To Study the Existence of Solar Rebound Effect Among Residential Prosumers: Challenges for Sustainable Energy in India

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To Study the Existence of Solar Rebound Effect Among Residential Prosumers: Challenges for Sustainable Energy in India

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Abstract: In the past few years, there has been a wide acceptance of renewable energy sources, particularly solar energy, as an outcome of multilateral organizations' and different economies' efforts to cope with issues like the energy crisis, global climate change, and the depletion of limited resources. India's growing solar energy market has provided numerous advantages to society including lower utility bills. However, it has been seen that prosumers increase their electricity consumption after installing solar panels due to lower electricity prices. This is known as solar rebound effect. This study aims to find out the existence of solar rebound effect in India. For this electricity consumption units of residential households from one year before and one year after solar panel installation have been collected and compared. The electricity usage trend indicates that majority of the prosumers have increased their overall electricity consumption following the installation of solar panels, which suggests the presence of solar rebound effect. This is lowering the projected advantages of using solar energy to some extent. Thus, it is imperative to take this phenomenon into account because, if we don't, we are overestimating the environmental benefits of solar energy, and it is also causing difficulty in accurately estimating future electricity demand.

Keywords: renewable energy sources; global climate change; Solar Rebound Effect; prosumers

1. Introduction

Extreme poverty, hunger, inequalities within and among nations, environmental degradation, climate change, and the depletion of scarce resources are just some of the challenges that prompted countries and the United Nations to unite in addressing these global issues. Among various issues, climate change and energy crisis are some of the greatest challenges that entire world is grappling with. Increase in global temperature, greenhouse gas emissions, rising sea level, depletion of natural resources are seriously affecting economies of world especially least developed countries. In response, the United Nations adopted 17 Sustainable Development Goals (SDGs) and 169 targets, with the support of 191member nations, aiming to overcome these challenges by 2030. The progress evaluation of these goals and targets conducted in 2024 exhibit that the world is seriously off course in achieving the 2030 agenda. All the targets were not been able to get accessed due to lack of adequate data, among evaluated targets, only 17% of the targets have shown sufficient progress, 18% are showing average progress, 30% of them have shown negligible progress in their growth, 18% have shown stagnation while 17% are showing regression[1)].

Among these 17 SDG's, SDG 7 aims to provide economical, clean and adequate energy to all in order to reduce carbon footprint in the economy, mitigate climate change and to provide access of energy to all by 2030. It includes 3 targets which are as follows: target 7.1 is to make clean and economical energy services available to all by 2030. Target 7.2 is to significantly increase the proportion of renewable energy sources in global energy mix. Target 7.3 is to increase the speed of improvement in energy efficiency by double by 2030[2)]. Significant progress has been made in increasing the share of renewable energy within global energy mix. In 2015, renewables accounted for 22.9% of total electricity consumption, which increased to 28.2% in 2021. The per capita installed capacity for generating electricity with renewable sources across the world shoot up from 250 watts in 2015 to 424 watts in 2022 (shown in Fig. 1)[1)]. As per Renewables 2023, edition of the IEA's annual market report on this field, the amount of energy generated from renewable sources surged by 50% in 2023, accomplishing 510 gigawatts, including solar PV representing three-quarters of growth across the globe[39)]. The usage of renewable energy in the power sector acquired an overall capacity of 3870 Gigawatts, as per Renewable Capacity Statistics 2024 released by International Renewable Energy Agency (IRENA). Asia accounted for 326 GW or 69% of the total renewable energy boom.

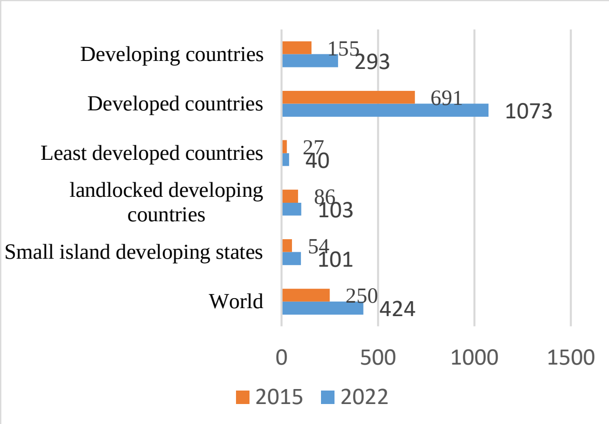

Fig. 1: Installed capacity for renewable electricity generation, 2015 and 2022 (watts per capita).
Source: The sustainable development goals report 2024.

