ROOFTOP SOLAR ENERGY IN INDIA

Risks and Challenges to India's Rooftop Solar Energy Target

DEVANSHU RASTOGI
N M VAN DER GRIJP

SOCIAL WATCH
Saraswati Seva Foundation

SSF
SARASWATI SEVA FOUNDATION

About SSF SOCIAL WATCH Report

Social Watch publishes research reports of high theoretical and evidence based outcome. Any part of the reports may be used with prior permission or appropraite academic acknoweldgement. We motivate use of research outcome as our principle.

Saraswati Seva Foundation is not for profit organisation engaged in partnering with society for development. The mission of SSF is to partner with soceity for unproviledged and equip them for self sustained living. SSF is committed to learn, research and publish.

Saraswati Seva Foundation
Greater Noida, India

Devanshu Rastogi

Devanshu Rastogi is visiting researcher at Saraswati Seva Foundation and has done Masters in Environment and Resource Management from Institute for Environmental Studies, VU University, Amsterdam. He has a Management degree in Sustainable Development from Birla Institute of Management Technology, Greater Noida, India. Devanshu has a worked in development sector and has handled projects on education, skilling, health care and women empowerment. He has helped in setting up and running two rural micro enterprises.

ROOFTOP SOLAR ENERGY IN INDIA

Risks and Challenges to India's Rooftop Solar Energy Target

DEVANSHU RASTOGI

N M VAN DER GRIJP

Acknowledgement

I would like to gratefully acknowledge the contribution of all the people who took their time out to take active part and provide valuable support. I would like to thank Dr. N.M. van der Grijp for her mentoring and providing continuous feedback for my research work at IVM.

My sincerest gratitude to Mr Vishal, Mr. Manish Hairat, Mr. Rakesh Kacker and Mr. Rob de Jeu who took out time from their busy schedule to respond to my interview questions. I will also like to thank Mr. Vivek Singh from Saraswati Sewa Foundation (SSF) and Dr. Rahul Singh (BIMTECH) who helped me in organizing my interviews and surveys in India.

I would also like to thank my colleagues for their sincere criticism and words of appreciation from time to time which motivated me towards my work and to continuously improve on my work.

Last but not the least, I would like to sincerely thank my colleagues from SRF Foundation who helped in organizing surveys for rural households at Mewat and also my parents who helped me in conducting surveys for urban households in Gurgaon.

Abstract

India is at the cusp of major energy transition as it has committed to achieve 40% of its energy demand from renewable energy in its Intended Nationally Determined Contributions (INDCs). In its INDC, India has committed to generate 100GW of additional energy from solar power connected to the grid by 2022. The target is further divided into two sub targets of energy generation of 60GW through solar farms and 40 GW through rooftop solar installation. The aim of the report is to explore the feasibility of generating 40 GW of solar energy through rooftop solar panel installations. The report will delve in detail analyzing the current renewable energy policy of India, explore the perception of the people in both rural and urban communities towards solar energy and also try to explore the major challenges and barriers people have in installing solar panels at their roof tops such as financial limitations, apprehensions towards solar technology, lack of understanding of net-metering concept, or technical issues such as complicated technology and operation, maintenance, service and reparability, life time etc. At the end, the report takes inputs from the experts in the domain of renewable energy, especially solar energy and seek their inputs on major issues in the current renewable energy policy and what can be the potential ways to address the issues from the perspective of community, industry and policy.

Abbreviations

AD	Accelerated Depreciation
CASE	Commission of Alternate Sources of Energy
CFLs	Compact florescent lamps
CSP	Concentrated Solar Power
DNES	Department of New Energy Sources
FIT	Feed-in Tariffs
GBI	Generation Based Incentives
GHGs	Greenhouse gases
GoI	Government of India
GW	Giga Watt
IEA	International Energy Agency
IEEFA	Institute for Energy Economics and Financial Analysis
IPPs	Individual Power Producers
IREDA	Indian Renewable Energy Development Agency
JLG	Joint Liability Groups
JNNSM	Jawaharlal Nehru National Solar Mission
kWh	Kilo Watt hour
kW	Kilo Watt
MMBD	Million Barrels per Day
MNRE	Ministry of New and Renewable Energy
$MTCO_2$	Million tonnes of carbon dioxide
MW	Mega Watt
NAPCC	National Action Plan on Climate Change
NITI Aayog	National Institution for Transforming India
NSM	National Solar Mission
PV	Photo Voltaic
RECs	Renewable Energy Certificates
RPOs	Renewable Purchase Obligations
SEBs	State-Owned Electricity Boards
SOEs	State-Owned Enterprises
UN	United Nations
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

CONTENTS

List of Figures and Maps

CHAPTER 1 - INTRODUCTION

1.1) PROBLEM DEFINITION

Having access to modern energy sources is considered a primary requirement and important for a nation to meet its developmental goals (Gaye, 2007). Accordingly, UN Sustainable Goal 7 states "universal access to affordable, reliable and modern energy services by 2030 and also to substantially increase the share of renewables in the global energy mix" (UN, 2015) while Sustainable Development Goal 13 recommends "integration of climate change measures into national policies, strategies and planning" (UN, 2015). Energy sector is the biggest contributor to greenhouse gas emissions (GHGs), accounting for 60 percent of the current global greenhouse gas emissions (UN, 2017).

UNDP sees access to modern energy as the critical factor in determining development trajectories of countries. UNDP describes energy poverty as the 'inability to cook with modern cooking fuels, and the lack of a bare minimum electric lighting to read or for other household and productive activities at sunset' (Gaye, 2007).

India is home to over 1.2 billion people (Census, 2011) which is roughly one sixth of the global population but its share in global energy consumption is only 6 percent (WEO Special Report 2016). India has the fifth largest electricity generation capacity worldwide with electricity generation capacity of 304.76 GW per day, not including captive power plants (MakeinIndia, 2017). Despite this high capacity, 300 million people or 45 million households do not have access to electricity while another 700 million people experience frequent blackouts[1] and brownouts[2] (India Energy Outlook, 2015). Approximately, 85 percent of the rural households out of 167 million households rely on traditional biomass for their energy requirement while 66 percent of the households still rely on dung based fuel to meet their energy requirement (The Indian Express, 2014) as it remains the only viable source both in terms of economics and geographical viability.

In India, the per capita energy consumption is around 1,075 kWh, around one-third of the world's average (Factly, 2016). In rural areas 30 to 40 percent of households belong to disadvantaged groups that use kerosene lamps for lighting purpose thereby putting them in the category of energy poor. A typical kerosene lamps delivers between one and six lumens

[1]Blackout also referred as power outage, power blackout, power-cut is a short or long term loss of electricity power in a particular area. It is complete interruption of power in a given area. Usually there is no prior information or warning.

[2]Brownouts refers to drop in voltage in an electrical power supply. Usually, brownouts are deliberately produced by power distribution companies or energy providers to prevent the distribution system failing completely and causing a blackout.

per square meter (lux) of useful light, which is very low in comparison with Western standards of 300 lux for basic tasks such as reading (Saran and Sharan, 2012).

Going in the future, India has the dual task of ensuring modern and affordable energy sources to all while at the same time it should reduce its carbon emission. As such India is virtually on a crossroad, whether it should invest in cheap electricity from coal which has very high carbon emissions and also create a scenario of future lock-in or take the path of fast evolving renewables such as solar or wind.

Historically, India has seen very low carbon emissions and its contribution in global past carbon emissions stands at a lowly 3 percent (NITI Aayog). India is currently world's third largest emitter of carbon dioxide with a share of 6.3 percent in annual global carbon emissions (Carbonbrief, 2016). India's energy mix is dominated by fossil fuels, 68 percent, with 59 percent of total power generated comes from coal alone (Ministry of Power, GoI, 2017). Due to lack of access to modern energy sources, such as electricity, there are large emissions from rural areas who rely mostly on low quality and highly polluting sources of energy such as crop residues, cattle dung and other biomass, coal and kerosene to meet their

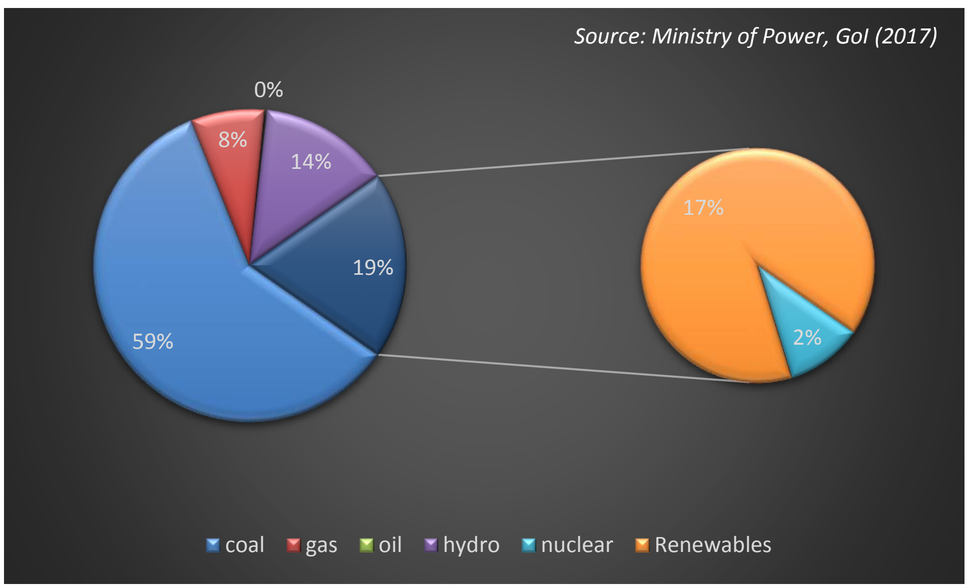


Figure 1.1: India's energy mix

energy requirements for lighting, cooking and heating. For example each year 65 $MTCO_2$ is emitted by burning kerosene for lighting and cooking purposes.

India which is on track to become the world's most populous nation and is already the world's third largest electricity market in terms of gross generation and of the ten largest global electricity markets, it is projected to be one of the fastest growing electricity market over the next decade (Tim Buckley, 2015). As economic growth slows in China, the world's largest consumer of energy (Enerdata, 2015, Institute for Energy Research, 2015) and largest emitter of carbon dioxide (USEPA, 2017), India assumes the role of prime motor of global energy demand and thus there is scope for rapid expansion in its energy sector (WEO Special Report 2016).

