Factors Affecting the Adoption of Renewable Energy - Inferences from Literature

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ABSTRACT

The Sustainable Development Goals (SDGs) explicitly require nations to ensure access to affordable, reliable, sustainable and modern energy for all under Goal 71. Acknowledging the significance of universal access to modern energy for achievement of other SDGs, several nations (including India) are considering this as a priority. Though significant progress has been made in this regard, the vision of achieving this goal continues to be blurred primarily due to certain barriers impeding the adoption of renewable energy (RE). In this backdrop, this study attempts to identify key barriers for adoption of REon the basis of a systematic review of Literature. The findings suggest that financial and regulatory factors have a major bearing on its adoption. Further, the sparsity of empirical study exploring barriers in the Indian context is also highlighted. Policy measures that enhance the attractiveness of RE for Private sector could assist in realising the potential of RE.

Keyword(s): Renewable Energy, Barriers, Sustainable Development Goal (SDG).

1. INTRODUCTION

India has adopted Agenda 2030 consisting of 17 SDGs and 169 targets and is also one of the signatories of the Paris Climate Agreement. In light of this, significant efforts are being made to imbibe multi-dimensional development agenda into national frameworks. However, in achieving the SDGs there are two major challenges. First being the Comprehensiveness of SDGs covering almost everything with varied forms and types of inter-linkages among the goals and targets. Second, is the requirement of huge financial resources. These challenges necessitate having the prioritization of goals and targets based upon synergistic interlinkages and national priorities.

On the basis of the inter linkages of energy with other goals, meeting energy needs has been highlighted as the priority goal by several researchers. Further, India's urbanisation coupled with its aspirations to be superpower underscore the need of creating new capacities to meet the insatiable energy demand. Given the factors such as heavy reliance on coal and crude oil imports, usage of subcritical generation technology by over 85% of coal plants, average efficiency of coal-fired fleet under 35%, depleting coal deposits, ageing power facilities and last but not the least the volume of CO_2 emissions the significance of RE

1 The Sustainable Development Goals (SDGs) are a collection of 17 global goals set by the United Nations General Assembly as a part of Resolution 70/1 of the United Nations General Assembly: Transforming our World: the 2030 Agenda for Sustainable Development.
Energy is dealt under Goal 7 of SDGs with overarching aim of ensuring access to affordable, reliable, sustainable and modern energy for all with three targets (1) ensure universal access to affordable, reliable and modern energy services (2) increase substantially the share of renewable energy in the global energy mix (3) double the global rate of improvement in energy efficiency

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in Indian energy mix becomes crucial.

Thus, considering a present scenario and India's varying endowment of resources and biodiversity, renewable energy will not only resolve the twofold challenge of meeting energy needs and lowering carbon emission but will also be a convincible answer to some of the most pressing socio-economic challenges. Realising the potential of RE, the Government has already set up an ambitious target of installing 227 GW of clean energy by March 2022 and made considerable progress in the last couple of years. However, as of December 31, 2018 total installed renewable power capacity stood approximately 74,786 MW(grid-interactive) and 1144.37 (off-grid)respectively which is merely 20% of the total installed capacity of power in India. The table below highlights the potential and installed capacity of various sources of RE in India as on 31.12.2017.

Table 1 Potential and Installed Capacity of Various Sources of RE in India

Renewable Energy	Potential (MW)	Installed Capacity (MW)
Solar	750000	17234.37
Wind**	137661	32848.46
Biomass	25000	8414
Small Hydro projects** (projects up to 25 MW station capacity)	21133.62	5172.315
Biogas (3-250 KW)	-	7.04
Small wind energy and hybrid system	-	3.287
Total	183794.62	63679.472

* validated potential has been considered *(Source MNRE Annual Report 2017-18. Data as of December 2017)*

** capacity created includes project under implementation

Here it may be noted that generation capacity and actual generation are two different things, since the Capacity Utilization Factor (CUF) of RE is less than other forms of energy, the capacity created should not be considered as the true indicator of adoption of RE. Table 1. depicts the data of potential versus capacity created of RE in India, as per the aggregates, only about 35% of the potential that has been tapped. This highlights that other than potential, certain factors are affecting the adoption of RE. This study tries to explore such factors and thus add to the existing literature in this context.

