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ECONOMICS OF HOUSEHOLD SOLAR ELECTRICITY GENERATION – A SYSTEMATIC REVIEW

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Abstract

Rapid economic growth requires uninterrupted power electricity supply. Most of the developing and developed economies utilize fossil fuels which generate pollution and endanger sustainable development. The perennial debate of development vs. environment could be addressed by adopting technologies as well as sources of energy that are economically viable as well as environmentally benign. Solar photovoltaic (PV) is a technology that could be utilized for power-generation at the micro-level. Rooftop solar PV panels utilized for generating solar energy at the household (HRSS) level has emerged as a cost-effective, efficient as well as environmentally sustainable method that could address multiple issues such as pollution through the production and use of fossil fuels, scarcity and iniquitous coverage of household electricity supply, as well as high cost of generation of thermal electricity. Several countries have undertaken various schemes including FIT Feed in Tariff) scheme in order to subsidize and encourage HRSS. Despite these the pace of adoption of HRSS has been slow. This paper attempts to understand the economics behind HRSS by reviewing the relevant published literature in this area from various databases. It uses the PRISMA (Preferred Reporting Items for systematic reviews and Meta- Analysis) method This paper attempts to identify the barriers that hamper the faster adoption and spread of HRSS.

Keywords *– Solar Photovoltaic (PV), Household Rooftop Solar System (HRSS), Net Present Value (NPV), Payback Period*

INTRODUCTION

An uninterrupted supply of electricity is crucial for the growth of each sector of the economy. The rapid growth of population and industrialization are the key drivers that create an increase in the demand for electricity (Ali O.M. Maka, 2022). As per the report of Energy Technology Perspectives, 2023, globally 80 % of the energy is harnessed from fossil fuels which are non-renewable sources that could deplete in the near future (Praveen Bains, 2023). It is observed that in most of the countries, the generation of electricity is a major cause for the increase in emissions of greenhouse gases (Kannan Kaliappan, 2019). In 2015, United Nations adopted 17 Sustainable Development Goals (SDGs). Among these, the 7th goal is 'to ensures universal access to clean and green energy at affordable prices' (Tracking SDG 7 : The Energy Progress Report, 2020). Here, the word affordability indicates the cost-effectiveness of various clean and green energy generation technologies. Many technologies generate electricity from various renewable sources such as hydropower, wind power, solar power, tidal power and geothermal power. Amongst all these technologies, the viability and efficiency of each technology is different, and relies on the meteorological and geographical conditions of the particular region. For instance, countries which are located in tropical and sub-tropical regions such as Australia, India, United States etc. have great exposure to solar energy. Hence, solar energy could be a relatively more viable renewable source for electricity generation (Kannan Kaliappan, 2019). Solar electricity generation paves the way for energy independence and energy security in the economy along with minimal environmental hazards (K.H. Solangi b, 2011).

Evolution of Solar Electricity Generation Technologies

In 1839 French scientist Edmund Becquerel invented the photovoltaic effect in which the photons striking the surface of a certain material (silicon) create an electric current. In 1956, a small team of scientists at Bell Laboratory in the United States, first used solar electricity for space programme by NASA in which the solar cell was working in extreme conditions od very high and very low temperatures. Initially, solar power generation technology was found much expensive compared to conventional fossil fuel technology. Over a period of time, in United States R & D was done and then several companies entered in solar PV business. Between 1972 and 1975 there were many companies from the Soviet Union, Japan, the United States and Europe in solar cell

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business despite lots of technical and economic challenges which were addressed by scientists and entrepreneurs and then the solar electricity technologies penetrated at residential sector (Flavin, 1982).

