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The status of renewable energy research on India

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Abstract

This study presents a status of renewable energy research specific to the Indian context. The Indian academic literature on renewable energy from 1998–2014 was reviewed. The major focus was to understand the direction of the energy research (solar) in consumer behavior context. Therefore, the technological research and patent studies were not taken into account for this study. The papers reviewed represent three broad categories, namely, "literature review", "empirical studies" and "qualitative studies". Through this study, it can be concluded that Indian energy market is not yet well researched academically. A slow growth has been observed since 1998, however, a major shift is observed from 2008 onwards.

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Keywords: Indian energy research; solar energy consumerism; India solar research

1. Introduction

The generation and adoption of renewable energy is an issue that is gaining increasing significance in India. It is also a big area for consumer research as the acceptance of renewable energy by Indian consumers is an extensive open question as yet. This paper presents a review of Indian renewable energy literature. In this review, articles are taken that focus on Indian solar/renewable energy (RE) generation and implementation. Literature is coded on the basis of type of articles, e.g. whether it is an empirical research article or review article? What article is focusing on? – barriers, investment, subsidy, perceptions etc. – and finally gaps were identified and presented (Appendix A).

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2. Adoption Parameters (Finances and investments)

There are several factors that play important role in the adoption of solar energy. It is important for various stakeholders to come up together and work in the area of solar adoption.

Liming & Huang (2009) realized the importance of financing needs for the renewable energy generation in India [1]. They classified the financial systems into several categories such as financing by government, international funding, commercial and non-commercial bank financing, public stock markets, private sector financing, venture capitals, subsidies etc. Individual ministries, such as Ministry of New and Renewable Energy (MNRE) and other renewable energy research centres such as Indian Renewable Energy Development Agency Limited (IREDA) and Centre for Wind Energy Technology (CWET) have been established by the Indian government for addressing the renewable energy requirements through financing researches, project development and project implementations.

In the area of rural energy consumerism, it is just before few years academicians started considering putting light on solar products to address the rural electricity needs, and their capabilities to reduce CO_2 emission. Chourey & Kandpal [2] conducted a hypothetical study to address solar lantern's viability in the rural area. They discussed financing methods through government subsidies for promotion of a product, and creation of charging centres for solar lanterns and subsequently creating job opportunities to people, and motivating rural entrepreneurs. However, the market was not picked up by that time, and due to higher perceived challenges, adoption is still a question. It is expected that there is still some time for organizations, and researchers to conduct consumer studies over addressing complex consumers' issues.

Considering 27.1 to 28.3 % of total Indian rural population below poverty line, Rao et al. [3] proposed energy micro-financing for rural people through conceptual framework [3]. It is considered that access to electricity will improve their livelihoods. Mysore case for renewable energy micro finance is quoted in studies where 15 % cost of investment has to be borne by entrepreneur where as 85 % of an investment can be financed by banks as a loan.

Singh [4] raised issues on regulations of buying renewable energies from small producers, feed in tariffs and renewable purchase obligations (RPO). Further, deeper and broader issues such as transmission cost, congestion & promotion of standalone systems based on renewable energy, competitive participation in the electricity markets, widening participation beyond distribution licensees, flexibility to meet RPO, investment barometers, effective utilization of government & technological support, reduction in regulatory risk, and effective compliances are also discussed. Implementation issues are also highlighted, where the coordination between regulators is a critical issue among states. Other stake holders that need to come together are buyers and sellers, generators, banking systems for loans etc.

However, with huge investment in Rajasthan, it is claimed by Pandey et al. [5] that Rajsathan is a preferred state in India for investment in solar energy with 722 companies registered for solar investment to install a solar energy plant with capacity of 16,900 MW. The main argument presented to attract investors is by creating investment friendly government in Rajasthan, thereby promoting policies, creating support infrastructure, facilitation and good governance.

3. Consumer studies

Higher investment cost on solar energy generation by individual households for low economy country has made few businesses to rethink about the proposition. Businesses majorly targeted the rural consumers, where discontinuous electricity or no electricity supply is a crucial phenomenon. Several technologies are introduced in rural and urban India to address the energy needs. Most of the attention was on addressing the cooking requirements. To address smokeless alternative cooking requirements, solar cookers were introduced and further markets were explored [6]. Hot water requirements are also addressed by introduction of passive solar technologies, and market also penetrated at relatively significant level [7]. However, the market for solar cooker doesn't seems appropriate and dynamism is in the favour of providing electricity. Within this framework, Velayudhan [8] studied consumer behaviour pattern of a government programme that disseminated solar lantern as a part of promotion of solar technologies. Most referred source of literature for this study is Rogger's model for diffusion of innovation. Technically reported issues are poor batteries and lack of charging facilities. Additionally, maintenance problems were not handled carefully. However, promotion was subsidy driven and final price was less than that of petromax, but, unplanned distribution strategy

resulted in the failure of the Government promotion scheme. According to Roger [9], financially advantageous consumers should be targeted first for the innovation adoption cycle to continue; however, in this case, instead of profile based targeting of early adopters, government targeted disadvantageous groups that resulted in a market failure.