The paper is organized into five sections, wherein Section 2 discusses the methodology used for the review. Third Section reviews the existing literature about the factors affecting RE. Section 4 discusses the gaps in the existing literature and the fifth section concludes the paper.

The ParisAgreement builds upon the United Nations Climate Change Convention and brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects.

India's power system needs to almost quadruple in size by 2040 to keep pace with rising demand i.e. increase at almost 5% per year (IEA 2015).

India accounts for roughly 12% of world coal imports and has become the third-largest crude oil-importing country, behind the United States and China.

India is world's third-largest country (behind China and the United States) in terms of volume of Co^2 emission

2. METHODOLOGY

The review has been initiated based upon the theory suggesting that the difference between the potential and capacity created can be attributed to certain factors. These factors may act as enabler i.e. have a positive impact on the capacity created or act as barrier i.e. have a negative impact on the capacity created. Since the country is trying to utilise its potential it aims at minimising the gap between the potential and capacity created by creating more capacity. By taking appropriate actions with respect to these factors, more capacity can be created.

Based upon this, the paper seeks to answer what are the factors that impact the adoption RE? Further, through literature review, it has been analysed whether these factors vary across countries and the type of technology. Also, the methodologies used for such studies have been analysed so as to identify the gaps, if any in the methodologies used in the existing literature.

A structured review covering academic resources and reports (released by National and International Organisations) has been conducted. Specific search protocol using search terms (1) renewable energy and related terms such as clean energy, solar energy, wind energy, etc. (2) barriers, hurdles, and factors affecting adoptions have been used to query relevant studies from three major databases namely J-Gate, Elsevier Science Direct, and EBSCO.In order to ensure that most relevant literature could be reviewed (within the given the time and resource) and the probability of including irrelevant literature could be minimised, initial screening was undertaken as part of the database search, wherein titles, and keywords are analysed based upon the following selection criteria:

1. Subject matter: This review is related to the renewable energy thus the studies elaborating on the energy in general without focussing on renewable energy are not emphasised. Studies analysing the factors affecting various sources of renewable energy have considered so as to ensure that the overall picture of the renewable energy sector could be understood.
2. Geographical scope: The study has not used geographical constraint. Though nations have different economic, demographic and political set up however all nations are at different stages of development and we can very well learn from the experiences of other nations.
3. Time horizon: Since the adoption of renewable energy has gained momentum from the year 2000 onwards, studies focussing on post 2000 period are considered.
4. Methodological approach: As per (DFID 2013), there are three types of studies, primary and empirical studies [P&E], secondary [S], theoretical or conceptual [TC], this study focuses more on P&E rather than other two types.
5. Language: Only studies available in the English language has been considered

The studies passing the initial screening were downloaded for further review. Thereafter, the second level of screening was conducted wherein the abstracts were reviewed in light of the research objective and inclusion criteria. The papers which were considered out of the scope of the review were excluded. In addition, Reports from National and International organisations such as International Energy Association, Ministry of Non-Renewable Energy, Ministry of Petroleum and Natural Gas, Council on Energy Environment and Water, NITI Ayog, United Nations and World Bank and papers/studies identified through back referen-

Ratio of actual energy generated by the project over the year to the equivalent energy output at its rated capacity over the yearly period.

As per the U.S. Energy Information Administration (EIA) capacity is the maximum output of electricity that a generator can produce under ideal conditions.

cing of searched papers were also included.

After selecting the final list of papers, reports, etc. were reviewed, annotated bibliography was prepared and literature was synthesised to identify the methodology used, factors identified and gaps.

3. REVIEW OF LITERATURE

The review has been classified into two parts, first elaborating on the methodologies used by the earlier studies for identifying the factors affecting the adoption of RE and second mentioning the factors identified by the previous studies. The literature reviewed has used varied methodologies ranging from primary data-based, secondary data-based and conceptual.

