, product development, operation, maintenance, and repair of deployed renewable systems by putting in place a scheme for training and study tours in renewable energy, which allowed for short training programmes of one to two weeks to be held both inside and outside the country and a

National Renewable Energy Fellowship Scheme was also set up. Model curricula for Industrial Training Institutes (ITIs), diploma, and degree courses that cover renewable energy were proposed to be developed to meet the needs of technical institutions' curriculums and the State Technical Education Boards and All India Council of Technical Education (AICTE) was involved in the process.

While the scheme had been meeting the short-term need for people, there was a systematic and long-term need for HRD in the country in light of the government's National Action Plan on Climate Change (NAPCC) and NSM. Accordingly the HRD Scheme was amended and provisions for fellowship to 400 students/researchers and fellowships at Post graduate and Doctoral and Post-Doctoral levels were created. Doctoral and Post-Doctoral was open to all Universities, Technical Institutions, and National Laboratories with facilities for research in identified thrust areas of the MNRE's R&D Program, M.Tech. and Integrated M.Sc. was implemented in educational institutions with M.Tech./Integrated M.Sc. courses in energy studies/renewable energy with specialisation in any branch of renewable energy. The selections were based on open call and upto 20 of these kinds of institutions, each with 15 seats were chosen. For the rest of the fellowships, the winners will be chosen by putting out an open call and having a committee of experts look over the applications. A grant was also created to the Labor's Advanced Training Institutes to help them improve their facilities for training trainers in renewable energy. MNRE created a panel of educational institutes and other organisations to run short-term training courses regularly.

The Green Jobs Skill Council:

The Skill Council for Green Jobs was set as a not-for-profit, autonomous, industry-led society up by the Government of India and is promoted MNRE alongwith the Confederation of Indian Industry (CII) in 2015 with a mission to identify skilling needs of service users as well as manufacturers/ service providers, within Green Businesses sector, and implement nation-wide, industry led, collaborative skills development & entrepreneur development initiatives that will enable meet India's potential for "Green Businesses". Solar being one of the primary sector in the greening economy is of the focus sector

for skilling taken up by the council. Recently the council is engaged in World Bank Grid connected Rooftop SPV Technical Assistance Programme in which Under the program, so far than 1542 trainees across the country including discom engineers, SBI bankers and entrepreneurs have been trained through 49 trainings, since the inception of program in May 2018. It also imparts Solar Energy Training program for ISA member countries to mitigate the gap with respect to policy, regulatory, legal, financial and technical aspects in International Solar Alliance (ISA) Member Countries for Bankers, Solar Entrepreneurs and others. As part of this activity, SCGJ has provided structured training 998 to bankers, Solar Entrepreneurs and others from 42 ISA member countries on solar proposal evaluation, solar roof top systems and solar mini grids (Skill Council for Green Jobs, 2022). United Nations Development Programme (UNDP) has recently awarded SCGJ a project on 'Development of 4 nos. of qualification packs and Skilling 1000 persons on Green Electric Vehicle Charging Infrastructure and Solar Cold Storage'.

Suryamitra Programme:

This programme was developed with the intention of producing a nationally competent technical workforce. Protection, planning, building, pre- and post-commissioning, service, and maintenance of solar energy-based projects have been qualified at every level.

In 2015, the Ministry started the Suryamitra Skill Development Programme to train people to work in the solar energy field. This was done because there was a big need for trained people to install, operate, and maintain the SPV system as part of the National Solar Mission. The National Institute of Solar Energy (NISE) was given the job of coordinating the trainings. The goal is to train 50,000 Suryamitras by 2020. The programme sticks to the rules set by the Ministry of Skill Development and Entrepreneurship. This programme trains young people over the age of 18 to be solar PV technicians who can install, run, and maintain solar power projects. Up until June 2022, 51331 candidates received skill-development training through the Suryamitra programme. Of those, 26967 got jobs. Suryamitra programme had a high level of impact on things like scale/spread of operation, filling skill gaps, trainees' readiness for work, and percentage

of employability. Also, the Impact Assessment Report for the Suryamitra training programme, which was made by the Skill Council of Green Jobs in December 2020, said that more than 90% of the trainees said their technical knowledge and performance in the sector had improved, and 88% of the trainees said they had more job opportunities (MNRE, PIB, 2022). Course for rooftop grid engineers: This training was provided by the National Institute of Solar Energy (NISE), New Delhi, at several state technological universities across the nation. The objective of this course is to educate students with an understanding of the fundamental ideas behind Grid-connected rooftop

solar power plants and their efficient functioning at all stages of plant design, installation, pre- and post-commissioning, run and operate a rooftop solar photovoltaic system, including understanding the various certifications and national and state legislation governing rooftop SPV plants, conduct project management for the installation of a solar photovoltaic roofing system, and comprehend the formalities required by the authority for applications, applications, applications, licences, interconnections, assessments, certifications, commissioning, etc., in order to promote SPV power plants.

