Perception towards rooftop solar PV in India: comparison between adopters and non-adopters

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Abstract: The purpose of the study is to analyse the perception of consumers in India towards rooftop solar PV and find out if the difference in perception between adopters and non-adopters is a major reason for its poor adoption. It is surprising that growth in rooftop solar PV in India has been quite disappointing so far despite many obvious advantages. This paper through literature review found out five important factors of adoption for rooftop SPV and those are complexity, financial attractiveness, environment benefits, social image and trialability. On these five factors, the paper verified how the adopters perceive the rooftop solar PV in India compared to the non-adopters through statistical analysis of data collected through survey in the states of Kerala and Odisha in India.

Keywords: rooftop; solar; PV; perception; adoption; hypothesis.

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1 Introduction

Widespread adoption of rooftop solar system is a key element in meeting the growing energy demand in India. The country has achieved installed capacity of only 2.8 GW of rooftop SPV (MNRE, 2020) against a target of 40 GW by year 2022 (Niti Aayog, 2015). This incredibly slow adoption can have far reaching consequences not only on India's big push towards renewable energy, but also on its economic growth.

India is right now the fifth largest economy in the world and is also one of the fastest growing large economies (Investopedia, 2020). As per World Bank, the real GDP of India has grown at an average 6.8% per annum during the period between year 2000 and 2018 (The World Bank, https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=IN). Despite this phenomenal growth, per capita GDP of the country is one of the lowest in the world. The country still remains one of the poorest countries in the world with millions of people living below poverty line. Sustainability of the current faster growth of India's economy is the key to elevate the lives of millions of people who live under utter poverty and do not have access to basic amenities.

Sustainability of this faster economic growth of a large country like India has multitude of challenges, and the most important is meeting the growing energy need. Steps taken by India in terms of energy mix will increasingly influence the global climatic condition. The challenges of meeting the growing energy demand include adhering to climate commitments of significantly reducing carbon emissions proportionate to its GDP by 33–35% by 2030 from 2005 level, and reducing country's reliance on imported energy (Niti Aayog, 2015). Experts feel that such challenges warrant an accelerated transition to a lower cost, domestically available, low emission, and less water intensive energy economy and it should begin with the greening of the electricity sector and then progressively moving on to electrify transport and other major industries.

Electricity demand in India is expected to reach 1,692 BU (billion unit) in year 2022, 2,509 BU in 2027 and 3,175 BU in 2030 from the present demand of 1,275 BU in 2018–2019 (TERI, https://www.teriin.org/files/transition-report/files/downloads/Transitions-in-Indian-Electricity-Sector_Report.pdf). This growing demand seems very evident from the fact that per capita electricity consumption in India is less than 10% of per capita consumption in developed nations like USA and Germany and one third of global average (The World Bank, https://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC).

At present, share of coal in total electricity generation is almost 75% whereas that of renewable is only 9.2% (Institute for Energy Economics and Financial Analysis, 2019). The government has realised that the future requirement has to come from renewable and so, has set an ambitious target of 175 GW of renewable energy capacity addition by year 2022, with 100 GW coming from solar (60 GW ground mounted and 40 GW rooftop) (Niti Aayog, 2015). Because of dense population and environmental issues, adding new hydro, coal or nuclear plants is far from convenient. With the country blessed with almost year-round good solar radiation, rooftop solar PV seems to be the most viable option, having an edge even over ground mounted solar PV as it does not require any land or transmission infrastructure.

In the subsequent sections of this paper, the authors first review various literature, specifically scholarly articles in the field of rooftop solar PV. From the literature review the authors identified the research objective. After the research objective is identified, the next section elaborately explains the research methodology. The research methodology section is followed by data analysis and findings. Then the final section is all about the conclusion.

2 Literature review

Rich literature is available on rooftop solar PV and this section reviews literature on three specific themes:

1 global status of rooftop solar PV including India

2 barriers to adoption of rooftop solar PV

3 factors leading to adoption of rooftop solar PV.

2.1 Status of rooftop solar PV

Solar PV, both rooftop and ground mounted, has become world's fastest growing energy technology with its demand expanding to several countries (REN21, 2020). By the end of year 2019, at least 39 countries have installed solar PV capacity of 1 GW or more. Solar PV is already a significant and growing source of electricity generation in many countries like Honduras where its share is 10.7% of total generation. Other such countries are Italy (8.6%), Greece (8.3%), Germany (8.2%), Chile (8.1%), Australia (7.8%) and Japan (7.4%) (REN21, 2020). The corresponding figure for India is only 3.3% (Central Electricity Authority, Government of India, 2019).

Share of rooftop PV segment in the total solar PV in India is only 8% (MNRE, 2020). In other leading countries, share of rooftop is considerably higher. In UK it was 100%, in Italy 89%, in Germany 69%, USA 69% and even in Malaysia it was 20% (Suppanich and Wangjiraniran, 2015). In Australia, one of the most successful countries in rooftop solar PV adoption, it is close to 100% (Renew Economy, 2019) and as of December 2018, over 20% of its households had rooftop solar PV systems (Best et al., 2019). This is a very surprising revelation as in India share of rooftop solar PV should be higher due to good solar radiation, land scarcity, and poor transmission and distribution infrastructure.

2.2 Barriers to adoption of rooftop solar PV

Despite growth of rooftop solar PV across the globe, there are barriers to its adoption. Several research are available both in India and other countries in finding out the barriers to adoption of rooftop solar PV.

A white paper published by MNRE (TERI, 2014) has identified some key barriers to large scale adoption of rooftop SPV across various consumer categories in India and those are:

1 high upfront cost

2 limited financing schemes by banks

3 lack of awareness among consumers

4 limited standardisation of rooftop solar PV systems

5 inadequate supply chain for rooftop solar PV systems

6 inadequate experience of grid connectivity at low voltage

7 limitations of solar PV systems to function during power outage

8 higher cost of dual function inverter (which allows consumption of solar electricity during power outage).