IEA states that over the course of the next 25 years, India will have the largest absolute growth in global oil and gas consumption of all countries (IEA, 2015). Future scenarios predict that by year 2040, India will be one of the world's largest oil consumer and importers with domestic oil product demand projected to be 9.8 million barrels per day (mmbd) and crude oil imports in excess of seven mmbd, a 100 percent increase over 2015 (IEA, 2015). A report by the Institute for Energy Economics & Financial Analysis (IEEFA) states "while Indonesia and Australia are the world's two largest exporters of coal, India's domestic production is larger than either. Combined, China, the United States and India produced nearly 68 percent of the world's total coal in 2014, and account for 72 percent of the world's total consumption" (Tim Buckley, 2015).

The current administration has pledged to provide electricity 24*7 to all citizens by 2022 and to meet its target, the country plans to add 289 GW of power through coal based power plants, of which over 75 GW will be realized by new coal based power generation capacity that is currently under construction and another 214 GW of cola based power plants at various stages of planning (Endcoal, 2016). To fuel these power plants and also to meet the energy demands of its growing infrastructure sector including cement and steel, the government plans to more than double the domestic coal production from current 660 million tonnes to 1.5 billion tonnes by 2022 (Tim Buckley, 2015) which will significantly increase its carbon emissions.

However Indian officials and leaders note that they are not building coal "instead" of renewables but "in addition" to renewables, reiterating that India's goal of constructing 175 GW of renewable capacity by 2022 is the most ambitious program in the world (Brian Palmer, 2016).

Given its future growth trajectory, the actions India will take or not take in shaping its future energy mix could be defining the success or failure of global efforts to mitigate climate change. As the government expands coverage of electricity and other forms of commercial energy to millions of people still lacking even rudimentary access to electricity and dependent on biomass and other traditional energy sources for cooking, along with millions of people experiencing frequent blackouts and brownouts, the country will see an unprecedented growth in energy demand over the next several decades. This puts India at the middle of global energy, environmental and geopolitical concerns.

1.2) RESEARCH OBJECTIVE AND QUESTION

The Government of India launched Jawaharlal Nehru National Solar Mission (JNNSM) in 2010 with the aim to achieve 20 GW of grid interactive or grid-connected[3] installed capacity of solar energy by 2022. In July 2015, the target was revised to 100 GW by 2022, which includes 60 GW from grid-connected medium and large scale power plants and 40 GW of grid-connected rooftop solar (Hairat & Ghosh, 2017). This requires a staggering compounded annual growth[4] rate of 60 percent till 2022 (Bandyopadhyay, 2017). The probability of successfully achieving the overall target lies with attracting private investors both institutional and individual with strengthening and proper implementation of different policies and instruments such as Renewable Purchase Obligations, Renewable Energy Certificate, National Clean Energy fund, Net-metering and feed-in tariff and tax deductions or concessions/waivers on renewable energy projects.

Though solar rooftop is already economically viable, to make it more attractive to home owners, industrial and commercial owners, the government provides a 15 percent subsidy for the period 2017-2022 (Moallemi & Aye, 2017).

It is interesting to note that at the time when government revised its cumulative target of solar energy five times from 20 GW to 100 GW, the total installed on grid solar capacity in the country was less than 5GW (Ebinger, 2016) and grid connected rooftop solar power was only 41 MW (CSE India, 2016). Despite falling module prices and competitive market, the IEA in its report has said that India is likely to achieve only 40 percent of its target of 100 GW. With government high focus on solar farms, it is likely to be that the major portion of that 40GW that would be achieved in 2022 will be through solar farms.

In case this scenario turns out to be correct, it is interesting to understand why India will fail to achieve its target of 100 GW of solar energy by 2022 and why the target of grid-connected rooftop solar installations fail and what potential measures can solve this. Based on this, the main research question formulated is as follows:

What are the major consumer challenges towards adoption of grid-connected rooftop solar panels and how will they impact the achievement of India's commitment to the UNFCCC related target of 40 GW of grid-connected rooftop solar power by 2022?

Sub questions will deal with the following topics:

- Energy transition to solar energy among rural and urban households?
- Perception about rooftop solar energy in rural and urban areas of India?
- Challenges to grid connected rooftop solar energy in rural and urban areas?

---

[3] A Grid interactive/grid-connected/on-grid solar PV means an electricity generating system that can feed electricity to the central electricity or utility grid to be further supplied to end consumers.
[4] Compounded annual growth rate is the mean annual growth rate over a specified period of time longer than one year (http://www.investopedia.com/terms/c/cagr.asp).

- What are the policy initiatives taken by the Central/Federal Government to promote uptake of grid-connected rooftop solar energy?
- What are the possible measures that can be taken to make a quick transition to solar energy and achieve the target of 40 GW of grid connected of rooftop solar by 2022?

1.3) THEORETICAL/CONCEPTUAL FRAMEWORK

Despite India making fast progress economically and technologically, it seems the country has stuck in rut when it comes to energy transition. Still 300 million or quarter of the country's population is dependent on firewood, coal or kerosene as a fuel for energy. Even where the people have transitioned to cleaner sources of energy, the transition has been stuck to gas and electricity. Electricity itself is produced from fossil fuels, 68% of the total installed capacity in 2016, with coal having the highest share at 59% of the total (Ministry of Power, GoI, 2017).

Increasing the share of renewables such as solar including both rooftop and solar parks, wind, biomass etc. is a conscious governmental effort for making an energy transition from "dirty" fossil fuels towards "clean" renewables. Having a change in the energy mix either at national or individual level is also a socioeconomic transition. With the challenge of eradicating energy poverty from its ranks, we need to look at the current switch from fossil based energy system to a cleaner and greener system through the lens of social transition besides economics and climate change.

To understand how the households in rural and urban centres of India make their decisions to meet their energy requirement and what reasons influence their decision making, two theories will be used in the research, namely, those of the Energy Ladder and Energy Transition. Finally, to understand and analyse the policy decisions taken by the government with respect to promote uptake of rooftop solar, the research will utilize the Transition Management Model as developed by Loorbach and Rotmans (2007).

Energy ladder is a concept that describe the way in which the households will move and adopt more sophisticated fuels as their economic status improves (Hosier & Dowd, 1988). The energy ladder, is also called Fuel-Ladder by Veer and Enevoldsen (1993), illustrates the general point of 'upward shifting' of consumer's preferences for more convenient sources/devices of energy. As found, most of the energy policies focus, almost exclusively on the possibilities to influence the transition at, or towards the top of the ladder, and benefit more for the urban users, than the rural (Hosier & Dowd, 1988).

Energy Transitions are characterized by changing patterns of energy use from solid to liquid to electricity, changing energy quantities, from scare to abundant and changing energy qualities, i.e., from polluting to cleaner non-polluting sources (Bashmakov, 2007).

Bashmakov defined the following three laws of energy transitions:

1) When cost of the current fuel becomes more expensive in relation to the income;
2) The alternate fuel is of superior quality and higher efficiency;
3) Use of alternate fuel leads to increase productivity.

Transition Management Model tries to apply and utilize innovative bottom-up developments in different levels of governance in a more strategic way by coordination and fostering self-organization and creating cycles of learning and providing further space for radical innovations offering sustainable benefits. Transitional Management model explains societal change due to interactions between all relevant stakeholders or actors at different social levels within the changing social landscape, and thus is concerned with coordinated interaction and co-evolution (Loorbach and Rotmans, 2007).

The Transition Management Model typically identifies five major issues or problems in managing societal change or transition including Dissent, Distributed Control, Determination of Short-term steps, Danger of Lock-ins and Political Myopia (Loorbach and Rotmans, 2007). These terms are further explained in section 2.4.

Energy transition have happened many times in the past, from man-power to animal power, traditional biomass to coal, from coal to oil, from oil to gas and from gas to electricity. These transitions as classified above fall in the category of changing pattern of energy use. India, currently, is still in various stages of energy transition and uses fuels from different levels of energy ladder. If indeed it has to mitigate the effects of climate change and global warming and to meets its INDC targets of 100GW of solar energy, India will need to do a mini-leapfrog of sort from polluting sources of energy to cleaner sources of energy.

1.4) RESEARCH APPROACH

The approach to the study can be divided into three distinguished parts:

a) **Literature study -** This involved reviewing of India's INDC submitted to the UNFCCC with a focus on renewable energy targets and also articles and journals written about the energy poverty, the energy transition towards renewable energy and the implementation of current renewable energy policy in India. Literature study will also include studying the prominent theories pertaining to energy poverty and energy transition including Energy Ladder, Energy Transition and Transition Management Model. The theories will help in creating a framework to analyse the results from the surveys and interviews conducted in the later part of the research and also including the secondary analysis on the energy policy of India.
b) **Surveys and interviews –** The second part of research included creating two case studies to capture the perceptions of rural and urban households. The surveys consisted of three parts covering socioeconomic and demographic profile of the participating households; data on energy consumption and energy consumption expenditure of the participating households and awareness of the households

towards solar energy technology and subsequently awareness of the policy initiatives by the central government towards the proposed energy transition, willingness to buy solar panels and their respective issues and challenges for the purchase of solar panels. Finishing with the case studies, interviews with solar energy experts, renewable energy advocates/academic researchers and experts from solar energy industry to take their views and opinion on the subject matter and possible solutions through both policy measures and private sector initiatives that may help in addressing the concerns related to solar energy transition.

c) **Quantitative and Qualitative Analysis –** A quantitative analysis was done of the responses from the surveys to ascertain electricity consumption expenditure of the households and identify the most common benefits and challenges perceived by rural and urban households of rooftop solar energy respectively. Progressing from the quantitative analysis, a qualitative analysis using the previously created theoretical framework comprising of Energy Ladder Theory, Energy Transition Theory and Transition Management Theory was done to ascertain the current direction of India's energy transition and assess the challenges it faces. Finally drawing on the results and dis the interviews conducted, some potential recommendations were derived to address some of the challenges related to rooftop solar concerning households in rural and urban areas.

1.5) GEOGRAPHIC COVERAGE

The case studies focussed on the city of Gurgaon and the district of Mewat (Nuh block, the district headquarter), rechristened Gurugram and Nuh respectively in 2016, of the state of Haryana. Gurgaon and Mewat both are one the constituent areas within the National Capital Region. Gurgaon, located 30 km south of national capital New Delhi, is one of the four major satellite town of Delhi (Govt. of Haryana, 2013). Gurgaon, the second largest city in the state of Haryana, is the industrial and financial powerhouse of the state, housing more than 300 of the Fortune 500 companies (Business Standards, 2016). It has the third highest per capita income in the country behind only to Mumbai and Chandigarh (Govt. of Haryana, 2013). Gurgaon is also headquarter of the International Solar Alliance (Intsolaralliance, 2016).