China was the primary contributor of this growth with an increase of 63% or 297.6 GW. However, various developing countries are left behind. Africa's growth was not impressive, with only 4.6% increase in renewable energy. Forecasts indicate that by 2030, 660 million people will still be living without electricity[3]. Energy serves as the biggest driver of the global climate crisis and also its sole solution. Consumption of fossil fuels in order to generate power and heat result in formation of an immense quantity of greenhouse gases. Fossil fuels including coal, oil and gas contributing over 75% of greenhouse gas emissions around the world and roughly 90% of carbon dioxide emissions are undoubtedly the leading contributors of climate change. Emissions need to be dropped by nearly half by 2030 and attain net-zero target by 2050 to stave off the devastating impacts of climate change. We have to speed up investment in cleaner sources of energy and lessen our dependency on conventional sources to be able to do this[4].

At UN Climate Change Conference (COP26) held in Glasgow in 2021, India announced to attain net-zero emissions by 2070. For this it amended its Nationally Determined Contribution (NDC) in august 2022. In this, India intends to generate 50% of its total electricity from renewable energy sources by 2030. Among various renewable sources of energy, solar energy has become most popular in recent years due to its abundance and lack of pollution. Solar power installed capacity of India reached to 87.21 GW on 31st July 2024 with grid connected solar rooftop contributing 13.4 GW (as shown in Fig. 2)[5]. Trend from 2018-2024 shows that all India rooftop solar installation capacity has grown from 1063.63 MW in 2018 to 11,869.63 MW in 2024. Rajasthan holds the share of 9.72% (1154.25 MW) in 2024 in total rooftop installed capacity of Pan India (as shown in Fig. 3[6]).

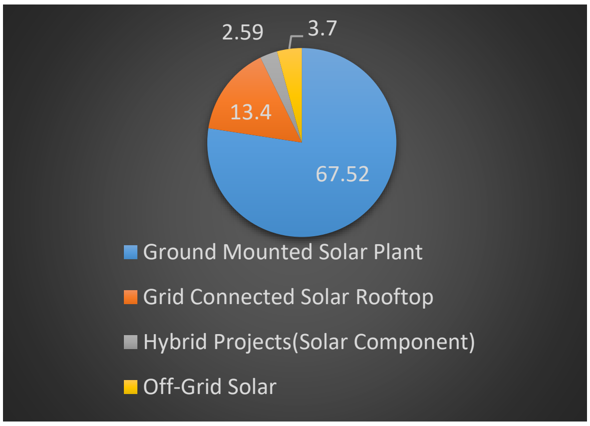

Fig. 2: Solar power (cumulative in GW) is 87.21 GW.
Source: Ministry of New and Renewable Energy.

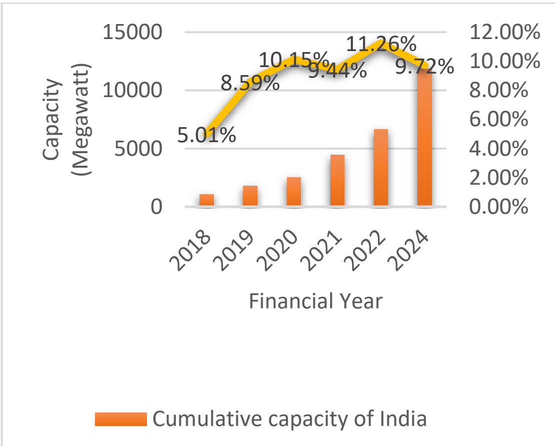

Fig. 3: Installed capacity of rooftop solar panels.
Source: Ministry of New and Renewable Energy.

Over the years, the Government of India has implemented various programs to promote solar energy development, including the National Solar Mission, the International Solar Alliance, and the Jawaharlal Nehru National Solar Mission, which have increased the rate of solar energy adoption among consumers. List of various schemes launched by government to promote solar energy has been given in Table 1.

Table 1. List of Government schemes to promote solar energy in India[7].