Similarly, Peter et al. [10] relied on Rogger's diffusion of innovation model to determine the factors that foster the adoption of solar photovoltaic (PV) through empirical studies. The government leadership role along with financing policies is crucial for the propagation of such a technology. However, through the study, targeted consumers are not clear and additionally, ongrid/offgrid issues are not addressed carefully.

Further, Pohekar & Ramachandaran [6] analysed cooking fuel choices of solar cookers for framing policies. The study used multi criteria decision support system methods for modelling the choices. Later, Pohekar & Ramchandaran [11] in another article used multi attribute utility theory. However, solar cookers were least preferred by consumers; reason were: cooker were high priced, there were maintenance issues, and they were bigger in size.

To more recent, Bhandari et al. [12] studied the preference of households among standalone solar photovoltaic (SPV) and mini grid home lightening system (HLS). The Logit model for econometrical modelling is used in this study to know the preferred choices. Through analysis, it is proposed that price of kerosene is a critical factor. If the expenditure on kerosene is increased, then the willingness to adopt solar electricity supply through mini grid increases. This is likely to happen because the kerosene price at higher level competes with mini grid supply prices.

To further address the CO_2 emissions by using kerosene, Pode [13] puts forth the idea of using solar light emitting diodes. However, he noticed various barriers to adoption, such as, economic & financial (low purchasing power), awareness, technical, market (lack of established dealers networks), social, institutional (inadequate policies) etc.

In line with Pode, Bhide & Monroy [14], also studied energy poverty in India, and argued on the problems that are basic to Indian consumers in energy sector. They identified the barriers to adoption, for example, lack of finances, lack of legal frame work because of which private participation is less, less or no incentives to businesses, unrealistic political commitments and alteration of electrification plans according to political interests, lack of sufficient geographical & technical awareness.

Further, Mani & Dhingra [15] explicitly argued and reinforced that solar technologies have not yet penetrated in Indian market. Expecting few years for technology penetration, solar adoption had not attracted enough scientists and researchers to widely conduct consumer research. They tried to explore the linkages with frameworks that were adopted for mobile and internet penetration in India. They further discussed the following key concepts of diffusion of innovation relevant to renewable energy production.

"1. Target Market and Market Segment – Identification of communities of Innovators and early adopters of RE sources who can be the initial users of RE sources.

2. Communication message – how to tailor the communication to highlight the value (Clean Environment, Energy Security), convenience (locally distributed) and cultural association (Sun, water, air, earth and fire are considered sacred and provider of life by Indians; hence solar, hydro & wind energies will evoke strong positive cultural connects) of RE sources to early adopters so that they are sufficiently motivated to adopt RE sources become opinion leaders for others to follow.

3. Specific focus on relative advantage of RE sources over fossil fuels, perceived compatibility, less complexity and overall observability of benefits (reduction in pollution levels, less suspended matter in the environment, etc.) needs to be kept in mind to accelerate acceptance of RE sources

4. Channels of Communication – How to leverage both personal and impersonal medium to reach the target market and support them through the adoption process of awareness, interest, evaluation, trail and adoption."

Despite dynamism of RE industry in India, so far there has been little discussion about consumer research. However, refuting to low level of consumerism of renewable energy in India, Harish et al. [16] conducted a qualitative study to understand the consumerism of solar products is Karnataka, for which they interviewed solar firms, banks and consumers. It is observed that a large proportion of households in sample were connected to the grid but chose to install solar lighting because they considered the power supply from the grid to be unreliable. Households in sample reported savings on electricity costs and reduced kerosene usage for lighting. In addition to providing credit, banks also play a key role in ensuring better service; the viability of the solar light house market is critically dependent on the role that the banks play as intermediaries between consumers and solar firms in rural areas.

Sovacool & Lakshmi [17] also proposed a triangular model for acceptance of renewable energy in India, which mentions that to penetrate in the market, socio political acceptance, market acceptance and community acceptance

play critical role in overall RE acceptance. Furthermore, in a very recent study, Forster [18] studied the solar consumerism efficiency on urban Indian consumerism and reflected on direct distribution model. Brief overview of historical development of solar energy in India

Kapoor et al. [19] mentions that despite the huge geographical potential, renewable energy generation was not the part of significant discussion until the sixth five year plan (1980–1985). Since 10th five year plan (2002–2007) the installation and generation through solar has shot up. In the year 2011, Indian government has started Jawaharlal Nehru National Solar Mission to accelerate the on grid and off grid generation of solar energy through PV, with a target to generate 22,000 MW of solar energy. In 2014, the grid connected solar exceeded 2.2 GW and is expected to increase more in coming years. In the 12th five year plan (2012–2017), the India plans to produce 1000 MW of silicon wafers. Each of the state has different incentive schemes to promote the solar energy production, however, there are market challenges for the acceptance of the technology [19]. India has also undergone the memorandum of understanding with UAE for the exchange of knowledge database and skilled resources for the development of both the countries [20].

