A Review of Consumer Adoption of Rooftop Solar PV in India and Effective Frameworks

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Abstract

It is always intriguing to know how and why individuals adopt innovations. This paper found out the variables that lead to adoption of rooftop solar PV and proposed a model that could explain the factors behind adoption of rooftop solar PV in India. The framework is very unique in nature as no such model is available exclusively for rooftop solar PV adoption and no research is available to find out the factors that lead to its adoption. Just like Rogers's theory of adoption, this paper also found out five key factors for adoption of rooftop solar PV systems. It identified all possible variables from an exhaustive literature review and then grouped them into five key factors that adopters considered for adoption of rooftop solar PV systems. Using the proposed model, it would be possible to identify the reasons for the poor adoption of rooftop solar PV in India so far and a possible roadmap to meet India's ambitious target of 40 GW rooftop solar PV adoption by the year 2022. The paper also explained the current energy scenario of the country and also the status of rooftop solar PV with respect to leading countries using descriptive statistics. The paper offered future research opportunities and spelled out the limitations as well. The research was carried out in May and June 2018.

Keywords : **adoption, solar PV, rooftop, photovoltaic, renewable**

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With the current focus on solar energy and especially on rooftop solar photovoltaic (PV) system and its future potential, an unprecedented need to study the consumer buying behavior of rooftop solar PV system has cropped up. Globally, or more specifically in countries like Germany, China, USA, and Japan, the growth of usage of rooftop solar PV system has been phenomenal. Several research studies are available to understand the major barriers to the adoption of rooftop solar PV. However, very little is known about how consumers adopt the rooftop solar PV system. The Indian economy is on a growth path and growth in the power sector is essential to the sustainability of this growth. A sustainable growth in the power sector will ensure that more than a billion people move towards prosperity, and the entire population gets access to electricity. This growth will be sustainable only when it does not come at the expense of the environment.

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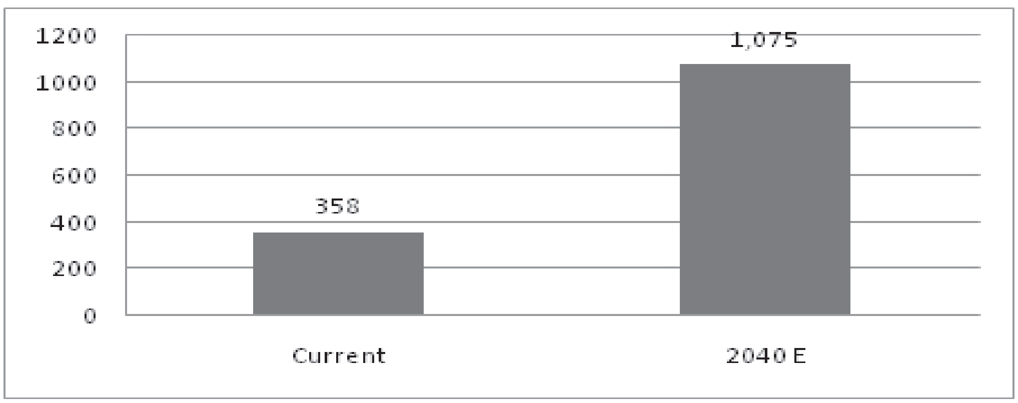
Power Sector Scenario in India

The current installed power generation capacity in India is 358 GW as on June 30, 2019 ("All India Installed Capacity (in MW) of Power Stations," 2019). Electricity in India reached out to around 81% of the total population as per World Energy Outlook 2015 (International Energy Agency (IEA)). India's installed capacity is nowhere compared to that of China or USA with China having 1,260 GW (IEA) and USA having 1,060 GW (IEA) of installed capacity by the end of 2013 (IEA). In most of the developing and developed countries, 100% of the population has access to electricity (IEA). Similarly, in terms of per capita electricity consumption, India at 1075 KWh as in June 2016 (CEA) consumed less than even a third of the global average. From the Figure 2, it can be seen that India's per - capita consumption is around a tenth of the consumption in countries like the U.S. or Canada.

As it can be inferred from the Figure 1, in India, there is a need to add close to 700 GW of electricity generation capacity by 2040 to be able to provide electrification to the entire population and meet the rise in demand (IEA).

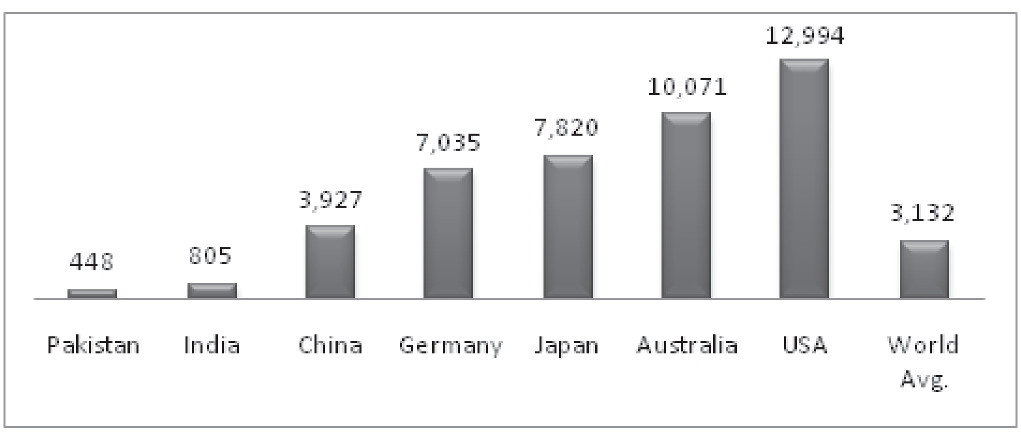
India depends heavily on coal fired thermal power plants that are highly polluting to the environment. The Figure 3 provides a break up of electricity installed capacity of India from different energy sources. As far as emissions of carbon dioxide are concerned, India is ranked fourth in the world. Half of these emissions are

