Viability of solar rooftop photovoltaic systems in grouphousing schemes

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With conventional energy sources being limited in their availability, the search for alternative renewable energy sources is inevitable. Solar energy, an inexhaustible renewable energy is considered a vital source for a developing country like India, where there is a major deficit between the demand and supply of electricity. Crowded urban structures have all the updated electrical appliances, but there is a deficit power supply during peak hour demand. In a tropical country like India, airconditioning for cooling has become the norm during daytime due to IT facilities and allied support services. The Sun shines for 8–9 h during daytime, which coincide with the time of peak energy demand. The crowded rooftop of cities can be converted to solar electricity generators through rooftop photovoltaic systems. We have done a field study of the energy consumption of post-occupancy medium-rise (G + 4) group housing and high-rise (G + 10) group housing schemes in two different cities in India. The feasibility study for solar photovoltaic systems, along with the scrutiny of various schemes that are available to the building owners are discussed for post-occupancy owners as well as yet-to-be owners of such group development schemes.

Keywords: Group housing schemes, rooftop solar photovoltaic, RTPV Indian scenario, solar energy.

CONVENTIONAL energy resources based on natural resources like coal and fossil fuels are limited in availability and may become extinct if they are used in abundance as is done at present. In addition, fossil fuel-based plants have substantial greenhouse gas emissions that lead to undesirable effects on global climate change. Renewable energy will help balance the adverse effects of global climate change. Solar energy is a non-depleting and abundantly available clean energy to mankind[1].

In a developing country like India, electric utility board generation does not meet the entire energy requirements of the population. To meet the demand, fossil fuel-based electricity has become commonplace during load shedding hours. Also 3 kW/l of diesel produced is unaffordable for majority of the population[2]. Various industries and commercial establishments like malls, hospitals, offices and group housing complexes developed by builders use diesel generator back-up during daytime. In cities like Chennai, airconditioning units are inevitable and the city consumes one-fifth of the electricity in the state[3]. The capacities of the generators vary from a few kilowatts to a couple of megawatts. Usually a number of generators, e.g. one for lighting and computers and one for emergency operations such as lifts are used during load-shedding hours.

With an objective to minimize generator usage which consumes fossil fuel, alternative generation of power through solar photovoltaic (PV) modules is proposed.

Solar energy as an alternative has a huge potential in India, which is near the equatorial belt where solar irradiance is available for 8–9 h every day, which is except during monsoons.

Rooftop solar photovoltaic system

When the Jawaharlal Nehru National Solar Mission (JNNSM) was implemented, initially the focus was on large-scale grid-connected power plants. At present, as the prices of solar PV modules has dropped considerably, rooftop PV (RTPV) systems have become popular and are seen as a viable option all over India[4]. According to Census 2011, India has 140 million houses with proper roof (concrete/asbestos)[5]. RTPV has a huge potential as it generates income through the unutilized rooftops and is not faced with unavailability of land as in the case of ground-mounted projects[6]. RTPV is best suited for urban areas where the buildings are highly dense and crowded. RTPV systems are PV systems installed on the rooftops of commercial, residential or industrial buildings[4]. These can be classified as non-grid interacative systems that are primarily for self-consumption and grid-interactive

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systems that could either be fed into the utility grid through a regulated feed-in-tariff (FiT) or used for self-consumption through the net metering approach.

Solar net metering

In grid-connected solar PV systems, the DC current from PV panels is converted to AC current through the inverter and fed to the distribution board for internal consumption like lights and fans. If excess energy is produced compared to that utilized for self-consumption, it is automatically exported to the utility grid. For this, a net meter is fixed in the place of normal utility service connection meter that can measure both energy import (from the grid to the consumer) and energy export (from the consumer to the grid) (Figure 1). These are known as bidirectional meters[7]. Solar RTPV systems have potential in India, where transmission and distribution losses through utility are more than 30%. As the RTPV is used mainly for self-consumption, such losses can be prevented[6].

RTPV – the global scenario

Japan, USA and Germany were early leaders in adopting RTPV systems and Italy, Australia and China are emerging with a strong growth in recent times. European Photovoltaic Industry Association estimates that 40% of the EU's demand would be met by RTPV by 2020. In the US, a 2008 study by the National Renewable Energy Laboratory (NREL) reveals that 22% of the electricity is met by RTPV, where the net metering arrangement is more popular. California has been leading the solar rooftop market in USA and more than 1000 MW is generated from net-metering consumers (101,284 consumers).

