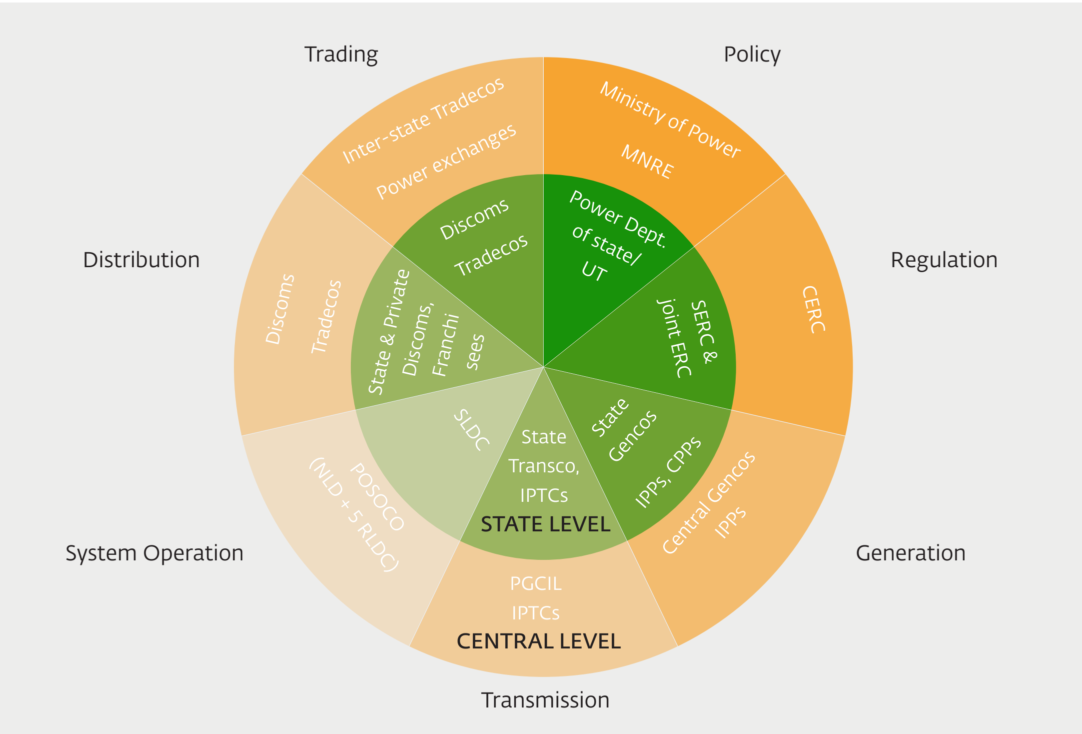
1.3 Financial schemes in solar buildings in India

Power Sector in India:

The Indian power sector is highly organized with functionally distinct organizations, departments and associations for the generation of electricity, its distribution and operation. The key stakeholders of the India power sector are shown in **Fig. 1.16**, framed with the involvement of both Central and State Governments with other private participants at different levels for efficient functioning. Ministry of Power, which oversees the entire energy sector and the Ministry of New and Renewable Energy (MNRE), is concerned with the central level policy making. Individual energy departments are also concerned with the policy making at the state level for the states & UTs. MNRE and its state nodal agencies are associated with the country's whole renewable energy sector, its promotion, international corporation, R&D activities, etc. MNRE also embodies five technical institutions in India: (1) National Institute of Solar Energy (NISE), (2) National Institute of Wind Energy (NIWE), (3) Sardar Swaran Singh National Institute of Bio-Energy (SSS-NIBE), (4) Indian Renewable Energy Development Agency (IREDA), (5) Solar Energy Corporation of India (SECI). NISE is the apex R&D institute for solar energy, which is also involved in solar component testing and certification. IREDA is a non-banking financial institution engaged in development and extension financial assistance for new and renewable energy projects. SECI is a Central Public Sector Undertaking (CPSU), formed to facilitate the implementation of Jawaharlal Nehru and National Solar Mission (JNNSM) activities. Apart from the ministries, the Central Electricity Authority of India (CEA), a statutory organization, advises the government on policy matters and formulates plans for the energy sector in India. CEA is also responsible for statistical data publishing of the Indian power sector for both state and central government utilities. Along with MNRE, CEA compiles the statistics on electricity capacity addition, generation, trade and forecasts. The Central Electricity Regulatory Commission (CERC) is a

Fig. 1.16 Organisational chart for the power sector in India. Source: [23].



statutory body in India functioning to regulate the generation, transmission, and distribution in the country.

The State Electricity Regulatory Commission (SERC), is involved in the rationalization of electricity tariffs, policies, subsidies, inter-state transmission and trade etc. In the electricity generation sector, both public and private involvement (including Central and Sate Generation Companies, Independent Power Producers (IPPs) and Captive Power Plants (CPPs)) equally contributes to India's energy sector [24]. Considering the electricity transmission in India, the Power Grid Corporation of India Limited (PGCIL) is the Central Transmission Utility (CTU) and is held responsible for most inter-state transmission projects. State Transmission Utility (STU) and Independent Private Transmission Companies (IPTCs) set up other transmission projects within the states. For monitoring and ensuring hassle-free operation of the electricity sector, companies like Power System Operation Corporation (POSOCO) and National, Regional and State Dispatch Centres (NLDC, RLDC, SLDC) work in conjunction to ensure grid security and balance. Considering the energy distribution sector, mostly state-owned companies conduct distribution and retail operations. Some private companies are also involved in Indian electricity distribution at different states. In addition to this, inter-state and other energy trading companies, power exchanges, and distribution companies (DISCOM) set the balance for demand and supply. As represented in **Fig. 1.16**; this whole ecosystem makes the energy sector in India, created for the smooth functioning of the power sector at both national and state levels.