S.no	Name of Scheme	Objective
1.	Pradhan Mantri Kisan Urja Suraksha Evam Utthan Mahabhiyan (PM-KUSUM) for decentralized solar	Main purpose of this scheme is to help farmers in installing off-grid solar pumps in rural areas.
2.	Roof Top Solar (RTS) Programme Phase-II	To increase total installed capacity of Grid Connected Rooftop Solar (RTS) installations by

		40,000 MW.
3.	Central Public Sector Undertaking (CPSU) Scheme for Grid-Connected Solar Photovoltaic (PV) Power Projects	The goal is to help government, central and state public sector units to install grid-connected solar panels with the help of Viability Gap Funding (VGF) for its own usage.
4.	Development of Solar Parks and Ultra Mega Solar Power Projects	To help developers of solar projects in building projects more quickly.
5.	PLI Scheme: 'National Programme on High Efficiency Solar PV Modules'	To help in manufacturing of high efficiency solar PV modules in india so as to reduce import dependence
6.	Green Energy Corridor	The goal is to align the electricity generated by renewable energy sources, such as solar and wind, with traditional power plants inside the grid.

1.1 Drivers of solar adoption in India and its benefits

Recent years have seen an impressive rise in the adoption of solar energy among residential households. Numerous factors influencing the adoption of solar panels and benefits associated with it have been discovered in prior studies. Government led initiatives and subsidies have played a significant role in attracting solar panel adoption among households. Some researchers concluded that government initiatives are more successful than federal government ones. State governments have brought about a number of enticing policies, such as tax breaks, no availability-based tariffs, accelerated depreciation, and no registration fees for land acquired for solar projects[8)]. Net-Metering policy of public authorities provides a number of advantages, including reduced reliance on grid, a decrease in transmission loss, compensation for transferring surplus energy, etc[11)]. Some also found that consumer perspective on solar energy items are greatly affected by government regulations and consumer behavior associated with purchase of green products[19)]. Various researchers observed that promotion of solar energy is mainly driven by care for environment, easy working of clean energy sources, their advantages over non-renewable energy and economic benefits of utilizing clean energy[12,13)]. Some scholars in their study found that knowledge of the environment influences people to buy solar energy, but perceptions from friends, family and society also serve a role in this decision[14)]. Many also stated that consumers' choice to purchase solar energy products are motivated by their concern for the environment and their ability to behave in a particular way, an attitude towards it impacts their decision as well[15)]. Technological innovation and research and development work better than monetary gifts to foster the use of solar energy[9)]. Having a higher income and literacy level enhances the desire to utilize more solar energy[10)]. Some claim that consumer understanding about solar products is determined by demographic characteristics like level of education, age and gender[16)]. Rural farmers in Punjab are greatly affected by the cost of solar water pumping systems when making purchases. Their operational effectiveness and public authorities measure also have an important say on purchasing decisions[17)]. Various studies revealed that people with average income tend to save power more often than do wealthy individuals High income people individuals have required financial means to adopt photovoltaic systems but are not inspired to do so because majority of them live on rent[18)]. Development of solar energy in the country has benefited the environment by reducing carbon emissions and conserving natural resources. Besides, it has also given society access to electricity for a greater number of people at lower cost, among many other advantages. Many in their study observed the consequences of consumption of solar energy which included a decrease in wholesale market price, a reduction in transmission and distribution losses, and a decrease in CO2 emissions[20)]. Some concluded that youngsters in rural regions studied longer at night after placing solar lighting in their homes. Other variables which impact students time spent on study are number of rooms in the house, educational background of family's head, and class of child in which he is studying[21)]. According to many, use of solar energy has lowered carbon emissions, enhanced people's income because of creation of more job opportunities and has made access of electricity easier than before[22)]. One study observed that solar pumps have raised yields from agriculture and farmer's income as an outcome of improved productivity[23)]. Solar energy has also improved health and life of people in village while also creating new job possibilities[24)].

Undoubtedly, the introduction of solar energy, particularly by residential homes, has resulted in numerous good improvements. The actual impact of solar energy on energy saving and reduction in carbon footprint is uncertain. Solar generated electricity has been shown to lower consumer electricity bill when compared to pre-installation levels. However, this reduction in cost may also cause consumers to alter their electricity consumption habits, probably increasing their overall usage. Without taking this behavior into account, benefits of solar energy are being overestimated and it also poses a challenge in accurately forecasting future energy demand of residential sector.

