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Indian BIPV Report 2022: Status and Roadmap

Status Report
2022

Report by

SUPSI-Swiss BIPV Competence Centre
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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
Animesh M Ramachandran, Adersh Asok

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 38 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.

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Indian BIPV roadmap

3.1 Roadmap for BIPV implementation

Unlike standalone PV utility systems and rooftop solar systems, the penetration of the BIPV sector in the market requires direct renewable energy policies integrated with other uninitiated policies and regulations in building energy and construction sectors. Building a roadmap for the Indian BIPV sector is challenging at the current state of non-uniform and expansive market, demographic distinction, stakeholder value and hierarchy, industrial inflexibility with the present state of affairs, and severe lack of awareness within every stakeholder level. To initiate and define a collective and concrete roadmap for BIPV implementation in India, this report focuses on five main factual contemplation levels;

1. Perspective: Government policies, Initiatives and Business models
2. Opportunities: Multifunctionality and cost reduction
3. BIPV Industrial Sphere: Technology readiness, Supply chain and Certification
4. Innovation landscape: Research projects & Engagement of international communities
5. Defining stakeholder involvement: Need for stakeholder awareness, extensive project planning & execution

(1) Perspective: Government policies, Initiatives and Business models

Scenario

Indian construction sector is expected to grow with an impressive trend, with a projection of ~45 billion square metres in floor area additions by 2060; among this, more than 80% of floor area accounts for residential buildings [1]. In this purview, India has a huge opportunity to build new renewable energy infrastructure in a more decentralised manner via the integration of solar energy systems in the built environment and also with the new building designs. To support sustainable renewable energy adoption, the Government of India (GoI) has developed many policies and initiated international alliances in the energy sector; this includes the handholding with International Solar Alliance for large scale solar adoption. Further, GoI has initiated many bilateral programs for attaining energy efficiency in the built environment, such as Indo-Swiss and Indo-US Building Energy Efficiency Projects (BEEP). In the similar line, national mission mode programs such as Smart Cities Mission and National Mission on Sustainable Habitat were initiated, where share for renewables is a major focus. Recently, GoI had released its National Action Plan on Climate Change, this is in line with the United Nations Sustainable Development Goals (UN SDG) and Mission Innovation (MI) launched during COP21. The MI is a global platform to foster and promote R&D for accelerated and affordable clean energy innovation, India and the EU are certain key members for this global initiative.

How can BIPV directly influence policies & regulations?

Replacing surfaces of building roofs and façades with active claddings, BIPV is a unique way to reduce the energetic impact of buildings, transforming them to nearly-zero energy or plus energy. Indeed, the multifunctionality of BIPV installations allows to produce on-site renewable electricity and to act for the performance as building skin with added functions of a building construction system. Moreover, as previously discussed, technology can be flexibly used for customising the architectural design of contemporary buildings. However, faster adoption of BIPV into the Indian building sector requires substantial efforts at the policy level. In this regard, Governments can pull two main levers: support the cost-effectiveness of BIPV products through the implementation of subsidies (similar to rooftop PV discussed in Chapter 1) or charge for the hidden costs of pollution and CO2 emissions in buildings. Ideally, any plan to address climate change via decentralised energy generation in buildings needs both. Implementing the right policies at the right time, especially in the construction sector, will open the possibilities to tap our most promising and sustainable landscape for sustainable design and decentralised renewable generation, extracted as "The building as energy generation nodes". To make this possible in the construction sector, Government could ensure that at least some of these carbon costs are paid by whoever is obligated and reduce the green premium, especially for multifunctional products that offer renewable integration into the buildings by exploiting already built surfaces. This would, in turn, create an incentive for building product manufacturers to come up with carbon-free alternatives, for example, building construction/ materials leading to sustainable solutions such as innovative BIPV products and their faster adoption in the construction sector.

Aside from that, governments, policy advisers and policymakers need to introduce new building energy policies and energy-efficient city planning. Even though amended building bye-laws have been passed by the Ministry of Urban Development (MoUD) and the introduction of concepts of "Smart City" [2] and "Solar City" [3] has been made by the government, yet the developments focussed only on RTS installations in buildings. However, exclusive BIPV policies connecting comprehensive decentralised distributed renewable energy, building energy conservation, individual building and city infrastructural planning, BIPV analysis, extended energy policies like for electric vehicles (EVs), etc., are essential. Regulations should also support solar investment within a community or nearby locales for BIPV specific building projects leading to the creation of green energy communities.

Regulations for stakeholder harmonization in solar and construction sectors

A balanced environment between the stakeholders is essential in the coming decades of solar avalanche, especially for solar power acquirement from buildings. With the better performance of the country in solar energy sector, India may need to shift the policies and regulations to favour both building owners and Distribution Companies (DISCOMs). Even though the current scenario with the RTS programme of JNNSM Phase II favours building owners, especially of the residential sector, by CFA allowance and increased cap of net-metering limits, there is a need to accommodate DISCOMs in the future. The charges compensated/ paid under the RTS scheme, which follows net-metering, aroused a considerable revenue impact for the DISCOMs. However, shifting from net-metering to gross-metering with a passable feed-in-tariff can be foreseen as an obstruction to the extensivity of the existing building rooftop model, especially in small scale and residential sector, as it increases the system payback period. The PV scenario in Europe supports the same, as they have encountered a market declination after the introduction of feed-in-tariff. However, this represented a great opportunity for the growth of the BIPV sector with the concepts of multifunctional, aesthetic, innovative products with new technologies and cost reduction potentials from both renewable energy and building (construction and architectural point) of view. Thus, state and central regulations should be revisited and modified regularly (with the PPA) in the future to create a balanced environment.
Considering these factors, BIPV could centre on the aspect of building elemental replacement and multi-functionalities, to create an impact on the building renewable energy and construction market in the near future. Further, with the end of the current phase of JNNSM by 2022, the extensivity of building solar programmes should be ramped up from RTS to more innovative schemes for BIPV/ BAPV interventions. However, rather than focusing completely on energy regulations and government financial assistance, new business models could be evolved that caters for the financial concerns of both the building owners for large scale deployments and the DISCOMs. Utility-driven models can be adopted as one of the trade-off approaches for the concerns. Central and state governments could implement different adoptable business model-based regulations, financial relaxations and policies within communities, or locations, or states for BIPV. These location-based implementation strategies could be adopted with proper consumer evaluation, technical assessment, and feasibility studies.