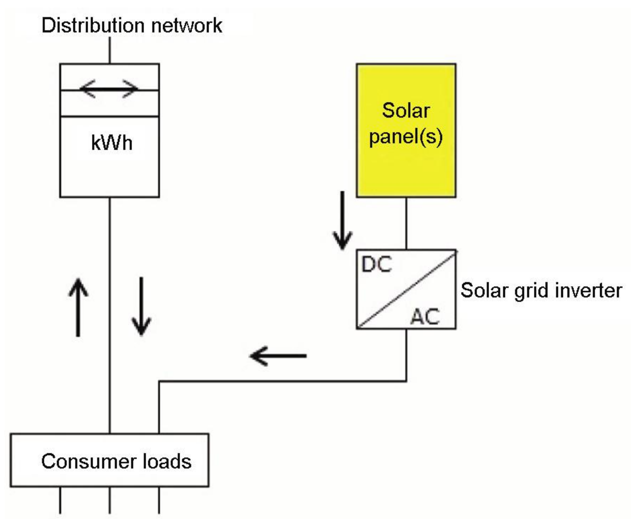

Figure 1. Solar panel-generated electricity.

Germany and Italy have installed the highest cumulative PV capacity of 24.6 and 12.7 GW respectively, out of which 60% in both these countries is from RTPV systems in the residential and commercial segments. In Europe out of 50 GW solar PV capacity, over 50% is from RTPV[4].

RTPV – the Indian scenario

A recent survey estimates the potential for RTPV in India to be 20–100 GW. The JNNSM mission documents mention both forms of RTPV arrangements, namely net metering and sale to utility through FiT. The Ministry of New and Renewable Energy Sources (MNRE), Government of India is the process of forming the new rooftop policy based on net metering including capital subsidy[4].

Gujarat has already adopted the policy of 'rent a roof', where the roof owner gets paid Rs 3 for every unit of energy produced[8].

Three ministries of GoI – MNRE, the Ministry of Heavy industries and Public Enterprises, and the Ministry of Power have joined hands to launch a 4000 MW ultra mega solar power project at Sambhar, Rajasthan, expected to be the largest in the world[9].

MNRE has identified 60 cities or towns as 'solar cities', since 2009 to integrate all the renewable energy projects to saturation level. A solar city aims at 10% reduction in projected demand for conventional energy at the end of five years. It is to be noted that Coimbatore, Tamil Nadu is one such solar city[10].

Electricity consumption and PV generation

Domestic consumption

In Tamil Nadu, domestic consumption (16,249 million units) stood second among the regional consumption of electricity for the year 2011–2012, the primary consumer being industries (22,663 MU). With regard to the number of consumer meters, the domestic sector (15,438,725) stood first with 18,534 MW of connected load[11].

RTPV generation and rooftop area

The average roof-space requirement for a typical 1 KWp solar PV power plant will be 80 sq. ft. (approx.) shade-free area for a 16% efficient module (Table 1).

The tentative cost of grid-interactive 1 KWp rooftop solar PV plant will be Rs 1.1–1.3 lakhs (approx.). Similarly, 1 KWp off-grid system with minimum battery back-up will require Rs 1.5–1.7 lakhs (approx.). In addition, for all such systems, 30% subsidy shall be availed from MNRE, GoI, through state nodal agencies[6].

The Tamil Nadu Energy Development Agency (TEDA), gives a subsidy of Rs 20,000 for 1 kW solar rooftop system. This is in addition to the subsidy of 30%

(Rs 30,000) given by MNRE, GoI. So the net cost becomes Rs 60,000 to the installer. The system would generate 1600 units a year. At a tariff of Rs 5.75 kW/h, the annual savings work out to Rs 9200 (ref. 12).

Study of post-occupancy group developments and energy need

For implementing RTPV in the domestic sector, we have assumed that the individual detached villa-type houses have enough rooftop area to meet the energy demand for self-consumption. For a medium-rise housing development (G + 4), in Chennai the energy consumed is studied and the rooftop area estimated to meet the energy consumption. Similarly, for a high-rise (G + 10) housing groups in Coimbatore, the energy consumed and the rooftop area are estimated to meet the energy needs.