Rooftop Solar Program & Policies in India

India launched JNNSM on 11th January 2010, which is the key solar program developed in India until now. The program was developed in accordance with India's National Action Plan on Climate Change to promote the concept of ecological sustainable growth and addressing the issue of energy security in India with the diffusion of solar technology across the country. The mission targeted 100 GW of grid connected solar energy capacity by 2022, and installed a total capacity of 49.3 GW grid connected solar installations as of December 2021. In order to achieve the above target, the Government of India (GoI) has launched various schemes like Solar Park Scheme, VGF Schemes, CPSU Scheme, Defence Scheme, Canal bank & Canal top Scheme, Bundling Scheme, etc. to encourage the solar power sector of the country. Considering the fact that integration of PV in the building sector provides a huge potential to tap for the Indian energy sector, the Grid Connected Solar Rooftop Scheme has been greatly promoted by GoI in the second phase of JNNSM. By this programme, it is targeted a cumulative capacity of 40 GW Rooftop Solar (RTS) installations by 2022. As reported by DISCOMs, an overall of 3.7 GW capacity of grid connected rooftop solar plants has been installed in the country by December 2020, and was extended to 6.1 till November 2021 [12] [25]. As of now, the Solar Rooftop Scheme remains the only programme promoting solar PV in the building sector, and discussions are based on the programme.

Main RTS program actors

Solar Energy Corporation of India (SECI)

SECI is a CPSU under the administrative control of MNRE, set up to facilitate the implementation of solar plants under the JNNSM. SECI plans of the targets of RTS installations in the country and decides on the allotted capacity following the competitive bidding process.

State Nodal Agencies (SNAs)

Under MNRE, SNAs have been established in the states and UTs for the promotion, coordination, finance and development of renewable energy projects in their state/UT. For the RTS program, the SNAs prepare targets as sanctioned by MNRE and select channel partners/installers through tendering with the rate contracts. SNA are also involved with the monitoring and inspection of the RTS installations.

Distribution Company (DISCOM)

Various public and private DISCOMs are concerned with the interpretation and implementation of the policies and regulations provided by both the Central Government and Governments of individual states. The overall technical feasibility study, evaluation of design and installation parameters for grid connected RTS system, installing metering arrangements have been carried out by the DISCOMs.

Chief Electrical Inspector to Government

The Chief Electrical Inspector (CEIG) ensures safety compliance and operations of RTS system. They involve in the approval of design and drawings, the pre-commissioning inspection and issuing of Charging Certificate.

Channel Partners

Channel Partners are the agencies associated with the sourcing of equipment/ solar components, or the implementation of RTS system for the clients, being empanelled by MNRE. The Channel Partners could include the solar Renewable Energy Service Companies (RESCO), vendors/ suppliers of solar equipment, project developers, manufacturer of solar components/ equipment, solar ambassadors etc. The empanelment with MNRE is based on certificate from a rating agency in the country for technical and financial strength. SNAs and DISCOMs have to undertake competitive bidding for selection of developers for RTS plants with the claim for Central Financial Assistance (CFA)/ subsidy. The channel partners submit the proposal to the clients (rooftop owners), sign the EPC/Power Purchase Agreement (PPA) agreement with clients and submits for the metering arrangement (to DISCOM) and subsidy (to SNA).

Financial Institutions/Banks
The financial Institutions and financial Integrators like NABARD, National Housing Banks, other Banks, IREDA, etc. are also eligible for implementing the RTS program. They may source funds from MNRE, their own resources or any other sources i.e., carbon credits, National Clean Energy Fund, funds from States, beneficiary contribution, CSR sources etc. Other Govt. Departments/ Agencies i.e., Railways, Defense/ Para Military Forces, Local Government Bodies including Municipal Corporations/ Municipalities, State Departments, etc. interested in directly implementing the program are also encouraged [26] [27] [28] [29].

Boundary conditions for PV in relation to building typologies (based on RTS scheme)

This section presents an overview of the different boundary conditions for the present state of solar PV adoption in Indian buildings. Financial relaxations for the different building typologies (residential, commercial and industrial) according to the benchmark cost provided under the RTS scheme establish the investment of solar installations in building. The cost of electricity and the levelized cost of electricity (LCOE) lays the foundations for an accurate cost analysis for solar installations. The analysis of electricity costs, the benchmark cost and financial relaxations will help to understand the framework and the strategies adopted for the RTS consumers in the country. The electricity costs within the different building typologies, the metering methods and available business model form the basis of attractiveness of RTS scheme in India. The different boundary conditions of Indian RTS scheme are discussed below.