Technologies for Solar Electricity Generation

There are several technologies to generate electricity from solar energy. Among these technologies two are tried and tested well (K.H. Solangi b, 2011), 1). Concentrating Solar Power (CSP) and 2) Solar Photovoltaic (PV). The core difference between these two technologies is the mechanism of electricity generation. CSP utilizes mirrors or lenses to concentrate sun rays in a small area so that the heat can be utilized to generate electricity through thermal turbines. Thus, this technology indirectly generates electricity from the solar irradiance. On the other hand, the solar PV directly generates electricity from solar irradiance by photovoltaic effect (K.H. Solangi b, 2011). Solar PV is cost cost-effective technology for small-scale household electricity generation as CSP is relatively costly and requires high solar irradiance, which therefore makes it suitable for large-scale electricity generation done on a commercial basis (K.H. Solangi b, 2011).

The residential sector accounted for a third of heat-trapping gas emissions (Nurwidiana Nurwidiana, 2021). To address this issue, government in several countries have formed clean energy policies in which economic incentives have been given to citizens who have adopted these green technologies, especially to the households who adopt HRSS and subsequently evacuate solar power into the main grid; by way of a scheme known as Feed in Tariff (FiT) such as tax rebates, subsidies etc. (K.H. Solangi b, 2011).

Despite government schemes and policies that provide economic incentives for the adoption of HRSS, the pace of penetration of rooftop solar in the residential sector has been slow. Besides the fact that the adoption of HRSS requires capital investment by the households; their decision-making is also influenced by several other economic aspects such as how much economic return they could earn from the HRSS, to what extent they could save on their payable electricity bills, what would be the Payback Period on the investment made on HRSS etc. In other words, the economics behind HRSS has a great impact on the adoption and spread of HRSS (Nurwidiana Nurwidiana, 2021).

The cost-effectiveness of HRSS and other solar electricity generation technologies is highly dependent on the components and the materials that are being used in the equipment (Praveen Bains, 2023). Several steps or stages are required to produce, supply, install and maintain HRSS in the market such as extraction of resources for material production here silicon which is used in solar cells), components, know-how and manpower for their assembly, installation and maintenance. This technology supply chain precedes the energy supply chain which consists of conversion of solar power into electricity, its storage, transmission and , distribution to the users (Praveen Bains, 2023) .Also, technology supply chain and energy supply chain are interconnected (Praveen Bains, 2023). Thus, even though solar power is free, the price and availability of the materials such as lithium, cobalt, nickel, and manganese (metals which are utilized in lithium-ion batteries) affects the cost-effectiveness of these technologies. Prices of these materials has doubled in 2022. Consequently, the share of prices of these materials in the HRSS that was less than 5% in last decade has risen by 20% in 2022 (Praveen Bains, 2023).

OBJECTIVES OF THE STUDY

1) To understand the economics of household rooftops solar systems (HRSS)
2) To Identify the factors affecting to adoption of HRSS

RESEARCH METHODOLOGY

The present study is based on Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) method. PRISMA entails four stages (i) identification (ii) screening (iii) eligibility and (iv) inclusion as shown in Figure 1. The exclusion and inclusion criteria are given below which comprise of various criteria of inclusion and exclusion such as databases (ScienceDirect and Google Scholar which are used to find the literature by the key words namely *households AND Rooftop Solar Economics and Determinants AND Household Rooftop Solar Economics* accessed on 7th September 2023), time period (the first technical report of solar electricity generation were published in 1979 after the invention of solar photovoltaic technology. Hence, in this paper, the literature published between 1979 to 2023 was selected), Type of the literature (technical reports, research articles and conference proceeding were included whereas other publications were excluded), subject area (Energy, Economics and Finance, Environmental Studies and Social Science were the subject areas which were chosen as per the nature of the present study whereas the remaining subject areas were excluded for the present study). The final screening was done by the criterion of the access to the literature (only the studies which were published in open access sources were included).