The studies based on primary data on the subject tend to give a micro level view of the barriers from the perspective of the investors and other stakeholders. These studies generally focus on analysing the barriers faced by a specific group of stakeholders rather than the sector as a whole and thus help in understanding the root cause of the problem. The primary data based micro level perspective was initially used by Wiser and Pickle (1998) and was later used by several other researchers in this domain. Notably, Painuly (2001) emphasised the significance of stakeholders' perspective in the framework for identifying the barriers to RE. The framework proposed by Painuly highlights that barriers have several elements (causes for presence of barriers) and dimension (direction and depth of barriers). Since then this method has been by various researchers with different categories of respondents including investors (Jonghet al. 2014), project developers (Friebe et al. 2014), consumers (Murakami et al. 2015), and energy experts (Eleftheriadis and Anagnostopoulou 2015). The studies based on this approach have used structured survey, semi-structured interview as well as hybrid techniques of data collection.

For instance, Ahlborg and Hammar(2011) and O'Keeffe and Haggett(2012)used semi-structured stakeholder interviews to identify barriers in two African nations and Scotland respectively. Moreover, Paul Lehman et al. (2012) used Survey and interview method while Jonghet al. (2014) used structured interview, Friebe et al. (2014) used a mix of qualitative data analysis and quantitative survey approach to identify key factors and evaluate their importance in the context of wind energy.

For analysis, researchers have used sophisticated methodologies such as Analytical Hierarchy Process (Nguyen et al. 2010), interpretive structural modelling (Eswarlal et al. 2011), MIMAC analysis (Eswarlalet al. 2011), choice experiment (Murakami et al. 2015), techno-economic power system model (Hirth and Steckel2016)for identifying the factors affecting RE.

The studies based upon secondary data tend to give a macro view of the state of factors in the nation as a whole. Most of the studies based upon secondary data have analysed the impact of finance, regulatory framework and macroeconomic factors on the adoption of RE.

In an early study of 2011, Zhao et al. used correlation to show an association between the regulatory framework for the RE and RE industry in China. In the same year, Shrimali and Kniefel (2011) estimated the effects of state policies on the penetration of various emerging renewable electricity sources using a state fixed-effects model with state-specific time-trends on the panel data of over 50 US states for the period 1991–2007.

Lean and Smyth (2013) applied stationarity tests and panel unit root test on the dataset of 115 countries over the period 1980–2008 to examine the effectiveness of policies in promoting renewable electricity. While Zhao et al. (2013) used the Poisson pseudo-maximum likelihood estimation technique with a panel dataset covering 122 countries over the period of 1980–2010 to study impact of policies on adoption of RE, Pfeiffer and Mulder (2013) used a two-stage estimation approach on a panel of 108 developing countries to study the adoption of non-hydro based renewable energy. Later on, Basher et al. (2015) noted not stationarity in the share of electricity generated through RE in many OECD countries which

posed a challenge in conducting time series analysis on such datasets.

Best and Burke (2018) used cross-sectional and panel regressions to assess the impact of aggregate policy support and Carbon pricing on the adoption of solar and wind energy.

Conceptual study based upon a review of Literature has also been reviewed in this regard(Bhattacharya et al. 2010; Mezheret al. 2011; Wang et al. 2014; Umamaheswaranand Seth 2015).

The literature points out that there is a gamut of factors that affect the adoption of RE. Some studies have classified these factors into different categories and dimensions. For instance, Painuly (2001) classified barriers to RE as a market, economic and financial, institutional, and technical barriers and highlighted that dimensions of each barrier may vary across Renewable Energy Technology (RET) and countries. Painuly and Wohlgemuth (2006) acknowledged that barriers exist on demand as well as supply side. While Mezheret al. (2011) grouped the barriers into three main categories: market technology, policy legislation, and cost Ahlborg and Hammar (2011) classified barriers into four categories namely technological, economic, financial and institutional barriers. Jongh et al. (2014) identified five aspects that mainly influence RE investment decisions these being investor background, political factors, economic factors, social factors, and technological factors. D and Komendantov (2015) highlighted that there are certain structural, cultural, systems and strategic barriers for the development of renewable energy. Nasirov et al. (2015) gave a much comprehensive category of barriers which include institutional, regulatory, economic, financial, technical, infrastructure, informational barriers. While Rehman and Hussain (2017) classified these as institutional, political and financial. Ioannou et al. (2017) viewed that RE is exposed to technological, financial, economic and regulatory barriers which vary across technology, country and policy regimes.