1. Financial relaxations and benchmark cost

For residential buildings
Under Phase II of Grid Connected Rooftop Solar, the CFA has been approved for the beneficiaries until 31st December 2022. Under the scheme, only domestic manufactured modules and solar cells have to be used and the CFA shall be on percentage of benchmark cost of MNRE for the state/ UT or lowest of the costs discovered in the tenders for that state/ UT in that year, whichever is lower. For the residential sector, the CFA is 40% for capacity up to 3 kWp, 20% for capacity beyond 3 kWp and up to 10 kWp, and 20% for Group Housing Society (GHS) / Residential Welfare Association (RWA) capacity up to 500 kWp (limited to 10 kWp per house). The scheme is to be implemented through Power Distributing companies (DISCOMs), and for the residential consumer the CFA can be availed by operating through the DISCOMs [30]. The benchmark costs for Grid-connected Rooftop Installation under Phase II for the financial year 2020-21, decided by MNRE as presented in the **Tab. 1.1** and **Tab. 1.2**. Cost are referred to turnkey PV plants (including installation and put in operation) for conventional PV plants (e.g. BAPV on-roof systems). The benchmark cost includes the cost of PV panels, inverter, balance of system (cable, switches/ circuit breaker/ connectors/ junction box, mounting structure), earthing, lightning arrester, Comprehensive Maintenance Contract (CMC) for 5 years, transportation, insurance, applicable taxes, etc. The cost for metering and battery backup are not included [31] [32] [33].

For other buildings
In the Phase II of RTS scheme, institutional, educational, social, government, commercial and industrial sectors are excluded from availing CFAs, as the beneficiaries of these sectors are advantaged without CFA, since they are mostly high tariff paying consumers. However, for the penetration of solar systems in these sectors for the implementation of 40 GW rooftop solar installation target, acceleration depreciation (AD) benefits and Viability Gap Funding (VGF) is provided by the GoI under JNNSM Scheme [34] [35].

For the DISCOMs
For DISCOMs progressive incentives provided by the government are based on achievement levels, calculated above baseline, i.e. the cumulative rooftop capacity achieved at the end of previous financial year. For capacity addition up to 10%, there is no incentive. For 10%-15% capacity addition there is 5% incentive, and for above 15% capacity addition 10% incentive is provided. The incentives are limited to the initial 18 GW capacity [30].

System capacity range	< 1 kWp	1-2 kWp	2-3 kWp	3-10 kWp	10-100 kWp	100-500 kWp
Benchmark cost (Rs/kW)	46,932	43,140	42,020	40,991	38,236	35,886
Benchmark cost (2021 €/kW)	554	509	496	484	451	424

Tab. 1.1 Benchmark costs for grid-connected rooftop installation under Phase II for the financial year 2020-21 for general category states/UTs (currency conversion 17/01/2022). Source: MNRE.

System capacity range	< 1 kWp	1-2 kWp	2-3 kWp	3-10 kWp	10-100 kWp	100-500 kWp
Benchmark cost (Rs/kW)	51,616	47,447	46,216	45,087	42,056	39,467
Benchmark cost (2021 €/kW)	609	560	545	532	496	466

Tab. 1.2 Benchmark costs for grid-connected rooftop installation under Phase II for the financial year 2020-21 for special category states/UTs: North eastern states like Sikkim, Himachal Pradesh, Uttarakhand, Jammu and Kashmir, Ladakh, Andaman and Nicobar and Lakshadweep islands (currency conversion 17/01/2022). Source: MNRE.

2. Billing mechanism and RTS considerations

The type of metering greatly influences the growth of the PV sector, as it directly affects both the consumer economy and the energy sector. The types of metering are detailed below.

Net Metering
In net metering systems, a bi-directional meter is used to measure the difference in energy consumption from the grid and energy export to the grid. Consumers are provided with the opportunity to offset their electricity bills accordingly. Surplus injection compensation may or may not be provided (depends on state regulations) for the excess energy supplied to the grid.

Gross Metering
In gross metering or feed-in metering, all the energy generated from the system is exported to the grid and is separately recorded through a different 'feed-in meter'. In this case, the third-party investors/RESCO developers enter into a long-term PPA with the utility. The developer exports the solar energy to the utility at a predetermined feed-in-tariff (FiT) approved by the regulator. The model is particularly aimed at rooftop owners/third party investors who would like to sell energy to the DISCOM.

According to the latest amendment by the Ministry of Power, every consumer can avail net metering system for RTS installation below 500 kWp [36]. Further, any state government can extend the limit according to their regulations for any solar installations. The net metering regulations for commercial and industrial buildings, the electricity retail tariff, feed-in-tariff for gross metering and the surplus injection compensation for consumers who supply excess energy to the grid (in the case of net metering) for the different building typologies are determined by the state commissions and the DISCOMs. These state regulations greatly determine state's friendliness for the RTS scheme and other solar PV integration in residential, commercial and industrial buildings [37].