Table 1: The Inclusion and Exclusion Criteria

Criterion	Inclusion	Exclusion	N = Number of research articles

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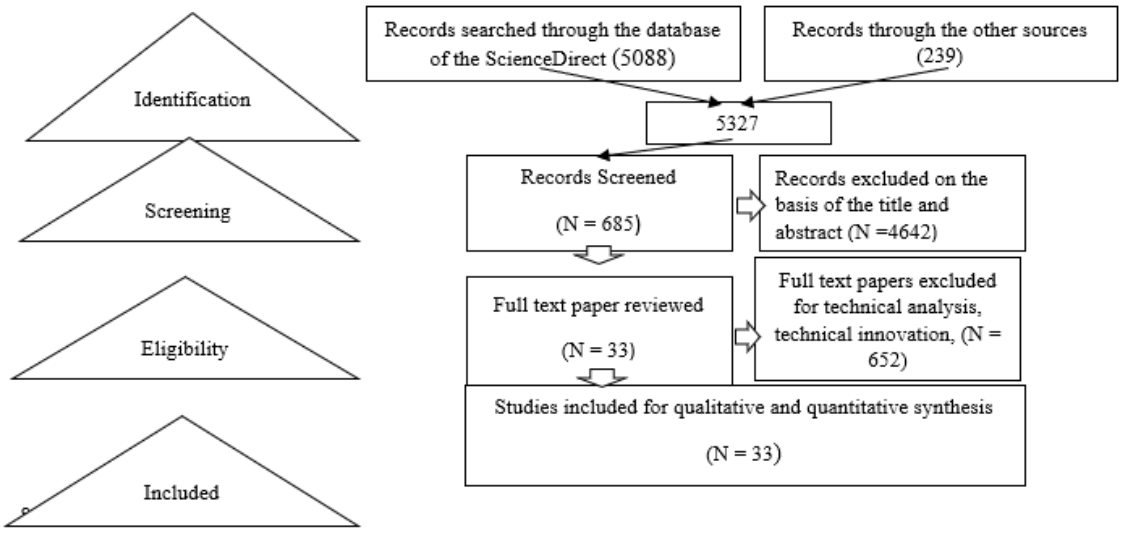
Search using keywords: "Households "AND "Rooftop Solar Economics, Determinants of Household rooftop solar Economics			5327
Period	1979 to 2023	Before 1979	5254
Document Type	Research article, working paper, conference proceeding, technical report	Review articles, encyclopedias, book chapters, conference abstracts, case reports, correspondence, discussion, editorials, errata, mini-reviews, news, product reviews, short communication, others	3782
Subject Area	Energy, Economics, Econometrics and Finance, Environmental Science, Social Sciences	Engineering, Material Science, Decision Sciences, Business, Management and Accounting, Computer Science, Agriculture and Biological Sciences	2685
Access type	Open access	Restricted access	685

Source: Author's own compilation

Figure 1: Flow chart of the literature selection process based on the PRISMA Method

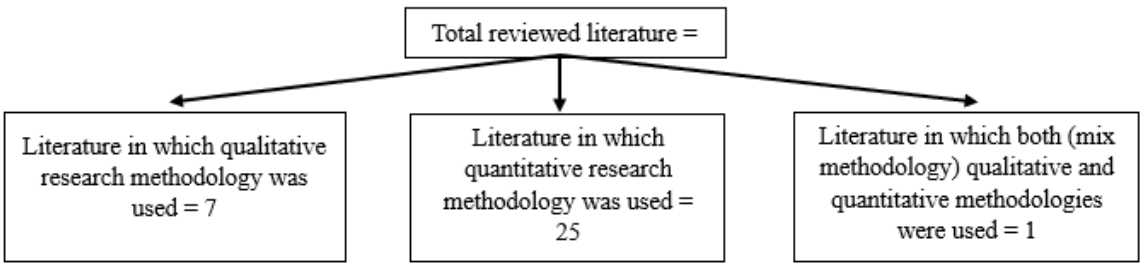


Source: Author's compilation

Process for the Literature Selection

In the initial stage 5327 studies were found; but between the time-period of 1979 to 2023 from ScienceDirect and another database 5224 studies were screened, afterwards from those 5224 studies were screened by document type and 3782 studies were research articles, working papers, conference proceedings and technical reports, whereas the remaining were from several other categories such as review article, Encyclopedia, Discussion and so on. As per the last two stages of the study selection (subject area and access type), 2685 studies were selected from those studies through subject area, based on access type. 685 studies were selected, and from those studies, only 33 were eligible for review, while the remaining were excluded on the basis of their title that was not in line with the objectives of the present study. Thus, a total of 33 studies were selected for the review process.