4. Conclusion

Considerable amount of literature has been published on RE. It is observed that despite huge possibilities, a high consumer base and renewable potential, Indian research needs a focus on this area too. The area seems dynamic as different types of research (majority type mentioned in table 1) are noticed in the area. Major shift is observed from year 2008 onwards. Despite a slow growth, solar photovoltaic (PV) is likely to be disruptive technology in energy sector. Energy generation through other technologies such a wind has also been commendable. In the 11th five year plan, the installed capacity exceed to 10,260 MW, whereas, the initial proposal was for 9000 MW [21]. Additionally, energy generation through Biomass also has huge potential. Out of total renewable energy production, biomass has a share of 12.83 % and the total capacity for biomass energy generation in India is around 17,500 MW [22]. Clearly, with huge forest and agriculture area, the biomass is also to likely to take up in future if sufficiently promoted and well supported through incentivization. Sisodia et al. [47] proposed that developing countries such as India can learn from the mistakes of developed nations (e.g., Europe) while planning the energy sustainable frameworks. Therefore, regions that have considerably recognized the research development and policy support for biomass innovation [48–50] can show new direction to the emerging economies in the context of biomass policy context.

Appendix A. Literature survey and gap identification table

YEAR	AUTHOR	TITLE	TYPE	FOCUS	GAP
1998 [23]	“Garg, H. P., & Khas, H.”	“Renewable Energy Programme and Vision in India”	review	policies	expansion plans
2000 [24]	“Suganthi, L., & Williams, A. “	“Renewable energy in India - a modelling study for 2020-2021”	empirical	energy demand	investment planning, regulations, finances
2003 [8]	“Velayudhan, S. K.”	“Dissemination of solar photovoltaics: a study on the government programme to promote solar lantern in India”	empirical	consumer/innovation	investment planning, regulations, finances
2004 [6]	“Pohekar & Ramachandran”	“Multi-criteria evaluation of cooking energy alternatives for promoting parabolic solar cooker in India”	empirical	policy development	investment planning, regulations, finances
2006 [25]	“Banerjee, R.”	“Comparison of options for distributed generation in India”	review	price viability	investment planning, regulations, finances
2006 [10]	“Peter, R., Dickie, L., & Peter, V. M.”	“Adoption of photovoltaic power supply systems: A study of key determinants in India”	empirical	determinants for success of PV adoption	investment planning

2006 [11]	"Pohekar & Ramachandran"	"Multi-criteria evaluation of cooking devices with special reference to utility of parabolic solar cooker (PSC) in India"	empirical	choice modelling, policy development	investment planning, regulations, finances
2007 [26]	"Chandrasekar, B., & Kandpal, T. C. "	"An opinion survey based assessment of renewable energy technology development in India"	empirical	opinions	investment planning, regulations, finances
2007 [36]	"Liming, H. "	"A study of China–India cooperation in renewable energy field"	review	India-China relationship development policy over renewables	investment planning, regulations, finances
2007 [27]	"Purohit,P. "	"Financial evaluation of renewable energy technologies for irrigation water pumping in India"	review	financial evaluation	investment
2007 [28]	"Ramachandra,T.,V., & Shruthi., B., V. "	"Spatial mapping of renewable energy potential"	empirical	potential mapping	investment planning, regulations, finances
2007 [29]	"Singal, S. "	"Review of augmentation of energy needs using renewable energy sources in India"	review	energy usage	investment planning, regulations, finances
2008 [30]	"Carolinmabel, M., & Fernandez, E. "	"Growth and future trends of wind energy in India"	review	energy usage	investment planning, regulations, finances
2008 [31]	"Purohit, P., & Michaelowa, A"	"CDM potential of SPV pumps in India"	review	potential mapping	investment planning, regulations, finances
2009 [32]	"Bhattacharya, S. C., & Jana, C"	"Renewable energy in India: Historical developments and prospects. Energy"	review	energy usage	investment planning, regulations, finances
2009a [33]	"Chaurey, A., & Kandpal, T. C"	"Carbon abatement potential of solar home systems in India and their cost reduction due to carbon finance. "	review	projection of reduction of CO2	investment planning, regulations, finances
2009b [2]	"Chaurey, A., & Kandpal, T. C"	"Solar lanterns for domestic lighting in India: Viability of central charging station model"	review	potential mapping	investment planning, regulations,
2009 [34]	"Golait, N., Moharil, R. M., & Kulkarni, P. S"	"Wind electric power in the world and perspectives of its development in India"	review	perspective	investment planning, regulations, finances
2009 [35]	"Hiremath, R. B., Kumar, B., Balachandra, P., Ravindranath, N. H., & Raghunandan, B. N. "	"Decentralised renewable energy: Scope, relevance and applications in the Indian context. Energy for Sustainable Development, 13(1), 4–10. "	review	perspective	investment planning, regulations,
2009 [37]	"Parikh, K. S., Karandikar, V., Rana, A., & Dani, P. "	"Projecting India's energy requirements for policy formulation"	empirical	projection for policy formulation	investment planning, financing
2009 [38]	"Purohit, P. "	"CO2 emissions mitigation potential of solar home systems under clean development mechanism in India."	review	projection for policy formulation	investment
2009 [3]	"Rao, P. S. C., Miller, J. B., Wang, Y. D., & Byrne, J. B. "	"Energy-microfinance intervention for below poverty line households in India"	review	conceptual framework	policies. Investment interest is not addressed adequately, regulatory