Field study 1 – medium-rise (G + 4) development in Chennai

The survey revealed that common facilities like the RO (reverse osmosis) plant and STP (sewage treatment plant) used the major chunk of energy; though the dwelling cumulative units were the major consumers. The total rooftop area available was 44,000 sq ft. From Table 1, this will produce 440 kW/day, whereas the energy needed during daytime is only 266 kW/h.

The solar insolation and shadow analysis reveals that the roof area is not shaded by the blocks between themselves (mutually shaded), except for low terrace (that has not been taken into account for insolation) and receives an insolation of 5.5 kW/day (Figures 2–4).

Field study 2 – high-rise (G + 10) development in Coimbatore

The survey revealed that the common facilities like the RO plant and STP used the major chunk of energy; though the cumulative dwelling units were the major consumers. The total rooftop area available is 26,490 sq. ft.

Table 1. Roof area needed based on PV module efficiency and PV capacity

PV module Efficiency (%)	Roof area needed (sq. ft) (shown in bold type) PV capacity rating (W) 100	250	500	1000	2000	4000	10,000
4	**30**	**75**	**150**	**300**	**600**	**1200**	**3000**
8	**15**	**38**	**75**	**150**	**300**	**600**	**1500**
12	**10**	**25**	**50**	**100**	**200**	**400**	**1000**
16	**8**	**20**	**40**	**80**	**160**	**320**	**800**

For example, to generate 2000 W from a 12% efficient system, we need 200 sq. ft of roof area. Source: Ref. 6.

From Table 1, this will produce 264 kW/day, whereas the energy needed during daytime is only 158 kW/h. The solar insolation and shadow analysis reveals that roof area is not mutually shaded and receives an insolation of 5.5 kW/day (Figures 5–7).

Comparison of area and city-wise consumption

Comparative study of energy consumption reveals an increase in energy consumption with increase in floor area (Figures 8 and 9). Compared to Coimbatore, energy consumption in Chennai was higher with almost equivalent floor area (Figure 10). The electricity consumption ranges from 130 to 980 units per two-months average.

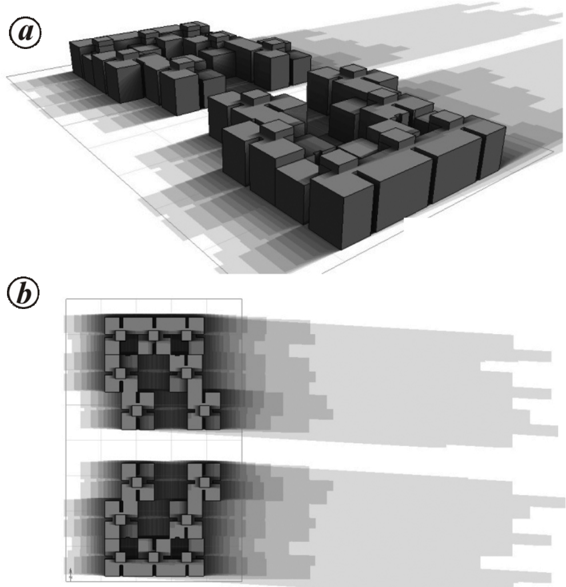

Figure 2. ***a***, ***b***, Ecotect: shadow analysis (G + 4) medium-rise apartment in Chennai.

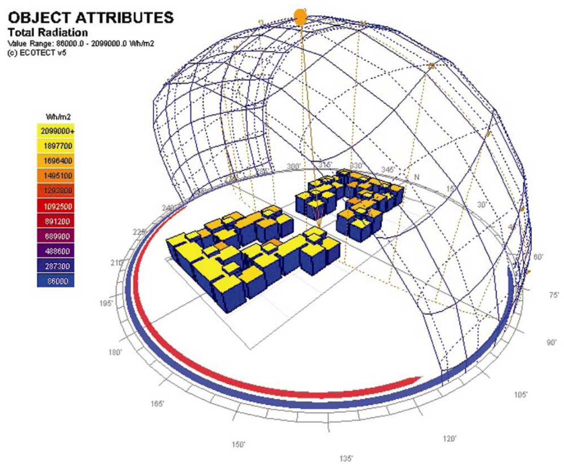

Figure 3. Ecotect: solar insolation study of (G + 4) medium-rise apartment in Chennai.