Nature of Selected Literature



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In the present study, a total of 33 studies (technical reports , conference proceeding, research articles) were reviewed. Out of these, 7 were qualitative studies, 25 were quantitative and 1 study was done as per the mixed methodological (qualitative and quantitative techniques).

Table: 2 Sample Size, Instruments, Sample Characteristics

Sr. No	Countries/Regions of the Study	Focus of Study	Stated Research Methodology	Sample Size	Research Instrument	Conclusions /Reported factors affected for adoption of rooftop solar
1	(Carl Blumstein, 1979)USA	To assess of the barriers to the uptake of Rooftop Solar (HRSS)	Interviews were conducted with stakeholders of HRSS	Interview and observation were the research instruments	The interviews of the landlords and managers of the residential sector were done	This study identifies the barriers (institutional and economic) that hinder the uptake of HRSS in the residential sector: high initial investment, lack of information or misinformation, misplaced incentives
2	(Patricia L. Smith, 1980),USA	To provide suggestions to policymakers regarding land use and solar electricity generation technology for end users of electricity	Identification of general impact on land use by decentralized solar electricity generation by review of existing literature and then in the second part of the methodology the identification of characteristics of environmental impact by solar electricity generation	The required data were collected from aerial photographs and documents from the planning department	The data on land use, energy use and technology output were used	This report concludes that the density of residence (attached townhouse) can save more solar electricity than detached houses
3	(Hartman, 1980)Massachusetts (United States)	To assess the commercial potential of solar PV in various user	Technology trade-off curve, household demand for	The economic potential of solar PV was calculated using several	Massachusetts was selected	This study finds that weather, climate, income of the

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		sectors (i.e., the residential sector which received scrutiny)	electricity, income, and price of grid electricity these variables were included in the model to assess the potential of solar PV	mathematical equations		household, price of grid electricity, capital cost and power consumption pattern were the factors that affect the economic potential of solar PV
4	(Curtis, 1982)Hawaii	To identify the barriers to installing HRSS at the household level	The data were collected through a micro-logger which measures AC-DC resistance, volt, microvolt, and AC power fed to the grid	Three households were selected from different insolation conditions and areas central city area (Pearl), rural area (Molokai) and sub-urban area (Kalihi)	Data were collected by micro logger system	The report showed that HRSS is beneficial for households although the high upfront cost and the panel degradation are the issues.
5	(Flavin, 1982)Washington D.C.	Research and Development in solar PV for cheaper electricity generation	Various technologies for solar electricity were compared for various end-user sectors	Existing literature was reviewed	Data were collected from Strategies Cita suttee and the U.S. Department of ELC Conason	The report revealed that solar PV is costly due to the material cost, labourer, assembling, and manufacturing procedure and the suggestions were that the automated assembly procedure and alternative material of crystalline silicon could be utilised
6	(Tabors, 1982)United States	To assess the economic potential of rooftop solar for the domestic sector	Survey method	100 families were selected from Lexington, Waltham, Bedford and Concord (areas of Massachusetts)	Questionnaires were administered by firstly telephone and then e-mail and to verify these two instruments	This report found that the proper and reliable information regarding payback of the HRSS is a major factor that drives the

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					focus group discussions were utilised (having a non-electric home and hot water heating system)	adoption of HRSS
7	(Seifert, 1999)Alaska	To make projection about the economic feasibility of solar electricity generation for the residential sector	Mathematical calculations were done to estimate the power generation of HRSS required data were collected from secondary sources	252 residences were selected from Alaska	Data were obtained from the census 1990 (regarding population, area)	The result of this study showed that HRSS can mitigate the electricity deficit as HRSS consumer's electricity demand reduces and they contribute to the supply side by excess electricity feeding to the power grid
8	(Ram Joshia, 2014)India	To identify the barriers that affect the implementation of energy-efficient building (EEB) and decentralized energy generation (DEG)	Administrative policies and Feed Tariff schemes of various countries for EEB and DEG were reviewed	The administrative policies on solar power in Germany, China and the UK were reviewed	Data were obtained from the official websites of the respective countries	This study identified these barriers of EEB and DEG (i) substantial initial investment (ii) lack of financial incentives (iii)lack of technical guidelines and availability of technology. This study concludes that the major benefit of DEG and EEB is both can mitigate the energy deficit by encouraging prosumerism.
9	(Kewei Xu, 2023; Ram Joshia, 2014)China	To identify the factors which impact the	Geographical detector model	367 cities in the whole of China accept	Data were obtained manually	14 factors were classified into 5 groups:

