University of Applied Sciences and Arts
of Southern Switzerland
SUPSI

CSIR-NIIST

Indian BIPV Report 2022: Status and Roadmap

Status Report
2022

Report by

SUPSI-Swiss BIPV Competence Centre
Paolo Corti, Pierluigi Bonomo

CSIR-National Institute for Interdisciplinary Science and Technology
Animesh M Ramachandran, Adersh Asok

The here involved Institute for Applied Sustainability to the Built Environment (ISAAC) is part of the University of Applied Sciences of Southern Switzerland (SUPSI). The institute, under ISO 9001 accreditation, covers several research areas in the field of renewable energy, rational use of building energy with particular attention to green building standards, building maintenance and refurbishment, as well as technological development.
The building sector is active in the field of research concerning building operation, advanced solar building skin, sustainable materials and constructions. The Research unit, with almost 20 years of experience in BIPV, is one of the leader groups active in federal, European and international projects of applied research, including R&D, services at industries, communication and sensitization. The team is active in global experts groups of International Energy Agency, in scientific expert committees for international conferences and journals, in standardization bodies and in the main networks supporting BIPV. The Institute also has a PVlab covering a wide range of electrical, climatic and mechanical tests according to IEC– standards and accredited ISO 17025.
The main research activities of ISAAC and specifically of the BIPV group are focused on:

- Applied R&D for developing, testing, validating, demonstrating and industrializing innovative construction solutions for multifunctional building envelope systems, conceived designed and engineered on the basis of an integrated approach;
- Developing, in collaboration with partners (architects, industries, real estate managers, etc.), innovative pilot buildings integrating PV with the role of building skin components;
- Methodologies and techniques that favor the exploitation of solar energy in the built environment, both for new and existing building stock, by analysing the techno-economic feasibility, the market needs and innovation trends;
- Development of a digitized and integrated process within the BIM-based approach involved simulation and analysis of BIPV systems

CSIR-National Institute for Interdisciplinary Science and Technology (NIIST), is a constituent Laboratory of the Council of Scientific and Industrial Research (CSIR), New Delhi, India. CSIR, established in 1942, is an autonomous society whose Presidential position is carried by the Prime Minister of India. It holds one of the largest R&D conglomerates in the world with a dynamic pan-India network of 37 national laboratories, 39 outreach centres, 3 Innovation Complexes and 5 units located across India. CSIR, known for its cutting edge R&D knowledge-base in diverse S&T areas, is a contemporary R&D organization and categorized amongst the foremost scientific and industrial organizations in the world. CSIR is ranked at 84th among 4,851 institutions worldwide and is the only Indian organization among the top 100 global institutions, according to the Scimago Institutions Ranking World Report 2014 (CSIR holds the 17th rank in Asia and leads the country at the first position).
CSIR-NIIST, one of the prime laboratory of the CSIR conglomerate is located at Thiruvananthapuram, Kerala, the south most part of India. CSIR-NIIST is mandated to conduct interdisciplinary research and development activities of the highest quality in areas related to the effective utilisation of resources of the region and of fundamental importance to the country. Apart from fundamental research of interdisciplinary nature, technology-based interventions have been greatly carried out in the last decade, especially in the field of solar energy. Innovative technological approaches like planar light concentrators, building integrated agrivoltaics, dynamic power windows, organic and inorganic hybrid solar cells, etc., can be mentioned as a few in the BIPV headway. The institute has already established and functionalised state-of-the-art facilities for conducting advanced research in the area of interest.

University of Applied Sciences and Arts
of Southern Switzerland
SUPSI

Council of Scientific & Industrial Research –
National Institute for Interdisciplinary Science and Technology
(CSIR–NIIST)