A survey in Puduchery, India found out important barriers to rooftop solar PV and those were:

1 lack of consumer awareness about rooftop solar technology

2 initial cost of installation

3 higher payback period

4 lack of clarity on subsidy

5 suitability of rooftops

6 requirement of storage battery (Kappagantu et al., 2015).

Higher capital cost as a barrier was again confirmed by another research in India (Gupta et al., 2009).

Goel (2016) identified the key challenges in growth of rooftop solar PV in India. Those were:

1 consumer awareness and acceptance

2 manufacturing of solar cells and R&D

3 installation technology and skilled worked force

4 need for new business model

5 micro and mini grid development for distributed generation

6 integration of solar energy into national grid

7 challenges in regulatory framework (Goel, 2016).

Similar type of barriers were indicated by one more study in India and these were:

1 lack of awareness among prospective users

2 limited outlets for procurement

3 unavailability of different models catering to varying needs among various user segments

4 high price

5 limited hours of usage possible for solar systems (Velayudhan, 2003; Chaurey and Kandpal, 2010).

A study in India said that some of the limitations of PV were its high capital cost and inability to support large load (Kamalapur and Udaykumar, 2011).

A research conducted in Indore, Madhya Pradesh, India 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 and Chowdhary, 2019).

In India, IRR of a small rooftop SPV of capacity 2.5 kW was found to be around 9% without any financial subsidy by the government and 13% with subsidy (Narula and Reddy, 2015).

Average cost of installing rooftop solar PV in India was around INR 100,000 per kW (The Economic Times, 2019). Major cost components of rooftop solar PV system are solar panel (57%), inverter (15%), mounting structure (13%) and other electrical components (15%) (Prasanna et al., 2014). With an initial capital investment of only INR 100,000 per kW before subsidy, most of the rooftop solar PV systems are small ticket investments and so NPVs (net present value) are negligible.

It can be noticed from all these research in India that there is considerable overlap among the barriers found out in each research. The important barriers can be summarised as:

1 financial unattractiveness

2 lack of awareness among consumers

3 technical limitations in both installation and usage

4 absence of effective promotional schemes

5 supply chain problems

Just like India, considerable research is available in other countries in finding out major obstacles to adoption of rooftop solar PV.

A study in China found out major barriers to rooftop solar PV as:

1 difficulty in identifying suitable rooftops

2 short life span of many rooftop panels in China, which are often designed to last only 10 to 15 years instead of usual life span of 20 to 30 years

3 lower residential electricity tariff compared to commercial and industrial tariffs, making the self-consumption feed-in-tariff less attractive for residential systems

4 China's relatively weak legal and institutional mechanisms for enforcing contracts and contract payments

5 difficulty in financing

6 absence of standards for connecting PV to the grid at different voltages

7 government time lag in policy implementation

8 labour availability (Zhang et al., 2015).

Another research in China indicated that the cost of solar PV system was the most obvious barrier (Liu et al., 2011).

One of the major reasons for slow adoption of PV domestic systems in Asia and Pacific region was the use of very broad terms of administrative criteria (Urmee and Harries, 2009; Chaurey and Kandpal, 2010). Broad terms of administrative criteria indicated the hassle of getting the procedural clearance as well as receiving government incentives for installing rooftop solar PV. In Pakistan the major barriers were high initial cost, inadequate renewable energy policy, lack of awareness in local communities, and inadequate availability of technical knowledge (Solangi et al., 2011). A research done in Nepal found that cost of electricity from solar PV was higher than grid price and that was the major reason for the hindrance to its growth (Bhandari and Stadler, 2011). In Honk Kong major challenges were high initial cost, large installation space, and heavily obstructed external environment (Li et al., 2012).

A study in Saudi Arabia mentioned key barriers for any renewable energy as huge public subsidies for fossil fuels, government preferences to large scale and centralised projects, investment risks, lack of administrative experience with renewable technologies, and regulatory issues (Asif, 2016).

One more unique problem was identified from a research in South Africa. Although, rooftop solar PV had very long lifespan of around 25 years, its performance degraded over time (Fan and Xia, 2013). The efficiency at which the solar PV operates gradually drops over the period. Research in Zimbabwe showed presence of a finance scheme acting as a catalyst for PV growth (Marawanyika, 1997; Chaurey and Kandpal, 2010). A study in Bahrain confirmed that high capital cost, lack of necessary information on PV, and apprehension about maintenance related issues were the major barriers (Alsabbagh, 2019).

A study in Egypt further confirmed higher initial investment to be the major barrier to adoption of solar PV (Qoaider and Steinbrecht, 2010). A research in Greece supported this claim. It found out that, although the barrier was delay in getting approval, higher growth was witnessed during a period when 55% of initial cost was given as incentive, and there was presence of high FIT (Bakos, 2009). The study emphasised the necessity for a simplified licensing procedure and a better coordination through institutions for environmental approvals. Experiences from Mexico indicated technology-user interaction being a more critical problem for adoption of solar PV as compared to cost, efficiency, or other purely technological issues (Chambouleyron, 1996; Chaurey and Kandpal, 2010).

Although cost of solar rooftop PV is coming down, it is still debatable whether it can compete with fossil fuel under different circumstances and at different locations. A 5 MW solar PV plant studied in Saudi Arabia offered an internal rate of return (IRR) mean value of 13.53% while the minimum and maximum varied between 10.73% and 16.65% (Rehman et al., 2007). In Korea electricity from solar PV was found more expensive than other sources (Koo et al., 2011). In Oman, one study on a 5 MW solar PV plant indicated PV cost of electricity was higher than that from gas, but lower than diesel (Al-Badi et al., 2011).

A research in Canada suggested that without drop in installation cost, levelised cost of electricity (LCOE) was not at par with grid price. The high initial upfront cost of solar PV still seemed to be a hurdle to adoption, despite declining cost of systems (Branker et al., 2011). A study in UK indicated that larger size solar PV plants were financially more competitive. Rooftop solar installations of 50 to 250 kW returned positive NPVs, while some of the smaller capacity installations at some sites returned negative NPV (Adam et al., 2016).