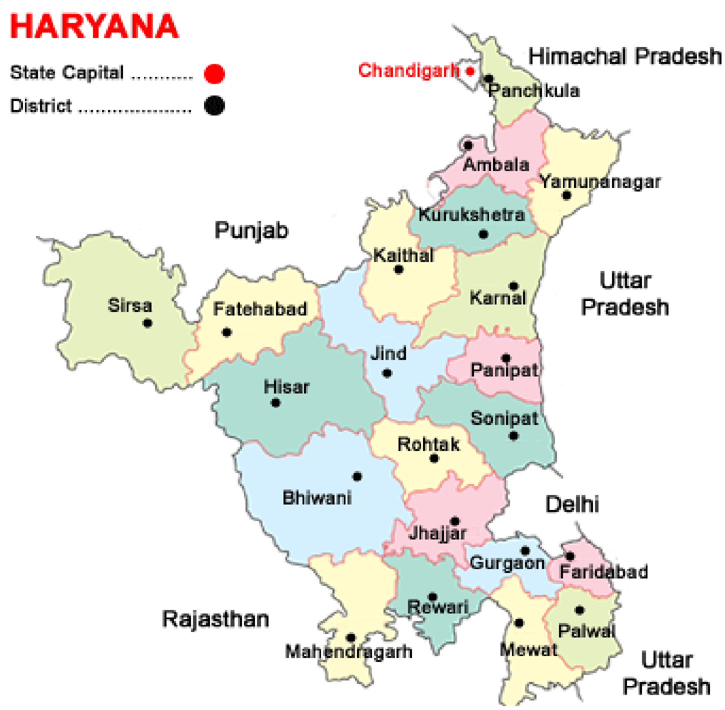
Mewat, less than 100 km away from New Delhi, lies in sub-tropical, semi-arid climatic zone with extremely hot summer. It is an agriculturally and industrially backward region and lacks necessary infrastructure such as education, health and railway links (ICSSR, 2008) with 88.6 percent of its population is being rural. Though majority of households, 61.3 percent, use electricity as a source of lighting, which is still very low in comparison to the state average of 92.1 percent, while 36 percent use kerosene and 48 percent use firewood as the major source of fuel for cooking followed by crop residue (NITI Aayog, 2015).

Gurgaon and Mewat, despite their close proximity to each other and to the national capital, remain far apart in terms of socioeconomic development. The positioning of Gurgaon as the headquarter of International Solar Alliance and Mewat's high dependence on primitive fuels such as firewood and crop residues to meet their energy requirement provides a striking contrast in this study. Also, as both regions are in the national capital region, they also provide a good example of the flow and penetration of information from the capital and the subsequent implementation of the policy related to renewable energy.

	*Gurgaon**	*Mewat**
Area	1,253 sq. km	1,860 sq. km
Population Total	1.5 million	1.09 million
Population Rural	0.47 million	0.96 million
Population Urban	1.04 million	0.13 million
Per capita income (annual)	INR 0.5 million	INR 45,934

(Govt. of Haryana, 2017 and The Hindustan Times, 2015)

*(*all data for the district)*



Map 1.1: A map of Delhi, Gurgaon and Mewat (Districts of India, 2016)

CHAPTER 2 – THEORETICAL FRAMEWORK

2.1) INTRODUCTION

As stated by the UN in its Millennium Development Goals and later the Sustainable Development Goals, availability and accessibility to affordable and modern energy sources is crucial for countries to achieve their developmental goals. At one side of the spectrum we have conventional sources of energy such as biomass, coal, oil and gas while on the other hand we have non-conventional sources including solar, wind, and hydro etc. The conventional sources of energy are typically exhaustible excluding biomass and as their availability will start to reduce their prices will start to increase. Besides the economic prices, the conventional sources also have an environmental and social cost associated with them. Their use causes carbon dioxide emissions which is one of the major greenhouse gas responsible for climate change and also indoor pollution because incomplete burning of fuels (IEA Insight Series, 2014). The renewables, on the other hand, are more eco-friendly as they do not emit carbon dioxide or any other greenhouse gas during their use and also do not create any pollution simultaneously.

In the section, we study different theories that deal with factors governing why an entity, a nation, an industry, a household or an individual, transition from one source of energy or fuel to another. The factors can be purely economic or financial, superiority and higher efficiency of the alternate fuel or just due to the pressure of social status. This section includes three theories related to factors governing transition from one type of fuel to another.

2.2) ENERGY TRANSITION THEORY

Energy transitions have happened in the past but since the industrial revolution of 19th century and in 20th and 21st century the rapid rate of global economic expansion has accelerated the energy transitions rates. Despite this, one-third of global population still relies on energy sources dominated by domestic needs and non-commercial forms such as crop residues, cow dung and other biomass, while another one third uses modern and commercial energy sources which are appropriate for the new era while the last third of the population is in the process of making the transition from traditional non-commercial sources of energy to new and modern energy sources. The first one third of the population depends on biomass as the major source of energy (Bashmakov, 2007).

Biomass, having a very low efficiency between 5 to 30 percent for space heating and cooking is rapidly losing its share in energy balance (Bashmakov, 2007). The trends in energy balance are closely related to the level of development. With higher level of development biomass is substituted by more efficient sources, mainly coal, which in turn by oil, natural gas and finally by electricity and district heat (Bashmakov, 2007)

Bashmakov's Energy Transition Theory has three laws which states as follow:

1) **The law of long-term energy costs to income stability:** The law states that energy demand and energy productivity are more dependent on energy costs to income ratio rather than on income and price separately (Bashmakov, 2007). The energy costs to income ratios include final energy costs to GDP or can also be to gross output ratio, housing energy costs to personal income ratio or energy costs for personal transportation to personal income ratio (Bashmakov, 2007). When energy costs increases, it reduces economic growth which provides a favourable condition for accelerated increase in energy productivity by improving efficiency thereby reducing the demand for energy (Bashmakov, 2007). The share of energy costs in the household income is only 4 percent higher for the high income households than low income households while the high income groups consume 100 percent more energy than low income households. For India, the energy costs to income ratio has been around 3.5 for 43 years (Bashmakov, 2007).
2) **The law of improving energy quality:** In order to improve overall economic productivity a better quality of energy services is required. When the energy costs increase, the rate of return decreases thereby slowing down the economic growth. This provides a favourable condition for improvement in technology and replacing poor quality production factors with higher quality (Bashmakov, 2007). Higher costs of firewood, coal and kerosene has led to adoption of more efficient
3) **The law of growing energy productivity:** Increasing use of expensive, superior energy carriers there has to be improved energy productivity, which means, more units of GDP are created per unit of energy (Bashmakov, 2007). With relatively stable energy costs to income ratios and as the quality of the energy source increases, there is an increase in the energy productivity and decrease in energy intensity (Bashmakov, 2007).

2.3) ENERGY LADDER

Historically, as the level of development increases, not only the energy consumption increases but also the sources of the energy to meet this increase undergo a change. Rich or more developed countries extensively depend on petroleum and electricity to meet their energy requirement, while in comparison poor or developing countries depend more on biomass fuel. As a country undergoes the process of industrialization its dependence on petroleum and electricity increases and reliance on biomass decreases (Hosier & Dowd, 1988).

The energy ladder is described as a model where as a family moves upward in terms of income level it switches from less efficient, inexpensive and more polluting energy carrier to more efficient, less polluting and expensive energy carriers (van der Kroon & van Beukering, 2013). Besides income, social status of the households also influences the energy use pattern

(Bajracharya, 1983, Hosier & Dowd, 1988). The model assumes moving towards a new fuel is simultaneously moving away from the old fuel (van der Kroon & van Beukering, 2013). This is also described as 'Traditional Energy ladder' (Masera, 2000). Energy ladder is a continuous state of flux, as income of the household increases, it moves up the ladder but if the income of the household decreases or the price of the fuel increases, the household will move down to lower, less sophisticated energy carriers (Hosier & Dowd, 1988). The energy ladder model assigns ranks to different fuels based on household's preference for different attributes of the fuel such as cleanliness, ease of use, cooking speed and efficiency (van der Kroon & van Beukering, 2013). The height of the ladder is dependent upon the factors such as household energy consumption, cost of the fuel and capital cost of the fuel utilizing device.

Studies done by Bhagavan and Giriapa, 1994, Brouwer and Falcon, 2004 and Mirza and Kemp, 2008 etc. have demonstrated a relationship between income and fuel choice at micro level but have also argued at the same time that the linkages between fuel choice and income level are not as strong as assumed by the energy ladder. Moreover, they have shown that firewood can be a major energy source in both urban and rural households of all income levels while at the same time low income households using advanced modern fuels such as electricity and LPG but in urban locations. However, there has been no study to show low income rural households advancing to modern fuels such as electricity and gas while skipping the intermediate fuels (van der Kroon and van Beukering, 2013).

A number of studies by Leach, 1992, Davis, 1998, and Arnold et al., 2006 have shown that that energy transition does not happen in a single, discrete step but that the use of multiple fuels is more common. Households with increasing income adopt new technologies which rather than serving perfect substitutes for traditional energy carriers serve only partially. The households continue to utilize traditional energy carriers such as biomass and accommodate new energy carriers to serve their changing lifestyle. Study by Masera et al., 2000 rejects switching model and proposes a multiple fuel model as an alternative. In a multiple fuel model, a household chose to consume a portfolio of energy options at different points of time which may comprise of fuels from both lower and upper levels of the ladder. The process of using of new fuels without abandoning the old fuels is called as fuel stacking and is unusual for households to make a complete switch (van der Kroon & van Beukering, 2013).