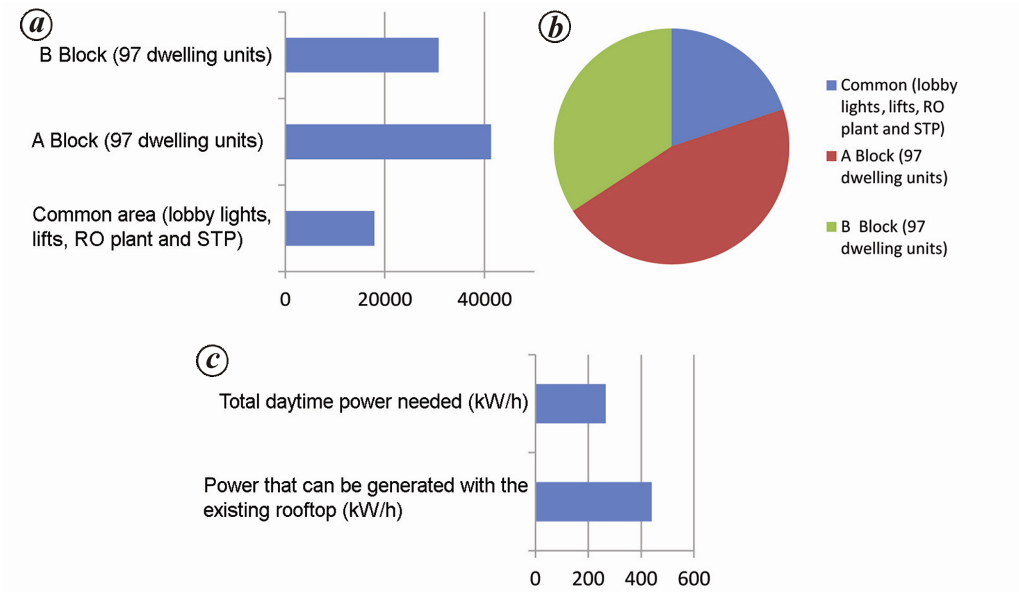

Figure 4. ***a***, ***b***, Power distribution among various blocks in a G + 4 apartment in Chennai (kWh). ***c***, Solar rooftop potential with the existing rooftop area.

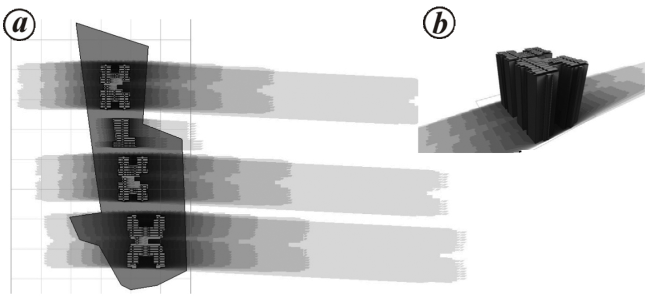

Figure 5. ***a***, ***b***, Ecotect: shadow analysis (G + 10) apartment in Coimbatore.

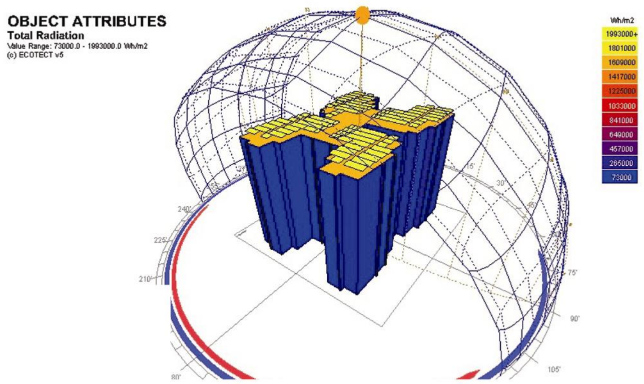

Figure 6. Ecotect, solar insolation study of (G + 10) apartment in Coimbatore.