Several studies have highlighted finance as a major barrier (Painuly and Wohlgemuth 2006), (Bellanca et al. 2012) in the path of adoption of RE and there are multiple sub factors leading to this barrier which include:

1. High cost associated with RET: Though operating and maintaining RET is relatively cheaper, the initial set up cost which constitutes of costs such as cost of technology (TWAS 2008), start-up cost(Painuly and Wohlgemuth 2006) and cost of resource assessment(World Bank 2011)are quite high. Considering the case of India wherein a significant portion of technology used for RE, particularly solar panels and modules are imported from China and Malaysia, the imposition of safeguard duty, and continuous fall of the Indian rupee against the US dollar has only contributed negatively to the adoption of RE. Though Government has tried to augment manufacturing of solar panels in India by floating a 10 GW tender in May 2018, however the same was postponed multiple times without garnering much of favourable response.
2. Risk perception: RET is inherently risky (Pegels 2010), the risk is due to resource risk, regulatory risk,(World Bank 2011), technology risk (ODI 2012),economic and financial viability (O'Keeffe and Haggett 2012; Jongh et al. 2014), investment risk (Butler and Neuhoff 2008; Sovacool, 2010; Mezher et al. 2011;Bhattacharya and Cropper 2010) market risk(Ioanna 2015). The high investment required vis à vis very limited returns in the short and medium run (Bonan et al. 2016). (Chaurey et al.) 2004 highlighted that Private sector financing is directly linked with growth and development of the market for renewable energy however, the preference of private investors for short-term gains over long term investments(Andrada 2015) adversely impacts investments from private participants.
3. Availability of finances: Given the requirement of high initial cost and varied types of risk, RE faces critical financing gap due to

lack of long term loans (World Bank 2011), pre-commercialization financing gap (Usman et al. 2012), capital restrictions (ODI 2012) scarce funding opportunities (Bhattacharya and Cropper 2010) constrained public finances (World Economic Forum 2013, Andrada 2015 Paris EUROPLACE 2016, Della Croce et al., 2011) and financial regulations that discourage long-term energy finance (Kaminkeret al. 2012; Ng and Tao 2016).

4. Pricing of Renewable Power: In India, Government has been providing investment as well as price subsidies to conventional energy since long because of which they are relatively cheaper than the RE and thus people prefer them. To address this issue and to get the DISCOMs to procure RE, Government has tried to put a cap on the RE prices. For instance, solar tariffs have been proposed at 2.68/kWh and Rs 2.5/kWh with and without safeguard duties on modules, respectively. However, researchers are of the view that such price controls (ODI 2012) act as a barrier as they raise concern over the sustainability of the RE projects.

In this regard, the impact of regulatory factors has also been highlighted. Several researchers have found that adoption of RE is complemented and supported by regulatory frameworks encompassing laws, rules, policies, schemes and other measures to enhance the share of RE in the energy mix. Over the last decade several kinds of literature have also analyzed the impact of the regulatory framework as an aggregate and impact of varied regulatory components such as fiscal measures including subsidies, tax rebates or specific schemes such as carbon pricing, purchase obligation, feed in tariff, etc. on adoption of RE, however the results have been mixed.

Researchers like Carley (2009), Pegels (2010) and Marques and Fuinhas (2012) have highlighted the negative impact of legislation on the adoption of RE, yet a number of studies have found a significant positive association of legislation and adoption of RE. (Menz and Vachon 2006; Atmanand et al. 2009; Yin and Powers 2010; Shrimali andKniefel 2011; Zhao et al. 2011).

Zhao et al. (2013) concluded that though policies play a crucial role in promoting RE generation, their effectiveness is subject to diminishing returns as the number of policies increases. He further found that the effectiveness of aggregate policy varies by the type of policy and energy source. For instance, policies involving voluntary participation appear to have a negative relationship with renewable energy investment (Aguirre and Ibikunle 2014).