2. Solar Rebound Effect

Since the amount of money on electricity a person spends depend on how much power they receive from the grid, using solar panel to generate electricity has surely reduced their reliance on it. Consequently, their expenses for electricity have also decreased. However, prosumers have been observed to have increased their consumption from pre-installation period onward, as opposed to substituting their previous electricity usage on one-for-one basis with solar generated electricity. Therefore, electricity intake from grid might not fall by the same amount as electricity produced by solar energy, as solar generated electricity may be used to fulfill growing demand for electricity. This situation of increase in people's overall electricity consumption following the installation of solar panels is known as solar rebound effect[27,28,30,32)]. Prosumers are those individuals who generate as well as use electricity[31)]. The phenomena of rebound effect simply mean partial reduction in anticipated gains of new technology that improves the resource utilization efficiency due to systematic or behavioral changes. William Stanley Jevons coined this term in 1865 and it is also referred to as Jevons paradox[38)].

Solar rebound effect tends to lower the potential benefits of solar panels on environment and can also impede our economy's goal of carbon emission reduction. Various study conducted in different countries have indicated the presence of solar rebound effect. Researcher showed that people receiving 60c Feed in Tarif experienced a solar rebound effect of 20.9% while those receiving 20c FIT, found it to be 16.7%[25)]. Rebound effect of 7% was found among Dutch households[26)]. A study conducted in U.S. observed a solar rebound effect of 28.5%[27)]. As the solar energy production rises, prosumers consumption of power grows in sync with selling price[42)]. Table 2. demonstrates the various variables studied in previous research on solar rebound effect outside India. Since there hasn't been any research done in India on the existence of the solar rebound effect yet, objective of this study is to determine if solar rebound effect exists in India. For this a comparison between pre- and post-installation electricity consumption of prosumers is done. Any increase in electricity consumption of prosumers after installing solar panel will depict solar rebound effect.

Table 2. Variables studied by various authors affecting solar rebound effect.

Sr. No.	Year	Title	Author and year	Journal Name	Country	Variables Studied
1	2017	Assessing the impact of solar PV on domestic electricity consumption: Exploring the prospect of rebound effects[25)].	Gary Deng, et al. (2017)	Energy Policy	Sydney	Feed in tariff, income, temperature
2	2019	Quantifying the rebound effects of residential solar panel adoption[28)].	Yueming (Lucy) Qiu, et al. (2019)	Journal of environmental economics and management	Phoenix Arizona, U.S.	Solar irradiance, net metering policy, thermal comfort
3	2023	The Rebound Effect of Solar Panel Adoption: Evidence from Dutch Households[26)].	Aydin, et al. (2023)	Energy Economics	Netherland s	Seasons and climate, energy literacy, energy saving, environment awareness
4	2021	Solar Rebound - The Unintended Consequences of Subsidies[29)].	Nicolas Boccard & Axel Gautier (2021)	Energy Economics	Wallonia	Tradable green certificate, Net-metering scheme
5	2023	Electricity Consumption Changes Following Solar Adoption: Testing for a Solar Rebound[27)].	Ross Beppler, et al. (2023)	Economic Inquiry	US.	Net-metering, co-adoption of electrical appliances, moral licensing, anchoring, mental accounting
6	2021	Mechanisms for Rebound Effects of Solar Electricity Prosuming in Germany[30)].	Ayse Tugba Atasoy, et al. (2021)	SSRN	Germany	Feed in tariff, moral licensing
7	2021	Identifying possible drivers of rebound effects and reverse rebounds among households with rooftop	Ray Galvin (2021)	Renewable Energy Focus	Germany	Cognitive variables (moral licensing, income from fit, environment commitment, autarky),