Figure 1. Required Installed Capacity in GW



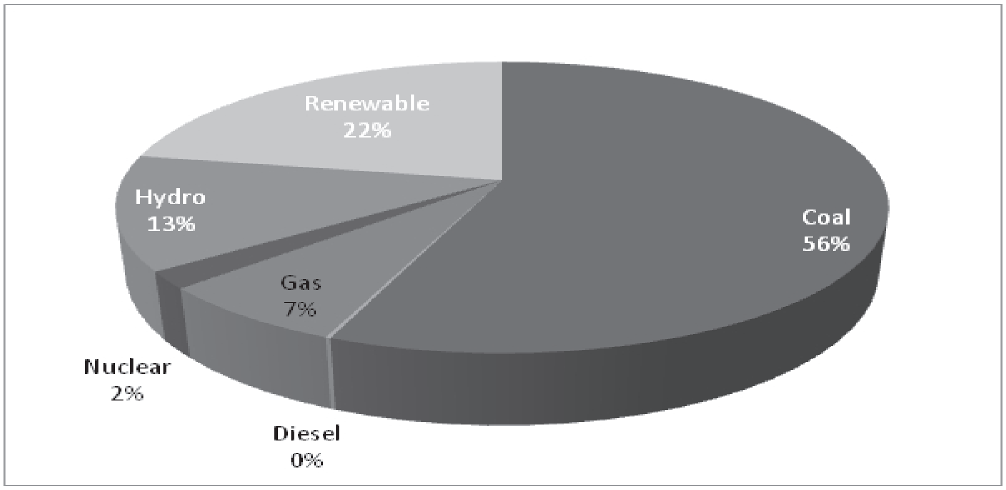
Source : All India Installed Capacity (in MW) of Power Stations (2019) and India Energy Outlook (2015)

Figure 2. Annual per Capita Electricity Consumption in KWH



Source : The World Bank (2014)

Figure 3. Break-up of India's Installed Capacity of 358 GW



Source : All India Installed Capacity (in MW) of Power Stations (2019)

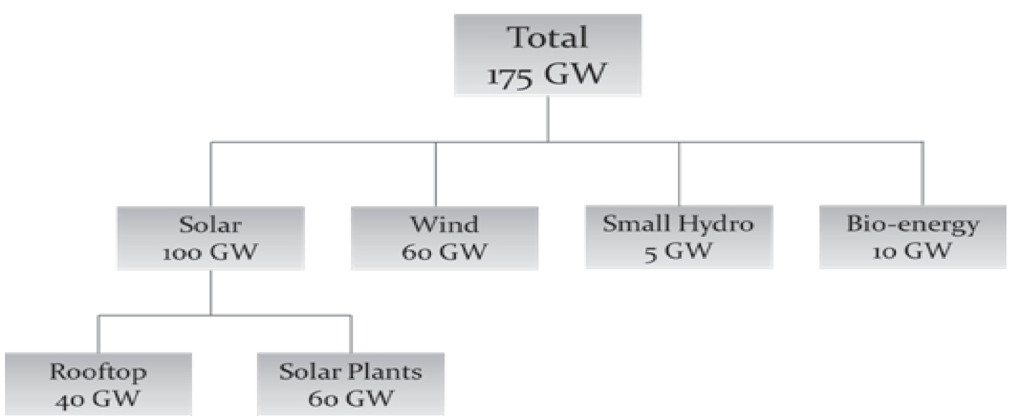
contributed by the power sector. It will be a disaster for the entire world if India continues with its existing way of using fossil - fuelled power plants to meet its massive future need for electricity.

Solar PV in India

Respecting the global concern for the environment, India has unveiled its own bold initiatives and has pledged to generate at least 40% of its energy requirements from renewable sources by 2030. The government has come up with an ambitious target of setting up of 175 GW renewable energy units by the year 2022 as shown in Figure 4 (Niti Aayog, 2015). Solar power will have the lion's share of the target at 100 GW.

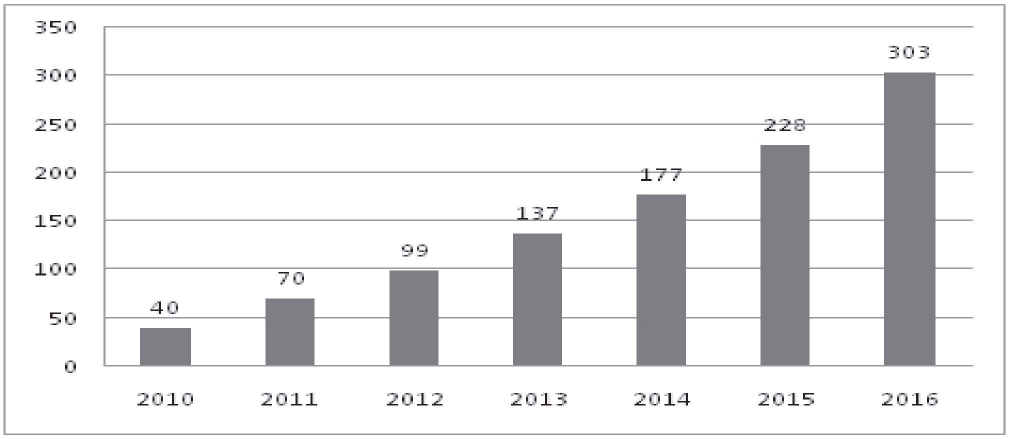
If we consider the current status of solar power in India, this plan sounds highly ambitious. Due to favourable solar radiation throughout the year, India has got massive potential for solar power. However, the contribution of solar energy to the overall growth of the Indian power sector has been abysmally low. In India, power generation from solar PV as a percentage of total power demand in India is less than even 1% (as of 2015) ; whereas, the