Figure 4 Cumulative Jobs Created for 35.6 GW of Installed Utility-Scale Solar Capacity until 2021 Source: India's Expanding Clean Energy Workforce. Council on Energy, Environment and Water, 2022

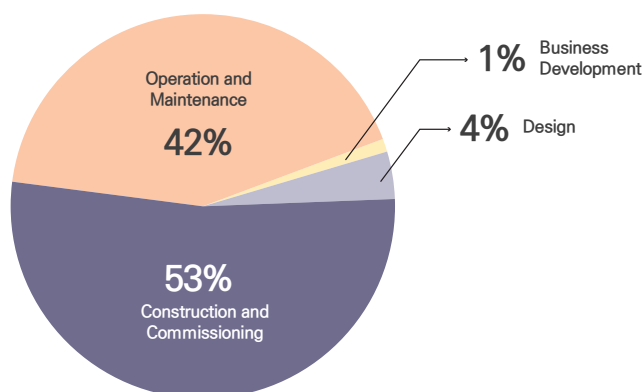
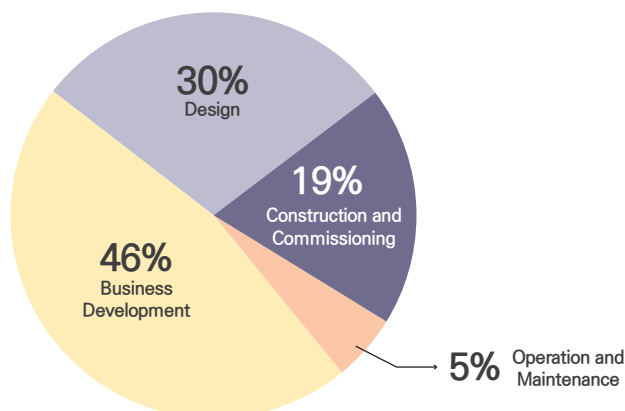


Figure 5 Cumulative Jobs Created for 6.5 GW of Installed Rooftop Solar Capacity until FY21



Source: India's Expanding Clean Energy Workforce. Council on Energy, Environment and Water, 2022

Fig 4 & 5 gives an idea of the jobs created in solar sector as a result of the HRD activities undertaken at various levels. Most of the jobs created in Utility-Scale Solar Capacity are for Construction and Commissioning and Operation and Maintenance whereas for Rooftop Solar Capacity business development and design have been providing maximum jobs.

3.6 R&D in Solar Energy

A typical and straightforward way of assessing the government support for innovation is to look at its contribution towards financing R&D activities broken down between direct and indirect mechanisms. Research, design, development and technology demonstration for its validation has been at its core in NSM. MNRE supports Research, Development and Demonstration (RD&D) to develop the technologies, processes, materials, components, sub-systems, products & services, standards and resource assessment so as to indigenously manufacture solar energy systems and devices with the objective to lower the cost of solar energy systems/devices, improve the efficiency, performance and reliability of systems/devices, strengthen domestic manufacturing base and to make the industry globally competitive and solar energy generation supply, self-sustainable/profitable and thereby contribute to increase share in total energy mix in the country. A comprehensive policy framework on RD&D is in place to support RD&D in new and renewable energy sector, including associating and supporting RD&D earned out by industry for market development. The policy framework provides guidelines for project identification, formulation, monitoring, appraisal, approval and financial support. The RD&D projects received from R&D/academic institutions, industries, etc. are assessed through experts and the one recommended by the committees are sanctioned to prospective implementing agencies. For all such projects granted a monitoring and appraisal for their achievements mechanism is in place.