Study by Davis, 1998 argues that fuel stacking forms the basis of poor household's livelihood strategies. Irregular and variable income from agriculture or daily wages do not allow the families to regularly consume modern energy carriers. Thus the households employ particular budget strategies to maximize their energy security. Rural areas usually experience fuel supply issues and thus promote fuel stacking behaviour to safeguard themselves against erratic supply of fuel and to have a backup or cushion fuel to fall on when in case of supply disruption. Moreover, poor households are prone to price shocks of fuel. In situations when the price of the modern energy carrier moves up, the households resort to moving back to their previous energy carrier. Finally, the culture and tradition of the households also a play a major role in making a complete transition from energy carrier to another. Thus, complex interactions between economic, social and cultural factors results in multiple fuel pattern in

Source: van der Kroon & van Beukering,

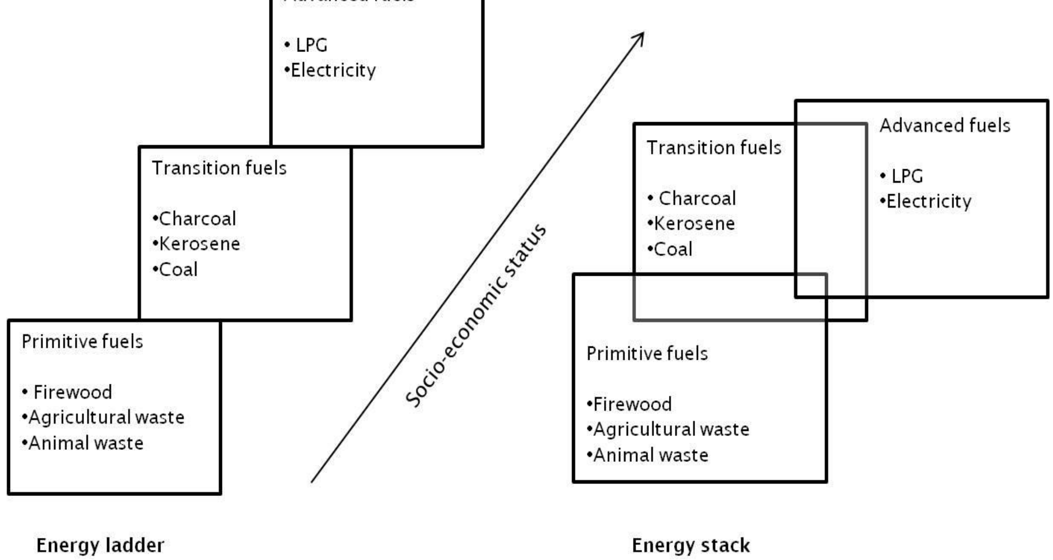


Figure 2.1: Energy Ladder and Energy Stack

households (van der Kroon and van Beukering, 2013).

2.4) TRANSITION MANAGEMENT MODEL

To deal with complex societal problems, Transition Management has emerged as new governance paradigm in the past few years (Loorbach & Rotmans, 2009). Using scenarios, the Transition Management Model is required to deal with uncertainties and to keep options open and deal with fragmented policies, stimulate knowledge and technological change, pursue innovation and incremental improvements. It includes to take a multi-domain view with attention to all relevant actors, balance long-term orientation with short-term policy measures and pay attention to international aspects of change processes and enforce laws through stimulation, mediation and creating other necessary right conditions (Loorbach & Rotmans, 2010).

In context of societal transition, governance activities can be classified into four different types:

a) **Strategic:** Structuring complex problems and creating alternative futures taking into account a long time horizon.
b) **Tactical:** Involves building or breaking down system structures.
c) **Operational:** Deals with every day, short-term decisions and actions. Actors either recreate system structures or choose to restructure them.
d) **Reflexive:** evaluation of existing situation at various level and their interrelation of misfit which are resolved through debate, structured evaluation, assessment, and research societal issues are continuously structured, reframed and dealt with (Loorbach & Rotmans, 2010).

The Transition Management Model gives sustainable benefits by applying and utilizing innovative bottom-up developments at different levels of governance in a more strategic way by coordination and fostering self-organization and creating cycles of learning and providing further space for radical innovations (Loorbach & Rotmans, 2007). The Transitional Management Model explains societal changes due to interactions between all relevant stakeholders or actors at different social levels within the changing social landscape, and thus is concerned with coordinated interaction and co-evolution (Loorbach & Rotmans, 2007).

The Transition Management Model typically identifies five major issues or problems in managing societal change or transition and are Dissent, Distributed Control, Determination of Short-term steps, Danger of Lock-ins and Political Myopia (Loorbach and Rotmans, 2007).

a) **Dissent:** Societal problems in general and related to sustainability in specific are complex and usually lack consensus on the nature of problem, priority of targets and goals and means to attain them. Different sections of people or stakeholders have different opinions and perspective related to the nature of a problem, priority and means to solve them.
b) **Distributed Control:** In a pluralistic society, control cannot be exercised from top. Stakeholders have their own sets of beliefs, interests and limited resources. In a pluralistic and democratic society control is vested among different sections of the society. Since, government represents different sections and strata of the society and government departments working in silos and layers, influence is directed from different points on government and hence making unitary decisions is difficult. Thus, cooperation and networking is necessarily required in distributed nature of control.
c) **Determination of Short-term steps:** The policy makers find it difficult to manage trade-offs and often prefer short-term actions over long-term structural changes such as ensuring present energy access and security while transitioning towards renewable energy.
d) **Danger of Lock-ins:** By choosing a sub-optimal solution in a process of long term structural change when other solutions are still developing may lead to or create a

chance that future options will be dominated by that option. To prevent such a situation it is always better to diversify options.

e) **Political Myopia:** Politics and politicians by virtue tend to be impatient and favour quick results whereas social changes and transitions span over a long time or over a generation during which there can be change of political dispensations. It is imperative that the politicians realize that time is needed for societal transformation (Loorbach & Rotmans, 2007).

2.5) RESEARCH METHODOLOGY

A research design has various components such as theory, reasoning, approach to research – quantitative or qualitative, sampling and data collection methods such as surveys. This section will describe some of the prominent research design techniques and what methodology this particular research follows.

A theory is defined as an ordered set of assertions about a generic behaviour or structure assumed to hold throughout a significant broad range of specific instances. Theory us important in a research for it provides a framework for analysis, provides an efficient method for field development and provides clear explanations for the pragmatic world (Wacker, 1998). So, if anyone wants to test a theory or to draw an inference from it that could be tested, the level of abstractness is likely not to be so great that the researcher would find it difficult to make the necessary links to the real world (Bryman, 2004).

To derive inferences from the research, reasoning is required. Reasoning is of two types a) deductive and b) inductive. In deductive reasoning, a hypothesis is first formed based on existing theory and then a research study is designed to test the hypothesis (Wilson, 2007).

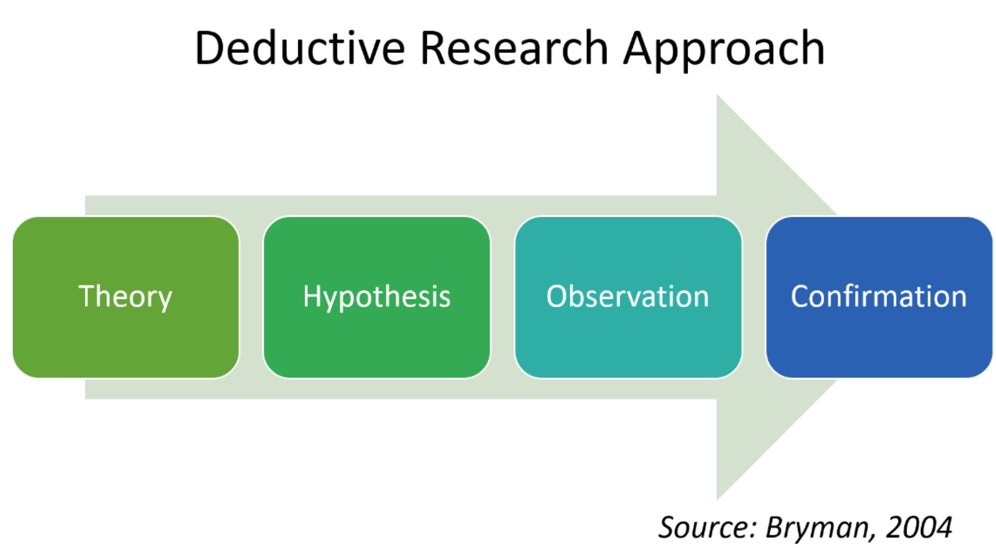


Figure 2.2: Deductive research design

The particular method is called deductive reasoning because the reasoning is drawn from particular to general situation (Bryman, 2004).

The alternate to deductive reasoning approach is inductive reasoning design. The Inductive reasoning approach starts with the observations and theories are proposed towards the end of the research process as a result of the observations (Goddard & Melville, 2004). In the inductive approach patterns are searched from observations and development of explanations and theories for these patterns through series of hypotheses (Bernard, 2011). Hence, no theory is applied to the research in the initial part and researchers are free in terms of altering the direction of the study (Bryman, 2004).

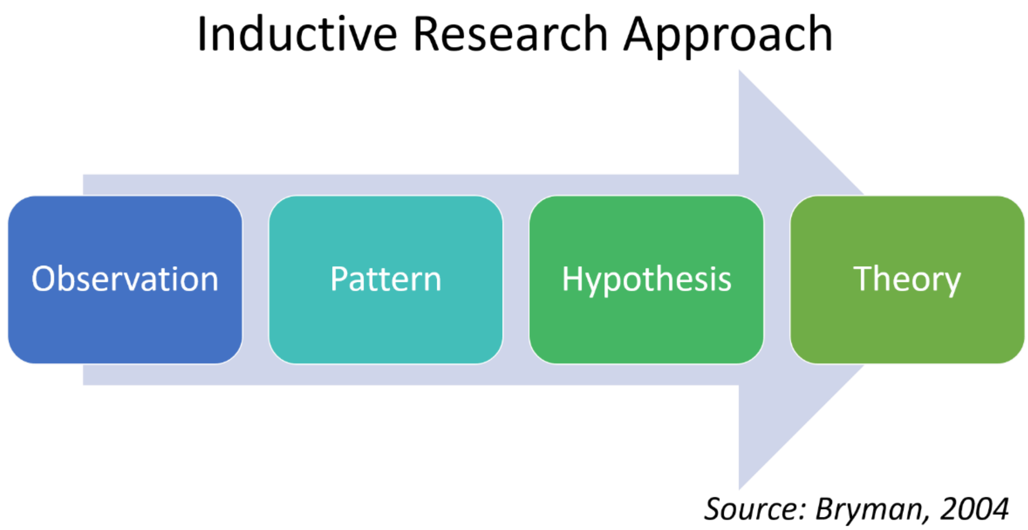


Figure 2.3: Inductive research design

Based on the specific research needs, a research can be quantitative, where data is collected in a structured manner through surveys and is analysed using statistical tools. Hence, quantitative is more objective. While qualitative research provides more perspective on the real life situations, people and to make sense of behaviour and to understand the behaviour within its wider context (de Vaus, 2014). Qualitative research is subjective and lacks replicability, therefore cannot be applied in a generalized manner (Bryman, 2004).

To investigate the research question and seek answers, a researcher has to decide what kind of population is best suited for the topic of investigation and also needs to identify the research instrument and how it has to be administered. The identification of the target population is done through sampling (Bryman, 2004).

Sampling is of various types and most common types of sampling techniques are simple random sampling, systematic sampling and stratified random sampling.

Simple random sampling – It is the most basic form of sampling. In random sampling, each population unit has an equal probability of getting included in the sample. The advantage of simple random sampling is that it is free from human bias and is not dependent on the respondent's availability (Bryman, 2004).