Figure 4. India's Renewable Energy Target by 2022



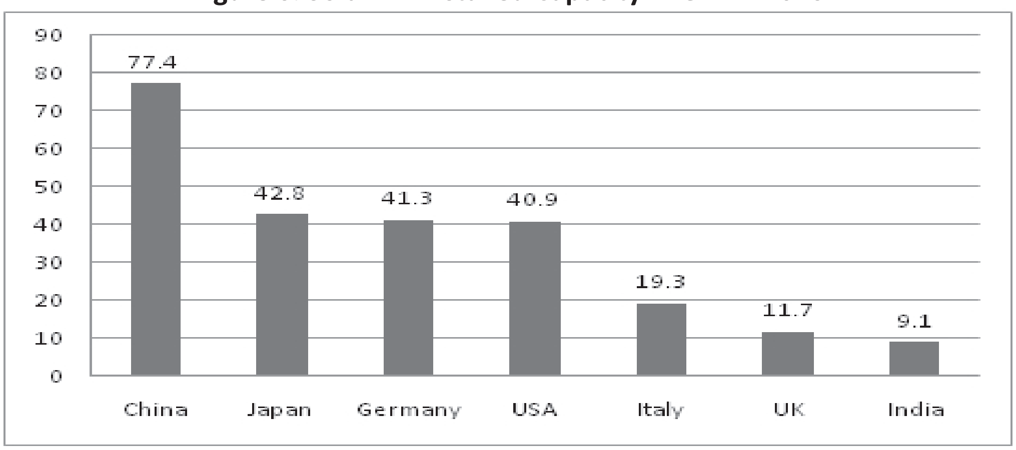
Source : Niti Aayog (2015)

Figure 5. Global Solar PV Installed Capacity in GW



Source : REN21 (2017)

Figure 6. Solar PV Installed Capacity in GW in 2016



Source : REN21 (2017)

corresponding figure for countries like Italy or Germany is almost 8%. The Figure 5 shows the growth in installed capacity for solar energy worldwide. From the Figure 6, it can be easily seen that solar PV installed in India is significantly lower as compared to countries like China, Germany, Japan, and USA.

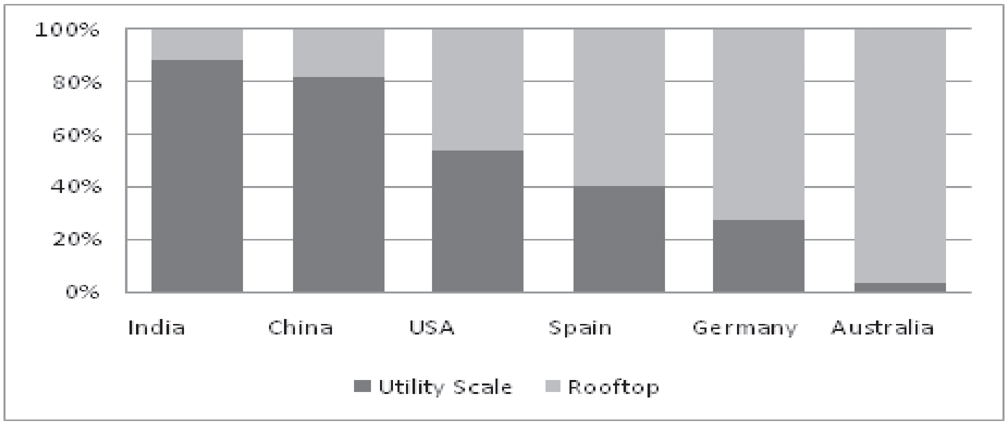
Rooftop Solar PV Systems in India

Over the last few years, the growth in non - rooftop solar plants has been extremely encouraging, however, that of rooftop solar PV systems is poor. Contribution of rooftop solar PV to the total solar PV is only around 10% - 12% in India ; whereas, the corresponding figure is more than 50% in countries like Germany, USA, or Australia (REN21, 2017). The Figure 7 explains the share of rooftop solar PV in the entire solar PV category in different countries.

Against a target of 40 GW by the year 2022, as of March 2017, the installed capacity of rooftop solar PV in India was only 1.4 GW as shown in Figure 8. The target of 40 GW is much lower than the 352 GW of technical potential in India as shown in Figure 9.

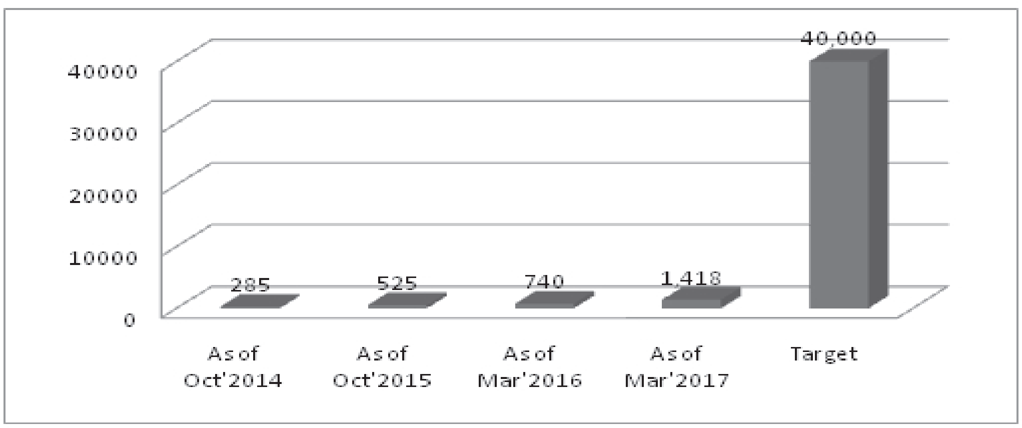
Role of rooftop solar PV in providing clean energy and also electricity to households in remote locations is