Business model revision for BIPV [4] [5]

The following factors majorly hinder the implementation and expansion of existing business models for BIPV in India

1. Existing net metering billing system can lead to substantial financial concerns for DISCOMs
2. Lack of technological and financial awareness among the building owners and project developers leading to scepticism among the owners regarding the implementation and financial benefits
3. Inability of consumers to invest upfront costs for the BIPV system
4. Uneven implementation feasibility (due to factors like shading, building typology, building orientation, etc.) among a community/locale can lead to a lack of enthusiasm within building owners

Some of the proposed business models for the cause are below:

- On-billing financial model: The model is useful when the individual building owner cannot make the investment upfront. Herein, a third party or DISCOM lends the money as a loan and own the system up to the loan repayment. Monthly instalments make the loan repayment to the DISCOM along with the net electricity billing (or signing PPA with DISCOM), and consumers can receive benefits of reduced grid electricity consumption (or monetary benefits of selling electricity to the grid). After the loan repayment, ownership is transferred to the building owner. Unlike normal rooftop installation, the model is very convenient from the consumer point of view, as there is a great necessity to own the BIPV system as part of the building, but cannot afford the investment cost initially.
- Solar partner model: The model is well suited for building spaces like that of multiple villas where individuals have access to the space. The model is driven by DISCOMs, which aggregates both the supply and demand sides. DISCOM aggregates the building skin owners in its locale and identifies developers for the installation through competitive bidding. Developers conduct the feasibility studies, project installation and own the system. Rooftop/facade owners are benefited either from monthly rent for their building space or a credit on their electricity bill with metering and solar subscription. DISCOM signs PPA with the developers for the period of the system's lifetime
- Utility driven community model: Utility driven community model is one of the straightforward approaches that can enable faster implementation of BIPV in a community, where DISCOM will lead the project and aggregate the consumers. Herein, consumers who do not own a BIPV feasible building space can also access solar electricity by sharing space of a common building like high rise multi-unit buildings or from a public or privately owned building spaces elsewhere. It also allows sharing the most favourable building surfaces with higher solar potential independently by single owners and local public/ private ownerships. The consumer can access the electricity by paying the system installation cost upfront or by paying a regular subscription fee. The model will be very advantageous for tenants living in a multi-storey building, and also suits for solar electricity distribution from a public/private owned institution. The model eliminates the ambiguity for the consumers, as they don't need to be involved in the BIPV project directly or create a long term agreement with DISCOM, but need to have only a one-stop contact with the DISCOMs directly.

(2) Opportunities: Practical tips for cost reduction

Multifunctionality as key for faster BIPV penetration

The multifunctionality of BIPV products could bring some advantages if compared with conventional building envelope solutions and non-integrated PV systems together, especially in terms of better aesthetic integration, cost-effectiveness, technological performance, environmental and social impact, etc. [6]. In recent years, all these advantages have aroused a growing worldwide interest in BIPV products and dynamic market trend for the replacement of less offering conventional building materials/ construction **(Fig. 3.1)**. However, one of the main challenges and needs of the market is to improve the energy performance of the facade to produce renewable electricity or solar thermal energy. Numerous studies and projects demonstrate that PV is the most straightforward technology to integrate into façades, suitable for meeting the net goal of zero energy buildings. While incorporated into the building envelope, photovoltaic solar cells can reduce their energy performance levels not only due to suboptimal working conditions (such as higher temperatures) but also suboptimal orientations (mainly due to building design and surfaces

Fig. 3.1 A multifunctional BIPV building in Pregassona, in addition to the home for the elderly, this multifunctional centre in Pregassona houses a kindergarten. Photo credits: Chiara Zocchetti – CdT.

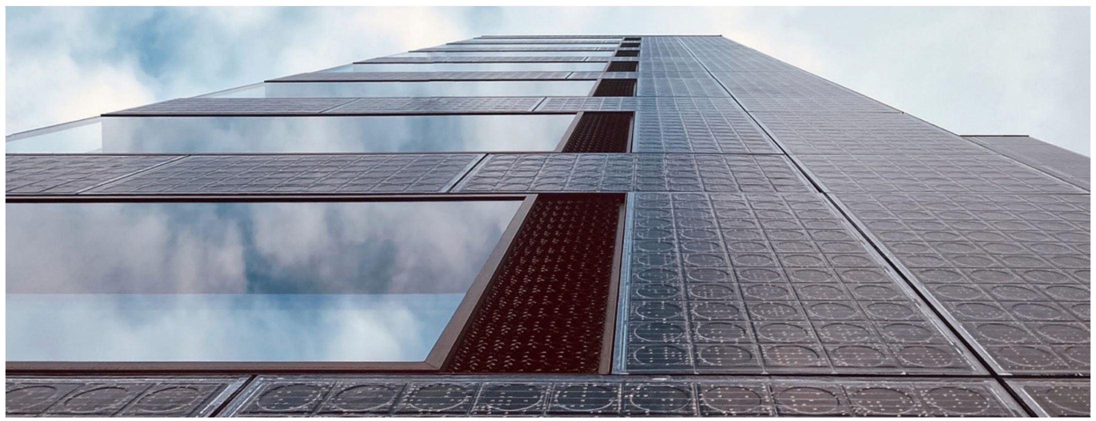
available) and also to aesthetic needs. As demonstrated in several studies [7], the treatments of the front glass to hide the photovoltaic solar cells, providing the colours to the BIPV module, can lead to relative efficiency losses from 10% up to 60%. However, this trend defined as "camouflaged" and "customised" PV with the aim of combining high solar energy production with a appealing aesthetic of its visual design (**Fig. 3.2**). This is based on the use of glass as a key material, not in its standard form of transparent and this dematerialised skin is the result of the joint efforts between the glass and the PV industry. Where, no technical limit seems to be conditioning for the revolutionary design flexibility of the glass on which disparate customisation techniques are applicable, even including intermediate sheets and photovoltaic cells [8].