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		RRS (Residential Rooftop Solar) in China.	(Utilized for spatial stratified heterogeneity analysis), Factor detector analysis was used	Hong Kong and Macao.	from various official websites	environmental factors, economic factors, demographic factors, subsidy factors and power-related factors.
10	(Gyanendra Singh Sisodiaa, 2015)27 European countries	To assess the relationship between HRSS electricity generation and retail price of electricity for residential sector and industrial sector	OLS regression model was used to analyse the data	Official websites and databases were used to obtain the data, and prices were considered before taxes	Required data were obtained from Eurostat and World Bank (from 1995 to 2011), and medium-sized households and industries were considered for the study	This study concluded that HRSS power generation has no significant association with the retail price of electricity in the residential sector but for the industrial sector the positive association but the value of the coefficient is near zero
11	(Nazmiye Balta-Ozkan a, 2015)UK	To assess the determinants of rooftop solar uptake in the residential sector	Regression models were used and for analysis of variation in relationship Durbin model was utilized (cross-sectional data)	The data regarding installation and capacity of HRSS were obtained by the central FiT register which was published by the Ofgem E – -serve database 2013 and the data, regarding socio-economic factors were taken from Census 2011 some data were collected from local administrative units	Households having up to 10 kW HRSS were considered across 134 regions	The result of this study showed that there is a negative relationship between the HRSS installation and the population density on the flip side education level and the share of detached houses are positively associated with HRSS.
12	(Mohammed Muaafaa, 2017)United	To examine whether the wider	ABD (Agent-Based Model) was developed	Selected 13 different sizes of rooftop	Data were collected from two	Size of home, peer effect, solar

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	States	adoption of rooftop solar can lead death spiral of utilities.	to understand the energy choices of people in the United States	solar for the residential sector ranging from 2KW to 12 KW and for non - residential ranging from 2KW to 500 KW	cities in the United States: Lancaster and Cambridge and secondary data were collected from the U.S. Census Bureau and other official websites	irradiance, it was found that the small-scale solar electricity generation was not led to utility's financial losses until there are large scale solar power generation which covers a huge area of land
13	(Opiyo, 2019)Kenya (Kendu Bay area)	To analysis of the factor affecting HRSS installation in the domestic sector	A survey method was utilized and for the data analysis ABM (Agent-Based Model) was utilised	Face-to-face interviews and questionnaires were used as a research tool	208 households (i) with grid electricity (ii) with HRSS installation (iii) having no electricity these three kinds of households in the Kendu Bay area were selected for the study	The findings of this study identified that peer effect (friends, relatives, neighbours, colleagues), advertisement (DS, TV channel, local radio), calculation of the benefits of HRSS, and social status as a green energy generator are the factors among peer effect is found the major influencer for HRSS installation
14	(Andrea Ruíz Lopez, 2019)Colombia	Assessment of the economic potential of rooftop solar at a household level	Mix methodology was used (quantitative and qualitative)	In expert elicitation, 14 experts from academicians, politicians, government officials and industrialists were chosen to broaden the understanding level of solar electricity generation	Online survey and elicitation were conducted by experts for three months on the predefined topic which covered the electricity generation process using	In regions where high electricity tariffs off-grid rooftop solar was relatively viable on the other hand grid-connected rooftop solar was found more viable where the