Systematic Sampling – In systematic sampling, sample population is directly selected from a sample frame without resorting to a table of random numbers. Since there is no ordering of sampling frame, it may result in biasness (Bryman, 2004).

Stratified Random Sampling – In stratified random sampling, sample population is selected on the basis of a wide range of relevant attitudinal features to the study. Stratified sampling ensures resulting samples will be distributed in the same way as the population in terms of stratifying criteria (Bryman, 2004).

Interviews is a prominent data-collection strategy in both quantitative and qualitative research. In structured surveys and interviews, the researcher aims to give exactly the same context of questioning to the interviewee thus providing exactly the same stimulus to each respondent as any other. The aim of structured interviews and surveys is to ensure interviewees' replies can be aggregated. The questions are very specific and very often offer the interviewee a range of fixed answers. Structured surveys and interviews promotes standardization of both asking questions and recording answers thus reducing error (Bryman, 2004). Semi-structured interviews and surveys typically refers to a context in which the interviewer has a series of questions which are in general form but is able to vary the sequence of the questions. The questions are somewhat more general in their frame of reference from that typically found in a structured interview. Also, the interviewer usually has some freedom to ask further questions in response to what are seen as significant replies. Unstructured interviews has only a list of topics or issues. The style of questioning is usually informal and the phrasing and sequence of questions will vary from interview to interview (Bryman, 2004).

This particular research follows a mixed approach. In an attempt to identify and answer the research question of "major challenges to adoption of grid connected rooftop solar and their impact on India's commitment to the UNFCCC", we will be testing the theories of Energy Transition, Energy ladder and its alternative Energy Stack and Transition Management Model as described above. The research will be using deductive reasoning but also utilize the concept of inductive reasoning. Though we already have the theories to identify energy transition, the hypotheses to ascertain their success or failure will be done later after the observations. In the research, we will be building two groups of case studies one among the rural households and the other in the urban households. The households will be selected on the basis of simple random sampling thus eliminating human biasness favouring towards any particular set of households and individuals.

The surveys for the urban households will be conducted both online and offline. The reason for conducting the surveys both online and offline is to gather responses from diverse section in terms of both socioeconomic background and regions within the city. The language for surveys will be English. The surveys for rural households was done only in offline mode due to the poor technological awareness and internet connectivity in the district of Mewat. The language of conducting surveys among rural households will be the local language of Hindi. The surveys are structured in a highly similar design but the survey question have built in differences to capture difference in the outlook of urban and rural households. The survey questions (see in Annexes A and B) have mix of closed and open questions. Closed questions are where a range of responses have been provided while in open questions the responders have liberty to answer as they see fit. Besides surveys, a set of interviews (see Annex C for interview questions) were also done with people from the solar industry and solar energy advocates or policy researchers in the domain of renewable energy, and specifically dealing with rooftop solar. The interviews were semi-structured in nature. This was done keeping in consideration that interviews were being conducted by observing the results from the surveys and it was necessary to get a broader insight from industry and policy experts on the observations from surveys.

In addition, a review of articles written on solar energy and energy policies was done to establish the link between the policy initiatives and the perception at ground level.

CHAPTER 3 – ENERGY POLICY

3.1) HISTORICAL OVERVIEW OF INDIAN ENERGY SECTOR

Since independence in the year 1947, Indian energy sector has seen enormous growth but the rate of increase in supply has always outpaced by increased rate of demand. Therefore, the country has experienced energy and peak energy shortage of 10 percent in 2014-15 (Moallemi & Aye, 2017). In the year 2016, for the first time India became an energy surplus nation (The Economic Times, 2017), despite which 700 million people in the country faces regular outages - black outs & brown outs and voltage fluctuations while almost 300 million people (Moallemi & Aye, 2017) are without access to electricity.

The required electricity in the country is generated via two different methods: on-grid[5] which is the main and major method to provide electricity to urban areas as well as to agricultural and industrial areas. The off-grid method is more commonly used in remote and unconnected rural areas and as captive power source in industries. On-grid renewables is emerging to be a viable way to address the concerns regarding supply and demand gap, energy access, equity, security while addressing the challenge of GHG emissions (Moallemi & Aye, 2017).

Under the Indian Constitution, energy is a concurrent subject which means, both central (federal) and state (provincial) governments can frame laws, legislations and policies pertaining to energy production, distribution and tariffs. For the development and operation of the power sector, The Electricity Act 1948, allowed for formation of State-Owned Enterprises (SOEs)[6] that focuses on electricity production and State Electricity Boards (SEBs)[7] for regulating generation, transmission and distribution of electricity (Moallemi & Aye, 2017). Due to state government ownership and lack of accountability, the SOEs and SEBs were working inefficiently leading to massive blackouts during the 1970s (Victor & Heller, 2008).

In response to these problems caused by higher dependence over states, the Central Government in 1975 increased the central control over the electricity sector. This led to the establishment of electricity generation and transmission companies in public sector following there was a substantial growth in the power sector, in terms of installed capacity, transmission network and distribution to various areas throughout the country (Moallemi &

---

[5] A Grid interactive/grid-connected/on-grid means an electricity generating system that can feed electricity to the central electricity or utility grid to be further supplied to end consumers.

[6] State-Owned Enterprises here refer to energy producing companies owned and control by central government, previously by state governments, such as National Thermal Power Corporation Limited and interstate transmission company such as Power Grid Corporation of India.

[7] State Electricity Boards are electricity distribution companies also called discoms in India and are owned by respective states.

Aye, 2017). However, another hosts of problems surfaced during this period. The SEBs incurred huge debts and became financially weak and impacted the borrowing capacities of these SEBs (Mukherjee & Sengupta et al., 2017).

In 1991, financially weak power sector was unable to provide for the infrastructure required to meet the growing demand of electricity. The Central Government then introduced several structural reforms such as disinvestment, increased private sector and foreign investment in the power sector to improve its finances and to address the shortage in the power generation capacity by boosting Independent Power Plants (IPPs) (Mukherjee & Mohua, 2014).

In the year 2003, the Central Government came out with The National Electricity Act 2003 which liberalized the Indian energy market, electricity generation and distribution, and facilitated open access of electricity from electricity market and electricity exchanges. The Regulatory Commission Act 1998, allowed creation and establishment of statutory agencies or commissions both at central and state levels to regulate the energy sector. The National Tariff Policy 2006 provided for determination of electricity tariff in a transparent manner through regulatory agencies or commissions established under the Regulation Commission Act of 1998 (Sharma & Thapar et al., 2016). The National Tariff Policy 2016[8] focusses on promotion of electricity from renewable sources (CEA, 2016 and Ministry of Power, 2016).

Till the 1970s, the country's electricity sector comprised of only conventional systems including large hydro and coal while renewable sources were completely absent from the system (Moallemi & Aye, 2017).The Central Government however changed tracks towards renewables after the Oil Price shock of the 1970s to ensure future energy security of the country (Mukherjee & Mohua, 2014) and in 1980s launched a programme for energy development (Goel, 2017). The central government in order to lead the transformation towards renewable energy devised supporting policies such as 80 percent accelerated depreciation (AD) on equipment as well as to create a competitive electricity market for private investments (Sawhney, 2013). This led to a drastic increase in the total installed capacities of renewables in the country. However it was mainly dominated by the wind (Moallemi & Aye, 2017).

To further bolster the development of renewable energy, the government introduced several new policy initiatives in 2002 like generation-based incentives[9] (GBI), Feed-in Tariff (FIT) and Renewable Purchase Obligation (RPO) (Sawhney, 2013) and also defined target of reaching 5 percent grid-connectivity by 2012 (Moallemi & Aye, 2017). The government provided further boost to renewable energy by launching National Action Plan on Climate Change (NAPCC) and Jawaharlal Nehru National Solar Mission or National Solar Mission

[8] National policies are revised by the central government every five years to prioritise the development work required in the immediate next five years.

[9] Generation based incentives is the per unit subsidy provided by the government for each unit of electricity supplied to the grid.

(JNNSM or NSM) in the year 2008 and 2010 respectively. The launch of NPACC and JNNSM brought on-grid solar back in focus in the electricity sector[10]. The JNNSM defined a target of reaching 20GW of on-grid solar energy through solar PV and Concentrated Solar Power (CSP) technologies by 2022 and to achieve the target programme proposed several generation based incentives such as Long-term Power Purchase Contracts between distributors and developers, Power Sale Agreement with distributors, Payment Security Mechanism besides already existing incentives of Renewable Energy Certificates (RECs), Renewable Purchase Obligations (RPOs) and Feed-in-Tariffs (FITs) (Kapoor & Pandey, 2014). While some issues persisted concerning the timely implementation of policies, the overall policy framework has been found generally influential in motivating private sector's participation and in boosting on-grid solar electricity (Sharma & Tiwari, 2012).

With the liberalization of power sector, the regulatory authorities remained in control of the government, India’s renewable energy sector is neither a pure liberal market economy like the United States nor completely government regulated capitalism as in China (Hall & Soskice 2003). It is a specific condition called State-influenced niche empowerment (Moallemi & Aye 2017). About 77 percent of the total 31 GW of installed renewable capacities in 2014 were operated by private entities (Moallemi & Aye et al., 2017). They operate in a partially liberalized market economic condition and are also influenced by command-and-control and market-based policies of the Central and State Governments (Gulati, 2012 and Shrimali & Rohra, 2012).

3.2) SOLAR ENERGY POLICIES

In India policy initiatives towards renewable energy started with the establishment of Commission of Alternate Sources of Energy (CASE) in 1981 within the Department of Science & Technology. In 1982 it became an independent Department of New Energy Sources (DNES) and a separate Ministry in 1992. The Ministry issued guidelines to various states to purchase renewable power at ₹2.25 (€0.03) per unit with 5 percent annual escalation with 1993 as base year. This triggered early development of renewable sector, especially wind energy. “The government has announced several policies to promote solar energy. Direct and indirect tax benefits such as sales tax, excise duty exemptions and custom duty exceptions have been given. “Project developers were exempted from income tax on all earnings from a project in its first 10 years of operation and accelerated depreciation (AD) for solar energy producers to claim 80 per cent of the costs in the first year itself” (Goel, 2016). Various policy initiatives have been taken by the Government of India to support and develop renewable energy sector in India are since the year 2000, including:

1) **Renewable Purchase Obligations (RPOs**) were first introduced in 2003 and are for designated consumers such as distribution utilities (discoms), large power consumers,

[10] During the period of 1990 to 2008, not much development happened on the front of solar power.

industries etc., which are required to buy a certain percentage of their total power from renewable sources or by the way of purchasing tradable renewable energy certificates from energy exchange (Sharma & Thapar et al., 2016). The NPACC in 2008 suggested to set the RPOs at 5 percent of total grids purchase and be increased at the rate of 1 percent per year for next 10 years (Goel, 2017). However, the RPOs were set at 3 percent initially and are revised to 8 percent in 2016 (CEA, 2016 and Ministry of Power, 2016). The increased renewable purchase obligations has resulted in guaranteed market for increased renewable energy in the production mix.