As implemented in different Swiss and European cases, various designs can be achieved by treating the outer surface of the glass (e.g., by sandblasting) which, in turn, can be combined with a colour of the glass to conceal the solar cells behind it. A design or colour on the front glass can be achieved with a screen-printing process that deposits a special ink on the surface of the glass, such as ceramic-based digital printing or, alternatively, by stabilising the colour at high temperature with monochromatic or multi-chromatic scales used to obtain high-resolution images or prints. By combining the satin finish on the outer surface of the glass with screen printing on the inner side, a resulting coloured matte surface can make the glass opaque and active. Nanotechnology-based solutions have been developed for selective filters that can be added as internal sheets to reflect and diffuse the visible spectrum, thus providing a colourful appearance without much losses in the PV efficiency. All these techniques are in progressive development to find the best compromise between visual effect and efficiency of photovoltaic production, and represent a dynamic branch of the "active glass" industry as the current frontier of BIPV for the next few years. This innovative trend aims to facilitate the transition to active buildings while providing infinite possibilities for aesthetic variation and for rethinking the concept of building skin [9].

Innovative approaches like Rooftop Agrivoltaics

With the continual trend in urbanisation across the globe, the possibilities of farming have been very much reduced to building rooftops in urban areas. Thus, any technology interventions that endow building skin potential for both energy generation and food production will have huge business potential and a breakthrough for faster PV adoption. Further, considering the difficulties of water resource management and temperature control in urban rooftop farming under tropical climatic conditions, the integration of rooftop PV systems with agriculture practices can be a promising BIPV approach. Rooftop Agrivoltaics (RAV) can replace conventional metal/polymer/ceramic external roofing systems for building protection or for reducing cooling load, it also supports agricultural/gardening practises in open building spaces. The solution will be multidimensional, offering synergetic subsidy benefits of PV integration and rooftop farming, as supported by various state governments of India. Hence, RAV technology makes an attractive business model for faster BIPV penetration in India, as it benefits the building owner with solar energy, farming space and also eliminates the "Heat Island Effect (HIE). However, the technical maturation of RAV systems is very limited with the installation of intermittent solar PV installation. To develop as a BIPV roofing solution, technical innovation-related improvements, especially in solar light

Fig. 3.2 Office for Environment and Energy (AUE), Basel. Source: solarchitecture.ch.



management, have a maximal potential impact than market maturation improvements, both on the end-user cost and on competitiveness. **(Fig. 3.3)**.

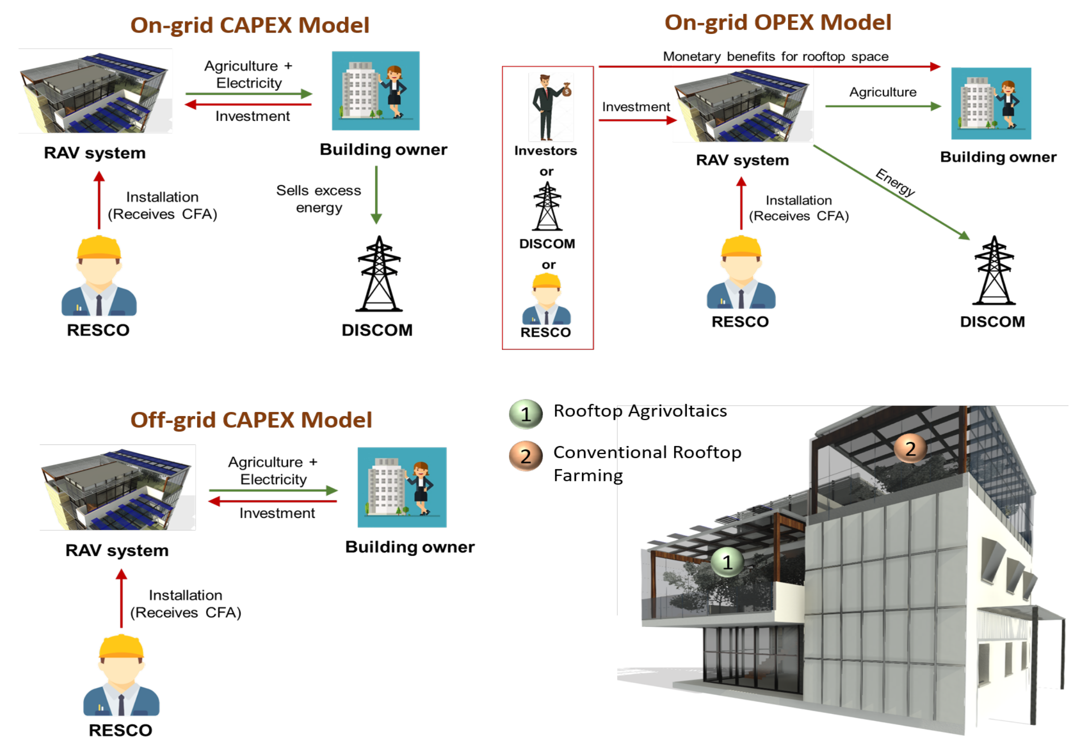
Prefabricated (Prefab) building construction and modularity