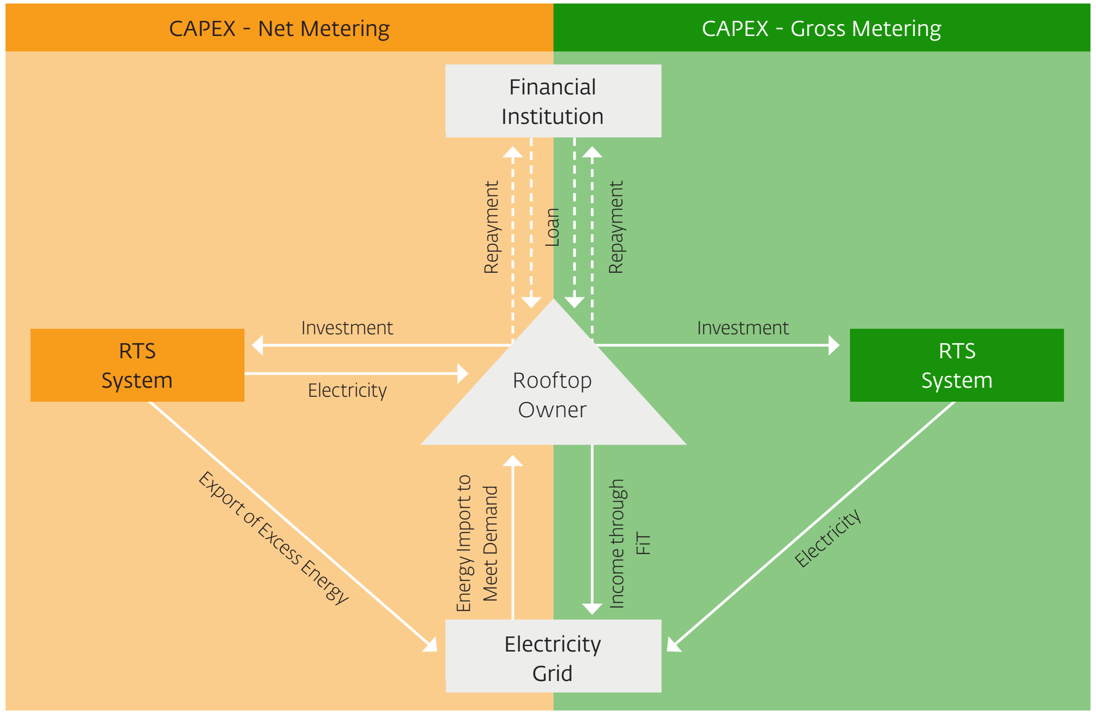
Appropriate business is always necessary to have a satisfactory revenue model for the stakeholders under consideration. In particular, it permits to the investor to understand the value of the investment in solar installations and to optimize the strategies of investment in solar systems. CAPEX model is considered as the first-generation model, which is a consumer self-owned model. RESCO model is the second-generation business model revolved around third party ownership and operation. Currently, these two models are majorly prevailing in India for PV building installations, the policies for each are according to DISCOMS and state government regulations. The third-generation, utility ownership driven model is considered as a future scope in global solar energy sector, but it is only emerging in Indian solar rooftop/ solar building scenario. Within these paragraphs, the two most popular business models in India for grid connected solar rooftops are elaborated. For other BIPV systems, CAPEX models are considered unchallenging, because of the ownership provision; other dedicated business models are necessary for the sector in future. CAPEX model is the most common business model for rooftop solar deployment in India. In this model, the consumer (rooftop owner) owns the system (expenses include the installation cost, O&M cost), by upfront payment or with other financial aid, often through a bank. These expenses include the cost to set up, maintain and operate the system. The power is either consumed or injected to the grid with a Feed-in-Tariff (gross metering) or net metering, as shown in **Fig. 1.17**. CAPEX models are well suited for consumers that can bring the investment upfront, and has a stake on the building.

In RESCO model, third party (RESCO) involves in financing and development of solar rooftop systems. Third party may rent rooftop space from rooftop owner and sell the electricity generated to the grid or the rooftop owner through a PPA, or may also lease out the PV system to the rooftop owner who may utilize the power from the system. For consumers who does not have a stake on the building, such as government building, public educational institutions, leased building, etc., or consumers who cannot bring the investment upfront, the RESCO operation models are best suited. The possible models upon different agreements are described and represented in **Fig. 1.18** and **Fig. 1.19**.

Solar system leasing

In this, third party investor leases the PV system to rooftop owner who makes payments as per the agreement for the consumption of the electricity generated. The third-party investor earns month-to-month lease payment. The savings from the generated electricity is the source of revenue for the rooftop owner.

Fig. 1.17 Financial schema: CAPEX net and gross metering. Source: NIIST.