Figure 7. Share of Rooftop Solar PV Systems in Total Installation



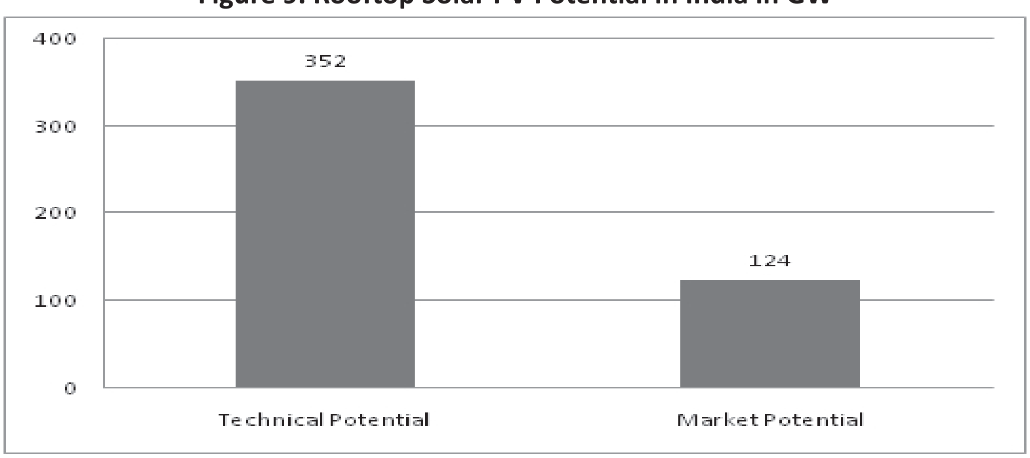
Source : REN21 (2017)

Figure 8. Rooftop PV Capacity in India in MW



Source : Bridge to India (2017)

Figure 9. Rooftop Solar PV Potential in India in GW



Source : Niti Aayog (2015)

undisputable. So, growth of adoption of rooftop solar PV systems in India holds importance in the growth of the entire power sector.

Literature Review

(1) Advantages of Rooftop Solar PV : The solar photovoltaic system has got many advantages. Such major advantages coupled with a few other factors act as a catalyst for the adoption of solar PV. A research identified the advantages of solar photovoltaic power as : (a) it does not emit green house gases, (b) the energy production is noise free, (c) the solar PV system has a long life and can work efficiently for around 25 years, (d) the maintenance cost is low, (e) the solar PV system is easy to install (Kamalapur & Udaykumar, 2011). The cost of the solar PV system has been falling very rapidly over the years. This drop in capital costs of solar PV system and growth in emission reduction ambitions is expected to result in solar PV becoming a major player in future power generation (Gilmore, Vanderwaal, Rose, & Riesz, 2014). Among renewable energy in India, the first one to enter was wind energy, much before solar energy. Although a late entrant, solar energy is the leader among renewable energy due to its significant advantages. The most notable advantages identified are that solar energy is more predictable and there is abundance of its availability (Muneer, Asif, & Munawwar, 2005). Solar PV is highly useful for people living in remote locations. A research paper in Tajikistan confirmed the huge potential of solar PV in improving the livelihoods of mountainous communities living in remote locations in a sustainable manner (Zandler, Mislimshoeva, & Samimi, 2016). In Bangladesh, it was noticed that the growing popularity of solar PV is due to a number of advantages. These advantages are mainly : (a) availability of smaller modules, (b) no use of scarce resources like fossil fuel and water, (c) the solar PV system does not have any moving parts resulting in low maintenance requirement (Mondal & Islam, 2011). A study in India confirmed the many advantages of solar PV and those are : (a) India receives very high solar radiation with 4 to 7 kWh/m^2 of daily incidence, (b) low marginal cost of generation, (c) augmentation of energy security due to diversification in supply, (d) drop in dependency on imports, (e) reduction in volatility of fuel prices, (f) spur in economic development of different regions (Sharma, Tiwari, & Sood, 2012). Concerns about climate change and various environmental hazards acted as the drivers of adoption of solar PV in Hong Kong (Li, Cheung, Lam, & Chan, 2012).

Global potential of solar energy is the highest among all renewable energy sources. In the American city of San Francisco, buildings receive annual solar radiation ranging from 967 to 2110 kWh/m^2 (Li, Zhang, & Davey, 2015). The enormity of rooftop solar PV is proved from the fact that in Lebanon, only 12.5% of the entire residential building rooftop surfaces should be able to generate the total electricity needed for the region, and thus, there won't be any need to burn fossil fuel in power plants (El-Bayeh & Moubayed, 2015). As suggested by a research in Denmark, it is actually possible for the entire world to shift to 100% renewable energy, and if it is actually done, the result will be astounding, and by the year 2050, GHG emissions can be reduced to 10.2% of 2000 levels (Vad Mathiesen, Lund, & Karlsson, 2011). A study in Oman indicated that 7025 tons of GHG emissions could be eliminated if a 5 MW diesel power plant was replaced by solar PV and the corresponding figure for a 5 MW natural gas power plant was 5944 tons (Al-Badi, Albadi, Al-Lawati, & Malik, 2011).

At a time when the average temperature of the world is increasing and heat waves are becoming intense, the rooftop solar PV system has got a major benefit that generally goes unnoticed. As the PV panels prevent the sunlight from directly falling on the roof, the buildings remain comparatively cooler, and so the load required for cooling the buildings gets substantially reduced (Sadineni, Atallah, & Boehm 2012). A similar study in Canada confirmed this claim about reduction in building cooling load (Rowlands, 2005). Applying computer simulation in a research in India, it was found that installation of rooftop PV system resulted in reduction of cooling load of the building by 73% to 90% (Kotak, Gago, Mohanty, & Muneer, 2014). Generally, it has been a practice to meet the peak load demand from electricity generated through fossil fuel plants. However, a research in Greece suggested that rooftop solar PV not only reduces conventional energy use, but also helps neutralize the peak demand. Another major advantage of rooftop solar PV is that there is a significant drop in transmission and distribution losses as electricity is generated at the point of use. Drop in transmission and distribution losses helps the utility companies reduce capital and maintenance costs (Bakos, Soursos, & Tsagas, 2003).

(2) Barriers Towards Adoption of Rooftop Solar PV Systems : Even if the rooftop solar PV system has many advantages, the adoption is still low due to a number of obstacles. The key barriers are : (a) high initial cost of installation, (b) availability of limited financing options by financial institutions, (c) consumers' lack of awareness, (d) absence of standardization in rooftop solar PV systems, (e) insufficient supply chain, (f) lack of experience in connecting the grid at low voltage, (g) limited ability of rooftop solar PV systems to operate when there is power outage, (h) expensive dual function inverters in India.