Prefabricated and modular active solar building envelopes are one of the key-strategies for reducing costs in the construction industry, thanks to product and process optimisation against the conventional building approaches. Also, in the BIPV sector, they're proposed as one of the cost reduction strategies, such as the one adopted by BIPVBOOST (www.bipvboost.eu), to accelerate the global uptake of BIPV. Majorly, the current Indian construction sector relies on the conventional construction method of "brick and cement". The reason is the less popularity of Prefab, and modular building construction solutions, though many solution providers are available with customised offerings. It basically involves manufacturing the building structural elements and envelope modules in an off-site manufacturing plant. The method is considered a more convenient and sustainable way of building construction and more advantaged with reduced material wastage, fast on-site assembly and dismantling, and compatible reuse. Apart from that, it has considerable cost reduction potential for the consumers, by reducing the labour cost, transportation cost, etc., with additional benefits of reduced construction time and higher quality, thanks to off-site integrated operations. A lower dependency on weather conditions, which can cause delays, is a benefit that can also be mentioned. Integrating BIPV installation with prefab construction can eliminate the need for other building elements like wooden panels, glasses, etc., further reducing the investment. Further, the installation of BIPV modules will become easier, compared to other conventional building construction methods. With the evolution of BIPV products in the future, which can fulfil and replace conventional building elements in every aspect, prefab construction may be more oriented towards it, with more convenient fastening and assembly of BIPV elements.

Lightweight and easy mounting systems

The most adopted PV technology among BIPV products is crystalline silicon based, representing a 90% and 44% market share for roof and facade applications, respectively. In the BIPV sector, they're typically realised

Fig. 3.3 The scheme describes potential business models for rooftop agrivoltaics (1) and its opportunities when compared with conventional rooftop farming (2) solution. Source SUPSI, NIIST.



in glazed panes such as laminated glasses [10]. However, in the recent years, thin-film based PV technologies have been developed to ensure flexibility, bendability and lightness in BIPV products. These technological alternatives consist of a PV active layer (CIS, CIGS, etc.) encapsulated in glass, metal or polymers. Thin-film based BIPV components have been demonstrated to be versatile and adaptable to different building applications in order to satisfy both the aesthetic and technological requirements. In many cases, the system results in a lightweight BIPV module on which the lower transportation, installation and labour cost can be further the key drivers for the cost reduction and the attractiveness on the market. For example, a typical product consists of a CIGS module on metal, which best suits industrial rooftop buildings and large surfaces. The use of easy mounting structures represents a cost reduction strategy to lower installation time related to assembly and the installation on site. Even though the above-mentioned solutions represent a clear strategy to directly reduce the costs of BIPV installations, their availability on the market is still a question, since only a few manufacturers offers market ready solutions.

(3) BIPV Industrial Sphere: Technology readiness, Supply chain and Certification

Enabling faster Technology Readiness among research and industry

To facilitate a faster route for the BIPV (or) BAPV innovations to market, country need to build the right ecosystem for R&D that will expedite the timeline for prototyping, benchmarking, and commercialisation. On the one hand, it is important to financially support science-based innovation projects conducted by industrial partners and private and public institutions jointly, with research partners in all subject areas to develop new types of products, services or processes together. This is crucial, not only for innovative product development but also for product modifications and corrections. On the other hand, it also helps to promote the development and testing of new technologies, solutions and concepts relating to the economic and ecological use of energy. Pilot scale demonstration programs act as a key interface between research and the market to improve the status of the development of new technologies so that they can ultimately be brought into the market. In this context, demonstration activities in BIPV are an important part of research for enabling its market exposure. For example, SUPSI activity across many years through BIPV national and international projects, translated it in the form of an applied research approach focusing on the BIPV product validation between indoor testing (Technology Readiness level - TRL 5), small-scale outdoor mock-ups (TRL 6) and demonstration in a real building environment (TRL 7/8). Hence for India, real-scale and modular testbeds are also necessary for innovative product development. They can act as a Research and Industrialisation hub housing R&D turnkey lines for BIPV module innovation, prototyping facilities for new product development, testing and certification facilities. To facilitate a faster route for the technology innovation to market, this concept of research and innovation testbed can be implemented at varies locations of the country with international exchanges and operate in synergy with market stakeholders.

Product customisation and supply chain management

Rather than a renewable energy technology, BIPV has been predominantly promoted worldwide as building materials in the last decade, because of its multifunctional categorisation [6]. With the contemporary building architectural and aesthetic inclinations, elemental building designs (size, shape, structure and external envelope designs) have been unrestricted with new construction technologies, innovative building products, and implied with local building codes and regulations. The perspective has extensively demanded building materials to add functional values, aesthetic appeal with customisation opportunities, especially for facade application. Hence, customisable BIPV module production, with the aspect of size, shape, texture, colour and functional properties, is a need of the hour. The manufacturing facilities could cater for these requisites, especially at the early stage of BIPV evolution.

The extent of the local supply chain strongly determines these customisations, product quality and reliability. Within the function of visible light transmission, selective light reflection, textural appearance, the importance of laminating glass and laminating polymer layer can be accounted to overall BIPV building aesthetics and functionalities. The connecting glass sector market can include solar clear glass, coloured glass, anti-reflective glass, insulated glass units, active shadings and blinds, textural and printed glass, etc. Considering the Indian context, the material supplying companies are scattered and lacks awareness regarding BIPV market possibilities. Creating awareness among these stakeholders and enabling a common material data information repository can deal the problem much effectively.

Designing and engineering BIPV products and their manufacturing is also crucial for the product performance, aesthetics, and final cost. For example, efficiently utilisable design considerations can be implied with textural/ coloured glass, where intermitted spaces can be used for PV integration, enhancing the aesthetics and reducing the material cost. Frameless glass-to-glass solar panels as rooftop shingles and canopy are comparatively the latest strike in the Indian BIPV market. Apart from that, BIPV product innovation can also be achieved with non-silicon photovoltaic technologies like thin-film solar cells (CIGS, GaAs, CdTe), coloured solar cells, organic solar cells, dye-sensitised solar cells (DSSC), that have varied optical transmission, colour, and flexibility. The technological and economic competitiveness are yet to be attained with these types of PV materials, when compared to silicon PV.