Lean and Smyth (2013) found that policies which result in one-time shocks, such as investment incentives or tax credits are less effective in comparison to stable policies which are designed to have a permanent impact. Pfeiffer and Mulder (2013) have shown negative impacts of institutional and strategic policy support measures, but positive impacts from economic and regulatory instruments.

Researchers have highlighted fossil energy pricing policies bear a crucial impact on RE adoption. In this regard, the idea of charging agents for the external costs dates back to Arthur Pigou however it has gained popularity with the idea of internalisation of the social and environmental cost in terms of carbon pricing. Thus, carbon pricing is another specific policy that could influence renewable energy adoption. Researchers have found it to be effective in enhancing RE adoption (Aldy and Stavins, 2012) as this leads to an increase in the price of fossil based energy which otherwise is cheap in comparison to RE. Best and Burke (2018) found that there is a positive association between aggregate and solar energy use only and the positive impact of carbon pricing on both solar and wind energy.

https://pub.iges.or.jp/pub_file/iresvol4-2249pdf/download

Though several researchers have found feed-in tariffs to be effective in promoting the development of all types of RE. (Zhao et al. 2013; Smith and Urpelainen 2014; Wang et al. 2014). Pegels(2010) found an alteration in Spanish feed-in tariff in 2008 led to a significant fall in market growth rates of solar technology. Adding to this, Polzin et al. (2015) noted that feed-in tariffs are more effective for less mature technologies.

Johnstone et al. (2010) found that policies provide an impetus to innovation: which consequently leads to enhancement in RE. The rationale for this could be that technology and policies act as a platform as well as a framework for the adoption of RE.

Also, the policies tend to improve financial landscape which results in correction of externalities (Masini and Menichetti 2012) and thus attract investments for RE. Further Andrada (2015) emphasised the role of Government in stimulating private financing towards sustainable development including renewables. Umamaheswaran and Seth (2015) highlighted that well defined regulatory framework coupled with effective implementation of RE policies and public finance mechanism can significantly improve the financing landscape and thus assist in better adoption of RE. Energy Policies are also effective in addressing Demand side barriers such as public awareness (Eswarlal V K et al. 2011) and acceptability (O'Keeffe and Haggett 2012) by spreading environmental awareness Zhang et al. (2011) and highlighting the significance of Sustainable Development discourse. (Atmanand et al. 2009).

Sarzynski et al. (2012) found that mere presence of policies is not effective in increasing the deployment of solar technologies; however, their implementation becomes effective at increasing the deployment of solar technologies as during the course of implementation significant experience is gained. Baldwin et al. (2016) found that the impact of policies varies across countries in different income groups.

Further, difference in the adoption of RE across countries could be attributed to various country specific factors (Paris EUROPLACE 2016);such as trade openness (Omri and Nguyen 2014; Lin and Omoju 2017), schooling levels, democratic regimes, fossil fuel production, energy mix Pfeiffer and Mulder (2013) , grid connectivity (O'Keeffe and Haggett 2012;Ahlborgand and Hammar 2011, governance gaps (D Nel 2015, Bellanca and Wilson 2012), Poverty and technological readiness (Jongh et al. 2014), trade intensity (Pfeiffer and Mulder 2013) historical national carbon dioxide emission levels. Theories such as, The National Endowment (use of energy as per the availability of resources) and the Energy Ladder (use of different types of energy as per-capita income) are also crucial approaches in explaining the adoption of RE.

Apart from the factors affecting the nations differently, there are certain factors that differ according to the type of RE. For instance, Nguyen et al. (2010) found barriers differ according to the type of RET in Vietnam. He highlighted that while small hydro generation has barriers such as insufficient capital, lack of domestic suppliers and unsatisfactory government policies geothermal power have barriers such as information and awareness gaps, industrial capability, lack of research and development facilities, weak policy framework and the remoteness of geothermal sites.