2009 [4]	"Singh. A"	"A market for renewable energy credits in the Indian power sector"	review	regulation	Investment variables are not clear
2009 [39]	"Urban, F., Benders, R. M. J., & Moll, H. C. "	"Energy for rural India"	review	potential mapping	investment planning, regulations, finances
2010 [40]	"Bal, L. M., Satya, S., & Naik, S. N. "	"Solar dryer with thermal energy storage systems for drying agricultural food products: A review"	review	potential mapping	investment planning, regulations, finances
2010 [12]	"Bhandari, A. K., & Jana, C. "	"A comparative evaluation of household preferences for solar photovoltaic standalone and mini-grid system: An empirical study in a coastal village of Indian Sundarban"	empirical	choice modelling, policy development	investment planning, regulations, finances
2010 [41]	"Mallah, S., & Bansal, N. K. "	"Renewable energy for sustainable electrical energy system in India"	empirical	potential mapping	investment planning, regulations, finances
2010 [13]	"Pode, R. "	"Solution to enhance the acceptability of solar-powered LED lighting technology"	review	choice modelling, policy development	investment planning, regulations, & finances not discussed in detail
2010 [42]	"Purohit, I., & Purohit, P. "	"Techno-economic evaluation of concentrating solar power generation in India"	empirical	potential mapping	investment planning, regulations, finances
2011 [14]	"Bhide, A., & Monroy, C. R. "	"Energy poverty: A special focus on energy poverty in India and renewable energy technologies"	review	barriers in adoption	details re not furnished on investments, and plannings
2011 [43]	"Parikh, J., & Parikh, K. "	"India's energy needs and low carbon options"	review	Demand forecasting	investment planning, regulations, finances
2011 [44]	"Ramachandra, T. V., Jain, R., & Krishnadas, G. "	"Hotspots of solar potential in India. "	review	potential mapping	investment planning, regulations, finances
2011 [15]	"Mani, S., & Dhingra, T. "	"Diffusion of innovation model of consumer behaviour – Ideas to accelerate adoption of renewable energy sources by consumer communities in India"	review	consumer behavior linkages to renewable energy adoption	investment planning, regulations, finances
2012 [5]	"Pandey, S., Singh, V. S., Gangwar, N. P., Vijayvergia, M. M., Prakash, C., & Pandey, D. N. "	"Determinants of success for promoting solar energy in Rajasthan, India"	review	policies	detailed investment policies, distribution
2012 [45]	"Timilsina, G. R., Kurdgelashvili, L., & Narbel, P. a. "	"Solar energy: Markets, economics and policies. Renewable and Sustainable Energy Reviews, 16(1), 449–465. "	review	policies	details on investment determinants, operationalization, distribution
2013 [16]	"Harish, S. M., Iychettira, K. K., Raghavan, S. V., & Kandlikar, M. "	"Adoption of solar home lighting systems in India: What might we learn from Karnataka? Energy Policy, 62, 697–706. "	Qualitative study	consumerism	details on investment determinants, operationalization, distribution
2014 [46]	"Sisodia, G.S. & Gupta, D. "	"Conceptual Framework for the adoption of solar products in India. In Press, ASB working paper"	review	Conceptual framework	details on investment determinants, operationalization, distribution

2014 [18]	Forster, R.	"Let there be Light… but what comes next? Changing energy needs and the ability of decentralised solar energy to provide sustainable solutions to urban slum communities in Bangalore, India"	Qualitative study	consumerism	details on investment determinants, operationalization

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