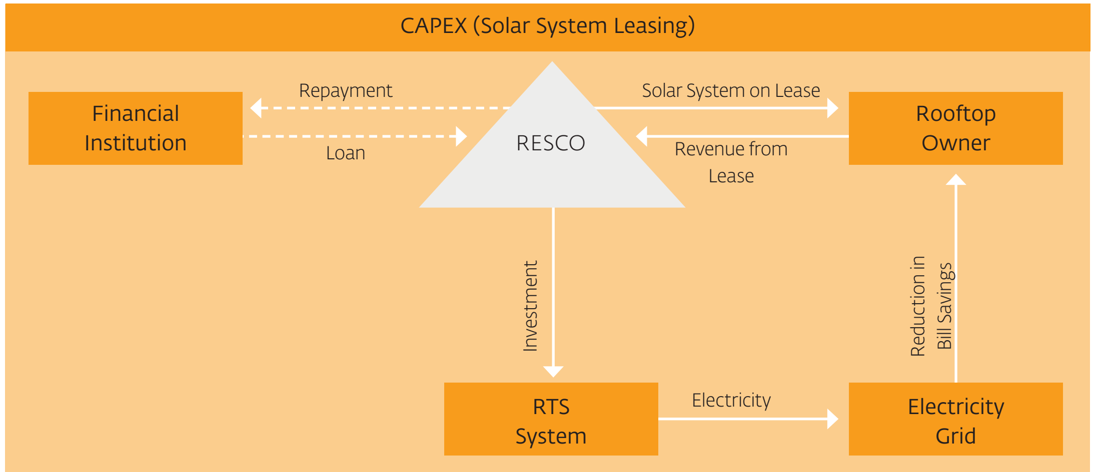


Fig. 1.18 Financial schema: CAPEX solar system leasing. Source: NIIST.

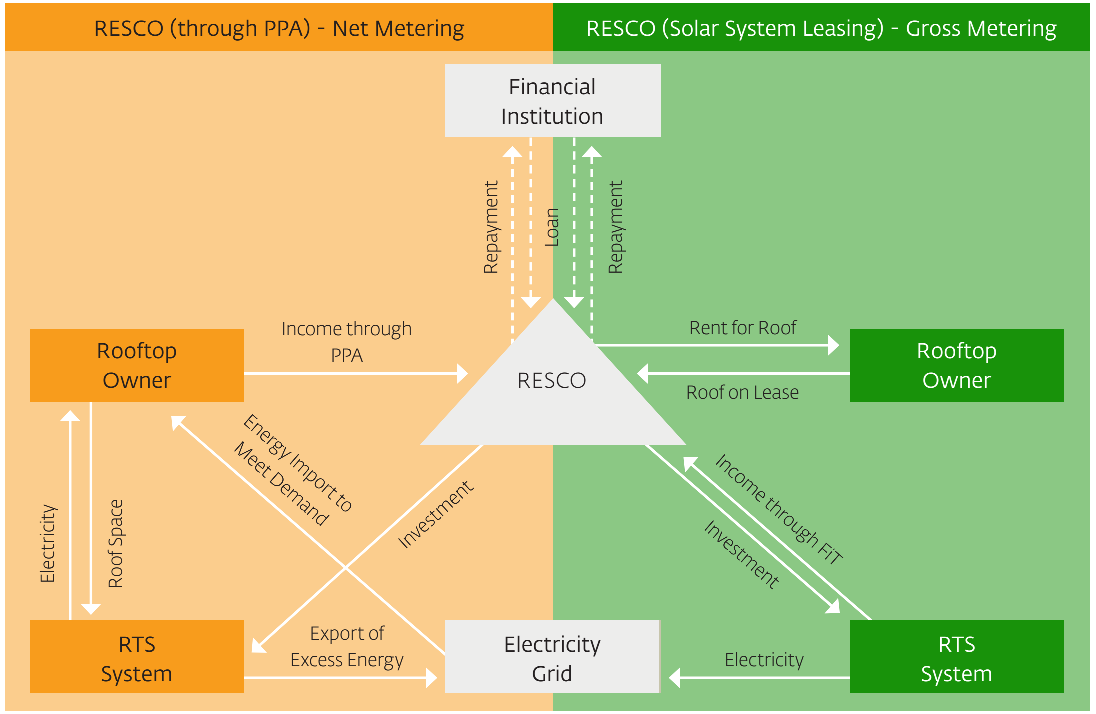
Rooftop Leasing (Under Gross Metering)

In this third party leases the rooftop and pays lease/ rent to the building owner in the lease period. The RESCO developer exports the generated power to the utility at a predetermined FiT approved by the regulator.

PPA (Under net metering)

In this, the third party invests in the solar system, and sells the generated power to the rooftop owner in with a lower solar power tariff compared to the grid tariff and the export of excess power through net metering makes savings for the rooftop owner.

Fig. 1.19 Financial schema: RESCO net and gross metering. Source: NIIST.



3. State-wise attractiveness of RTS scheme

Indian PV scenario has not achieved uniformity regarding the attractiveness of solar programmes, especially RTS installations. Many state-wise physical, technical, political, social, institutional, and economic factors such as solar policies, incentives, metering regulations and rooftop availability, electricity tariffs, distribution infrastructure differ the sector in each state. An ambiguous situation is thus prevailing for the stakeholders associated with the solar sector in India, especially for the renewable energy companies, entrepreneurs, developers, financial institutions, as well as government in policy making. Thus, it is critical to have a platform at national level for the evaluation of states' support level for the RTS programme.