Need for exclusive standards and comprehensive ratings

Integrating PV in building skin today requires an accurate performance assessment in accordance with construction norms and PV standards, depending on the type of use and functions. The topic of BIPV as a multifunctional product, more than many other construction products placed on the market, deals with harmonising performance information by finding the right approaches considering its dual function as an energy and construction component, and the growing customisation of technologies. The current complexity of the normative assets, as it is today, is still considered a practical barrier for market implementation, and innovators often struggle between interpretation and experience. However, new testing approaches ensuring product quality, cost reduction and more substantial penetration of BIPV in the market are under investigation and development in current projects. With the expansion, up-gradation and development of PV technologies, there is a bigger concern of product performance and reliability. With the introduction of BIPV, development and regular amendments of individual product standards/testing with the application is getting crucial. Also, their testing and certification should be conducted in time for the industries and be standardised with reliability for the consumers. Thus, a proper standardisation, testing and certification of BIPV products helps in the regulation of costs, thereby increasing the market. In India, the National Institute of Solar Energy (NISE) has been the apex institute for the testing and certification of PV devices and components (NISE, together with the National Institute of Wind Energy (NIWE) and the National Institute of Bio-Energy (NIBE) acts as the primary test labs for the whole renewable energy sector). In addition to that, three testing labs in R&D organisations, supported by MNRE and two private-sector labs (UL India Pvt. Ltd., and TUV Rheinland), are involved in testing and certification of solar PV programmes in India (according to MNRE data (2017) published in website). With the demand of testing centres, MNRE is trying to expand their reach to the Council of Scientific and Industrial Research (CSIRs), Indian Institutes of Technology (IITs) and National Institutes of Technology (NITs) for their assistance. All the test labs should have a National Accreditation Board for Testing and Calibration Laboratories (NABL) accreditation and be approved by the Bureau of Indian Standards (BIS). These centres will act as secondary labs, for result comparison and calibration practises for quality assurance. In India, manufacturers and solar modules approved by BIS and MNRE, and are published in the Approved List of Modules and Manufacturers (ALMM) will be eligible for the government's solar schemes. The detailed guidelines for certification and Indian Standards for the modules and components have been published by MNRE [11]. For testing a new product, the sub-SQCC initially checks the applicability of existing standards. A new procedure will be developed based on the requirements and product properties. Testing will be conducted in three different labs with the same procedures, and the results will be validated with errors and uncertainties. The method will be reviewed with the consultation of other test labs and finally decided by MNRE. The Standards, Test and Quality Control Committee (STQCC) is organised with Secretary, MNRE as Chairman, subject experts including from NABL and BIS as members, and adviser as Member Secretary to oversee and coordinate the standardisation and testing of the renewable energy system, components, and devices. Sub-SQTCC are formed in each of the three primary labs with experts from R&D/ academic institutes and industries to develop and update standards and testing protocols for the respective product area.

With the expecting and upcoming phase of BIPV, and the possibility of utilisation and flexibility of it in building elemental replacement, will create huge stress on the area of standardisation, testing policies and protocols of the products, components and systems, especially for the vast Indian geography and market. Since additional testing and standardisation of different product performances are required for BIPV systems, a vigorous involvement of experts from different fields, including architects, subject experts from R&D institutes, experts from building construction, and members from solar industries, are required in prior for the development. More BIPV exclusive testing centres could be formed across India in different zones, and a specific pattern of testing protocols could be considered according to the different regional climatic conditions. In the H2020 BIPVBOOST project (www.bipvboost.eu - European Union's Horizon 2020 reasearch and innovation programme under grant agreement No 817991), a first effort for developing new BIPV test procedures has been made as reference for the BIPV community with the goal of supporting the sector overcoming the current missing gap among construction and PV performance assessment and also addressing the cost reduction targets [12], [13]. Hence, as a recommendation, a comprehensive and easily understandable BIPV rating system could also be considered for the better penetration of BIPV products in the Indian market. The rating system could be standardised with controls and exclusive testing protocols for each of the property evaluations, which could be classified for mandatory and non-mandatory tests based on the application.

(4) Innovation landscape

Research Projects

In India, the R&D for BIPV specific technology and products development is at a nascent stage. However, fundamental research of interdisciplinary nature is being carried out by both academic and research institutes leading to high-quality publications, facilities and patents required for the BIPV technology development and deployment. On the basic R&D front, the efforts majorly concern newer topics for energy generation and efficiency, such as functional materials for energy-efficient devices, , sensitisers, photo/thermo/electrochromic materials, third-generation PV technologies etc. One risk of basic research is not to have immediate commercial objectives or that it may not necessarily result in a solution to a practical problem in the form of products, procedures or services which are ready for the market. 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. This includes innovative solar energy management technologies like planar light concentrators, dynamic power windows, organic and inorganic hybrid solar cells, rooftop agrivoltaics etc., which can be mentioned as a few in the BIPV headway. In this framework, the applied research methodology is a complementary discipline to solve specific, practical problems bridging scientific aspects with the industrial, market and stakeholder's needs and challenges. India needs to develop expertise in manufacturing production equipment for PV/BIPV technologies since the country had been depending on technologies elsewhere and was importing them at a high cost. With the indigenisation of technology, it is possible to achieve a very impacting cost reduction compared to the existing ones in the international market, which could help with large scale deployment for various BIPV sectors in the near future.