		photovoltaics[31].				sociotechnical variables (monitoring of consumption and production, visual appeal), forces of nature (fluctuation of solar energy, angle of sun path, orientation of roof) regulatory norms (cap on feeding in electricity, fit)
8	2022	Renewable Energy Householders in the Sunshine State: Do They Perceive a Rebound Effect?[32].	Breda McCarthy (2022)	Journal of Resilient Economies	Australia	Frugality, thermal comfort, bills consciousness, pro-environment awareness
9	2023	To use or not to use, that is the question: Income and substitution effects in the feed-in tariff system for solar-generated electricity[33].	Xinyue Yang & Shigeru Matsumoto (2023)	Japan and the World Economy	Japan	Fixed feed in tariff policy of japan
10	2024	Moral licensing and habits: Do solar households make negligent choices?[34].	Breda McCarthy (2024)	Renewable and Sustainable Energy Reviews	Australia	Attitude, social norms, perceived behavioral control, moral licensing, habit
11	2024	Do laundry when the sun shines: Factors that promote load shifting in Dutch households with solar panels[35].	Naomi D. Hubert, et al. (2024)	Energy Research & Social Science	Netherland	user belief, sufficiency attitude, hassle, habit, monitoring skill, know how, feedback provision by system design, practical knowledge provided
12	2023	Solar rebound effects: Short and long term dynamics[36].	Luan Thanh Nguyen, et al. (2023)	Renewable Energy	Vietnam	Income, demographic factors (employment rate, urbanization rate, no. of children living in that house), electricity price,
13	2021	Measuring the rebound effect: A case study of residential photovoltaic systems in San Diego[37].	Jae D. Kim & William Trevena (2021)	Utilities Policy	San Diego	Climate, income, size of house, temperature

3. Data collection and compilation

Sampling is the procedure of choosing a portion of the target population in order to ascertain the attributes of the entire population. Target population describes the whole set of people about whom a researcher seeks to arrive at a conclusion in the course of their research. The study's target population consist of homes with solar panels. In this study, 100 residential prosumers who have solar panel installed on their homes were examined regarding their electricity consumption trend.

Data on electricity usage units of residential households from the year before and year after solar panel installation have been collected and compared. Units of electricity consumed by sample households before adopting solar energy has been shown in Table 3.

Table 3. Electricity consumption units of Residential Prosumers one year before solar panel installation.

Residential Prosumers	Electricity Consumption (pre-installation)	Residential Prosumers	Electricity Consumption (pre-installation)	Residential Prosumers	Electricity Consumption (pre-installation)	Residential Prosumers	Electricity Consumption (pre-installation)
1	14,897	26	10,087	51	7,937	76	3,386
2	3,823	27	3,901	52	5,370	77	2,097
3	11,773	28	9,788	53	1,978	78	3,730
4	4,197	29	6,836	54	14,005	79	4,626
5	3,384	30	2,860	55	3,876	80	9,993
6	8,065	31	2,039	56	8,640	81	1,698
7	15,064	32	1,706	57	3,615	82	10,036
8	14,602	33	4,964	58	8,718	83	8,540
9	12,739	34	6,496	59	4,633	84	5,718
10	6,749	35	2,503	60	3,395	85	9,461
11	4,536	36	5,004	61	1,883	86	4,541
12	6,204	37	6,431	62	4,794	87	3,943
13	6,398	38	5,561	63	3,607	88	4,349
14	11,507	39	7,920	64	12,383	89	2,812
15	5,981	40	6,837	65	7,646	90	4,340
16	2,669	41	3,285	66	1,416	91	3,608
17	14,469	42	1,896	67	14,599	92	8,343
18	2,446	43	12,974	68	9,824	93	5,811
19	13,354	44	2,303	69	1,378	94	3,279
20	5,102	45	5,055	70	2,870	95	8,682
21	3,929	46	3,220	71	3,482	96	13,913
22	6,184	47	4,337	72	13,219	97	1,084
23	5,832	48	4,555	73	9,212	98	4,970
24	3,169	49	5,456	74	4,561	99	4,759
25	4,346	50	9,877	75	1,712	100	5,757

Total electricity consumed during a year after installing solar panel was not directly available. Data was available in the form of units of electricity generated by solar panels, units of electricity exported by households to electricity grid during a year and the units of electricity they have imported from grid during the same year (shown in Table 4). Using these three types of data we have first calculated the total electricity consumed by households during a year. we have first deducted units of electricity exported to grid from units of electricity generated from their respective solar panels to get how much of solar generated electricity prosumers had self-consumed, then we have added units of electricity imported from grid to arrive at the total consumption of electricity made by them during a year (Total electricity consumption = Solar generated electricity - Electricity exported to grid + Electricity imported from grid).

Table 4. Electricity consumption units of Residential Prosumers one year after solar panel installation.