Public sector organizations are entitled to 100% financial support of the total project cost and for private sector which includes Start-ups, entrepreneurs, Manufacturing units it is restricted up to 50% of the project cost.

Policy support is the major actor in this ecosystem, and it is responsible for the development of numerous renewable incentive programmes that have boosted the viability of increasing deployment and development of solar energy technology in the country. Table 5 elucidates the technology gaps identified under NSM and need for research in the relevant areas. The National Institute of Solar Energy (NISE) and the Solar Energy Corporation of India (SECI) are the most prominent R&D institutions in line with the goals of the National Solar Mission. They are members of the Solar Energy Research Advisory Council, which looks after the existing research infrastructure and develops a framework that fosters an atmosphere conducive to increasing R&D operations in the country. To help educational and research institutions set up infrastructure like labs and other teaching tools MNRE had devised a mechanism to fund educational institutions one-time financial aid of Rupees Fifty Lakhs to enhance their existing laboratory facilities; every year this grant goes to no more than five institutions.

Presently MNRE is undertaking the R&D activities in a major way as reflected in Fig 6. MNRE has also taken up the task of development and updation of standards for quality control of solar energy systems and its components. In 2020, a Renewable Energy Standardization Cell (RESC) was set up by MNRE to identify the areas where standards need to be developed, updated and adopted keeping international standards such as ISO and IEC in mind, for applications in Indian climatic conditions. Recent initiatives include revising the Standard on Battery Storage, developing Standard on SPV Grid-Tie Inverter and Quality Control Order on Solar Thermal Collectors. R&D in solar energy is also been undertaken by the various Indian Institute of Technology, Universities, Public research Institutes like the various laboratories of the Council of Scientific and Industrial Research and others. Fig 7 shows the trend of publications in solar energy research globally vis-à-vis India in which the trend is increasing after the NSM was launched. Fig 8 further adds-up that India has ranked third in terms of publication and has bagged over 10% of the publication share globally. An analysis of collaboration in solar energy research over the last 10 years revealed United States followed by South Korea, United Kingdom, Saudi Arabia as top

collaborators. It is interesting to note that amongst many other prominent countries Indian researchers are working in collaboration with countries such as

Taiwan, Egypt, Greece and Malaysia acknowledging their complementary strengths in solar energy research (Fig 9).

Table 5 Technology Gaps and Target Research Areas for Solar Energy under NSM

Area	Agency	Brief
Solar Photovoltaic	Import dependence for wafers, cells and modules. Mass manufacturing of cells and modules. Availability of alternative options in emerging technologies.	i. Indigenous PV cell technology with globally competitive prices and performance; ii. Cutting edge manufacturing techniques for indigenous manufacture; and iii. Next generation PV technologies including Perovskites, Thin films, Multi-Junction Solar Cells, Dye induction photovoltaics, organic/inorganic composites etc. iv. Development of cost competitive packages for applications beyond grid electricity, including cooking, lighting, water pumping, irrigation etc.
Solar Thermal Applications	Import dependence for solar field components. Conversion efficiencies derive	i. Improving conversion efficiencies and reducing costs through improved designs, new materials, manufacturing processes, deployment of higher conversion temperatures, alternative heat transfer fluids etc. ii. Thermal storage systems integrated with power, heating or cooling applications iii. Indigenizing Reflector materials with good outdoor durability, high solar reflectivity, and good mechanical resistance.