2) **Renewable Energy Certificates (RECs)** is a market based mechanism and was introduced by the government in the year 2011 to create a level playing field for renewable resources in renewable resource abundant and resource poor states. The states or SEBs which are unable to meet their RPOs can buy energy certificates from the states which have a surplus of renewable energy through energy exchanges (Goel, 2017 and Sharma & Thapar et al., 2016).
3) **Clean Energy Cess** is a carbon tax levied on coal. It was Introduced in 2010 and ₹50 (€0.67)[11] was levied on every ton of coal imported or produced domestically. The receipts from the levy goes to a National Clean Energy Fund (NCEF) created to finance clean energy projects and provide up to 40 per cent of the total costs of renewable projects through the Indian Renewable Energy Development Agency (IREDA). The cess has now been increased to ₹400 (€5.3) per ton of coal used (Goel, 2017).
4) **Joint Liability Group (JLG) for Off-grid installations** – The JNNSM under NAPCC has envisaged use of solar power to bolster rural income by providing an opportunity to rural youth to become solar entrepreneurs. A small group of 4 to 10 local entrepreneurs can form a JLG to avail loans available for non-farming activities which could be applied for micro-grid installations (Goel, 2017).
5) **Grant or Subsidy** – The government provides an initial monetary assistance on capital costs and equipment to reduce the cost of the solar project and hence make it more viable. The grant or subsidy money is not paid back to the government. The government had started the scheme in 2011 under JNNSM and currently provides a subsidy of up to 30 percent of the project cost (Sharma & Thapar et al. 2016 and Shrimali & Shrinivasan, et al., 2017).
6) **Tax Concessions** – The government of India provides a tax concession on renewable energy projects for a duration of 10 consecutive years within the first 15 years from the commissioning of the project. However, project developers are required to pay a Minimum Alternate Tax. For the remaining years of the project life, the producer has to pay corporate tax at the then prevalent rate (Sharma & Thapar et al., 2016).
7) **Preferential Tariff –** The state utilities or discoms are bound to buy power from renewable energy projects for a fixed price for specified number of years. The prices are determined by SERCs or CERC (Sharma & Thapar et al., 2016).
8) **Generation Based Incentive (GBI) –** Under this scheme the government, state or central as applicable, provides a subsidy to the producer for each unit of renewable energy supplied to the grid (Shrimali & Shrinivasan, et al., 2017). The Government of Delhi

[11] On average ₹1 = €0.67. Conversely €1 = ₹75 on average.

currently provides an incentive of ₹2 to domestic producers for per unit of solar energy produced and fed into the grid (Economic Times, 2016).

These incentives are applicable for almost all type of renewable energy projects whether on-grid or off grid. However, majority of incentives are for institutional project developers who are developing projects bigger than a particular capacity. Only few incentives, currently are available for individual level solar projects. Currently, out of the listed only Grants/subsidies are available to individual on-grid rooftop solar users nationally while Generation Based Incentives are present only in limited number of states through state governments such as in the state of Delhi. There are few other policies initiatives taken by Government of India related to renewable energy but discussing them here are beyond the scope of the research.

CHAPTER 4 – RESULTS

4.1) INTRODUCTION

To test the theory of Energy Ladder, Energy Stacking and the Energy Transition Model and also to identify and understand the difference in perception and challenges concerning rooftop solar, surveys were conducted in urban and rural households of Gurgaon and Mewat respectively. At the same time a couple of interviews were done with renewable energy advocates and industry experts. In this section we present the results from the survey and interviews.

The survey questions had three different section built in them and hence this chapter follows the same pattern. The first section concerns about the socioeconomic condition of the responding households, the second section covers the energy consumption, sources of energy and energy consumption expenditure of the households while the final section covers the perception of the households towards solar energy and the challenges they have faced or perceive to face when making a transition to rooftop solar.

4.2) SOCIOECONOMIC PROFILE

Under socioeconomic profile of the households, we have tried to capture, the age, gender of the responding member of the household. The average monthly household income, type of accommodation (independent in urban or pucca in rural), number of household members or family size was also covered.

Age - In rural households the majority of the respondents were in the age group of 18 to 30 years of age, while in the urban households the majority of the respondents were between the ages of 20 to 40 years. The average age of respondents in rural households is 27 years while in the urban households, it is 38 years.

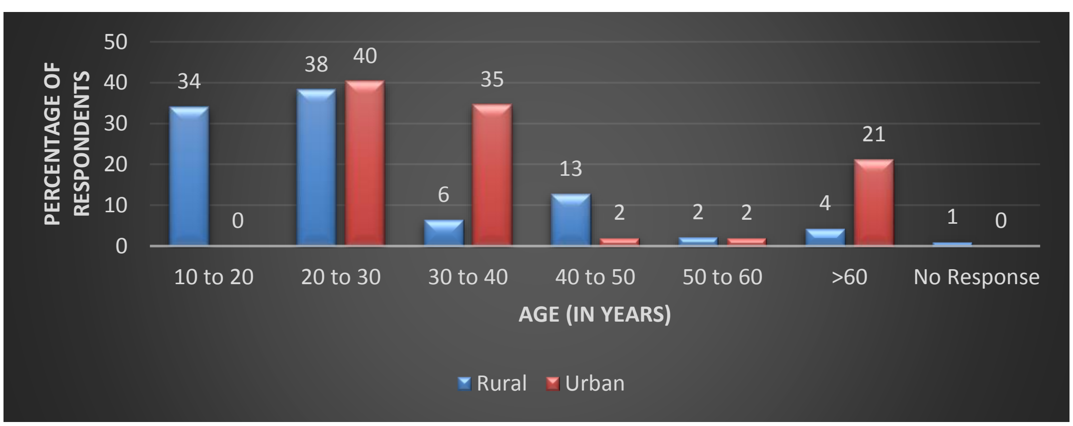


Figure 4.3: Age distribution among rural and urban households.

Gender – Among rural households the majority of respondents were males (91 percent) as females are usually not allowed to talk to unknown males. In urban areas, female participation was relatively higher.

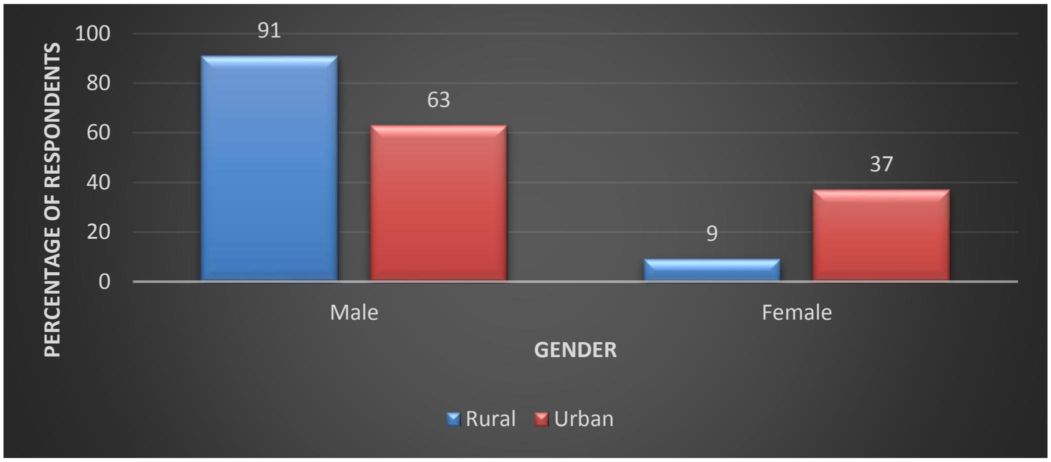


Figure 4.4: Gender distribution among rural and urban households

Accommodation – Concerning the type of accommodation type, we had two distinct sets of questions for rural and urban households due to the difference in the economic development of the two regions. Among rural households, we wanted to extract the built type of house based on structure and strength. In urban areas, the focus on the kind property rights, such as independent housing, flats or rented etc. Among rural households 88 percent of the families live in pucca (made of brick and mortar with a concrete slab as roof) houses, while among urban households 62 percent of the families live in independent type of housing while 25 percent families live in the flats.

Household Size – Rural households have a larger family size with majority of the families having between 4 to 8 or 8 to 12 members, 36 percent each, while few households, 4 percent, have an even larger family size between 20 to 24 members. While among urban households we could see the contrast with 66 percent of the households having a family size between 3 to 6 members, while only 2 percent of the household had a family with more than 12 members. The average family size among rural households is 8 members while among urban households average family size stood at 5 members.

Average Monthly Household Income – There is a huge disparity in income levels between the rural and urban households. Among rural households 30 percent of the families have an average monthly household income of less than €70 (₹ 5,000) while families having monthly household income in the range of €70 -135 and €135-270 stood at 28 percent each. In contrast, among urban households 52 percent of the families have an average monthly income of more than €1,340 and only 2 percent of the families have income below €335.

4.3) ENERGY CONSUMPTION

Under this section we will see how energy consumption varies between rural and urban households and also between various income groups. In this part of survey, we had asked the responding households their choice of fuels, monthly electricity consumption, monthly energy consumption and their experiences with black-outs or power cuts.

Electricity Consumption – With regards to electricity consumption we see a high disparity between the rural and urban households. Overall, the use of electricity on an average is considerably lower in rural than in the urban households. Among rural households, majority of the families, 23 percent, consume 50 to 100 units (1 unit = 1kWh) of electricity per month 45 percent of families consume less than 50 units of electricity per month. 11 percent of the rural households do not have an electricity connection, which means, they do not have access to electricity. The amount of electricity consumption is in line with a consumption pattern where households use electricity majorly for lighting purposes. Each household typically has 2 CFLs, a ceiling fan and some other electrical appliances such as television and mobile charger.