A survey conducted in the Indian territory of Puducherry identified the major obstacles and those are : (a) discomfort among prospective consumers about rooftop solar PV technology, (b) higher installation cost, (c) longer pay - back period, (d) confusion over government subsidy, (e) unsuitability of rooftops for PV installation, (f) need for a battery (Kappagantu, Daniela, & Venkatesh, 2015). In her paper, Goel mentioned the major barriers to growth in adoption of rooftop solar PV in India as : (a) lack of awareness among prospective consumers, (b) absence of sufficient solar PV manufacturing and R&D facilities, (c) less know-how of installation technology, (d) absence of sufficient skilled workforce, (e) absence of alternate business models, (f) difficulty in developing smaller grid for rooftop solar PV, (g) difficulty in integrating solar PV electricity with the grid, (h) drawbacks in the regulatory framework (Goel, 2016). Another paper identified higher cost of capital as a major obstacle to the adoption of rooftop solar PV systems in India (Gupta, Sharma, & Jasuja, 2009). Another research in India mentioned lack of awareness, non - availability of sufficient outlets to procure, insufficient number of business models that can match the needs of different user segments, high installation cost, and limited hours of electricity generation as some of the major factors for poor adoption of solar PV systems (Chaurey & Kandpal, 2010 ; Velayudhan, 2003). A study in India revealed that some of the limitations of the PV system are its high capital cost and inability to support large load (Kamalapur & Udaykumar, 2011).

A study in Punjab identified five major factors that determine the acceptance of solar energy products and these are benefits, attitude, awareness, investment, and promotion. The study also identified lack of financial support by the government and high initial cost as major barriers to the diffusion of solar energy products (Kansal, Pathania, & Saini, 2017). Another study in Telengana state in India indicated that perceived benefits combined with demographic variables played a major role in the adoption of solar energy products (Srivastava & Mahendar, 2018). A study conducted in Indore, Madhya Pradesh on adoption of solar energy products like solar inverters, solar water heating systems, solar lights, etc. identified the major barriers to the adoption of solar products as perceived high cost, financial constraints, lack of awareness about government initiatives, and absence of promotional activities (Nag & Chowdhary, 2019).

In China, the key barriers to rooftop solar PV adoption, as found out by a recent study, are : (a) inappropriate or unsuitable rooftops, (b) poor durability of a number of rooftops, (c) lower residential electricity tariff, (d) poor legal and institutional system for enforcing and protecting contracts, (e) financing difficulty, (f) absence of proper technical standards for connecting solar PV to the grid at various voltage levels, (g) substantial delay by government in implementing policies, and (h) non - availability of labour. Surprisingly, while one research supported cost as a key barrier (Liu, Lund, Mathiesen, & Zhang, 2011), another contradicted it (Zhang, Deng, Margolis, & Su, 2015).

A study in Bangladesh found out the factors of solar PV adoption and classified those as geo-physical, economic & socio-political, and environment factors. Geo - physical factors are available rooftop area, location of the building, and solar radiation received by rooftops. Economic & socio-political factors are political commitment, social acceptance, technology support, and capital investment. Environment factors are basically GHG emission reduction and protection of the environment (Kabir, Endlicher, & Jägermeyr, 2010).

In Thailand, even if its National Energy Policy Commission adopted new FIT (feed-in tariff) in 2013 for both rooftop and community ground-mounted solar installations, the target for the residential rooftop segment was not achieved (Suppanich & Wangjiraniran, 2015). The paper identified 20 critical variables both for acceptance and rejection of rooftop PV systems and those are : global warming, technology development, unlimited power, environmental protection, building location, social value, land use, power system, solar energy knowledge, global trends, power production monitoring, building structure, installation space, GHG reduction monitoring, neighbour's attitude, maintenance, income statistics monitoring, service providers' availability, cost of installation, and revenue generation.

In Pakistan, the major barriers were found out to be : (a) high upfront cost, (b) ambiguous renewable energy policy, (c) lack of awareness among people, and (d) poor technical knowledge (Solangi, Islam, Saidura, Rahim, & Fayaz, 2011).

A research done in Nepal almost seven years back noticed that cost of electricity from solar PV was more than that of the grid price and that was the major reason for poor adoption of solar PV systems (Bhandari & Stadler, 2011).

A study in Canada indicated that without a fall in the installation cost, LCOE or levelized cost of electricity was substantially higher than grid price and adoption of solar PV would be low till both become equal. It also found that high upfront cost of solar PV systems was still a hurdle in its adoption (Branker, Pathak, & Pearce, 2011).

A research in Egypt mentioned that higher initial cost of installation was a key barrier (Qoaider & Steinbrecht, 2010).

In Greece, delay in getting government approval was a major barrier. However, it was observed that that barrier was overcome by providing incentives in the form of subsidy on initial cost and higher FIT (Bakos, 2009).

A study in Mexico indicated that apprehension over the ease of use of technology was a critical barrier for adoption of solar PV rather than the widely viewed factors like cost, efficiency, or other technological issues (Chambouleyron, 1996 ; Chaurey & Kandpal, 2010). In Zimbabwe, it was noticed that finance schemes acted as catalysts for growth of solar PV (Chaurey & Kandpal, 2010 ; Marawanyika, 1997). In Hong Kong, the key barriers were high initial cost, requirement of large rooftop space, and clumsy external environment (Li et al., 2012).

Timilsina, Kurdgelashvili, and Narbel (2012) classified the barriers to solar PV adoption as : (a) technical, (b) economic, and (c) institutional barriers. Technical barriers were : (a) poor efficiency of PV modules, (b) incompatibility with other system components, (c) inadequate supply of raw materials, (d) compatibility of the existing electrical system with conventional energy. The economic barriers were : (a) initial cost of installation, (b) cost of generating electricity from solar PV, (c) financing problems due to risks involved. The institutional barriers were : (a) absence of appropriate laws or policies for utilities, (b) difficulty in training sufficient number of technicians, (c) lack of understanding of the basic solar PV system and the finance factors among local as well as national institutions, (d) procedural problems pertaining to financing and getting approvals from various agencies.