Sr. No	Countries/Regions of the Study	Focus of Study	Stated Research Methodology	Sample Size	Research Instrument	Conclusions /Reported factors affected for adoption of rooftop solar
					rooftop solar	solar irradiance is relatively less Additionally for off-grid systems the fall in storage price can become more financially attractive
15	(Alsabbagh, 2019)Bahrain	To understand the perception (economic perception) of people towards HRSS to address the issues that hinder the penetration of HRSS in the residential sector	The data collected from the online survey was analysed through SPSS	The online survey was used as a research instrument	764 responses were received from Google form, The responders were permanent residents of Bahrain and 18 years above	This study revealed that high upfront costs and lack of information regarding HRSS are the major barriers and perceptions of people, It was suggested in this study that the government should provide subsidies on HRSS installation and the loan facility should be there through government institutes
16	(Marc Londo, 2020)Netherlands	To analyse consumers' purchasing behaviour of rooftop solar	CDCE (Consumer Decisions Comprehended) model were used to analyse consumer's purchasing behaviour	Six policy alternatives were assessed (i) fully net metering, (ii) maintaining net metered, (iii) limiting net metering (iv) investment subsidy (v) feed-in tariff subsidy (vi) abolishing net metering	Data were collected by in-depth interviews with consumers, expert consultation, online survey and literature review	Several financial aids such as loan and lease methods led the better results of rooftop solar diffusion in the domestic segment
17	(Palm, 2020)Sweden	To distinguish the motivating factors of rooftop solar	The systematic review method and	Swedish rooftop solar adopters' data from nine	Data were collected from the Swedish	Early adopters were driven by environmental

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		adoption between early and late adopters	empirical method both were utilized in the empirical method regression model where the independent variable was the share of votes obtained by the Swedish Green Party in the national election 2014 and the independent variable was per capita solar rooftop adoption from 2009 to 2017	years were used and political preferences were used as a proxy for environmental concern	Energy Agency.	concerns on the flip side late adopters were motivated by economic returns.
18	(Digvijay Singh, 2020)India	To make a comparative analysis of various solar electricity generation technologies and their viability for different climatic zones in India ground at the mounted level and domestic level HRSS installation	For technical analysis (solar irradiance, energy deviation capacity factor, performance factor the PVGIS (Photovoltaics Geographic Information System) was utilized	Simulation software PVGIS was used to measure the monthly electricity generation in different climatic zones	2 kW system was selected at a 90-degree latitude located at different six climatic zones in India (i) hot and dry (Jodhpur) (ii) warm and humid (Chennai) (iii)moderate (Bengaluru) (iv) cold and cloudy (Srinagar) (v) cold and sunny (Leh) (vi) composite (Delhi)	The result of this study revealed that the altitude of the location at which the HRSS is installed affects the potential of power generation (in Leh power generation is 10 to 15 times more than in Chennai), whereas from an economic perspective, monocrystalline technology is cheaper although the efficiency level is relatively low
19	(Isak Öhrlunda, 2021)Sweden	To assess the behavioural changes of HRSS	Panel regression was utilized for data	The questionnaire survey was used for	54 households of the apartment	In this study, the observation was that being

Sr. No	Countries/Regions of the Study	Focus of Study	Stated Research Methodology	Sample Size	Research Instrument	Conclusions /Reported factors affected for adoption of rooftop solar
		consumer's electricity consumption pattern	analysis	pretreatment and post-treatment.	were selected from Uppsala city, the electricity consumption data were collected from tenants' owner boards	a prosumer (HRSS consumer) without having any direct reward on surplus generation as a study conducted on apartment households there is no change in power consumption pattern
20	(Felipe Sabadini, 2021)(Munich City) Germany	To assess the economic feasibility of rooftop solar at the domestic level in Germany	A financial model was used which included NPV and (LCOE) Levelized Cost of Electricity	Required data were collected from secondary sources such as electricity generation data obtained from (NREL)National Renewable Energy Laboratory), and solar irradiance data were taken from software	Households were selected as per five categories (i) 2 adults (ii) 2 adults 1 child (iii) 2 adults 2 children (iv) 2 adults 3 children (v) 2 adults 2 children and 2 seniors	Whether conditions such as solar irradiance, size of family, or annual average electricity consumption of household are the factors that affect the feasibility of rooftop solar, it was suggested that peer-to-peer trading of electricity can exceed the profitability of rooftop solar
21	(Pietari Puranen, 2021)Finland	To assess the techno-techno-economic viability of grid-connected and off-grid rooftop solar	Three storage methods were examined to check their viability (i) monetary storage (ii) network storage (iii) virtual storage	Data of the two separate prosumers were collected for 2017 to 2019	Data for electricity import-export of three years were collected from two different prosumers of two districts of Finland	Network storage was more viable
22	(David J. Wright, 2021)Ontario (Canada)	To understand the Impact of Different tariff structures of HRTSS	LCOE (Lifetime Cost NPV, IRR	The data of Class A (residential building) and Class B	The data were obtained from various sources	The profitability of rooftop solar is affected by the power