Source: Compiled by Authors from MNRE website

Figure 6 R&D Projects of MNRE undertaken in 2020–21

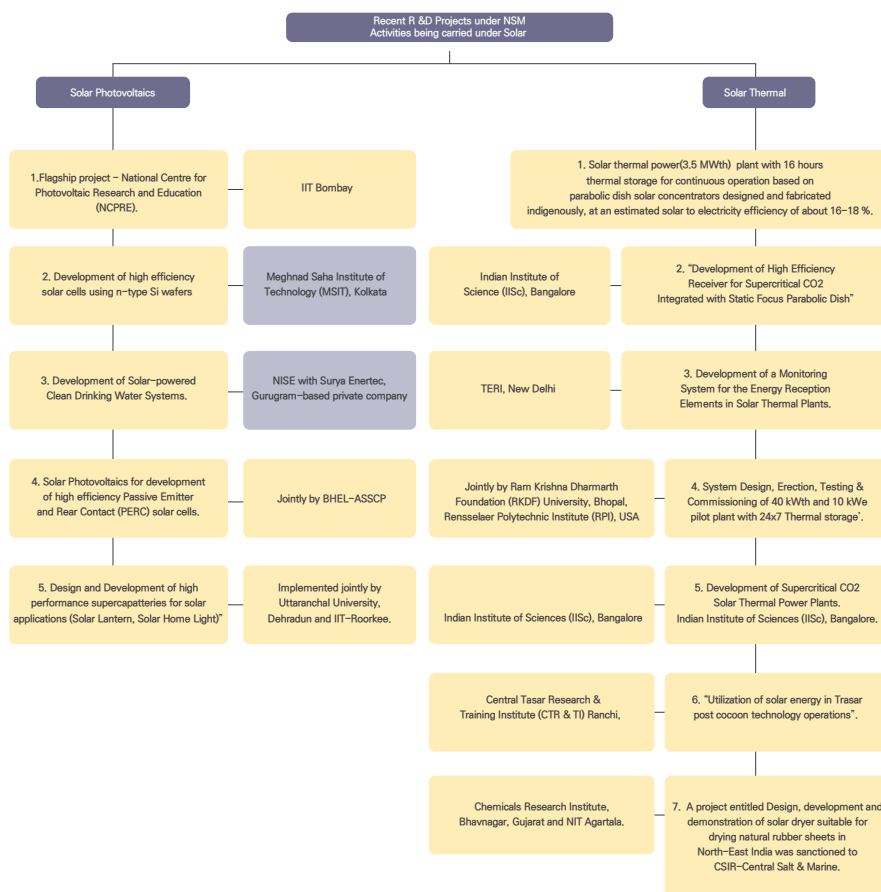


Figure 7 R&D output in solar energy research (Source: Analysed by authors from SCOPUS)

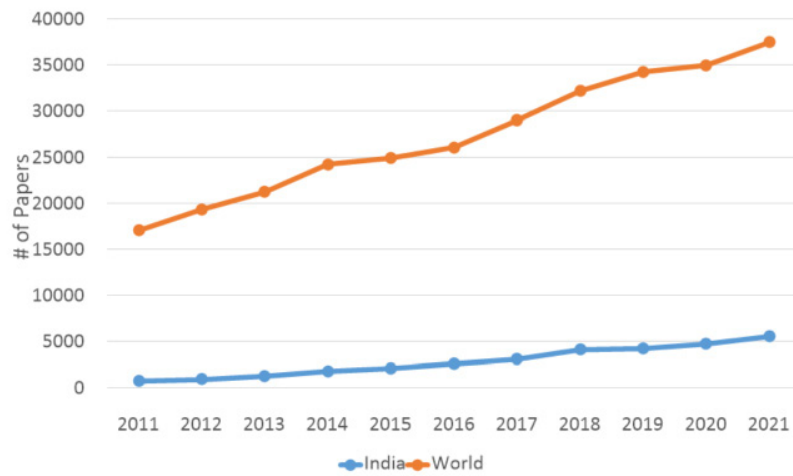


Figure 8 Global R&D Trend in Solar Energy (Source: Analysed by authors from SCOPUS)