ARKA Experience centre

Offering advanced solar roofing solutions to Indian consumers

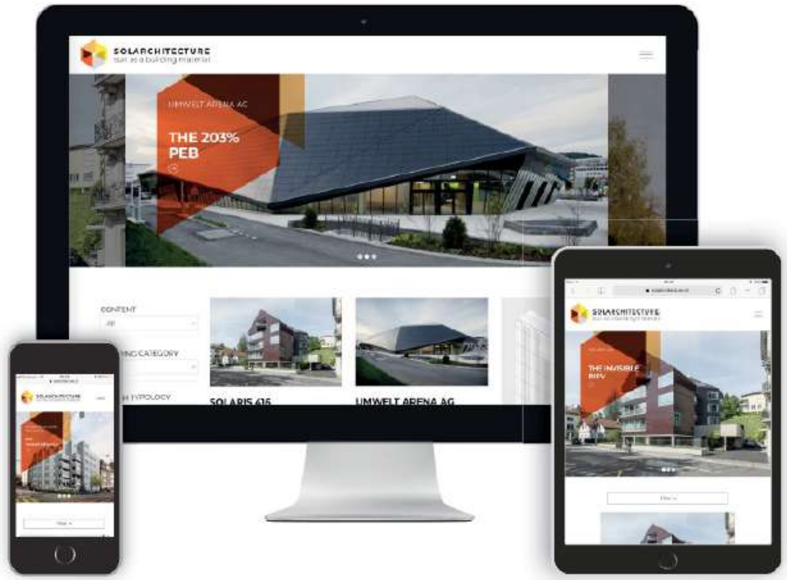
Completion year	2022
Planning & Installation	SunEdison, ARKA Energy
Building typology	Open House
Category	New building
Installed PV power	4.4 kWp
Energy production	6,970 kWh/yr

+91 1800 102 0765
sunedison.in/arka-collection
sales@sunedison.in

Renewable energy pioneer SunEdison launched a new type of residential solar solution in collaboration with ARKA Energy, a Silicon Valley based startup. The 'ARKA Collection' by SunEdison is designed for durability, performance & aesthetics. The PowerGazebo is an architectural solar installation that can help one expand their living space and the PowerRoof provides a way to create a roof that can power your home. SunEdison believes that the Arka Collection is the finest BIPV solution which is designed and manufactured in India for Indian customers.
The first activity that the teams undertook was the ideation phase, in which SunEdison reached out to architects specializing in green buildings for design ideas.
Since the ARKA Collection is an experiential product line which has not been seen before in India, setting up an experience center was one of the first projects that SunEdison wanted to accomplish. The project called for an open-house architecture design followed by a fibrocement cladding with a provision for a sky roof. The experience center is placed in the center of a busy residential neighborhood surrounded by independent housing. The center is equipped with the latest installation of their SunEdison ARKA collection's flagship products – the PowerRoof & the PowerGazebo.
Three PowerGazebos are also constructed in the available open-floor area which can be used as breakout zones inside the hub. The space doubles up as a corporate meeting space and an experience center setup.
The glass-on-glass PV tiles offer an elegant monochromatic black finish. Non-PV tiles which look like PV tiles can be used in areas with persistent shadow and nooks of any slopped roof structure; they are also available in smaller sizes to cover the complete roof.
A false ceiling is added as the final layer in the PowerGazebo. This can be fitted with lights and plug points to make it a pleasing usable space.
The cascading roof design is tested for hail and cyclonic weather. The tiles are tested as per the most stringent BIS, IEC and UL standards. Additional testing shows that the tiles are up to six times more resilient than the sturdiest clay tiles available.
SunEdison uses its expertise in the retail solar industry for harvesting solar power in a safe and efficient manner. Robust processes govern the installation of power electronics, cabling and other protective equipment. The mounting structure is tested for wind load calculation of upto 170km/hr from a 3rd party reviewer.
A dedicated app allows the performance data from the system to be viewed at 15 minute intervals.