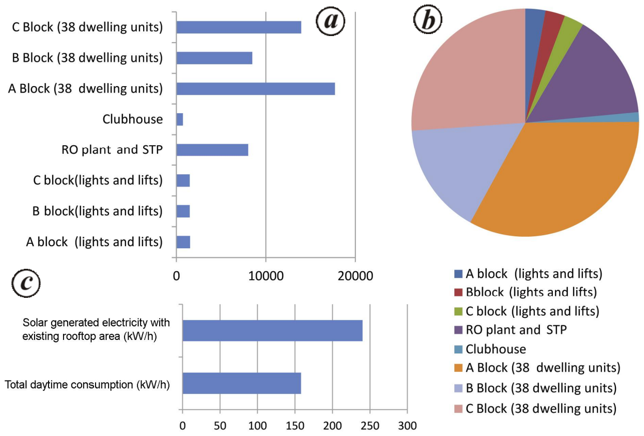

Figure 7. ***a***, ***b***, Power distribution among various blocks in a G + 10 apartment in Coimbatore (kWh). ***c***, solar RTPV potential.

Business models

Net-metering business models

Net metering-based rooftop solar project is used primarily for self-consumption and the excess energy genetrated is fed into the utility grid. The net metering-based consumption works on two business models at the international level. In India too, most of the states follow both the models[6].

- Self-owned arrangement wherein rooftop owner also owns the PV system (Figure 11).
- Third party ownership in which a developer owns the PV system and also enters into lease/commercial arrangement with the rooftop owner (Figure 12).

The business models proposed by MNRE, GoI are as follows:

(a) Solar installation owned by the consumer: (i) Solar rooftop facility owned, operated and maintained by the consumer(s) (Figure 11). (ii) Solar rooftop facility owned by the consumer(s) but operated and maintained by a third party.

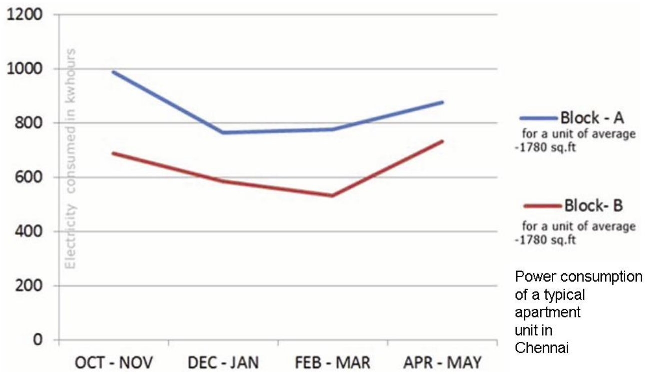

Figure 8. Comparison of power consumption for a dwelling unit in the G + 4 apartment in Chennai.

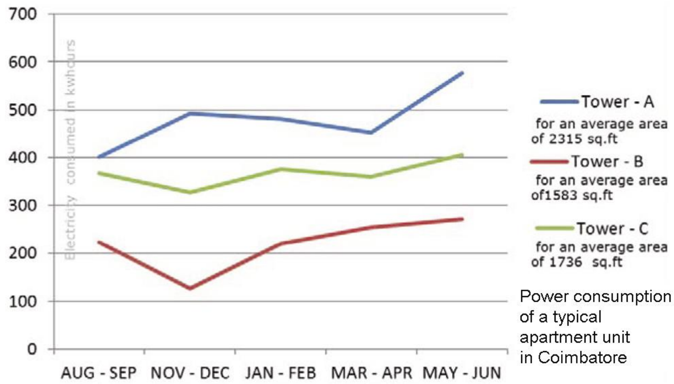

Figure 9. Comparison of power consumption for a dwelling unit in the G + 10 apartment in Coimbatore.

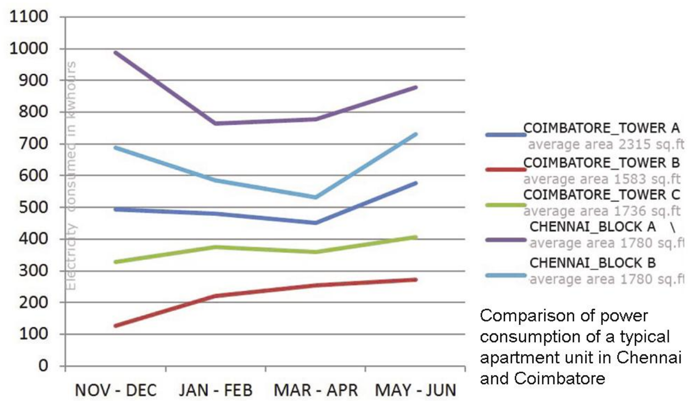

Figure 10. Comparison of power consumption for a dwelling unit in apartments in Chennai and Coimbatore.