Considering this, State Rooftop Solar Attractiveness Index (SARAL ranking) has been designed by MNRE in collaboration with Shakti Sustainable Energy Foundation (SSEF), Associated Chambers of Commerce and Industry of India (ASSOCHAM) and Ernst & Young (EY) for ranking the overall attractiveness of RTS programme in different Indian states with a dedicated evaluation method. The aspects considered for the evaluation are:

- Comprehensiveness/robustness of policy framework (Level of policy support, Covenants, Billing mechanism)
- Ease of implementation/effectiveness of policy support (Ease of application, Power offtake attractiveness, State of affairs of DISCOMs, Impact of Policy)
- Investment climate for the rooftop solar sector (Driver for rooftop solar uptake, Ease of financing, Maturity of market)
- Consumer experience (Pre-installation consideration, During installation, post-installation experience/costs)
- Business ecosystem (Business Enablers, Fiscal and Regulatory environment, Economic outlook)

The detailed evaluation mechanism is explained in SARAL reports. According to the 2018-19 report Karanataka, Telangana, Gujarat, Andhra Pradesh scored the first four positions in the ranking [38].

4. Electricity cost & Levelized Cost Of Electricity

The electricity cost in India is calculated under consumption slab basis, i.e., the final cost is determined by the range of total energy consumption. The average electricity cost for residential building in India is around 4.2 INR/kWh to 6.7 INR/kWh, which varies according to the state, the DISCOM, and the amount of unit (in kWh) consumed. For commercial buildings, it is coming around 7.5 INR/kWh to 8.6 INR/kWh, and for industries it is around 6.6 INR/kWh to 7.6 INR/kWh. The determination of average electricity cost does not clearly indicate the overall scenario and unevenness of electricity cost in India, which changes with the electricity policies adopted by different state governments and DISCOMs. As for example, the electricity cost in residential sector varies from 0.85 INR/kWh in Tamil Nadu to 7.38 INR/kWh in Rajasthan up to 100 kWh slab, and the maximum rate of 13.4 INR/kWh can be seen in Maharashtra for up to 1000 units' slab. CEA has published the electricity tariff across India for the different building sectors [39].

The price of electricity influences the economic payback of solar systems. The revenues, which consist in savings on the yearly electricity bill, are also associated to the self-consumed electricity. For each kWh that is self-consumed, a saving up to the amount of the compensable retail electricity price can be made in the case of net metering arrangement. In this sense, consumers (rooftop owners) have a better payback rate for states having higher electricity cost. However, the revenues coming from building integrated solar systems includes the excess electricity that is fed-back to the grid and also from the multifunctionality of any Building Integrated Photovoltaic (BIPV) systems that can be considered as a replaceable element for conventional construction materials and power generators [40].

LCOE can be considered as the best measure of an electricity generating system in an economic perspective. It denotes the average net present cost (including the fixed and variable cost) of generating electricity from a system in its lifetime to break even. Lower the LCOE value denotes better economics from the consumer point of view.

A recent study conducted by Siddharth Joshi et.al., for evaluating the potential of rooftop solar PV installations across the globe (with building footprints, solar radiation mapping with seasonal variability, and technology-specific information like panel size, conversion efficiency, and system losses) showed the potential competency of Indian conditions. The study concluded that, India is one of the countries with least LCOE value of 66 $/MWh for attaining the country-specific potential of 1,815 TWh/yr. The global map generated in the study for the assessed LCOE value is shown in **Fig. 1.20**.

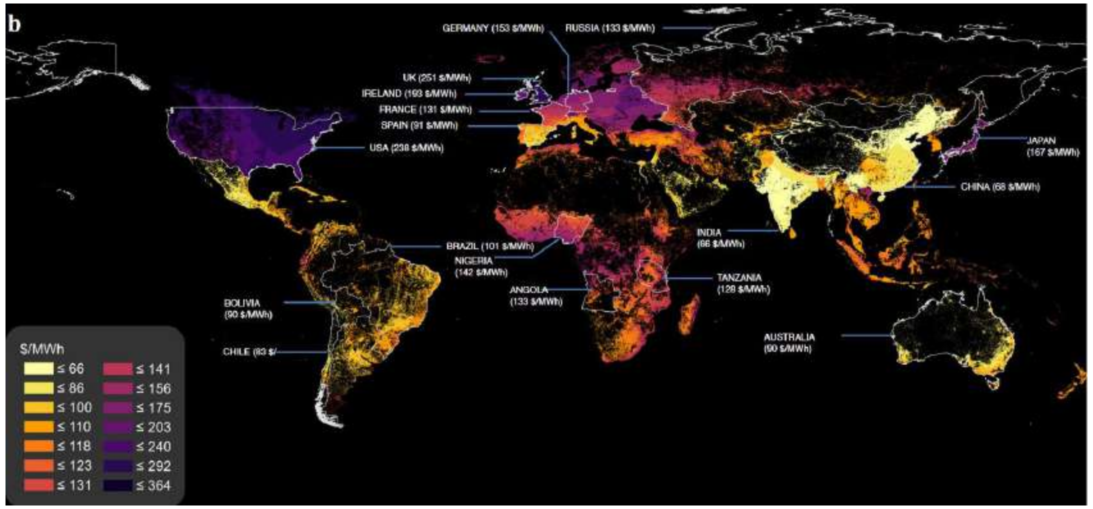


Fig. 1.20 Global Distribution of RTS technical potential and LCOE values. Source: [41].