Residential prosumers	Size	Solar panel generated electricity	Units exported	Units imported	Total consumption units	Residential prosumers	Size	Solar panel generated electricity	Units exported	Units imported	Total consumption units
1	10	10,403	6,252	11,225	15,376	51	10	12,361	8,977	7,229	10,613
2	10	9,778	6,859	10,068	4,843	52	10	10,170	7,440	9,714	13,297
3	8	19,251	9,673	14,405	12,987	53	15	19,167	18,118	1280.3	2,329.3
4	10	13,050	10,015	6,654	9,689	54	10	15,355	10,080	14,116	19,391
5	8	10,196	8,111	3,100	5,185	55	4	4,957	3,308	4,188	5,837
6	10	11,353	7,792	8,836	12,397	56	10	13,711	10,688	8,984	12,007

7	10	12,235	8,134	14,808	18,909	57	6	8,686	7,122	5,205	6,769
8	15	22,133	12,586	9,489	19,036	58	6	7,071	4,552	7,568	10,087
9	10	13,549	7,160	7,724	14,113	59	5	4,967	3,694	4,560	5,833
10	6	6,720	4,846	8,517	10,391	60	6	8,536	6,723	3,414	5,105
11	4.77	6,710	4,567	5,768	7,911	61	6	7,807	6,403	2,655	4,059
12	10	14,150	12,002	6,034	8,182	62	6	8,565	6,020	4,218	6,763
13	5	6,775	5,384	3,987	5,378	63	5	6,418	4,777	3,527	5,168
14	5	6,224	3,273	15,205	18,156	64	8	7,462	5,493	10,940.1	12,909.1
15	8	11,693	9,360	6,416	8,749	65	5	5,277.4	4,959.2	8,599.5	8,917.7
16	5	6,813	6,502	4,640	4,951	66	3	3,698.1	2,898.5	1,493.3	2,292.9
17	10	13,656	8,374	12,419	17,701	67	10	12,020	8,741.8	3,429.7	6,707.9
18	8	11,082	9,118	3,982	5,946	68	10	10,427	6,974	8,304.7	11,757.7
19	15	21,422	15,252	11,175	17,345	69	5	1,359	1,005	988	1,342
20	4.7	6,917	5,353	5,220	6,784	70	5	4,051.9	1,168.1	4,232.6	7,116.4
21	5	6,963	4,491	6,445	8,917	71	8	5,779	4,465	4,633	5,947
22	10	14,071	11,221	5,932	8,782	72	6	7,329	4,404	14,554	17,479
23	6	8,138	6,132	7,983	9,989	73	8	11,553	6,594	6,807	11,766
24	6	8,336	6,993	3,380	4,723	74	8	9,080	7,456	5,874	7,498
25	5	6,477	6,207	5,794	6,064	75	5	7,456	7,122	6,051	6,385
26	10	13,180	9,394	9,418	13,204	76	3	2,952	1,932	4,274	5,294
27	5	5,917	3,036	5,203	7,930	77	6	8,439	6,240	5,265	7,464
28	8	9,244	6,706	7,473	10,011	78	10	15,963	12,868	7,713	9,613
29	5	6,699	4,360	4,723	7,062	79	5	6,994	6,049	3,655	4,600
30	5	6,639	6,131	4,138	4,646	80	10	17,394	13,280	10,737	14,851
31	5	6,530	6,301	3,186	3,415	81	8	7,970	7,970	8,764	8,764
32	5	5,857	2,694	6,035	8,993	82	10	11,049	7,540	18,002	21,511
33	10	13,135	11,040	5,519	7,614	83	7	8,685	6,326	6,919	9,278
34	8	7,621	3,656	9,559	13,524	84	5	6,304	5,907	6,651	7,048
35	8	10,693	8,048	5,235	5,634	85	6.5	9,640	7,435	9,813	12,018
36	10	12,637	9,550	4,413	7,500	86	6	6,909	5,482	3,698	5,125
37	5	5,039	3,387	5,725	7,377	87	6	8,757	7,189	3,592	5,160
38	8	10,201	7,763	5,001.5	7,439.5	88	10	12,716	7,182	13,669	19,203
39	10	13,674	10,739	4,844	7,779	89	6	7,379	5,427	2,698	4,650
40	4	4,837	2,723	6,962	9,076	90	6	3,584	2,314	5,744	7,014
41	3	4,207	3,836	3,168	3,539	91	10	12,947	10,063	6,930	8,584
42	5.3	6,693	6,125	1,177	1,745	92	8	6,176	4,988	5,333	6,521
43	8	10,252	6,823	10,466	13,895	93	6	8,306	6,520	4,967	6,753
44	17	24,739	21,388	5,730	9,081	94	6	8,368	7,034	3,660	4,994
45	5	7,517	5,407	6,377	8,487	95	7	10,878	5,164	7,827	13,541
46	5	7,019	5,906	2,696	3,809	96	10	10,621	7,990	10,265	12,896
47	5	6,124	4,275	3,502	9,160	97	8	10,097	8,498	3,645	5,244
48	10	12,751	10,826	7,692	9,617	98	6	6,940	4,968	5,609	7,581
49	6	8,253	6,822	4,210	5,641	99	3	3,865	3,722	5,455	5,598
50	15	18,148	13,548	9,695	14,295	100	6	8,268	7,353	6,726	7,641