4. INFERENCES FROM LITERATURE

There have been mixed responses with regard to the impact of vivid factors, this may be attributed to certain gaps in the literature, some of them are highlighted below:

The studies have either focussed on the macro view or on the micro view, to the best of knowledge, there is virtually no study that combines the both. There is a need to conduct a study that combines the macro and micro perspective so as to assist in better understanding of the root cause of the issue and thus using targeted muti-dimensional policy approach to address the issue. Further, as the prices of fossil fuel have a significant impact on RE, the variables impacting the prices of fossil based

energy such as subsidies to fossil fuel, oil prices, etc. also need to be considered. The macro studies have focussed more on the regulatory barriers while several other variables such as pricing of RE, subsidies to fossil based energy, etc. have not been considered. Further, Basher et al. (2015) highlighted that most of the secondary data based studies have relied upon the panel analysis and have typically used the share of RE generation (%) as the dependent variable, highlighting that there may be an issue of spurious regression (Granger and Newbold 1974). In most of the cases, capacity created is considered as an indicator for the adoption of RE, however, the actual share of RE in energy generated may be different, depending upon the efficiency of the technology being used. However, no study has considered this aspect as well.

Geographical scope: Although several papers have examined vivid nations and regions, however, to the best of our knowledge, a systematic analysis of this problem in the context of India is still lacking. There is no econometric study which explains the factors impacting the adoption of RE in India. Barriers are country-specific and thus it is essential to analyse the barriers in the Indian context.

Scope of RE: It has been found that most of the studies focus on either renewable energy as a whole or have focussed on classification such as hydo – non hydro energy, wind and solar energy. Studies acknowledging the comprehensive meaning of the term RE, encompassing all types of RE and individually examining barriers of each type of RETare quite sparse. It is important to consider energy types separately due to the differences in technology attributes and stage of technology maturity. Further, in most of the discussion and researches, RE connotes to the energy as a source of electricity and ignoring the type of fuel being used for cooking. Thus there is a need for considering comprehensive definition of the term energy.

5. CONCLUSION

Significant potential for generating RE remain under-utilised due to a number of factors. The literature reviewed suggest that financing is seen as a major challenge in the adoption of RE along with certain policy barriers and information gaps.

Donastrog et al. (2017) highlighted that financing renewable energy projects require significant resources, access, and availability of which is a major challenge for many developing countries. It estimated that to double the share of renewables by 2030, global annual investments in the renewable power sector need to be in the range of USD 500 billion to USD 750 billion between 2017 and 2030. Monk et al. (2013) pointed out that limiting global warming to 2 degree Celsius can save fuel worth the US $ 100 trillion but requires the US $ 36 trillion more investments until 2050. As far as India is concerned, it requires a cumulative $2.8 trillion in investment in energy supply (International Energy Agency 2015). Bhamra et al. (2015) estimate that the overall finance required for meeting energy goal for India as INR 54 lakh crores (USD 854 billion) with an expected gap of INR 26 lakh crores (USD 406 billion). Studies highlight that Public finances, although fundamental in energy projects, would be insufficient to meet the demands for financing. Thus, there is a need to explore other sources of development financing. In this context, studies stress upon the crucial role of Private finance. Even the Addis Ababa Action Agenda (AAAA), the outcome document of the Third International Conference on Financing for Development has emphasized the crucial role of private finance for development and calls for better alignment of private investment with public goals (United Nations Department of Economic and Social Affairs 2015).

The literature reviewed suggest that promoting investment friendly environment through policy measures is essential for overcoming financing barriers. (Brunnschweiler, 2010; Donastrog et al. 2017; Lin and Omoju, 2017). Hu, et al. (2018) stressed on addressing fundamental policy barriers rather than symptomatic barriers to attract more investments towards RE. Thus, it is essential to understand the multi-dimensional barriers that have an impact on the adoption of RE so as to address them.

A country having a target of increasing RE share of electricity generation need to have mechanisms to promote power generation through renewable resources. It can't target to enhance the share of RE on one hand and award fossil based subsidies or allocate budgetary layouts towards fossil based projects on the other hand. To ensure that the policies reflect the commitment of the nation towards RE, it is essential to identify and address the barriers to RE.

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