Compared to rural households, urban households have a very uniform distribution of electricity consumption, 52 percent of the households consume more than 500 units of

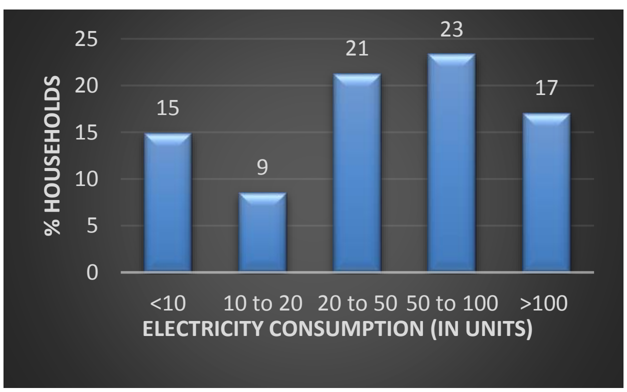


Figure 4.3: Rural monthly electricity consumption

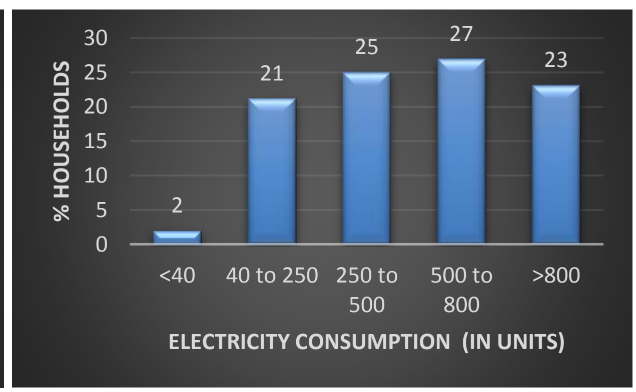
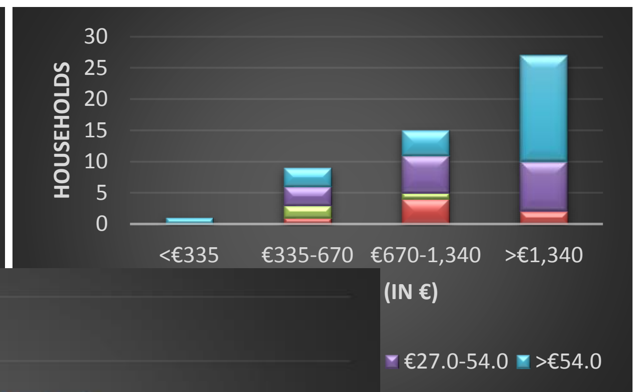


Figure 4.4: Urban monthly electricity consumption

electricity while 46 percent of the households consume electricity between 40 to 500 units per month.

Monthly Expenditure on Electricity – The fact that rural households consume a very low amount of electricity per month is also reflected in their monthly expenditure on electricity. Moreover, electricity in rural areas is highly subsidised for agricultural activities. Thus, it further deflates their electricity bill. While in urban households the majority of families have a high income and use relatively more electricity, they also pay more for electricity.

Power-cuts and other fuels – Both rural and urban households from all income strata have unanimously agreed that during certain times of the day they have experienced power-cuts or blackouts. However, the rural households have experienced blackouts of longer duration than their urban counterparts. The majority of rural households experience blackouts of the duration between 8-12 hours or more than 12 hours a day. While the majority of urban households experience blackouts for less than 4 hours a day. In absence of electricity, the rural households depend on traditional fuels such as cow dung or firewood to fulfil their energy requirements. The rural households from the lowest income group have coal and kerosene completely absent from their energy mix and overall the share of coal and kerosene



Fig

y consumption vs income

Figure 4.7: Rural households and sources of energy

in the rural household's energy mix is low compared to that of gas suggesting the households are moving towards gas directly from biomass based fuels and in the process skipping transitioning to coal and kerosene. Urban households usually have power back-ups such as an inverter (a system consisting of a charging unit and lead acid batteries) or diesel generators.

4.4) SOLAR ENERGY

This was the final segment of the survey where we asked the participating households about their general awareness towards solar technology, India's commitment towards solar energy. Households were also asked to state their own perceptions about solar energy and how having rooftop solar will benefit them and what are the challenges they are aware of related to purchase of rooftop solar PV technology. The final questions were about seeking awareness and opinion of the households on some the already existing policies initiated by the government and the private sector. This section will share the results on public perception towards rooftop solar.

Awareness – A very high percentage of participating rural households, 79 percent, are aware about solar technology and while 100 percent of the participating household are aware about solar technology. The awareness regarding the government's target for solar energy was low, 47 percent of the rural and 62 percent of the urban households are aware about it. We also explored the willingness to buy solar panels/lights of the household and here rural households were ahead of their urban counterparts. 68 percent of the participating rural households are willing to buy solar lights/panels in comparison to only 38 percent of the urban households.

Perceived Benefits – When the households were quizzed about their perceived benefits of rooftop solar there was a big divide between the rural and urban perceptions. Rural households viewed rooftop solar as a way to energy access, energy security and

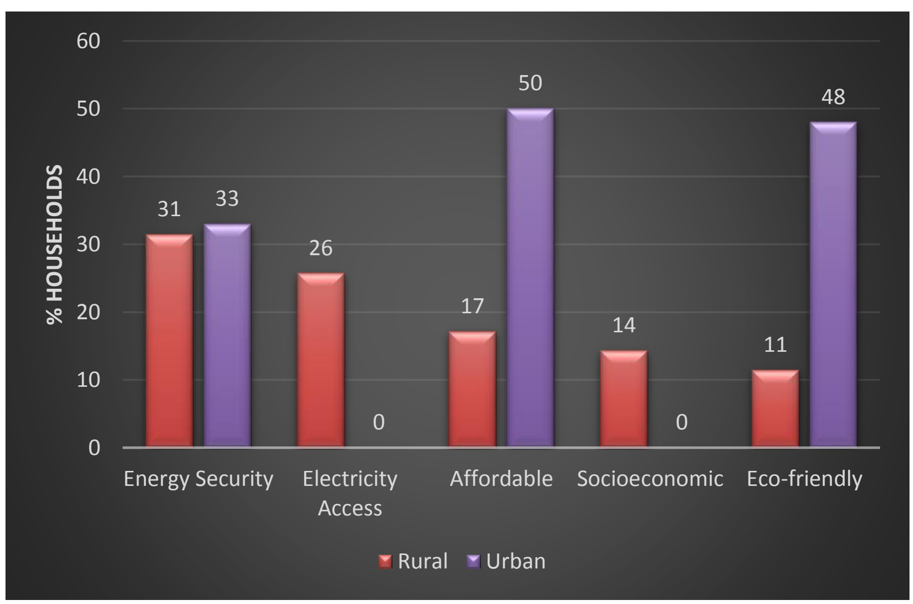


Figure 4.8: Perceived benefits of solar energy

socioeconomic development through increased household income and improved education and healthcare. Comparing this to urban households, they view solar energy from the viewpoint of savings on electricity costs, clean and eco-friendly source of energy and energy security.

Perceived Challenges – Participating households have a good knowledge towards benefits of solar energy and also have a high willingness to buy. Despite this only 11 percent of the rural and 8 percent of the urban households own a solar light/panel. The reasons which stop the households from purchasing solar panels are almost identical between rural and urban households. Cost of the solar PV system is the single biggest deterrent for not purchasing solar panels followed by space constraint, reliability, quality and lack of information are the next prominent reasons for rural households. For urban households, lack of information is

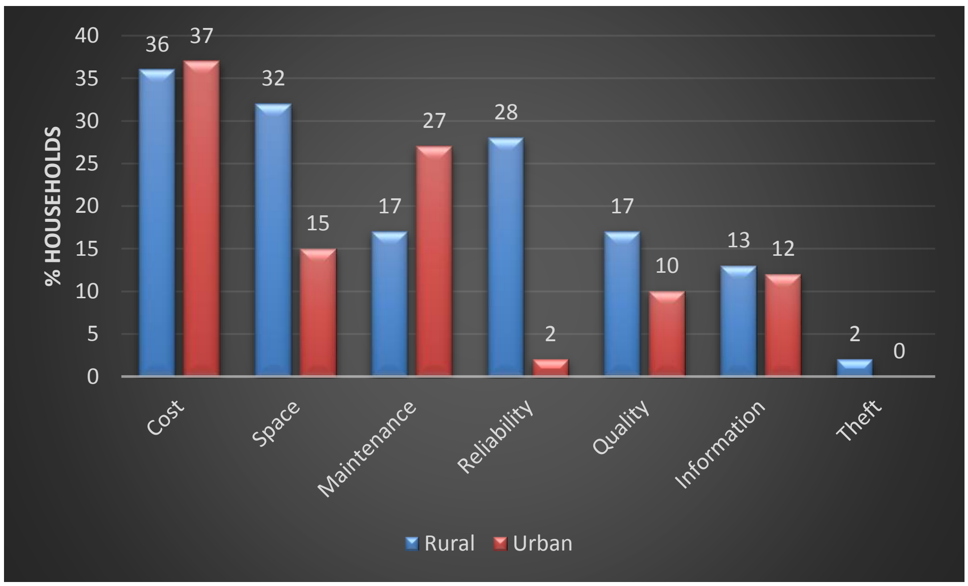


Figure 4.9: Challenges to purchase of solar panels

one of the biggest reasons for not buying solar panels.

Policy Awareness – The government has already taken some policy measures to address the concerns of the households regarding solar such as subsidies and net-metering. We checked the awareness of households regarding these policy initiatives and also cross-checked this with their response to particular challenge for which a policy initiative already exist. As the major challenge for households was the cost of the panels, the government has already been providing a subsidy on solar panels and majority of the households are unaware about the subsidy program while few people are aware about it but still consider cost as a factor despite subsidy.

Net-metering - Similarly, the government has also started the policy of net-metering for residential or domestic users to enable them to get a return on their investment by feeding surplus energy during the day time into the grid and getting reduction on their monthly electricity bills. However, the majority of the households, 79 percent for rural and 77 percent for urban, are unaware about this particular policy initiative.

Joint ownership and rooftop renting – The preference for voluntary community or joint ownership was in a balance for the rural households with 47 percent willing while 32 percent are not open to community or joint ownership. Urban households too share a similar feeling towards joint ownership with 44 percent of the households favouring against 37 percent of the households who are not in favour. However, for rooftop renting, 49 percent of the rural households are in favour while 30 percent families are yet to decide. For urban, 54 percent households are in favour of renting out rooftops while 27 percent households have yet to decide.