Chapter 2
Solar constructions

2.1 Green building revolution and role of BIPV

The real estate sector in India is the second-highest employment generator in India after the agriculture sector. In the coming years, rapid growth in the construction market and the adoption of state-of-the-art construction technologies are expected in India. More specifically, by 2024, the real estate market will grow to about 9 US$ billion, with a high Compound Annual Growth Rate (CAGR) of 19.5% from 2017-2028 is expected [1]. The current housing shortage in India's urban areas is estimated to be about 10 million units; thus an additional 25 million units of affordable housing are required by 2030 to meet the demand of growing urban population [2].

Worldwide, buildings account for nearly 39% of annual CO2 emissions, among this 28% is related to building operations and 11% to building materials and construction [3]. The high energetic footprint of the construction sector emphasises the need for introducing strategies to reduce the energy impact on buildings. To address these issues, the World Green Building Council has launched 'Advancing Net Zero' worldwide to promote and accelerate the growth of net-zero carbon buildings to 100% by 2050. According to the World Green Building Trends 2021 report by Dodge Data and Analytics, India is expected to raise the green building sector from 12% in 2021 to 25% by 2025 (survey conducted within respondents having more than 60% green projects) [4]. However, according to the report, the Indian green building sector is driven mainly by the country's environmental regulations rather than the market or public awareness. The lack of trained/educated green building professionals and unaffordability in every building sector constitute the major hindrances in the Indian green building sector. Currently, the market of green buildings in India has been concentrated in new commercial, institutional and large residential spaces.

Different green building rating systems have been introduced worldwide to promote net-zero building strategies with certificates, incentives and financial assistance. Three rating systems are predominantly existing in India: 1) Globally framed Leadership in Energy and Environmental Design (LEED), 2) rating system of Indian Green Building Council (IGBC), and 3) Green Rating for Integrated Habitat Assessment (GRIHA) of MNRE. The IGBC was formed in 2001 under the Confederation of Indian Industry (CII), which was one of the initial revolutionary course. Through the years IGBC promoted green revolution ranging from buildings, industries, cities and other habitats with individual ratings (with the involvement of key stakeholders including architects, builders, consultants, developers, owners, institutions, manufacturers and industry representatives), certification, training programs and green energy building conferences.

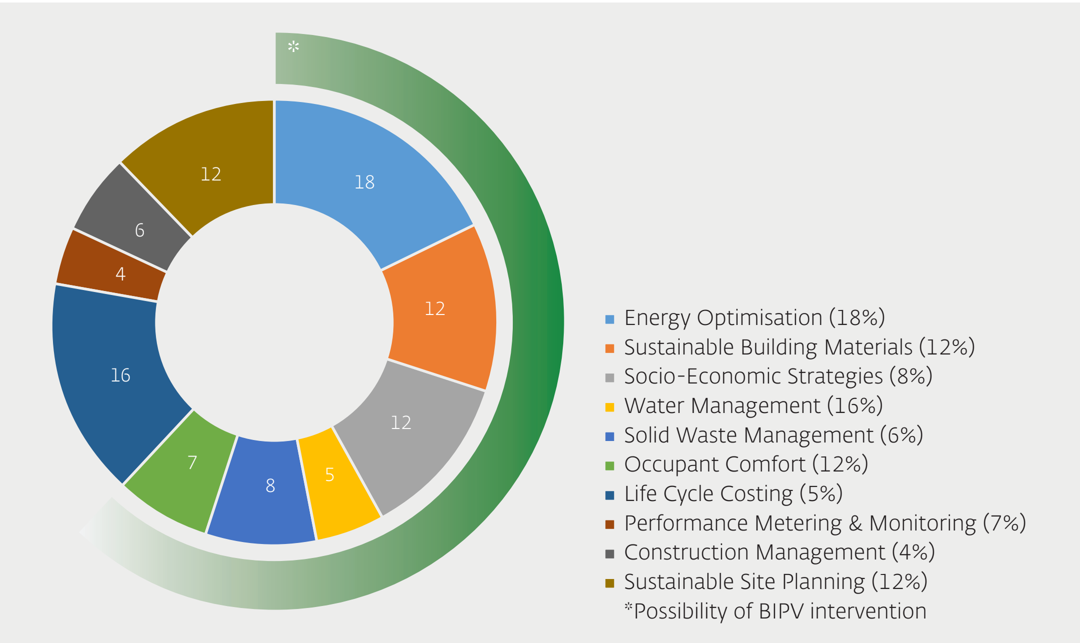
Also, MNRE has been widely promoting programmes and regulations for energy efficiency in the building environment to advocate the concept of self-sustenance, both in resources and energy, in the country. The national rating system GRIHA was developed by The Energy and Resources Institute (TERI) and endorsed by the ministry in 2007 with modifications as suggested by a panel of architects, builders, renewable energy and sustainability experts. GRIHA has been developed to rate commercial, institutional and residential buildings in India emphasising national environmental concerns, regional climatic conditions (building design considerations are done based on the six climatic zones, according to a study conducted by IIT Delhi, and adopted by MNRE), and indigenous solutions. It is a more holistic and life-cycle approach (from site selection to planning, construction and demolition) with an objective to reduce resource consumption, reduce greenhouse gas emissions and promote the use of renewable and recycled resources in buildings to rate the "greenness" of a building. It integrates all relevant Indian building codes (National Building Code 2005; the Energy Conservation Building Code (ECBC) 2007 announced by Bureau of Energy Efficiency (BEE), and other Indian Standards [5].