Research highlighted the unavailability of skilled technicians required for promotion and installation of the systems in developing countries as a barrier (Yordi et al., 1997; Chaurey and Kandpal, 2010). Similarly lack of investments and financing, high transaction costs, subsidies to conventional fuels, and lack of awareness about PV systems at all levels were found to be market barriers for rooftop solar PV in least developing countries (Muntasser et al., 2000; Chaurey and Kandpal, 2010).

A research in the USA identified the barriers to the growth in adoption of rooftop solar PV as: lack of awareness by the end users and major stakeholders, extreme levels of risk aversion, worries about the system performance, and absence of suitable rooftop space for installations. However, the greatest obstacle perhaps was the combination of all these barriers (Castellanos et al., 2017).

Integration of rooftop solar PV systems at a high penetration level could impose a number of challenges for distribution network operators and one major problem was voltage rise in the network (Alam et al., 2012).

In another study, the authors classified the barriers to solar PV into technical, economic, and institutional barriers (Timilsina et al., 2012).

- Technical barriers were:
  1. low efficiency of PV modules
  2. performance limitations of other system components
  3. inadequate supply of raw material
  4. incompatibility of the existing electrical system with conventional energy.
- Economic barriers were:
  1. initial system cost
  2. high cost of electricity generated from PV
  3. financing problem owing to higher risk.
- Institutional barriers were:
  1. lack of effective and appropriate laws such as renewable portfolio standards or RPS for utilities
  2. limited ability to train adequate number of technicians to effectively work in a new solar energy infrastructure
  3. limited understanding among key national and local institutions of basic system and finance factors

4 procedural problems such as the need to secure financing from multiple sources and approvals from several agencies.

2.3 Factors of adoption of rooftop solar PV

Just like adoption of any new technology, a few key factors lead to adoption of rooftop solar PV as well.

A study in Punjab, India identified five major factors that determine the acceptance of solar energy products and these were 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 et al., 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 and Mahendar, 2018). The demograhic factors were mainly age, education, and income.

A recently done research in India identified five most important factors for adoption of rooftop solar PV in India and those were financial attractiveness, environment factors, operational ease and compatibility, social image, and flexibility or freedom (Satapathy et al., 2019)

A study in Bangladesh suggested that the determining factors for solar PV adoption were geo-physical factors (location, sunshine, solar radiation, available surface area), economic and socio-political factors (capital investment, technology support, political commitment, social acceptance), and environment factors (GHG emission reduction, environment protection) (Kabir et al., 2010).

In Thailand, despite its National Energy Policy Commission adopting new feed-in tariff in 2013 to support rooftop and community ground-mounted solar installations, the goal of the residential rooftop solar was not achieved (Suppanich and Wangjiraniran, 2015). The study found out 20 factors each for acceptance as well as rejection of rooftop PV. These can be broadly categorised as:

1 financial attractiveness

2 environmental benefits

3 ease of use

4 improving social image

5 influence of others.

2.4 Theory of innovation

For rooftop solar PV adopters, the process of adoption is an involved decision. Study on diffusion of innovation suggests that individual decision-making significantly impacts the success of widespread technology adoption (Robinson et al., 2013; Rogers, 2003) and this holds true for rooftop solar PV as well. Rogers' diffusion of innovation theory is the most well established and used theory in the area of adoption of new technologies (Kapoor et al., 2014). As per Roger's theory, there are five attributes most important for adoption of innovation. These five factors, known as perceived attributes of innovations, are: relative advantage, observability, trialability, compatibility and complexity. It is observed that 49–87% of the variance in the rate of adoption of innovations is explained by these five attributes. Rogers (2003) did admit there was lack of research on the effects of the perceived characteristics of innovations on the rate of adoption.

From all these literatures, the factors of adoption of rooftop solar PV can be summarised as:

1 financial attractiveness
2 complexity
3 environmental benefits
4 social image
5 trialability.

As individual decision-making significantly affects the widespread adoption of rooftop solar PV, perception of the individuals on these factors is very critical. There is possibility that perception of adopters on these factors is more favourable than that of non-adopters. It will be intriguing to verify and find out if there actually exists difference in perception between adopters and non-adopters of rooftop solar PV in India.

3 Research methodology

1 *Objective:* To find out the consumer perception of adopters and non-adopters towards rooftop solar PV in India.
2 *Approach:* Quantitative.
3 *Data collection plan:* Survey technique was used to collect primary data. Survey technique applies to studies that use deductive approach for exploratory and descriptive research. It is commonly used to answer questions like what, where, how much, and how many (Saunders et al., 2007). Another important aspect of questionnaire is the scale. The researcher preferred to select interval scale and the responses were collected on a seven-point interval scale with 1 means strongly disagree to 7 as strongly agree.
4 *Target population:* Households in states of Odisha and Kerala, India.
5 *Sampling design:* Random sampling in states of Odisha and Kerala.
6 *Sampling size:* 150 households, 75 each from adopters and non-adopters. Sample size depends on the required accuracy of result with a higher sample size reducing the probability of missing a hypothesis that actually exists, that means the type II error reduces. Also depending on the size of the sample, different statistical tools are recommended to test the hypotheses. A sample size of greater than 30 is considered large enough. However sample size was calculated using the formula $n = (Z\sigma/E)^2$ where Z is the value from Z table for a confidence level of 95%, σ is the standard deviation found through a sample of 30, and E is the margin of error acceptable. The questionnaire was administered through e-mail, online survey, telephone, and direct administration.

7 *Data analysis tools:* Hypothesis testing: hypothesis testing is a statistical procedure used by most experimenters (Frick, 1996). It is a systematic way of testing claims or ideas about the population. Despite a few critics, hypothesis testing still dominates research in social sciences (Loftus and Masson, 1994). Findings from previous research are used to formulate hypothesised directions of beliefs concerning rooftop solar PV.