Preface

In agreement with the IPCC special report, emissions must drop dramatically if we stand a chance of keeping global warming below 1,5°C [1]. Curtailing our dependency on fossil fuels and faster adoption of renewable energy sources to meet our energy demands are necessary to limit global warming below 1,5°C, avoiding environmental degradation. Currently, India is the third-largest energy consumer after China and the United States, and 80% of it is met by coal, oil, and biomass [2]. In this context, the Government of India's (GoI's) ambitious "Mission 500 GW", recent COP26 climate goals and favourable policies are expected to propel the green energy revolution in the Country. With the trend of rapidly rising per capita energy consumption, renewable energy growth, electrification in sectors like automobiles, and the urge of urbanisation and industrialisation, the electricity demand will be set to have a rapid rise in the coming years. Hence, the Country's energy requirement is expected to grow more than 2,5 times from 2019 to 2040, and it will be equivalent to an addition of the European Union's current electricity generation [2]. In this framework, the operation of buildings consumes a significant portion of electrical energy generated. As per projections among all regions of the world, India's fastest growth in buildings energy consumption will occur with an expected average increase of 2,85% per year between 2020 and 2050, which is more than twice the global average [3].
Renewable energy integration in the building is critical for the intended energy transition. Its importance has been recognised globally, supported by the 21% global increase of renewable energy sources from buildings from 2010 to 2018 [4]. This shows a positive development in the energy transition, but there is still a long way to achieve the 2050 net-zero emission target [5].
Among various renewable energy sources, solar energy is the fastest growing renewable energy resource globally, especially in Indian and EU settings, with the potential for promoting inclusive economic growth without contributing to the carbon footprint. To meet the Country's targeted Intended Nationally Determined Contribution (INDC), the GoI advocated an ambitious plan targeting the installation of 175 GW of renewable energy capacity by 2022, majorly promoted through grid-connected solar photovoltaics (PV) [6]. The fact that around 21% of electricity is lost in transmission and distribution in India (in the year 2019-20) [7], which is more than twice the average across the world, highlights the importance of more Decentralised Distributed Generation (DDG), as recommended in National Energy Policy by National Institution for Transforming India (NITI) Aayog, GoI [8]. In this context, the integration of PV in building construction as Building Applied Photovoltaic (BAPV) and Building Integrated Photovoltaic (BIPV) has a vast potential for onsite green power generation, with the reduced transmission losses, zero space wastage and improved overall building performance. Today, existing BIPV products offer architects, building owners, façade makers and real estate developers a diversified range of products that can be manufactured and customised like any conventional building envelope solution. Even though the importance of BIPV is extensively recognised in the rest of the world, the perception of some barriers and constraints, such as energy production, costs, technical feasibility, and lack of specific standards still exists, which hamper its diffusion in India. Some typical limitations in existing urban areas are seen as no go rather than boundary conditions, which can be optimised and presented with application advantages through design and technical solutions.
In this purview, the "Indian BIPV Report 2022: Status and Roadmap" aims to provide an overview of the Indian solar market by retracing historical milestones and the Country's evolutionary process, including policies, regulations, technological improvements and case studies. The report provides insights to the stakeholders of the solar value chain by focusing on the integration of photovoltaic systems into the built environment. An overview of standard building technology systems and their solar potential is presented and discussed to support investors, manufacturers, architects, and the construction value chain stakeholders in making the timeliest decisions. Further, to construct future milestones in the Indian BIPV sector, an overview of the current scenario and deliberations on expected stakeholder efforts are also discussed to generate a critical roadmap. The crucial business model questions, barriers and boundary conditions are illustrated with actual data from some case studies realised in recent years in India. Today, in the EU, BIPV has achieved a high level of technical maturity, and the market perspective looks promising [9]. The report is structured around four chapters to provide an in-depth overview of the status of solar PV installations in Indian buildings, the possible implementations and BIPV roadmap contemplation. Five BIPV case studies realised in India are presented at the end of the report, including an architectonic and energetic analysis of the showcase.



www.solarchitecture.ch

In the age of sustainability, most architects still see the issue of energy in buildings primarily as a constraint to work on. Particularly in the case of solar energy many of the new technological possibilities and integration potentials are not known and therefore not applied in the current design practice due to perceived barriers. Nowadays, new technological possibilities and inspiring projects of solar architecture have been demonstrated and need to be promoted in order to captivate architects, showing the architectural quality of "solar" and the huge potentials of a multidisciplinary approach bridging energy, design and construction. To appeal to architects, it is important to communicate in their language, in an innovative way and using a more complex approach where energy, architecture and construction are part in a unique design concept.

The main goal of www.solarchitecture.ch is to promote the construction of solar buildings by shifting the attention from technology to architecture. Real examples and stories of best practice prove today the feasibility and the quality of solar buildings in terms of aesthetics, construction technology and sustainability.
Solachitecture.ch, as a multidisciplinary and inclusive Swiss platform on solar energy, is managed and defined thanks to the collaboration between four main partners:

- SUPSI – ISAAC
- ETH Zurich
- Swissolar
- SwissEnergy

Table of content

Nomenclature

BAPV: Building Applied Photovoltaic
BEEP: Building Energy Efficiency Project
BIPV: Building Integrated Photovoltaic
BIS: Bureau of Indian Standards
CAGR: Compound Annual Growth Rate
CASE: Commission for Additional Sources of Electricity
CEA: Central Electricity Authority of India
CEL: Central Electronics Limited
CFA: Central Financial Assistance
CPSU: Central Public Sector Undertaking
DDG: Decentralized Distributed Generation
DISCOM: Distribution Company
DNES: Department of Non-Conventional Energy Sources
FiT: Feed-in-Tariff
FYP: Five Years Plan
GDP: Gross Domestic Product
GHI: Global Horizontal Irradiance
GoI: Government of India
GRIHA: Green Rating for Integrated Habitat Assessment
IGBC: Indian Green Building Council
IREDA: Indian Renewable Energy Development Agency
JNNSM: Jawaharlal Nehru National Solar Mission
LCOE: Levelized Cost Of Electricity
MNRE: Ministry of New and Renewable Energy
NASPAD: National Solar Photovoltaic Energy Demonstration Program
NISE: National Institute of Solar Energy
NZEB: Net Zero Energy Building
PPA: Power Purchase Agreement
PV: Photovoltaic
RAV: Rooftop Agrivoltaic
RESCO: Renewable Energy Service Company
RTS: Rooftop Solar
SECI: Solar Energy Corporation of India
SNA: State Nodal Agency
STIP: Science, Technology and Innovation Policy
TRL: Technology Readiness Level
UT: Union Territory

Chapter 1
Photovoltaic sector and its potential in India

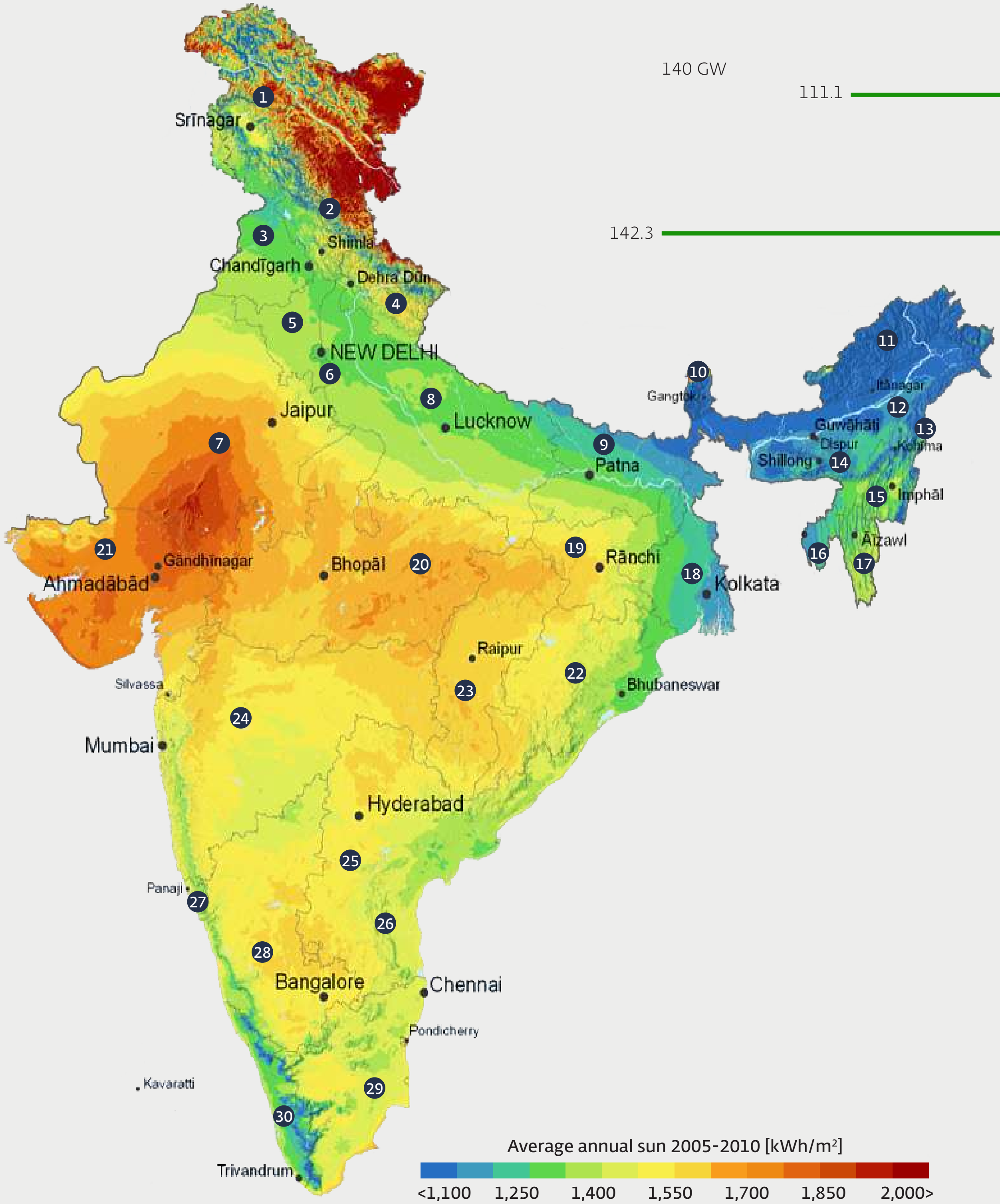
1.1 PV sector: potential, market and growth