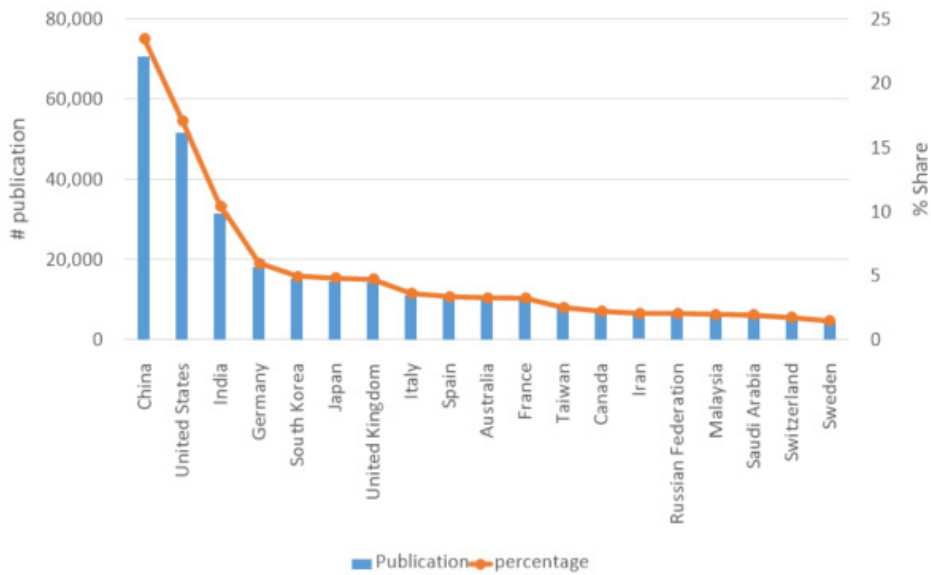
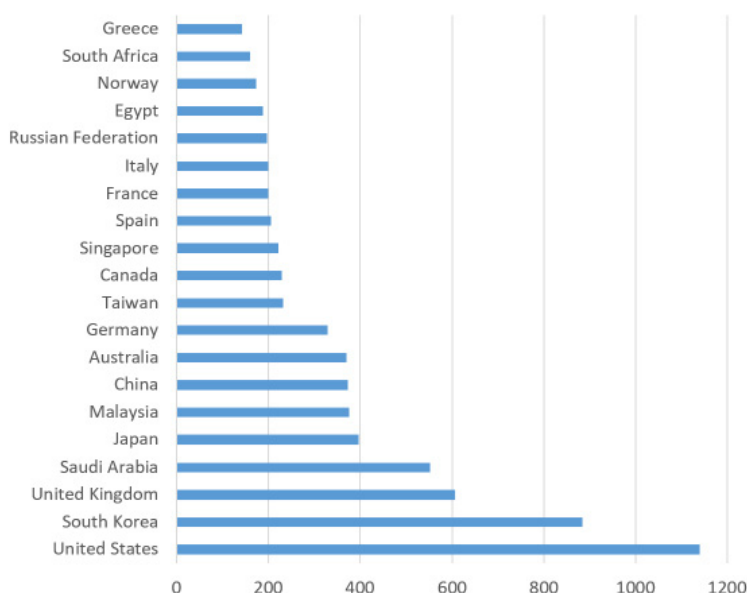


Figure 9 Top-20 collaborating country in Solar Energy Research in India (Source: Analysed by authors from SCOPUS)



Discussion & Conclusion

In mission-oriented approach, innovation policy's intention to improve the national, sectoral, or technological innovation system should be well defined and for a mission-oriented policy to be effective, the capabilities must be in alignment. In MOIP by identifying the technology challenge at a more specific level, setting of intermediate goals, deliverables, and procedures for accountability and monitoring is made simpler. (Mazzucato and Penna, 2016a). As R&D and innovation involves a lot of risks and uncertainties, MIOP advocate for a portfolio of R&D and innovation projects, instead of just one. In the process, all related stakeholders are in one place to acknowledge failures and learn from them. MIOP calls for investment from a diverse actors as it is found that for missions to be most effective, participation should be encouraged from every economic sectors; involving both public and private sectors.

In the case of NSM in India we have found in the above sections the government has taken several steps to give a momentum to the mission and the evolution pathway it has taken from time to time by introducing new institutions, amending schemes and program, providing a variety of fiscal benefits, such as tax breaks for the development of mega-manufacturing plants for solar panels, lithium storage

batteries, electric vehicles, and charging stations, proposing positive policies to encourage international investment in renewable energy by allowing FDI in the sector etc as missions demand cooperative policymaking, where the priorities are translated into concrete instruments of policy and activities to be carried out by all levels of the public institutions involved. MOIP necessitates that goals should involve a range of public organisations, and it is crucial that there be a distinct division of labour among them, with roles for coordination and monitoring clearly defined. Accordingly we find a wide range of actors around the NSM as reflected in the governance structure which has evolved over time in which MNRE also plays a fundamental role from planning to execution, in promoting solar energy by raising public awareness and launching initiatives to improve use of solar energy in the fields of lighting, cooking, heating, drying, irrigation, and motivating energy in rural, urban, industrial, and commercial applications. Legislation has been enacted to encourage consumers to become energy producers who are ambassadors promoting use of solar energy and in the process have become environmental savers rather than destroyers. Understanding the need for skilled manpower for the development of the sector as well as the employment opportunities it can create, the government had also focuses on improving people's technical skills and