Procedure

1 *Hypothesis formulation:* Adopters and non-adopters differ on their perceptions towards rooftop solar PV system. As compared to non-adopters:
   - a adopters rate such system as lower in complexity, both complexity in installation as well as operation
   - b greater in financial attractiveness
   - c greater in environmental benefits
   - d better in social image building
   - e more possible to try on a limited basis.

2 On a scale of 1 to 7, perception of adopters as well as non-adopters on the five factors were captured through a questionnaire.

3 From the data collected, the hypotheses formed were tested with a significance level of 5%. Both ‘z’ tests and chi-square tests were conducted to test the hypotheses. Among the alternate test statistics, the widely used z-test on the difference between two proportions performed reasonably well, except when sample size was extremely small (Collins and Morris, 2008). However, in ‘z’ test, sometimes type I error gets little inflated. So, chi-square test for goodness to fit is also applied to reduce type I error. Chi-square test was found to be one of the five most frequently conducted statistical tests (Ottenbacher, 1995).

4 Data analysis and findings

Data analysis was done to test six null hypotheses. The null hypotheses are:

1 adopters perceive rooftop solar PV less complex to install than non-adopters

2 adopters perceive rooftop solar PV less complex to operate than non-adopters

3 adopters perceive rooftop solar PV financially more attractive than non-adopters

4 adopters perceive environmental benefits of rooftop solar PV higher than non-adopters

5 adopters perceive adoption of rooftop solar PV improves social image more than non-adopters

6 adopters perceive trialability of rooftop solar PV system higher than non-adopters.

Data were collected from 150 respondents, 75 each from adopters and non-adopters of rooftop solar PV through a survey questionnaire. There were six questions to which the respondents were asked to give a score between 1 and 7 with 1 as strongly disagree and 7 as strongly agree. The six questions are:

1 installation of rooftop solar PV is complex
2 daily operation of rooftop solar PV is complex
3 installing rooftop solar PV is financially attractive
4 rooftop solar PV is environmentally beneficial
5 installing rooftop solar PV enhances social image
6 it is easy to install rooftop solar PV on a trial basis.

4.1 Hypothesis test on installation complexity

Ho Adopters perceive rooftop solar PV less complex to install than non-adopters.

Ha Adopters do not perceive rooftop solar PV less complex to install than non-adopters.

Table 1 ‘z’ test result for installation complexity of rooftop solar PV

Adopters		*Non-adopters*		*SD of both variables*	*‘Z’ value*	*Acceptable ‘z’ value*	*Hypotheses*
Mean	*Std. dev.*	*Mean*	*Std. dev.*				
3.16	1.49	3.93	1.61	0.25	–3.07	1.645	Failed to reject

‘z’ value of this two-sample variable $(3.16-3.93)\Big/\sqrt{(1.49^2/75+1.61^2/75)}=-3.07.$ On complexity of installation the mean score among adopters is 3.16 whereas it is 3.93 among non-adopters. Acceptable ‘z’ value is 1.645 for a 95% confidence level. From the means of the sample of adopters and non-adopters, the ‘z’ value found out was –3.07. As the ‘z’ value is less than the acceptable value of 1.645, the null hypothesis could not be rejected.

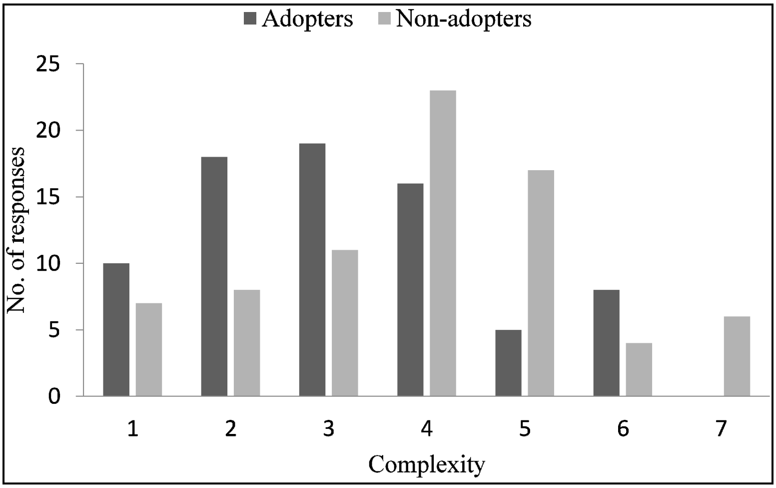
Table 2 Chi-square test summary for installation complexity of rooftop solar PV

Adopters		*Non-adopters*		*Chi-square value*	*Acceptable value for p = 0.05*	*Hypothesis*
Mean	*Std. dev.*	*Mean*	*Std. dev.*			
3.16	1.49	3.93	1.61	21.64	12.592	Failed to reject

Chi-square test proves that the difference in perception of adopters and non-adopters towards installation complexity of rooftop solar PV is statistically significant. But the difference is as expected as per hypothesis, and so the hypothesis could not be rejected.

As it can be seen, most of the respondents among adopters of rooftop solar PV chose low score on installation complexity, whereas a large section of non-adopters chose high score like 4 or 5. None of the adopters gave the highest score of 7 on complexity whereas a sizeable chunk among non-adopters opted for a score of 7 indicating the installation process is highly complex. The findings support the belief that one possible reason behind people not adopting rooftop solar PV, is that they perceive installation process to be very complex.

Figure 1 Perception on installation complexity of rooftop solar PV



4.1.1 Hypothesis test on operational complexity

Ho Adopters perceive rooftop solar PV less complex to operate than non-adopters.

Ha Adopters do not perceive rooftop solar PV less complex to operate than non-adopters.