Demonstration of prototype solar PV systems was found out to be critical in spreading awareness among prospective consumers. A research confirmed the benefits of demonstration of PV systems in raising and spreading awareness among the prospective consumers and arranging finance for the purchase of PV systems by consumers (Adanu, 1994 ; Chaurey & Kandpal, 2010).

A research done almost a decade back reconfirmed the importance of bringing parity between cost of electricity from solar PV systems and grid price and how we are far away from becoming cost-effective in distributed residential systems (Yang, 2010). Research highlighted the unavailability of skilled technicians in developing countries as a barrier (Chaurey & Kandpal, 2010 ; Yordi, Stainforth, Edwards, Gerhold, Riesch, & Blaesser, 1997). In one more research, absence of effective financing options, lack of investments, lack of awareness, high installation costs, government subsidies provided to conventional fuels were found to be the market barriers for PV in least developing countries (Chaurey & Kandpal, 2010 ; Muntasser, Bara, Quadri, El - Tarabelsi, & La-azebi, 2000).

Policy Landscape in India

India, although a slow starter, has undertaken the largest capacity expansion of renewable energy in the world, with solar PV having the maximum share. Various policies, both at central and state levels are available for faster adoption of solar PV. As far as the Central government policies are concerned, the notable ones are capital subsidy, tax benefits through accelerated depreciation and tax holidays, and low cost funding. The Ministry of New and Renewable Energy (MNRE) is offering subsidy up to 30% for residential and institutional consumers. So, consumers can install the solar PV system technically at 70% of the cost. Apart from capital subsidy, tax benefits in the form of accelerated depreciation and tax holidays are being provided. Accelerated depreciation of 80% and 10-year tax holiday (MAT payable) are provided as incentives. The government also provides low cost funding through some banks. However, the most important policy - Feed-in-tariff that made solar PV adoption successful in so many countries is absent in India after the state of Gujarat introduced it in 2010 and found the financial burden too difficult to handle. Since then, no other state government got into this FIT scheme in India.

Several policies were enacted for faster adoption of solar PV system of which Electricity Act, 2003 is the most notable and a game changer. Also, through its well documented 5 year plans, the government has formulated various plans for adoption of solar PV systems.

Timeline for GOI's Journey Towards Renewable Energy

1981 : Commission of Alternate Sources of Energy (CASE) was created.

1982 : Within a year of its formation, CASE was made independent and named as Department of New Energy Sources (DNES).

1992 : DNES was made a full fledged ministry and called MNRE or Ministry of New and Renewable Energy.

2003 : The Electricity Act, 2003 is considered by many as a game changer for the Indian power sector. Through this act, it was made mandatory for distribution licensees to purchase renewable energy.

2005 : National Electricity Policy 2005 was introduced and the Act introduced preferential tariff for electricity generated from renewable sources.

2006 : Tariff Policy 2006 Act allowed special tariff for solar energy.

2006 : India started setting up targets for capacity addition through Integrated Energy Policy 2006.

2008 : For the first time, India adopted RPS or renewable portfolio standard through introduction of National Action Plan on Climate Change (NAPCC) 2008. It suggested renewable portfolio standard by targeting a minimum of 5% of total grids purchase from renewable sources initially and subsequent increase of 1% per year for 10 years.

2009 : To further incentivize solar PV, generation based incentives for solar energy were introduced.

2010 : Just like the Electricity Act, 2003, this year, another game changer, Jawaharlal Nehru National Solar

Mission (JNNSM) 2010, was introduced. The government set targets of 20 GW of grid connected and 2 GW of off-grid solar power capacity by 2022. The present government later amended the target to 100 GW.

2011 : The government brought in Renewable Energy Certificates (RECs).

2015 : MNRE reintroduced the 30% capital subsidy for residential consumers.

This section provides a glimpse of India's journey toward solar PV installation and how various policies were introduced to foster growth of adoption of solar PV systems. In India, the policies do vary across states, and state policies hold extreme importance for adoption of solar PV in India.

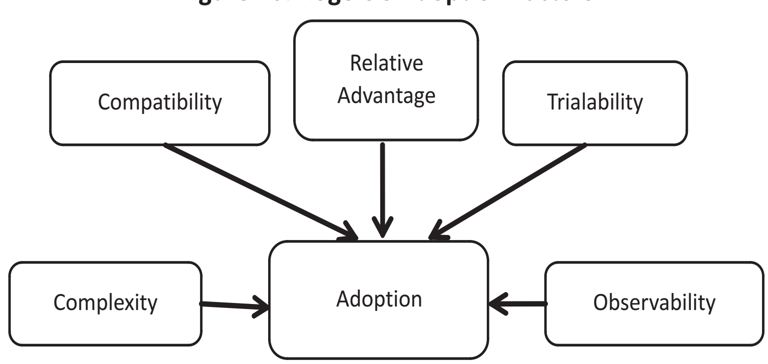
Theory Underpinned

It is always intriguing and fascinating to know how and why individuals adopt innovations. We all know Rogers's (1962) innovation diffusion theory and how it is considered a landmark in this field. As defined by Rogers, innovation is an idea, practice, or object that is perceived as new by an individual or a group of people. For an individual to adopt innovation, it is not necessary that it should be better or more beneficial to him/her. Rather, it can be noticed that all the innovations are not successful even if genuine attempts are made. Statistics from more than 30 years of research confirmed that almost a third of all innovations fail. So, it is very important to find out the factors that cause any innovation to fail. There is no dearth of rich literature with theoretical models that can address issues in the field of adoption of innovation.

Among all the theories discovered in this field, Rogers's diffusion of innovation theory or DOI is the most accepted and used theory. As per Rogers, there are five attributes most important for adoption of any innovation, and the importance of these factors can vary from one innovation to other. The Figure 10 describes these five attributes known as perceived attributes of innovation - relative advantage, observability, trialability, compatibility, and complexity.