knowledge in order to raise their standard of living, protect the environment, and contribute to the nation's economic development. The government has launched numerous skill development programmes, such as the Suryamitra programme and the Rooftop grid engineer course, in order to create a qualified technical workforce across the country. Many regulations, such as tax exemptions, allowances, attractive tariff grants, knowledge awareness, renewable energy standards, economic incentives, technological research and development, and so on, provide significant encouragement and interest in developing and using clean energy. A significant reduction in tariff costs of solar power has been made possible by competitive bidding efforts undertaken through tenders, as well as various public awareness campaigns and events organised by government authorities to promote solar energy. Like complementary policies which are considered of great importance for success and focus on to coherence with other goals

Although the NSM in India have demonstrated remarkable progress due to its approach in mission mode, yet it is far from reaching its 100 GW target. At this juncture, we may draw lessons from MOIP which mentions that mission-oriented public investments are not about de-risking and levelling the playing field, but tilting the playing field in the direction of the desired goals for which strategic decisions on the kind of cross-cutting technological changes play an important role as it affects opportunity creation across sectors (e.g. internet, battery storage); anticipating the type of finance that is required, identifying the innovative firms that will need added support, the types of collaborations with other actors to follow, and the types of regulations and taxes that can reward behaviour that is desired (e.g. rewarding long-term investments and reinvestment of profits rather than hoarding) (Mazzucato, 2017) add up cumulatively to the success. Systemic MOIP is based on a sound and clear diagnosis and prognosis (foresight) which not only identifies the missing links, failures and bottlenecks – the weaknesses or challenges of a national system of innovation – but also recognizes the system's strengths. Foresight is necessary in order to scrutinise future opportunities and identify how strengths may be used to overcome weaknesses. This diagnosis should be used to devise concrete strategies, novel institutions and new linkages in the innovation system. In the

case of NSM in India, some components of the MOIP were missing like nurturing of the innovative firms, strong collaborations, undertaking foresight exercises on regular basis and so on. Different types of capacity building are central to MOIP. These include Scientific-technological capacity, Demand capacity, Productive capacity, State capacity, Policy capacity, Foresight capacity. Successful mission-oriented policy experiments require all six factors in place. However, most of such capacities of MOIP is well evident in NSM as reflected in previous sections. However to pace up the growth rate, the roadmap for linking solar energy goals to current missions on 'Make in India,' 'Smart City Project,' 'Startup Mission' and 'Virtual India' is recommended as a pledge for the country's entire energy system's growth and transformation.

NSM was well defined in terms of economically feasible technical solutions to particular societal problems and the direction of technical change was influenced by a wide range of actors including government, private firms and consumer groups. To increase the production of electricity in the state using solar energy, state governments have enacted numerous supportive policies /complementary policies which are considered of great importance for success and focus on to coherence with other goals and developed solar PV projects. There are numerous unused rooftop spaces in government, institutional, industrial, commercial, and residential buildings that are being used to install grid-connected rooftop solar PV projects, assisting the country in meeting its goal. Solar energy generation is a green alternative that contributes to significant reductions in carbon dioxide emissions while consuming no fuel during operation. Presently Government is focusing on improving the grid so that renewable can be deployed more smoothly and efficiently. The vulnerability of investors can be reduced by improving transmission infrastructure, relaxing land acquisition requirements, ensuring no contract flip-flops, and reconsidering aggressive tariff limits at reverse auctions. Discoms in India will meet their renewable procurement commitments (RPO-promises to purchase a certain amount of their electricity needs from renewable energy producers) and pay investors on time. Laying solid groundwork through net metering strategies and updating the DISCOMS incentive programme for reducing electricity bills by selling at a lower cost in

proportion to the higher wattage produced by solar panels, maximising homeowners' contribution to energy savings has started but needs to be taken at a greater pace. Future priorities should include the implementation of grid-ready off-grid networks for rural and remote areas, as well as the establishment of grid-connected by-laws for new grid buildings that are 'Rooftop ready.'

As evident in MOIP, NSM may require consensus building in civil society, combining the need to set directions from above with processes of bottom-up experimentation from below. Missions around sustainability and green growth also need many different sectors to rethink themselves, and to work together in dynamic and interconnected ways; such an approach is missing in NSM at present and therefore there is need to rethink and reorient the mission based on MOIP.

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