Table 3 'z' test summary for operation complexity of rooftop solar PV

Adopters		*Non-adopters*		*SD of both variables*	*'Z' value*	*Acceptable 'z' value*	*Hypotheses*
Mean	*Std. dev.*	*Mean*	*Std. dev.*				
2.39	1.51	3.76	1.67	0.26	–5.26	1.645	Failed to reject

On complexity of operation the mean score among adopters is 2.39 whereas it is 3.76 among non-adopters. Acceptable 'z' value is 1.645 for a 95% confidence level. From the means of the sample of adopters and non-adopters, the 'z' value found out was –5.26. As the 'z' value is less than the acceptable value of 1.645, the null hypothesis could not be rejected.

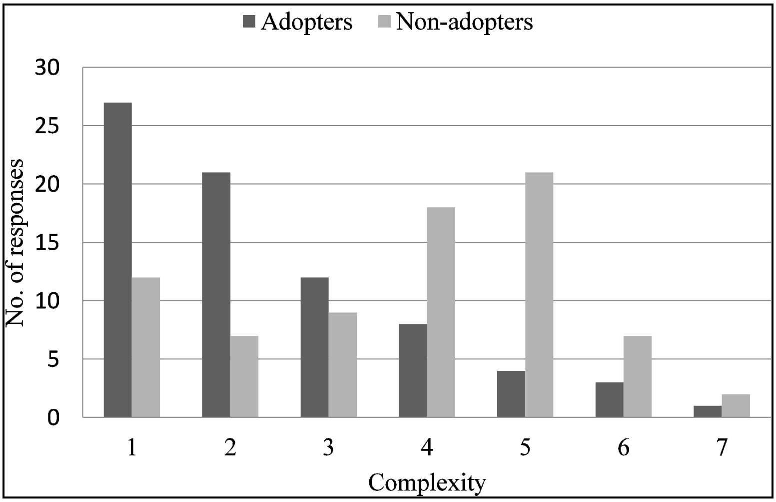
Table 4 Chi-square test summary for operation complexity of rooftop solar PV

Adopters		*Non-adopters*		*Chi-square value*	*Acceptable value for p = 0.05*	*Hypothesis*
Mean	*Std. dev.*	*Mean*	*Std. dev.*			
2.39	1.51	3.76	1.67	30.54	12.592	Failed to reject

Chi-square result indicates the difference in perception towards complexity of operating rooftop solar PV in India between adopters and non-adopters, is statistically significant and as per hypothesis.

A large number of adopters responded with a very low score of complexity for operating the rooftop solar PV whereas the number of non-adopters providing such low scores is significantly lower. The result demonstrates that only after consumers start operating the rooftop solar PV system in India, they realise that it is not complex to operate. The difference in perception between adopters and non-adopters is quite significant on this factor of complexity to operate.

Figure 2 Perception on operating complexity of rooftop solar PV



4.2 Hypothesis test on financial attractiveness

Ho Adopters perceive rooftop solar PV financially more attractive than non-adopters.

Ha Adopters do not perceive rooftop solar PV financially more attractive than non-adopters.

Table 5 'z' test result for financial attractiveness of rooftop solar PV

Adopters		*Non-adopters*		*SD of both variables*	*'Z' value*	*Acceptable 'z' value*	*Hypotheses*
Mean	*Std. dev.*	*Mean*	*Std. dev.*				
4.88	1.31	4.09	1.53	0.23	3.39	–1.645	Failed to reject

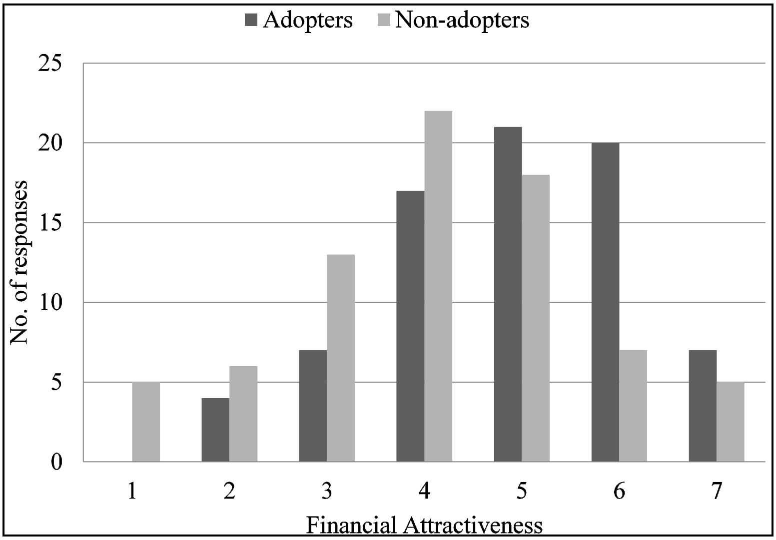
On financial attractiveness of rooftop solar PV in India, the mean score among adopters is 4.88 whereas it is 4.09 among non-adopters. Acceptable 'z' value is –1.645 for a 95% confidence level. From the means of the sample of adopters and non-adopters, the 'z' value found out was 3.39. As the 'z' value is higher than the acceptable value of –1.645, the null hypothesis could not be rejected.

Table 6 Chi-square test summary for financial attractiveness of rooftop solar PV

Adopters		*Non-adopters*		*Chi-square value*	*Acceptable value for p = 0.05*	*Hypothesis*
Mean	*Std. dev.*	*Mean*	*Std. dev.*			
4.88	1.31	4.09	1.53	14.66	12.592	Failed to reject

Chi-square test proves that the difference in perception of adopters and non-adopters towards financial attractiveness of rooftop solar PV is statistically significant. So, the hypothesis that adopters perceive rooftop solar PV to be financially more attractive than how non-adopters perceive could not be rejected.

Figure 3 Perception on financial attractiveness of rooftop solar PV



On perception about financial attractiveness of rooftop solar PV, the average scores of both adopters and non-adopters are more than 4. Not surprisingly, among adopters there is no one giving a score of 1. A certain number of non-adopters gave the lowest possible score, perceiving the rooftop solar PV to be financially not attractive at all. This is a very surprising revelation as there are different financial incentives that government provides to the consumers.