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				(commercial building) regarding power consumption and peak demand were collected	(official websites) comprising government research lab (National Renewable Energy Laboratory), research papers, consulting companies	consumption pattern of the consumer, solar irradiance per square meter, the ratio of daytime use of power and total power consumption
23	(Prudence Dato, 2021)Hong Kong	To assess the FIT (Feed in Tariff) scheme in Hong Kong	Payback period calculation	The apartment in Hong Kong was chosen as a sample	The data were collected by questionnaire suevey	The payback period was found 50 years which was longer than the system's lifespan therefore the scheme was not found sufficient to encourage the adoption of rooftop solar
24	(Jordi Olivella, 2021)Lndon	To assess the monetary and non-monetary advantages of rooftop solar adoption	NPV and IRR methods were utilized	To assess the monetary and non-monetary advantages of rooftop solar various categories of reward schemes i.e., subsidised, non-subsidized, compensation	The technical potential was collected from the smart meter energy consumption dataset which was publicly available, the data related to solar radiance collected from the environmental analysis database of UK-related power consumption were collected from 5567 households in London but eventually, 4677 were studied due	Monetary advantages were reduction in electricity bill, earning on surplus power consumption whereas non-monetary advantages of autarky in power generation and being an eco-friendly power generating consumer create a sense of aware citizen of the country.

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					to technical error there were in power consumption was zero therefore they were eliminated	
25	(Xuejiao Han, 2022)Switzerland	To analyse the economic viability of Solar PV for different consumer groups	Calculation of Payback period	The data of annual consumption were obtained by 2200 consumers of rooftop solar (median data from cluster which represent all solar PV from 26 regions of Switzerland	Electricity tariff and annual solar irradiation-related data were collected from secondary sources	The payback period is affected by solar irradiance, rooftop size and energy demand
26	(Deng Pan, 2022)Southern region of China	Assessment of technical and economic potential of rooftop solar in Guangzhou (southern China)	NPV (Net Present Value), IRR (Internal Rate of Returns)	210 samples were taken from various buildings such as residential buildings, schools, universities, commercial and industrial buildings	Data were collected from	IRR was found to be more sensitive towards the PV module price and electricity tariff on the flip side less sensitive towards subsidies.
27	(Galvin, 2022)Germany	To assess the profitability of rooftop solar with the use of a heat pump and rebound effect	Quarterly - hourly data regarding photovoltaic were calculated by dividing the annual value by 4	Detached houses with 4 members were considered for the calculation of the profitability of rooftop solar in the domestic sector.	Data related to photovoltaic power generation, and household power consumption were collected from secondary sources	A larger system with heat pumps and a rebound effect led to more returns and a shorter payback period