A key point will be the interdisciplinary and quality of the research projects, together with the territorial and academic networks' efficacy in both quantitative and qualitative terms. Along with a wide research portfolio, ranges from sensitisation and education, to technological developments with industrial partners, including testing and validation in real scenarios, Pilot & Demonstration projects in collaboration with industries, architecture/engineering offices, installers and other authorities and real players will have to be one main focus. This will bring down the cost of multifunctional BIPV systems, limiting the over cost concerning traditional, non-PV, construction solutions and non-integrated PV modules, towards the mass realisation of nearly Zero Energy Buildings. The strong complementarity and synergy between the levels of maturity of technologies, which are ranging from TRL1 to 4 (technology Laboratory Validated) for fundamental research and between TRL5 and 7/8 (System prototype demonstration in operational environment/System complete and qualified) for applied research will be a key-point. This opens for potential joint programs in planning, managing, and assessing a successful technology transition for the Indian research sector through a core set of activities that can support pushing towards the mature products with a greater degree of readiness, including systems re-engineering that are tailored to the BIPV technology development for the Indian market and local goals.

Engagement of international communities

BIPV has achieved a high level of technology maturity globally, especially in Europe with multiple live demonstration projects. Engagement of PV industries and constructions sectors has taken the EU BIPV sector towards higher Commercial Readiness Levels (CRL). Currently, realising the involvement of multiple stakeholders, the BIPV Capacity Building programme is structured through the involvement of R&D institutions and industries to bridge the knowledge gap within the PV and construction sector stakeholders, thereby meeting UN SDG's 4, 9 and 11. With its wide demography, a country like India can consider developing BIPV specific capacity building programme jointly with international partners, which will, in turn, accelerate the CRL of the BIPV industry in the country by generating the know-how about the state-of-the-art in the BIPV industry. Hence, it is of utmost importance to formulate a dynamic, evidence-informed and proactive international S&T engagement strategy for India's BIPV sector to keep pace with the global benchmarks. Under the aegis of the Ministry of Science and Technology, GoI; DST has come up with a draft Science, Technology, and Innovation Policy (STIP) that supports international engagement to address global challenges, thereby supporting UN SDG's. The draft STIP has multiple objectives, such as *"addressing some fundamental issues in science by participating in international collaborative research, establishing scientific facilities of international standard in India, developing cutting edge technologies, training of researchers, engineers and industry professionals, design and delivery of major precision equipment for these and utilising spin-off technologies emanating from them towards societal benefits*" [14]. Thus, it is expected that the new STIP policies will ensure cohesive and transparent evaluation of all kinds of research and innovation, with global partners. This will enable the Indian BIPV sector to develop a standardised research and innovation excellence framework in collaboration with international communities. Further, the engagement of the Indian BIPV sector with global industries, R&D institutes, and academia will enable global R&D progress indicators, know-how for state-of-the-art technologies and products, patents, and other critical knowledge required for faster diffusion of BIPV. Further, such frameworks will also act as a fertile innovation landscape for BIPV specific innovation and indigenous product development in the country.

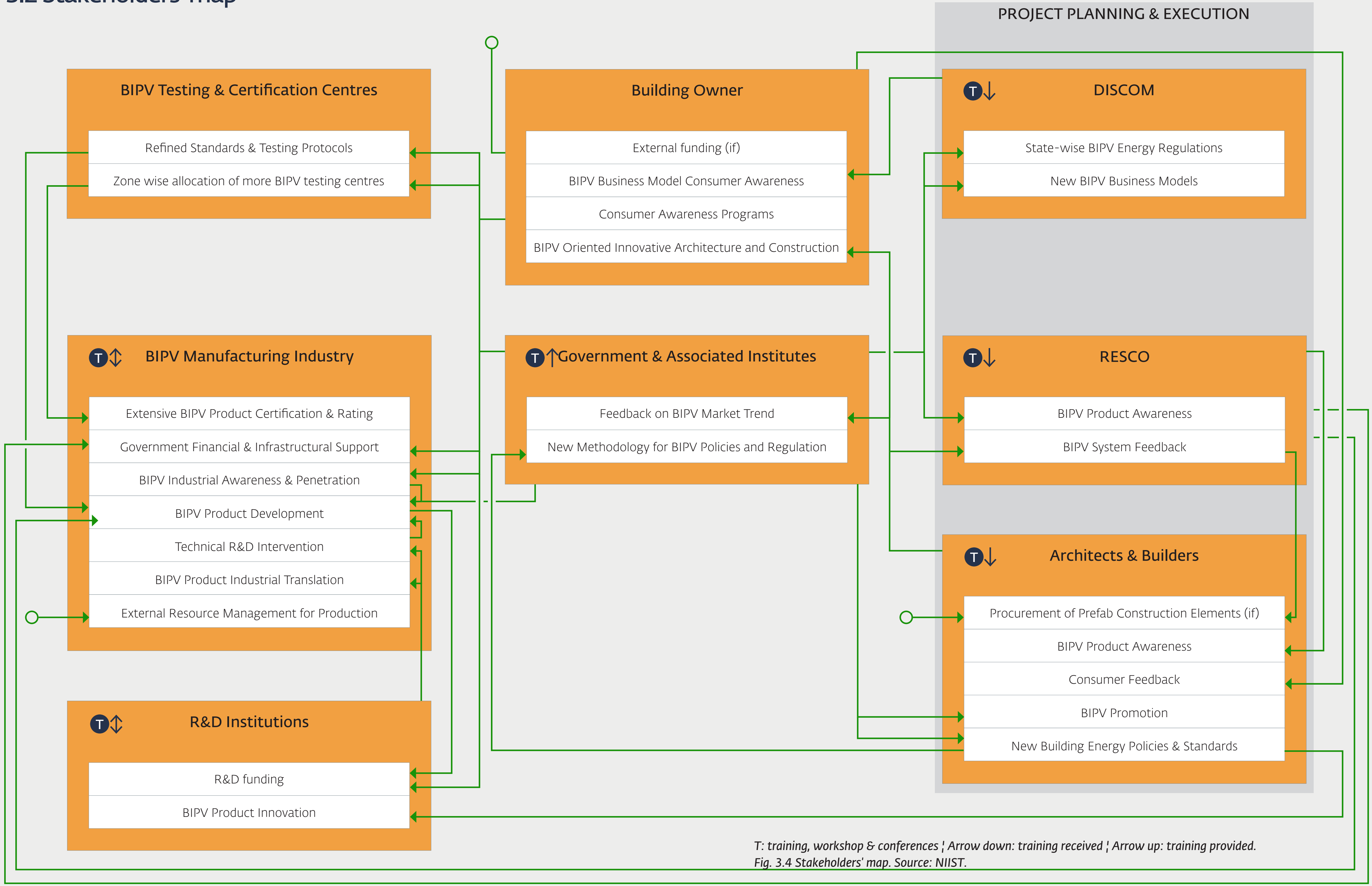
(5) Defining stakeholder involvement: Need for stakeholder awareness, extensive project planning & execution