As financial attractiveness is one of the most important factors, more study can be carried out to find out the reason behind such poor perception. The problem can be either the existing incentive schemes are not effective or awareness about such schemes is not reaching the people.

4.3 Hypothesis test on environmental benefits

Ho Adopters perceive environmental benefits of rooftop solar PV higher than non-adopters.

Ha Adopters do not perceive environmental benefits of rooftop solar PV higher than non-adopters.

Table 7 'z' test result for environmental benefits of rooftop solar PV

Adopters		*Non-adopters*		*SD of both variables*	*'Z' value*	*Acceptable 'z' value*	*Hypotheses*
Mean	*Std. dev.*	*Mean*	*Std. dev.*				
5.92	1.58	5.98	1.41	0.24	–0.27	–1.645	Failed to reject

On environmental benefits of rooftop solar PV in India, the mean score among adopters is 5.92 whereas it is 5.98 among non-adopters. Acceptable 'z' value is –1.645 for a 95%

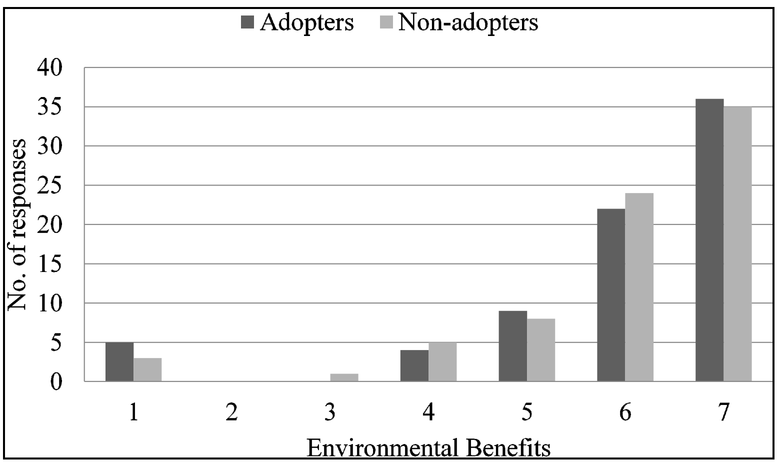
confidence level. From the means of the sample of adopters and non-adopters, the ‘z’ value found out was –0.27. As the ‘z’ value is higher than the acceptable value of –1.645, the null hypothesis could not be rejected.

Table 8 Chi-square test summary for environmental benefits of rooftop solar PV

Adopters		*Non-adopters*		*Chi-square value*	*Acceptable value for p = 0.05*	*Hypothesis*
Mean	*Std. dev.*	*Mean*	*Std. dev.*			
5.92	1.58	5.98	1.41	1.77	12.592	Failed to reject

Chi-square test proves that the difference in perception of adopters and non-adopters towards environmental benefits of rooftop solar PV is statistically not significant and so the null hypothesis could not be rejected.

Figure 4 Perception on environmental benefits of rooftop solar PV



From plotting the responses, it is easily noticeable that both adopters and non-adopters perceive rooftop solar PV system to have considerable environmental benefits. This is one factor where it seems both adopters and non-adopters are highly appreciative about the environmental benefits of rooftop solar PVs. The findings are not very surprising as benefits of rooftop solar PV or any other renewable energy, to the environment is very well known among people across the world.

4.4 Hypothesis test on improving social image

Ho Adopters perceive adoption of rooftop solar PV improves social image more than non-adopters.

Ha Adopters do not perceive adoption of rooftop solar PV improves social image more than non-adopters.

On improvement of social image due to adoption of rooftop solar PV in India, the mean score among adopters is 4.12 whereas it is 4.28 among non-adopters. Acceptable ‘z’ value is –1.645 for a 95% confidence level. From the means of the sample of adopters and non-adopters, the ‘z’ value found out is –0.57. As the ‘z’ value is higher than the acceptable value of –1.645, the null hypothesis could not be rejected.

Table 9 ‘z’ test result for improvement in social image through rooftop solar PV

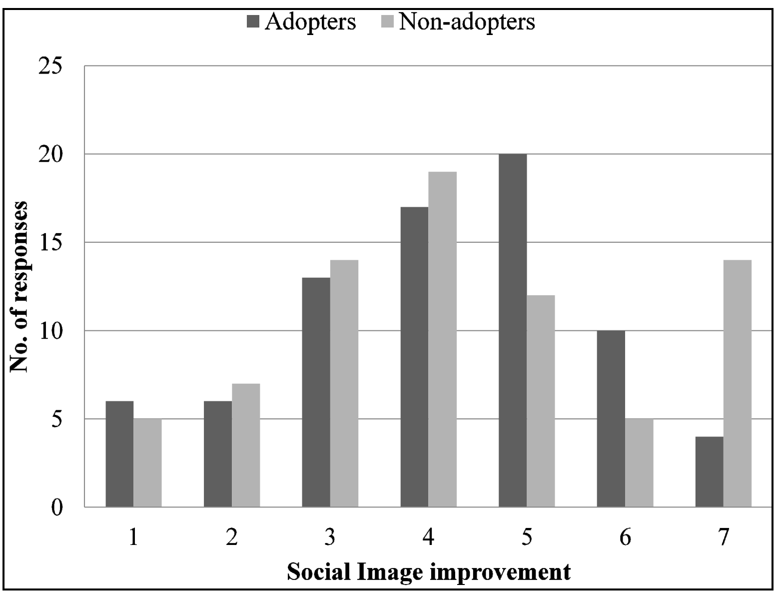
Adopters		*Non-adopters*		*SD of both variables*	*‘Z’ value*	*Acceptable ‘z’ value*	*Hypotheses*
Mean	*Std. dev.*	*Mean*	*Std. dev.*				
4.12	1.58	4.28	1.8	0.28	–0.57	–1.645	Failed to reject

Table 10 Chi-square test summary for social image through rooftop solar PV

Adopters		*Non-adopters*		*Chi-square value*	*Acceptable value for p = 0.05*	*Hypothesis*
Mean	*Std. dev.*	*Mean*	*Std. dev.*			
4.12	1.58	4.28	1.8	9.54	12.592	Failed to reject

Chi-square test proves that the difference in perception of adopters and non-adopters towards environmental benefits of rooftop solar PV is statistically not significant and so the null hypothesis could not be rejected.