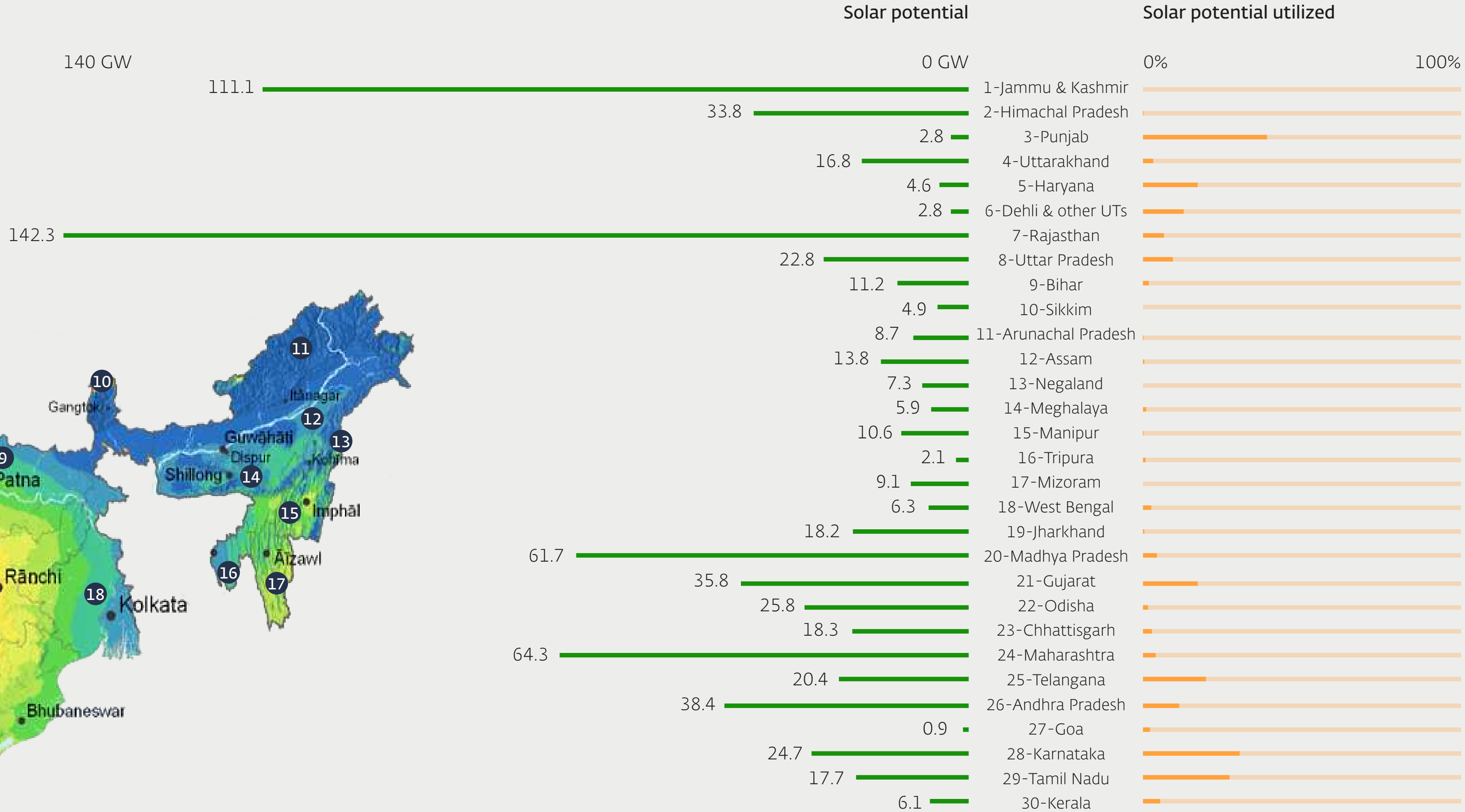
According to the 2016 Paris Climate Accords, countries have established their Intended Nationally Determined Contribution (INDC) by setting their targets and policies for gas emissions. In line with this, India has set an ambitious target to reduce the emissions intensity of Gross Domestic Product (GDP) by 33-35% by 2030 from 2005, by committing a 40% non-fossil-based electricity production by 2030 [1]. Renewable energy targets of 175 GW (with 100 GW from PV and among that 40 GW of grid-connected solar rooftop) by 2022 and 450 GW (with 300 GW from PV) by 2030 was announced to address the cause [2] [3] [4]. Further, in the recently concluded COP26 Glasgow meeting, the Government of India (GoI) announced its timeline to achieve net-zero carbon emissions by 2070. In addition to this, GoI increased its renewable energy target from 450 GW to 500 GW by 2030 to achieve half of its energy from renewables, a reduction of emissions by one billion tonnes and emissions intensity of the GDP by 45% in the same year [2]. Solar energy, being an abundant resource of the country, will play a significant hand in coping with the situation; the rising trend in solar photovoltaics (PV) capacity compared with other renewable energy sources in recent years accords the same [5].