Apart from Rogers's DOI theory, two other such theories are also considered good as far as finding attributes leading to adoption of innovations is concerned. One of these is meta - analysis (1982) by Tornatzky and Klein, and it identified 30 attributes that include the five attributes of Rogers. The other one is perceived characteristics of innovating theory (1991) by Moore and Benbasat. This theory, like Rogers, has identified five attributes that include two from Rogers. Kapoor, Dwivedi, and Williams (2014) recommended a brilliant theoretical framework taking into consideration all the three important aforementioned theories. The attributes proposed are summarized in the Table 1.

Figure 10. Rogers's Adoption Factors



Source : Rogers (1962)

Table 1. Attributes Proposed by Kapoor et al. (2014)

Attributes	Definitions	Sources
Relative Advantage	By what extent the innovation is better than the idea it displaces.	Rogers (2003) (as cited in Kapoor et al., 2014)
Compatibility	How far the innovation is consistent and compatible with existing values, past experiences, and needs of prospective consumers.	Rogers (2003) (as cited in Kapoor et al., 2014)
Complexity	Relatively how complex or difficult it is to understand and use the innovation.	Rogers (2003) (as cited in Kapoor et al., 2014)
Trialability	How easy or feasible it is to experiment the innovation on a lower scale.	Rogers (2003) (as cited in Kapoor et al., 2014)
Observability	The clarity of the results of an innovation visible to others.	Rogers (2003) (as cited in Kapoor et al., 2014)
Cost	All the costs associated when the innovation is used.	Tornatzky & Klein (1982) (as cited in Kapoor et al., 2014)
Risk	All kinds of risks associated with the innovation - like performance risk, financial risk, social risk, physical risk, psychological risk, etc.	Tornatzky & Klein (1982) (as cited in Kapoor et al., 2014)
Ease of Use	The perceived ease of using the innovation in terms of physical or mental effort.	Davis (1986) ; Moore & Benbasat (1991) (as cited in Kapoor et al., 2014)
Image	To what extent the innovation is perceived to enhance the societal image of the adopter.	Tornatzky & Klein (1982) (as cited in Kapoor et al., 2014)
Visibility	To what extent the use of the innovation is noticeable or apparent.	Tornatzky & Klein (1982) (as cited in Kapoor et al., 2014)
Voluntariness	To what extent the use of the innovation is perceived as pure voluntary without any compulsion.	Tornatzky & Klein (1982) (as cited in Kapoor et al., 2014)
Result Demonstrability	How tangible are the results of using the innovation that include observability and communicability.	Moore & Benbasat (1991) (as cited in Kapoor et al., 2014)
Social Approval	Level of social acceptance of the innovation.	Tornatzky & Klein (1982) (as cited in Kapoor et al., 2014)
Communicability	The ease and clarity of understanding the innovation can be clearly and easily understood.	Tornatzky & Klein (1982) (as cited in Kapoor et al., 2014)

Source : Kapoor et al. (2014)

Discussion

In India, no research is done to find out a framework of factors that explains the adoption of rooftop solar PV, which is the most prominent element of the entire gamut of solar energy in India. Through the literature review, all the variables that could affect the adoption of rooftop solar PV systems are identified. The list is made exhaustive through expert opinions too. We identified 45 variables; these variables were then grouped together under factors found from the literature review and thus could be clubbed into five factors. Using these factors, a framework is prepared to find out the perception of non - adopters towards rooftop solar PV so that action can be taken on factors where perception of non - adopters is not encouraging.

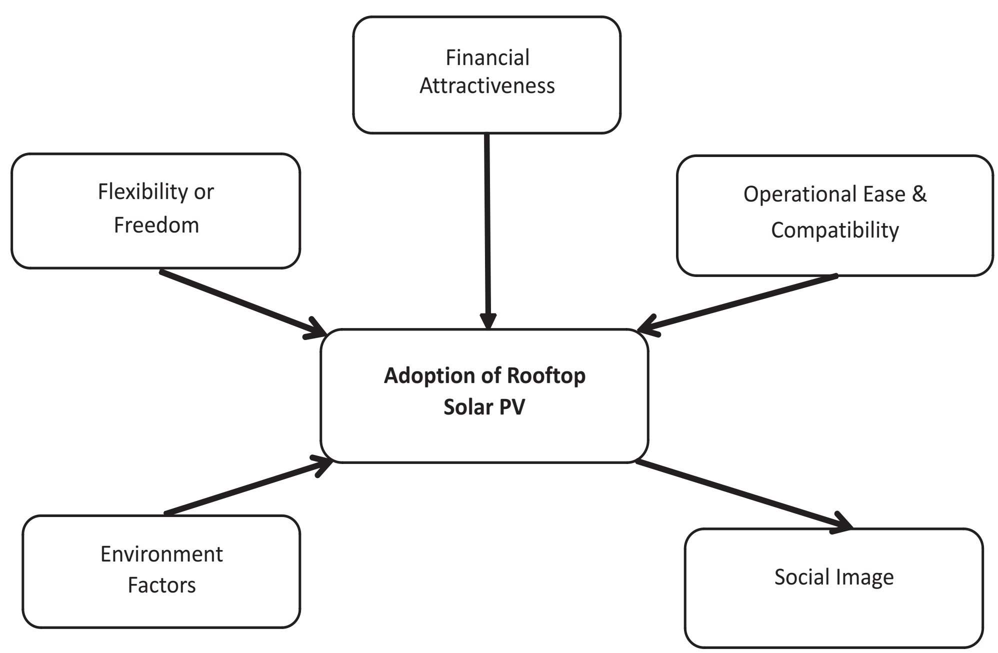
(1) Variables that Affect Rooftop Solar PV Adoption : From the existing theory, we have identified the various variables affecting adoption of rooftop solar PV and we did a grouping of the variables into five factors through exploratory factor analysis using '*r*' (Table 2).