Figure 5 Perception on improvement in social image through rooftop solar PV



It is noticed from the chart that both adopters and non-adopters are not very clear about the improvement in social image due to adoption of rooftop solar PV. Surprisingly, non-adopters are believing a little more than the adopters that adoption of the system will improve the social image.

4.5 Hypothesis test on trialability

Ho Adopters perceive that trialability of rooftop solar PV system is higher than non-adopters.

Ha Adopters do not perceive that trialability of rooftop solar PV system is higher than non-adopters.

Table 11 ‘z’ test result for trialability of rooftop solar PV

Adopters		*Non-adopters*		*SD of both variables*	*‘Z’ value*	*Acceptable ‘z’ value*	*Hypotheses*
Mean	*Std. dev.*	*Mean*	*Std. dev.*				
3.97	1.65	3.95	1.68	0.27	0.09	–1.645	Failed to reject

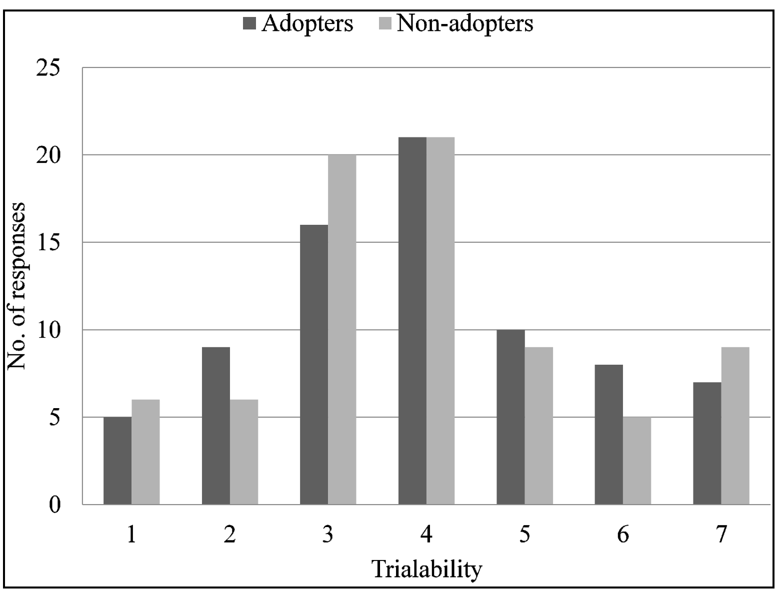
On trialability of the rooftop solar PV in India, the mean score among adopters is 3.97 whereas it is 3.95 among non-adopters. Acceptable ‘z’ value is –1.645 for a 95% confidence level. From the means of the sample of adopters and non-adopters, the ‘z’ value found out was 0.09. As the ‘z’ value is higher than the acceptable value of –1.645, the null hypothesis could not be rejected.

Table 12 Chi-square test summary for improvement in social image of rooftop solar PV

Adopters		*Non-adopters*		*Chi-square value*	*Acceptable value for p = 0.05*	*Hypothesis*
Mean	*Std. dev.*	*Mean*	*Std. dev.*			
3.97	1.65	3.95	1.68	2.13	12.592	Failed to reject

Chi-square test proves that the difference in perception of adopters and non-adopters towards trialability of rooftop solar PV is statistically not significant and so the null hypothesis could not be rejected.

Figure 6 Perception on trialability of rooftop solar PV



It is noticed from the chart that both adopters and non-adopters are not very clear about the trialability of rooftop solar PV. The mean scores of both adopters and non-adopters are almost identical. This is one more major concern as people will feel that adopting rooftop solar PV can turn out to be a trap for very long period. This is where demonstration projects are useful as we could see its impact in the growth of rooftop solar PV in Germany.

4.6 Summary of perception

Here is the summary of response we received and the ‘z’ test results for the hypotheses. The ‘z’ tests were conducted with 95% confidence level.

To eliminate possibility of type I error, chi-square tests were also conducted to test the null hypotheses.

Table 13 Perception against attributes of rooftop solar PV

	Mean score on a scale 1–7	
	Adopters	*Non-adopters*
Installation complexity	3.16	3.93
Operating complexity	2.39	3.76
Financial attractiveness	4.88	4.09
Environmental benefits	5.92	5.98
Social image building	4.12	4.28
Trialability	3.97	3.95

4.6.1 Hypotheses test result summary from ‘z’ test of rooftop solar PV

Using ‘z’ test results, none of the null hypotheses could be rejected at 95% confidence level. The perception of adopters towards rooftop solar PV was found to be more favourable than non-adopters. Especially on two critical factors, complexity and financial attractiveness, the perception difference is quite substantial. On other three factors, environmental benefits, social image building and trialability, both adopters and non-adopters have almost similar kind of perceptions.