4. Results and Discussion

After collecting the pre-installation and post-installation electricity consumption data of 1 year of residential prosumers and comparing them (as shown in Table 5), the electricity consumption trend reveals that most of the prosumers have increased their overall consumption after installing solar panels in their homes indicating the presence of solar rebound effect. After installation average amount of electricity consumption has increased by 67.14%. Only 8 prosumers have been found to reduce their consumption (highlighted in Table 5). Thus, it is evident that solar rebound effect exists among residential prosumers in India, which is the main purpose of this study.

Table 5. Comparison of electricity consumption pre-solar installation and post solar installation.

Residential prosumers	Size of solar panel	Electricity consumption (pre-installation)	Electricity consumption (post-installation)	Change in consumption (%)	Residential prosumers	Size of solar panel	Electricity consumption (pre-installation)	Electricity consumption (post-installation)	Change in consumption (%)
1	10	14,897	15,376	3.22	51	10	7,937	10,613	33.72
2	10	3,823	4,843	26.68	52	10	5,370	13,297	147.62
3	8	11,773	12,987	10.31	53	15	1,978	2,329.3	17.76
4	10	4,197	9,689	130.86	54	10	14,005	19,391	38.46
5	8	3,384	5,185	53.22	55	4	3,876	5,837	50.59
6	10	8,065	12,397	53.71	56	10	8,640	12,007	38.97
7	10	15,064	18,909	25.52	57	6	3,615	6,769	87.25
8	15	14,602	19,036	30.37	58	6	8,718	10,087	15.70
9	10	12,739	14,113	10.79	59	5	4,633	5,833	25.90
10	6	6,749	10,391	53.96	60	6	3,395	5,105	50.37
11	4.77	4,536	7,911	74.40	61	6	1,883	4,059	115.56
12	10	6,204	8,182	31.88	62	6	4,794	6,763	41.07
13	5	6,398	5,378	-15.94	63	5	3,607	5,168	43.28
14	5	11,507	18,156	57.78	64	8	12,383	12,909.1	4.25
15	8	5,981	8,749	46.28	65	5	7,646	8,917.7	16.63
16	5	2,669	4,951	85.50	66	3	1,416	2,292.9	61.93
17	10	14,469	17,701	22.34	67	10	14,599	6,707.9	-54.05
18	8	2,446	5,946	143.09	68	10	9,824	11,757.7	19.68
19	15	13,354	17,345	29.89	69	5	1,378	1,342	-2.61
20	4.77	5,102	6,784	32.97	70	5	2,870	7,116.4	147.96
21	5	3,929	8,917	126.95	71	8	3,482	5,947	70.79
22	10	6,184	8,782	42.01	72	6	13,219	17,479	32.23
23	6	5,832	9,989	71.28	73	8	9,212	11,766	27.72
24	6	3,169	4,723	49.04	74	8	4,561	7,498	64.39
25	5	4,346	6,064	39.53	75	5	1,712	6,385	272.96
26	10	10,087	13,204	30.90	76	3	3,386	5,294	56.35
27	5	3,901	7,930	103.28	77	6	2,097	7,464	255.94
28	8	9,788	10,011	2.28	78	10	3,730	9,613	157.72
29	5	6,836	7,062	3.31	79	5	4,626	4,600	-0.56
30	5	2,860	4,646	62.45	80	10	9,993	14,851	48.61
31	5	2,039	3,415	67.48	81	8	1,698	8,764	416.14
32	5	1,706	8,993	427.14	82	10	10,036	21,511	114.34
33	10	4,964	7,614	53.38	83	7	8,540	9,278	8.64
34	8	6,496	13,524	108.19	84	6	5,718	7,048	23.26
35	8	2,503	5,634	125.09	85	6.5	9,461	12,018	27.03
36	10	5,004	7,500	49.88	86	6	4,541	5,125	12.86
37	5	6,431	7,377	14.71	87	6	3,943	5,160	30.86
38	8	5,561	7,439.5	33.78	88	10	4,349	19,203	341.55
39	10	7,920	7,779	-1.78	89	6	2,812	4,650	65.36
40	4	6,837	9,076	32.75	90	6	4,340	7,014	61.61
41	3	3,285	3,539	7.73	91	10	3,608	8,584	137.92
42	5.3	1,896	1,745	-7.96	92	8	8,343	6,521	-21.84
43	8	12,974	13,895	7.10	93	6	5,811	6,753	16.21
44	17	2,303	9,081	294.31	94	6	3,279	4,994	52.30
45	5	5,055	8,487	67.89	95	7	8,682	13,541	55.97
46	5	3,220	3,809	18.29	96	10	13,913	12,896	-7.31
47	5	4,337	9,160	111.21	97	8	1,084	5,244	383.76
48	10	4,555	9,617	111.13	98	6	4,970	7,581	52.54
49	6	5,456	5,641	3.39	99	3	4,759	5,598	17.63
50	15	9,877	14,295	44.73	100	6	5,757	7,641	32.73