(b) Solar installations owned, operated and maintained by a third party. (i) Arrangement as a captive generating plant for the roof owners (power sold to roof owner). (ii) Solar lease model, sale to grid (rooftop owner gets a rent) (Figure 12).

(c) Solar installations owned by the utility. (i) Solar installations owned operated and maintained by the DISCOM (distribution companies). (ii) Distribution licensee provides appropriate viability gap funds (third party to implement on behalf of DISCOMS).

There can be many such business models which may be developed/adopted depending upon the market conditions, user's interest, and initiatives by ESCOS (energy services company)[13].

Conclusion

Suggested development regulations

The present studies undertaken at Chennai and Coimbatore were both from high income group (HIG). For HIG

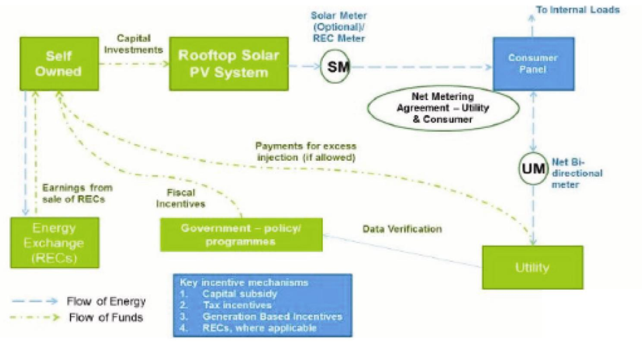

Figure 11. Self-owned arrangement wherein rooftop owner also owns the PV system. (Source: http://www.teriin.org/eventdocs/files/rooftop-solar-PV-Exp_mar.pdf.)

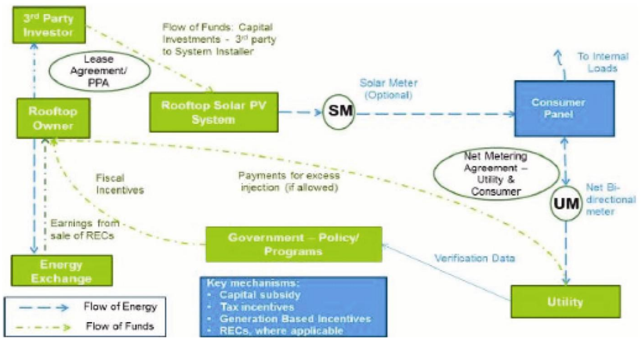

Figure 12. Third party ownership in which a developer owns the PV system and also enters into a lease/commercial arrangement with the rooftop owner. (Source: http://www.teriin.org/eventdocs/files/rooftop-solar-PV-Exp_mar.pdf.)

the maximum number of floors for an average of 1500 sq. ft (from case studies) area per dwelling unit is 15 floors (energy need assumed to be 1 kW/household). But with middle income group housing, where the area ranges from 600 to 1200 sq. ft (ref. 14), the energy need would also be 1 kW/household as they would have the same electrical gadgets as that of the HIG housing. In that case the maximum number of floors that can be regulated may be 10 or less if we take on an average of 1000 sq. ft rooftop area required to generate 10 kW of electricity (Table 1).

Suggested schemes (business models) from field studies for RTPV

The study of medium-rise and high-rise developments in Chennai and Coimbatore, reveal that there is enough rooftop for self-consumption in both cases. However, the owners are not willing to invest in the RTPV scheme with the available subsidy of both local and central governments. The reason for this is that most of the occupants in both these schemes are tenants and not owners. As the rental returns are low compared to their investments, the owners are hesitant to invest more. The net metering type of business model that is already in vogue in the international scenario may be feasible in India, where the roof is rented to a third party for lease and the generated electricity in turn is fed into the utility grid and for self-consumption to the rooftop owners at a subsidized cost or less that of the cost of the utility grid, thereby promoting the RTPV scheme is feasible.

Tamil Nadu can invite potential investors to follow such business models to ease the burden of individual residential consumers. But for new construction, the implementation scheme for a medium rise is 10 kW for every 4000 sq. ft (four floors @1000 sq. ft each for a single flat) of built-up area adds on Rs 600,000 (including the subsidy of central and state governments) that would add up to Rs 150 per sq. ft, which is highly affordable for the potential buyers.

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