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28	(Takahiko Kiso, 2022) (study period was 2009 to 2014)Japan	To assess the impact of electricity price on HRSS installation	The regression model was used	Data regarding the application of HRSS installation were collected from Japan Photovoltaic Energy Association	Two categories of installations were selected for the study (i) retrofit installation (installation in existing building) and (ii) new building installation (installation in newly constructed building)	It was found in this study that retrofits installations were more sensitive to electricity price whereas new building installations were less sensitive towards the price of electricity thus it was suggested that the government should adopt different rates of subsidy for both the category of installation
29	(Archanaa, 2022)India	To analyse the various issues faced by stalk holders of HRSS	Thematic analysis and fuzzy cognitive mapping were utilized to comprehend the association between stakeholders of HRSS and technical advancement	5 semi-structured interviews were conducted with expeHRSS,16 questionnaire surveys and 10 workshops were conducted with HRSS staff stakeholders	Semi-structured interviews with experts, questionnaire surveys, and workshops conducted with stakeholders	The major barrier to Discoms was the financial burden and the major barrier from the consumer side is the lack of financial incentives for sustainable practices from government officials the barrier is the lack of proper implementation strategy. In this study it was suggested that with technological advancement it is essential to increase the social acceptances.

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Sr. No	Countries/Regions of the Study	Focus of Study	Stated Research Methodology	Sample Size	Research Instrument	Conclusions /Reported factors affected for adoption of rooftop solar
30	(Edwin Garabitos Lara, 2022)Cuba (Dominican Republic)	To assess the economic profitability of HRSS for the residential sector based on net metering programme	NPV, IRR and Payback period calculations were done in a Microsoft Excel spreadsheet	The city of Santo Domingo was selected for the study area	The concept of peak solar time irradiance (equation) and PV watt calculator were used to obtain the generation regarding data and the price, and costs of data were obtained from the official website	The result of this study showed that within 580 kWh consumption, the NPV was $7656, the IRR was 6 % and the Payback period was 6.29 years.
31	(Yanquan Zhang, 2023) Australia	To examine the socio-economic factors affecting the adoption of rooftop solar	K- means clustering method and hierarchical regression method	For socioeconomic analysis the data on solar PV adoption rate, solar irradiance	Data were collected from (AGCER) Australian Government Clean Energy Regulator)	Personal characteristics (aged people, young people, married people) people had negatively associated with solar PV uptake, on the flip side household factors (detached houses, house ownership, multi-person households) were positively associated with the same
32	(Belal Ghaleb, 2023)Saudi Arabia	To assess the various barriers that affect mini-solar grid adoption	SPSS, R statistics, Cronbach alpha,	31 respondents from various stakeholder categories (Consumer, policy maker, PV professionals)	In-depth interviews and questionnaire -based surveys were used	21 barriers were categorized into four categories: socio-economic barriers, management barriers, economic barriers, policy barriers

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33	(Samuel H.C. Collier, 2023)England and Wales	To identify the factors associated with the uptake of residential solar PV	Ordinary Least Square (OLS) was utilized	348 households were surveyed	Data were collected from the research articles conducted in Western Europe and the United States and installation regarding data were collected from the energy regulator of the United Kingdom government and ONS Census	Education level was positively associated with solar uptake and homeownership is negatively associated with solar uptake in the residential sector

Source: Author's own compilation

CONCLUSION

After reviewing 33 research papers it can be concluded that the qualitative and quantitative studies on solar electricity generation revealed that many economic factors such as high initial investment, Net Present Value (NPV), Internal Rate of Return (IRR), Payback period, subsidy, tax rebates and price of grid electricity affect HRSS adoption in the residential sector. Social factors that influence HRSS adoption in the residential sector are peer effect, word-to-mouth publicity and social status as a green energy prosumer. Technical factors for the same include availability of solar panels, i.e., the extent of manufacturing the same; the degradation rate of panels, types and efficiency of solar panels and several other factors such as individual behavioural and psychological factors. In the literature review, several suggestions were found to be given in order to mitigate the issues regarding HRSS uptake in the residential sector such as solar electricity generation through HRSS for households should be incentivised on the basis of performance by the government. Moreover, the government should pay attractive unit rates for purchasing of surplus electricity from the households adopting HRSS. This could also go a long way in energy conservation. The government should permit the households for peer trading of the surplus units of electricity. In summary, the HRSS technology is off to a slow start, but shows a promise of expanding rapidly if it is accompanied by appropriate policy support and economic incentives.

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