As per the discussion in the previous sections, the stakeholder involvement mapping (as shown in the **Fig. 3.4**) is essential for the evolution of the BIPV sector in India. Considering the project implementation of Rooftop Solar installation in India, the stakeholder involvement is majorly limited to the DISCOM and RESCOs for the project development phase. The involvement of architects and builders are almost zero in this regard, as less project design or solar architecture is involved in this. However, for BIPV installations, the synergetic involvement and collaboration of architectures, builders, DISCOMs, and RESCO is necessary at different project execution levels. Herein, some of the foreseen project implementation concerns and directions to defy them are described.

For easy BIPV sector expansion as augmented marketing technology, the product, system implementation, technical, and technological awareness growth could always be prerequisites for the consumers. Unlike normal PV systems, these multiple layers of awareness should always follow the proper channels, making it a complicated framework to develop. Products, system and economic knowledge is always a primary concern for every stakeholder in project implementation, including the consumer, architects, builders, RESCO and DISCOM. Certified BIPV products of different companies could be conveniently enlisted and exhibited in a decentralised common platform for better product knowledge and technical awareness.

At the time of project initiation, architects, being the centre of planning, could collaborate with RESCO for developing innovative building plans with BIPV integration possibilities. Unlike normal rooftop PV systems, better knowledge of solar architecture for RESCO could be acquired with proper training. Architects could be oriented with Building Information Modelling software which are BIPV product oriented can be very helpful for parametrising and optimising building design features. For example, computational models for different building typology, exhibiting all the visual and functional aspects of BIPV elements, can attract the consumers better and shows better execution plans. Government regulations and financial relaxations could be published by DISCOM for the awareness of architects and consumers thereby realising more renewable energy integrated building plans. A detailed proposal with the energy capacity, proposed yearly energy generation, building codes, energy conservation features, etc., could be submitted to the DISCOM for evaluation and approval for financial relaxations, if any. Any other building investment allocation approval from the government, if any, could be submitted separate by the consumer. At the time of commencement, the involvement of builders with structural engineering and RESCO is extremely important for a BIPV specific building design. For a prefab building, the structural parts are designed and acquired from the prefab companies, according to the BIPV module specifications. Strong interaction of architects, builders and prefab companies are thus required even from the early stage of deployment. Innovative structural design, assembly design and methods, tend to build on the BIPV outlook. Lack of interaction and knowledge sharing between RESCO, and the building industry tend to fade the project standards and timely execution. Easiness and timely planning and execution can be regarded as one of the indicants of better market penetration and business model evaluation of BIPV. Rigorous and coordinated training is necessary for stakeholders directly involved in the project planning and execution. Government, SNAs, R&D Institutes, BIPV manufacturing companies could conduct stakeholder-oriented workshops, conferences and training programmes, for better understanding of the technical and non-technical aspects of BIPV sector. Training on systematic design tools and geographic data acquirement could be provided for RESCO and architects from R&D and other Government institutes. BIPV manufacturing companies could conduct regular marketing programmes with absolute technical and economic evaluation, followed by building economic evaluation of BIPV from architects and builders. Regular interaction and market feedback from consumers, architects, and RESCO

3.2 Stakeholders' map



T: training, workshop & conferences ¦ Arrow down: training received ¦ Arrow up: training provided.

Fig. 3.4 Stakeholders' map. Source: NIIST.

Strength

High Solar attractiveness: According to EY May 2021 report, the Renewable Energy Country Attractiveness Index (RECAI) ranking of India has raised from fourth to third rank globally, in the renewable energy investment and deployment opportunities, and scored first in the Solar PV category [15].

Lower Levelized Cost of Electricity (LCOE): With the increasing exploitation of the vast solar potential and lower benchmark cost of Rooftop Solar (RTS) systems, India has the least LCOE for RTS systems across the globe. Compared to countries like the USA (238 $/MWh) and Spain, the lowest in Europe (90 $/MWh), the LCOE is very low in India (66$/MWh) [16]. The trend is expected to favour the BIPV sector in India too.

Consumers attractiveness with net metering regulations: As per MNRE OM dated 2021, GoI has extended the limit of net metering RTS installations from 10kW to 500kW. Also, many individual states have been promoting PV building integration with state regulations and policies with DISCOMs for residential, commercial, institutional and industrial sectors, widely influencing the consumers [17].

GoI's initiative to promote Indian solar industry: Currently, India has a domestic module manufacturing capacity of 15 GW/year and a cell manufacturing capacity of 3 GW/year [18] and heavily depends on countries like China, Taiwan, etc. for solar equipment, components and sub-systems. To enhance the growth of solar industry in India, there is a considerable need to develop solar associated products and elements domestically. With the GoI's Atma Nirbhar Bharat strategy, the Department for Promotion of Industry and Internal Trade (DPIIT) produced an order to give preference to local suppliers for purchases. MNRE also imparted an order to promote Class-I local suppliers (local content <50%) for products having sufficient local capacity and competition. Other schemes like special incentive package scheme (M-SIPS), Production Linked Incentive (PLI) Scheme and policies like discontinuation of customs duty concession and imposing duty on imported PV modules and cell are some measures taken by GoI for the cause.