Table 2. Proposed Factors and Variables for Adoption of Rooftop Solar PV Systems

Financial Attractiveness	• Upfront cost : The initial cost to install rooftop solar PV. • Return on investment with incentives : The return on investment after considering various incentives that the adopters receive. • Investment horizon : The lock-in period of the investment. • Grid power tariff in future : Possibility of grid power becoming cheaper or expensive in the future. • Grid power tariff at present : Current grid power being cheap or expensive. • Tax benefit in terms of depreciation allowed : Quantum of tax benefit due to depreciation allowed on rooftop solar PV installation. • Uncertainty over future FIT : Uncertainty over the FIT rate and continuation in the future. • Inadequate FIT : The attractiveness and magnitude of existing feed-in-tariff that you receive for selling power to the grid. • Subsidy : Amount of subsidy from the government for installing rooftop solar PV. • Operating cost : The operating cost for rooftop solar PV. • Difficulty in getting government incentives : Difficulty in receiving various incentives that the government provides for installing rooftop solar PV systems. • Difficulty in financing: Difficulty to arrange the initial financing required to install the rooftop solar PV systems.
Ease and Compatibility of Operation	• Compatibility of equipments : Compatibility of electrical appliances with power from rooftop solar PV. • Compatibility of building: The design of the roof is apt to support PV installation. • Inconvenience in use of rooftop: Installing rooftop solar PV makes it inconvenient for other use of roof. • No requirement of additional resources : Rooftop solar PV does not require any scarce natural resources like water or fossil fuel. • Ease of use: It is very easy to operate the rooftop solar PV system. • Inadequate supply of raw material: Availability of rooftop solar PV system in the market. • Quality of systems available in the market: Quality of rooftop solar PV systems available in the market. • Impact on building cooling load: Solar PV cells on the rooftop keep the roof protected from solar radiation and thus keep the building cool. • Availability of rooftop space: Sufficient rooftop space availability for PV installation. • Availability of service providers: Availability of service providers to install the solar PV system. • Building location : The building is receiving sufficient solar radiation or not. • Difficulty in maintenance : Difficulty in maintaining the rooftop solar PV system. • Building strength: Building is strong enough to take the additional load of rooftop solar PV. • Better peak load management: As more solar power is generated during the hotter part of the day ; thus, at a time when more power is needed to meet the cooling load of the building, rooftop solar PV helps in peak load management. • Monitoring of electricity usage: Due to new metering everyday, generation and consumption of electricity can be monitored easily. • Visibility: Benefits from use of rooftop solar PV systems are apparent.
Social Image Building	• Compatible with social value: Rooftop solar PV installation is compatible with social value. • Helping others to install: Your installing a rooftop solar PV system helps other people learn about it and then adopt the same. • Environment concern image: Helps create an image for the adopter about his/her concern for the environment. • Social acceptance: Society's favorable / unfavorable acceptance of rooftop solar PV. • Global trends: There is a trend globally to go with rooftop solar PV. • Image in the society: The social image gets enhanced due to rooftop solar PV adoption. • Communicability: The concept of rooftop solar PV can be understood easily.

	• Monitoring of income: Income from selling power generated through solar PV can be monitored by the government due to net metering.
Environment	• Global warming: Adoption of rooftop solar PV systems will help in global warming reduction. • GHG emissions: Adoption of rooftop solar PV will result in drop in green house gas emissions, especially Co_2. • Actual concern for the environment: Adoption of rooftop solar PV system shows consumers' actual concern for the environment.
Flexibility	• Independence : Adoption of rooftop solar PV system provides independence from utility providers or other agencies. • Trialability : Rooftop solar PV can be experimented on a limited basis before the final installation. • Result demonstrability : The benefits of using rooftop solar PV can be demonstrated easily. • Ease of dealing with utility provider : Process of net metering and getting connected to the grid. • Unlimited power: Rooftop solar PV provides unlimited power. • Inability to support large load: Rooftop solar PV system can't support very large electrical load.

Figure 11. Proposed Framework for Rooftop Solar PV Adoption in India



(2) Proposed Framework : After identifying the factors, a framework to study the adoption of rooftop solar PV systems in India is proposed as shown in Figure 11. This framework can find out the perception of adopters as well as non - adopters on the basis of the five factors discussed above.

Conclusion

Although a few research studies are available to understand the adoption process of some new technology like mobile phones or other electronic equipments, no such model is available to find out the factors for adoption of rooftop solar PV systems. A similar study was conducted in Punjab to find out the factors of adoption of solar energy products like solar cooker, solar water heater, solar light, etc., and the research found out five factors key to the adoption of these products. These five factors are : Benefits, Attitude, Awareness, Investment, and Promotion. These are different from the factors critical to adoption of rooftop solar PV systems found in the present study. The five factors found in this study are specific and easy to test. If we compare our findings with the five factors from Rogers's theory of adoption, Relative Advantage and Complexity are very much included. Relative Advantage in terms of Financial Attractiveness and Environmental Benefits are included in the framework. Similarly, Complexity in terms of Ease of Operation is included.

Implications

There is a significant need to overcome the barriers that limit the growth of rooftop solar PV adoption in India. Unless those barriers are identified and overcome, it won't be possible for India to achieve its ambitious target of reaching 40 GW of rooftop solar PV installation by the year 2022. Financial Attractiveness, Environment Benefits, Ease of Operation, Enhancement of Social Image, and Flexibility are the major factors that affect the adoption decision of the consumers for rooftop solar PV. Financial Attractiveness is a key factor for the growth of rooftop solar PV adoption in India. Although the Government of India has launched different schemes to make it attractive, it is equally important to spread awareness of such schemes among the prospective consumers. Ease of getting rooftop solar PV installed and operated is another critical factor. Unless consumers find the installation process as well as daily operation hassle free, adoption will be slow. Similarly, spreading awareness about the environment benefits of rooftop solar PV system and also the image enhancement it does through its installation will certainly help in greater adoption of rooftop solar PV in India.

Limitations of the Study and Scope for Further Research

The present study is conducted using extensive literature review. So, the findings may be limited to available literature and might have excluded research not yet available. Future scope of research is to test this framework by carrying out field surveys to capture the perception of both adopters and non - adopters regarding the extracted factors towards rooftop solar PV and find the difference.

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