This rise in electricity usage following the deployment of solar power could be attributed to numerous sources (as shown in Table 6). Government rules and incentives such as feed-in tariff and Net-Metering prompts prosumers to use more energy[25,29,33)]. Solar rebound effect is typically greater in areas where solar owners receive larger compensation[40)]. Electricity usage of prosumers rises after the deployment of solar under net-billing plan as they place more value on bill saving under net FIT plan than they do on revenue under gross FIT scheme[41)]. The Net-Metering mechanism which allows prosumers to sell excess solar electricity to the grid in exchange for credits which can be used to buy grid electricity may be one of the causes. Since prosumers only pay for the net amount of electricity taken from the grid and not for the whole amount of electricity used, this process lowers their utility bill and they might utilize more electricity as a result of this lower bill, owing to law of demand. Some people feel that by shifting from conventional to solar energy they have already fulfilled their environmental responsibilities, therefore now they can use more energy than they did before because it is greener, it is referred to as moral licensing[27,31,34)]. It is also likely that after implementing solar energy, households would decide to embrace other electricity-intensive devices, such as electric vehicles, in an effort to become even more environmentally conscious. This may further increase their electricity consumption[27)]. Besides, geographical location, climate, demographics, and economic conditions also have an influence on solar rebound effect[26,36,37)]. There can be additional drivers of solar rebound effect which can be investigated in future studies as the study of solar rebound impact variables is outside the purview of this research paper.

Table 6. Key drivers of solar rebound effect in India.

S.no	Drivers
1.	Government incentives
2.	Moral licensing
3.	Co-adoption of electrical appliances
4.	Climatic condition
5.	Demographic characteristics

5. Conclusions

Study of solar rebound effect and its drivers holds a very important value at this time when regulatory bodies are only focusing on increasing the adopters of solar energy in the country and not much attention is being paid on the behavioral change of prosumers which is partially reducing the estimated benefits to be derived with the use of solar energy. Ignorance of this phenomenon is actually acting as an obstacle in our way to achieve the aim of energy saving and reduction in harmful pollutants in environment. Government must take solar rebound effect and its determinants into consideration to have true evaluation of the benefits of solar panels on environment. This will further assist government officials in implementing suitable policies and incentive programs. Public authorities with the help of NGO's, educational institutions, social media, influencers can make people aware about solar rebound effect and also persuade them to pay attention on their energy consumption pattern and inculcate the habit of energy saving among them. Campaigns should be organized to make prosumers realize that installing solar panels in their homes alone would not fulfill their responsibility towards environment, instead, they must continue their efforts to save environment by controlling their needless electricity consumption hikes. Government and Prosumers need to realize that mere usage of solar panels will not make our environment pollution free, lessen climate change and save energy unless it is accompanied by conscious use of that energy.

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