GRIHA has a 5-star rating system, evaluated with a set of criteria included for aspects of design, construction and operation of a green building. The pre-assigned points for each criterion are calculated with benchmark performance goals and added up to obtain the star rating. GRIHA rating is applicable for all newly constructing habitable building typologies (Residential, Healthcare, Hospitality, Institution, Office, Retail, Transit Terminals, etc.) with a minimum built-up area of 2,500 m2. Other GRIHA ratings are adopted for less built-up area buildings (Simple Versatile Affordable GRIHA), existing buildings, existing schools, large developments, etc. According to the rating directives of GRIHA [6] around 42% of point share is dedicated to Energy Optimisation (18%), Occupant Comfort (12%) and Sustainable Building Materials categories (12%). Thus, the GRIHA rating can be considered as a technical tool for green building development in India. Even though renewable energy utilization constitutes 5% of it, BIPV integration has enumerate possibilities and advantages in the mentioned categories, other than energy generation, such as:

- Passive solar construction techniques including material, architectural design and product design interventions through BIPV products
- Energy savings through PV integrated daylighting systems
- Energy conservation through thermally insulated BIPV roof and facade
- BIPV products that can offer both visual, thermal and acoustic comfort as per Indian standards
- Utilisation of alternative materials in building using BIPV, prefabrication and modular construction: Offsite construction of building components and its onsite assembly is an upcoming approach for green building construction. Prefabricated structural construction and modular assembly can be greatly congruent with BIPV elements such as building skin as façades, glazing, external roofing, etc. It greatly reduces the material consumption of conventional building construction, reduces its wastage, induce safer working conditions, reduces the time of construction, and can provide better energy and comfort performance in line with the BIPV product specifications, expanding provision for higher GRIHA rating.

Other possibilities of BIPV interventions in the GRIHA rating system includes the sections of Life Cycle Costing, Socio-Economic Strategies, and Performance Metering and Monitoring. The various sections of GRIHA rating and potential areas for BIPV interventions are briefed in **Fig. 2.1**.

Fig. 2.1 Pie chart representing different shares for GRIHA rating in percentage and potential share for BIPV interventions. Source: [2].



2.2 Building Integrated Photovoltaic systems

If the necessity to improve the energetic performance of buildings induces the stakeholders of the construction sector to use solar systems, the rapidly growing construction market in India requires introducing new ideas and technologies. The installation of solar systems as building envelopes not only permits to transform buildings into solar power plants but also to integrate multifunctional properties of the construction system, replacement of building cladding materials and improving aesthetics considering the architectural image. The integration of solar energy systems in the buildings is well recognised with the acronym BIPV (Building Integrated Photovoltaic) as defined within the solar community. For example, now the BIPV products are available in different colours and sizes [7]. The reported market overview for state-of-the-art coloured BIPV products clearly reveals that, for all parts of a BIPV module, there are technical solutions available for colouring and customisation. Pilot projects utilising coloured BIPV products have been built in numerous (mainly European) cities, clearly demonstrating the maturity of these solutions. Besides the colour perception of the BIPV elements under solar irradiation, which is essential for the acceptance of the exterior appearance of a building, also the transparency and inside visual comfort of BIPV sells itself as essential window and façade elements for the users [8].

Since the building envelope normally cannot be produced in one piece, it is necessary to break it down into individual parts. For many years, the BIPV community did not reach a consensus about a reference categorisation of BIPV applications in the building skin. In this chapter, the definition of BIPV is provided on the basis of the specifics promoted by the IEA PVPS Task 15 [9]. The categorisation is based on three levels that include the i) application category, ii) system, and iii) cladding properties.

A definition of BIPV

IEC 63092-1:2020 [10] specifies BIPV module requirements and applies to photovoltaic modules used as building products. It focuses on the properties of these photovoltaic modules relevant to basic building requirements and the applicable electro-technical requirements. This document addresses requirements on the BIPV modules in the specific ways they are intended to be mounted but not the mounting structure itself, which is within the scope of IEC 63092-2. This document is based on EN 50583-1 [11]. The basic requirements for construction works are:

- Mechanical resistance and stability
- Safety in the case of fire
- Hygiene, health and the environment
- Safety and accessibility in use
- Protection against noise
- Energy economy and heat retention
- Sustainable use of natural resources

As already mentioned, the BIPV module is a prerequisite for the integrity of the building's functionality. If the integrated PV module is dismounted (in the case of structurally bonded modules, dismounting includes the adjacent construction product), the PV module would have to be replaced by an appropriate construction product. Inherent electro-technical properties of PV alone do not qualify PV modules as to be building-integrated.

Referring to the above-mentioned references, a definition of a BIPV module is exposed [12]:

A BIPV module is a PV module and a construction product together, designed to be a component of the building. A BIPV product is the smallest (electrically and mechanically) non-divisible photovoltaic unit in a BIPV system that retains building-related functionality. If the BIPV product is dismounted, it would have to be replaced by an appropriate construction product.

A BIPV system is a photovoltaic system in which the PV modules satisfy the definition above for BIPV products. It includes the electrical components needed to connect the PV modules to external AC or DC circuits and the mechanical mounting systems needed to integrate the BIPV products into the building.