The National Institute of Solar Energy (NISE), under the Ministry of New and Renewable Energy (MNRE) has assessed the solar photovoltaic potential of the country as about 748 GW [6]. India has been ranked 104th in the Global Horizontal Irradiance (GHI) and 98th in the average practical PV potential (Photovoltaic long-term power output produced by a utility-scale installation with fixed-mounted, monofacial c-Si modules with optimum tilt; measured in kWh/kWp/day.) [7]. However, the country has been ranked third in the Renewable Energy Country Attractive Index (RECAI: it ranks the world's top 40 markets on the attractiveness of their renewable energy investment and deployment opportunities) and first in Solar PV according to EY May 2021 Report [8]. Yet the country's solar power generation constitutes less than 4% of total value in contrast to 75% contribution from coal and gas, during the fiscal year 2019-20 [5]. Even though there are conspicuous changes in the PV development and its associated cost reduction in the past decade, yet their deployment is hindered by the limiting spatial availability and disadvantaged locations for grid-connected or Decentralised Distributed Generation (DDG).

India has tremendous potential to harness solar radiation while considering its geographical advantage favouring more solar energy tapping. The country's solar potential is estimated to be 5 quadrillion kWh per year, with an average GHI of 5.1 kWh/m2 per day [7] and an average of 2,300-3,200 sun hours [9]. The PV seasonality index (Ratio between the highest and the lowest of monthly long-term PV output averages) is 1.75 across India, advocating PV output reliability in Indian conditions [4].

The **Fig. 1.1** shows the annual solar irradiance distribution across the country. The irradiation distribution is higher and even for North-West, Central and most Southern states, covering the majority land area in India. As mentioned, the solar potential of India is about 748 GW, as estimated by MNRE, assuming only 3% of the wasteland area to be covered by solar PV modules [4] [10]. India's current solar power installed capacity (including ground mounted, rooftop and other off-grid installation) is around 49.3 GW till December 2021, which is 47% of renewable energy capacity, and contributing to 46% of India's total renewable energy generation in 2021 (exclusive of large hydroelectric power plants) [10]. The trend of installed PV capacity addition in India for the last decade, according to the MNRE data for the period of 2010-2021, is as shown in **Fig. 1.3** [10] [11]. For the last decade, a cumulative capacity of 40.1 GW was installed in India, and in 2021, India had added another 9.2 GW (from April 2021 to December 2021) marking the highest yearly addition till date, and reaching a total installed capacity of 49.3 GW. The Indian PV sector is experiencing a positive growth trend, with a more stepper growth during the last 5 years, which persuaded the GoI to raise their target of 22 GW solar power capacity to 100 GW by 2022 (**Fig. 1.3**) [4]. This can be accounted for around 13% of the MNRE estimated solar PV potential of 748 GW. Hence, there exists a massive opportunity for the Indian PV sector to tap this potential. However, this assumption does not consider the potential of PV integration in the major possible deployment opportunities like buildings that can exploit the market in congruence with the rapid growth of the construction sector in India.





The solar potential of India is about 748 GW assuming a 3% of the wasteland area to be covered by solar PV modules. India's current solar power installed capacity (including ground mounted, rooftop and other offgrid installation) is around 49.3 GW till November 2021.

Fig. 1.1 left Indian solar irradiation map. Source: 2011 GeoModel Solar s.r.o.
Fig. 1.2 up Indian PV potential and utilised potential. Source: [11].