Table 14 ‘z’ test result

	Adopters		*Non-adopters*		*SD of both variables*	*‘Z’ value*	*Acceptable ‘z’ value*	*Hypotheses*
	Mean	*SD*	*Mean*	*SD*				
Installation complexity	3.16	1.49	3.93	1.61	0.25	–3.07	1.645	Failed to reject
Operating complexity	2.39	1.51	3.76	1.67	0.26	–5.26	1.645	Failed to reject
Financial attractiveness	4.88	1.31	4.09	1.53	0.23	3.39	–1.645	Failed to reject
Environmental benefits	5.92	1.58	5.98	1.41	0.24	–0.27	–1.645	Failed to reject
Social image improvement	4.12	1.58	4.28	1.8	0.28	–0.57	–1.645	Failed to reject
Trialability	3.97	1.65	3.95	1.68	0.27	0.09	–1.645	Failed to reject

Table 15 Chi-square test summary of rooftop solar PV

	Adopters		*Non-adopters*		*Chi-square value*	*Acceptable value for p = 0.05*	*Hypothesis*
	Mean	*SD*	*Mean*	*SD*			
Installation complexity	3.16	1.49	3.93	1.61	21.64	12.592	Failed to reject
Operating complexity	2.39	1.51	3.76	1.67	30.54	12.592	Failed to reject
Financial attractiveness	4.88	1.31	4.09	1.53	14.66	12.592	Failed to reject
Environmental benefits	5.92	1.58	5.98	1.41	1.77	12.592	Failed to reject
Social image building	4.12	1.58	4.28	1.8	9.54	12.592	Failed to reject
Trialability	3.97	1.65	3.95	1.68	2.13	12.592	Failed to reject

Apart from the understanding that adopters perceive rooftop solar PV more favourably than non-adopters, the perception of even the adopters leaves much to be desired. Except one factor, environmental benefits, perceptions on other factors are slightly better than average, thus leaving a lot of room for improvement.

On complexity, even the adopters perceive the installation process not to be hassle free. This is a clear indication that procedural bottleneck remains in important areas like getting approval from utilities and receiving government incentives. For operating the rooftop solar PV, the non-adopters have considerable apprehension about the ease of use. Absence of demonstration projects can be attributed to this.

On financial attractiveness, the finding is in line with what is observed from various literature. Despite drop in cost and availability of government incentives, rooftop solar PV does not sound very attractive to the consumers. However, efforts are needed to eliminate significant difference in perception between adopters and non-adopters.

On social image building and trialability, the consumers do not show a very favourable perception with the score almost at the middle, that is neither agree nor disagree.

Table 16 Objective output of rooftop solar PV

Factor	*Finding*
Complexity	Non-adopters are more sceptical
Financial attractiveness	Non-adopters perceive this to be less attractive
Environmental benefits	Perception of both similar
Social image	Perception of both similar
Trialability	Perception of both similar

The authors also verified demographic factors of adopters and non-adopters. On demographic factors, adopters are found to be significantly different than the non-adopters. Compared to non-adopters, adopters are found to have higher income, better education, and higher occupational status. Surprisingly, contrary to the wide belief that adopters of new technology are younger, the authors found that it was not true in case of adoption of rooftop solar PV in India.

5 Conclusions

Understanding adoption of any technology is an intriguing task. For adoption of any innovation, a few important factors explain the reason behind adoption. Although Rogers's theory of adoption confirmed five key factors behind adoption of any technology, these attributes could explain only 49% to 87% of the variance in the rate of adoption. So, the authors through literature review found out five attributes that are specific to adoption of rooftop solar PV and could better explain the adoption.

Three of the five factors from Roger's theory of adoption: relative advantage, complexity and trialability got included. Relative advantage was more specifically defined by the author in terms of financial benefits and environmentally benefits. Compatibility and observability are two factors removed from Roger's proposed factors. The five factors thus selected that better explain adoption of rooftop solar PV are: complexity, financial attractiveness, environmental benefits, trialability, and social image.

A favourable perception of consumers on these five attributes should lead to widespread adoption of rooftop solar PV and similarly negative perception can lead to rejection.

The study confirmed the hypotheses that on the five critical parameters, perceptions of adopters were more favourable than the non-adopters.

An old study done in USA to understand perception difference between adopters and non-adopters of residential solar energy system (solar home heating and water heating systems) confirmed that adopters perceived the technology more favourably than non-adopters. On Roger's proposed five parameters, compared to non-adopters, adopters rated the technology as greater in relative advantage, lower in financial and social risk, lower in complexity, more compatible with personal values, more observable, and more possible to try on a limited basis (Labay and Kinnear, 1981).

A similar study in Indonesia indicated that consumers perceived price at which electricity from solar PV exported to the grid was not profitable (Setyawati, 2020).

From the research it was noticed that on five key attributes of rooftop solar PV, perception of adopters of rooftop solar PV in India varies from that of non-adopters. Especially on the key factors of complexity and financial attractiveness, perception of adopters is more favourable. Compared to non-adopters, adopters perceive rooftop solar PV to be less complex to install and operate. Also, adopters perceive financial benefits to be more attractive. On other three factors, environmental benefits, social approval and trialability, difference in perceptions of both adopters and non-adopters is not very apparent.

Another key take-away is that even among adopters, the perceptions about financial attractiveness and complexity are not very encouraging. The mean score on financial attractiveness is only 4.88 on a scale where four indicates neither attractive nor unattractive with a possible best score of 7. In several countries around the world, governments tried to incentivise the rooftop solar PV through various schemes like offering attractive feed-in-tariff, providing subsidy on installation cost, providing tax incentives, or offering low cost financing.

In India poor financial health of the distribution companies made offering attractive feed-in-tariff almost impossible. Still with an IRR of around 13% with government subsidy, more needs to be done to put across the financial benefits to consumer in a more effective manner.

On one more key factor, complexity, even the adopters do not think the installation process is hassle free. With a mean score of 3.16 by adopters, it indicates a perception of neither very complex nor very easy. So, a lot of efforts to remove procedural hassles for the prospective consumers are needed.

As similar type of research to find our perception of adopters and non-adopters of rooftop solar PV on critical factors has not been carried out anywhere to the best of my knowledge, a comparison with other countries is not possible. However, looking at overall perception of consumers in a country like Australia, perception of consumers in India needs to improve. A survey in Australia found that about two-thirds of the respondents would be willing to install a photovoltaic system (Zander et al., 2019).

The findings can be applied at different locations to understand the perception of consumers towards rooftop solar PV on the five key attributes. Understanding the perception will help policy makers address the factors on which the perceptions are poor either through implementation of effective policies or through effective communication.

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