Opportunities

Growth of Indian building construction sector: As mentioned, the Indian construction sector is expected to grow with an impressive trend, with a projection of ~45 billion square metres in floor area additions by 2060.

Era of electrification in transport sector: The GoI aims to penetrate the transportation sector by electric vehicles for 30% of private cars, 70% for commercial vehicles and 80% for two- and three-wheelers by 2030. Even though this can constitute around 2% of national electricity demand, the distribution and charging of Electric Vehicles (EVs) are expected to contribute more from building energy than public distribution systems [19].

Building energy demand rise: By 2050, the building energy demand is expected to rise 10 times from that of 2020, with stable GDP growth, baseline cooling, and home EV charging [20].

Prefabricated and cost-effective construction: As discussed in this chapter, BIPV implementation can have a strong economic impact and implementation potential when allied with prefab modular construction.

BIPV as a disruptive technology: BIPV's selling point is always marked as a multifunctional renewable energy technology that can replace conventional building elements. However, sector maturation is not yet achieved in the Indian context. With product and construction standardisation, and better economic awareness and feasibility, BIPV technology can have a rapid disruptive growth in the building construction sector in the coming decades.

Weakness

BIPV Product certification: As it is an emerging technology in the country, the product standards and building codes have not yet been established for BIPV systems. Apart from basic energy certifications, the requirement of explicit functional, safety and performance standards are necessary.

GoI subsidy limitation across states: As the Indian building solar sector is concentrated on rooftop solar systems, the regulations are specified and followed under this category. Thus, for BIPV system, the lower capping of subsidy limits (as for residential buildings, it is 10kW; subsidies are not allowed for other sectors) will hinder the growth of the BIPV sector with the current business plans.

Extensive administrative procedures: Majorly centred with DISCOM, the need for standardisation and simplification of installation procedures is required to implement fast processing and implementation, and also to decrease the administrative burden on DISCOMs. Recently, regulations have been announced to conduct vendor selection and submission of the application directly from consumers for RTS installations. However, for proper conduction of this, reduced number of interactions, complex paperwork and process duration, along with consumer awareness on procedures and techno-economics, are requisite.

Lack of manufacturing industries & awareness: On May 2020, India had a module manufacturing capacity of only 10 GW, which hampers the growth of innovative solar technologies and solar energy growth of India [18]. The existing stakeholder community has less awareness and knowledge of BIPV products/ BIPV building constructions. Regarding project planning and execution of BIPV projects, multiple stakeholders, their awareness, effective interaction and collaboration is necessary. The involvement of architects and builders are meagre with the current rooftop solar business models.

Unevenness of solar policies and regulations in India: State-wise policies and regulations are uneven in India, which effects the reach and growth of RESCOs in a zone.

BIPV demonstrations in India: Not many BIPV demonstrations with benchmarking, energy and performance evaluation has been carried out in India, which can upshot less confidence within stakeholder community & investors.

Threats

Regulation imbalance: For the expansion of the BIPV sector in India, there is a greater need for a balanced obligation in regulations and business plans between consumers and DISCOMs. The mostly adopted CAPEX-net metering solar building business plan will create more financial plight for the DISCOMs on the long course.

Possibility of pseudo and inferior BIPV products/installations: India is yet to have the verge of expansion in the BIPV sector. Further, the regulations, standardisation and certification of BIPV products and deployment are indeed lacking. If a sudden market urge evolves in the coming years, there will be a significant threat of sub-standard and pseudo BIPV products penetration in the market.

Lack of coordination and awareness leading to uninspired project demonstrations: As mentioned, BIPV project planning requires rigorous coordination and execution from architects, builders, RESCO and DISCOM. Lack of BIPV products and building design awareness can cause insignificant models in the market.

Elevating import duty: India is a country that majorly depends on imported raw materials, from solar cells to modules. India is planning to set basic customs duty of 40% on solar modules and 25% on solar cells from April 1, 2022. Even though it promotes local manufacturing of solar modules for utility farms and rooftop installations, it may contradictorily affect the not yet evolved BIPV sector by hampering its growth or elevating the price.

Operation and maintenance: Operation and maintenance of BIPV installed buildings can also be a major concern in the future, as it is prevailing now with the poor air quality in India [21].

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CHAPTER 3

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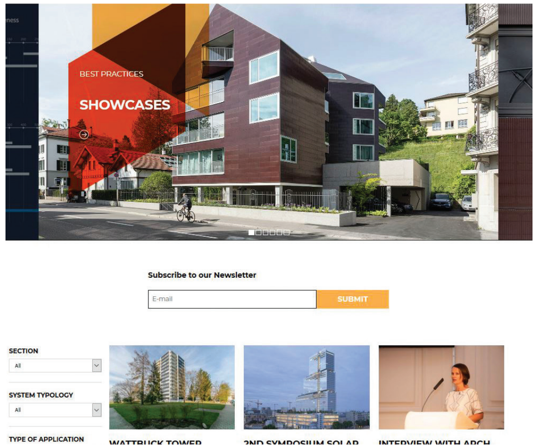

The website www.solarchitecture.ch is one of the communication means of the Swiss BIPV Competence Centre.
Here you find essential information concerning pv technology integration in buildings and different projects realized both in Switzerland and abroad. Moreover, a large database of BIPV modules and fastening systems collecting the main product's information in a datasheet is available. The website is an active interface opened towards different stakeholders thanks to the possibility to upload and store your BIPV examples (architects, installers, owners, etc.), products (manufacturers, suppliers, installers, etc.) as well as to the technological/client support through the contact info@bipv.ch.

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