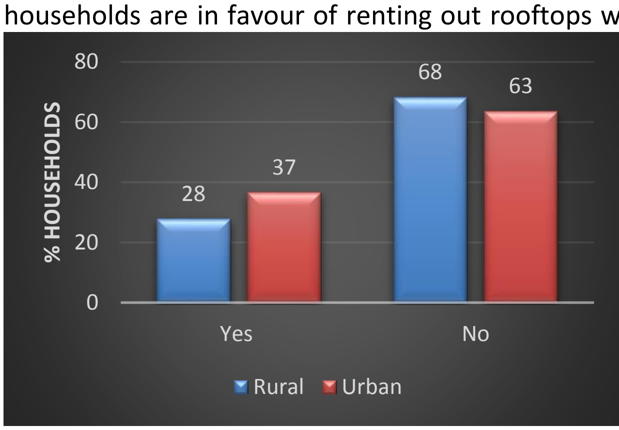


Figure 4.10: Awareness towards solar subsidy (total households)

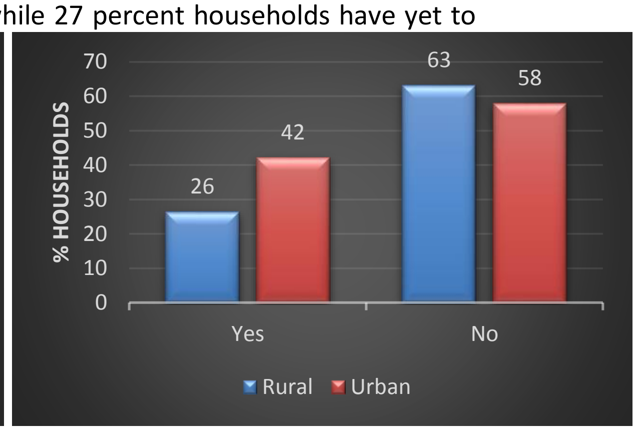


Figure 4.11: Cost vs Subsidy

4.5) INTERVIEWS

During the course of the research, four interviews have been done. The interviewees are from different sector but related to solar energy. The interviewees are Mr. Vishal, a solar energy consultant, Mr. Rob de Jeu, a social/solar entrepreneur working with rural communities in India on energy access through off-grid solar solution, Mr. Manish Kumar Hairat, academic researcher at Centre of Public Policy and Governance, Management Development Institute, Gurgaon and Mr. Rakesh Kackar, Director India Habitat Centre and a solar energy advocate. The following section contains the excerpts from the interviews.

The first the foremost question to all the interviews was about the target of 40 GW of grid-connected of rooftop solar energy and three of the four interviewees have complemented the government for having the most ambitious solar energy program in the world but at the same time they had their reservations about achieving the 40 GW mark by 2022. However, our energy consultant have stated that rooftop solar may overtake large scale solar farms by 2025. Our solar energy have categorically mentioned about the effort required not just from the government but industry as well individuals to achieve the target.

The next round of questions revolved around the challenges to rooftop solar energy and the solar energy consultant have spoken about profitability of the technology to both solar industry and consumers in current scenario of high cost, low reliability and quality standards. He also mentioned the fact the focus of both government and industry is currently on large scale solar farms and hence the slow pace of development in rooftop solar. The sentiments were shared by policy researcher Mr Hairat and further stated lack of effective implementation of policies, lack of funding and trained man-power with limited awareness about the technology and the policies too are responsible for the slow pace of development in rooftop solar. While the solar entrepreneur has talked about the bureaucracy as how it delays in releasing the subsidies while solar advocate went to add that the state electricity boards or discoms fearing loss of revenue and business are not very cooperative with commercial and industrial establishments when it comes to net-metering and open access to energy markets.

The third question revolved around the approach required to manage challenges in rural and urban areas and does a different approach is warranted to tackle challenges in rural and urban areas differently. All the interviewees have agreed that a different approach is required to address the challenges in rural areas to that of urban areas. Rural areas have dual challenges of less disposable income in households and missing supply chain. For this Rob has suggested leveraging existing networks and linkages to deliver solutions in rural areas and using microfinance institutions to provide funds to rural households at affordable rates. Mr. Rakesh has suggested setting up of ground mounted systems as more viable solution in rural areas where as Mr. Manish has argued for decentralized micro grids in rural areas.

To address the challenge of finance Mr. Manish has suggested payments over an extended tenure and the dealers and buyers both providing a collateral with relevant authorities in rural areas to cover defaults in payment by households or in case of insufficient service by the dealer.

The final question was related to address the issue of lack of information and Mr Manish has suggested to introduce a curriculum regarding solar technology at school level as children in households started to have a bigger say in decision related to purchase of technological related products while Mr Rakesh has suggested government should lead with example and using rooftops of social and charitable institutions to create awareness among masses.

The sharing of expert opinions and information by all four our interviewees is further used in discussing the direction of energy transition is headed in the country while also formulating further policy recommendations to both government and private sector.

Chapter 5 - Discussion and Recommendations

This chapter discusses the results from the surveys and interviews in relation to the theoretical framework as developed in Chapter 2. One of the main issues for the successful achievement of the policy objective of 40 GW of rooftop solar energy in 2022 relates to the freedom of Indian households to choose between different energy sources or carriers. Are they free to move through the energy ladder and make their choice between different energy sources or are they restricted by the limitations of their economic power and other physical constraints such as supply? This chapter will discuss about the possibility of the energy transition as envisaged by the central government and the barriers faced by the households in rural and urban areas in making that transition and what should be done to address these barriers.

Energy Transition: Development and Challenges

Among rural households, cow dung (53 percent households) and firewood (47 percent households) is used across all income groups followed by gas (32 percent households). Surprisingly the use of coal and kerosene is quite low, amounting to just 9 percent and 19 percent respectively. One of the major reasons for low share of coal and kerosene in the rural households energy mix is because of the targeted distribution of kerosene to families below poverty line thus reducing black marketing of kerosene, while households have less preference for coal. The transition of rural households from all income groups towards higher quality fuels such as gas has reaffirmed Bashmakov's Energy Transition Model, where households are moving towards better fuel because of superior quality and increased productivity due to higher efficiency of the alternative fuel.

The other significant observation is that the low income households in rural areas are using modern fuels alongside traditional sources such as cow dung and firewood at the same time as argued by Van der Kroon and Van Beukering (2013) in relation to urban households. Also, no participating family was using just a single energy source which according to energy ladder should have been the case. Instead, the families are using a mix of energy carriers to meet their energy requirement which is more in coherence with the concept of energy stacking as argued by Van der Kroon and Van Beukering (2013).

As households are making a transition from lower to higher ranked energy carriers and ultimately towards renewables and in particular solar there has been a unanimous support from political groups, industrial sectors, NGOs, and also the public. The reason for this support from all fronts is that the government has made everyone believe that the transition towards solar and other renewables will solve the issues of energy access and energy security while also addressing the challenge of climate change at the same time. Thus unanimous support from all sections of the society has left no space for any dissent.

As discussed earlier, the energy sector in India is has been liberalized over the years but still majority of energy production and distribution is managed by public sector though central or state owned enterprises. Nowdays, the private sector is present in oil and gas industry in India, but the country has low reserves of both oil and gas and the retailing of the fuels is still largely done by public sector companies. Among coal, India is the third largest producer of coal in the world behind China and USA (Enerdata, 2016) where Coal India, a public sector enterprise and a coal sector behemoth, is responsible for 84 percent of the total coal production, commanding 74% market share in the country (Coal India, 2017). State enterprises such as the National Thermal Power Corporation (NTPC) and its subsidiaries are installing solar panels on sites initially reserved for thermal power plants and plans to raise the share of non-fossil based energy sources in their energy mix to 30 percent by 2032 (Bloomberg, 2017). The country needs no further coal based power plants till 2027 (CEA, 2016) and has cancelled plans to build 13.7 GW of coal based power plants (The Independent, 2017). Even after cancelling the plans to build coal based power plants of 13.7 GW capacity, 75 GW of coal based power plants are already under construction. After completion of the power plants of 75 GW of capacity and with government keep increasing the share of renewables in its energy mix, there won't be a need to build any more coal based power plants till 2032 (CEA, 2016) while the government is still planning to build 214GW of coal based power plants. This stems from the government's promise of 24*7 electricity for all. Though an ambitious target but it is a rather short term step and is in itself conflicting with the government's target of making a transition to renewable energy. It thus prevents the government to go for renewables or create a risk of leaving the power sector with idle capacity or it will lead to power plants operating at sub-optimum level and thus straining the financial viability of the energy sector.

5.1) BARRIERS TO GRID-CONNECTED ROOFTOP SOLAR

India's renewable industry is in the early stages of development and solar rooftop is still at a nascent stage. There are several barriers to mass scale adoption of grid-connected rooftop solar which hinder the development of the sector and at the same time the achievement of the national target of 40GW of grid-connected rooftop solar energy. Here we look at the challenges or barriers which affect and impact consumers though barriers to industrial players too have cascading impact on consumers. However, they are beyond the scope of the current research. In conclusion, the major challenges identified to grid-connected rooftop solar are, a) high initial capital cost, b) service and maintenance, c) information, d) reliability, e) safety, f) quality and g) space. They are explained below.

a) **High initial capital cost –** The cost of solar panels of 1 kWh capacity in India ranges from around €1,000 without backup and €1,800 with a backup of 6 hours. A rooftop solar system without back-up is considerably cheaper but as pointed out by the consultant, with erratic power supply, a solar system with no backup system is of no use especially at night and the home still need to have a power backup option as inverter or a diesel generator. Thus without a backup option, solar system is a less reliable option and with backup a costly option. The higher cost also increases the duration of the payback period of the system.

b) **Service and Maintenance –** The issue of service and maintenance is a bigger challenge in rural areas than in urban areas. In our case study, people who had a solar light/panel complained about a lack of service centres and skilled people to repair solar panels and light and in case any repair is needed, people either travel to the city (Gurgaon) or have to pay higher fee to call a technician from the city. In urban areas, after the warranty period, the cost of service and maintenance is high and it is also hard to find a trained technician for maintenance.

c) **Space Constraint –** Space is an issue both in rural and urban areas. Among rural households, families have said that the roofs of the houses are neither big or strong enough to bear the load of solar systems while among urban households, owners of independent housing have no issues but people living in apartments, flats or rental housing have limited or no access to rooftops and for people living in rental homes, portability too becomes an issue.

d) **Reliability –** There is an inbuilt factor of unreliability in renewable technology such as solar, as it depends on weather conditions for electricity generation. In addition, with erratic power supply from the state electricity boards and no power backup option, the reliability of rooftop solar is further reduced which makes it a less attractive option.

e) **Information –** There is a lack of information about every aspect of the solar PV technology such as solar radiation data, and technological standards, but also about reliable brands or dealers, available subsidies and other government support. Currently, each solar PV manufacturer in the country has his own technical specifications and benchmarks which confuses potential customers. Since the solar market is still in early stage of development, the market is fragmented and currently there are not many big players dealing in rooftop solar PV. Hence, finding information about a reliable and trustworthy dealer also discourages people from adopting solar.

   At the same time, a lack of awareness or clarity on policy measures taken by the government to promote the use of solar PV is also prevalent. There is confusion about the availability of subsidy, subsidy amount, limit of subsidy etc. Since 2016, the concept of net-metering for home and small electricity users is already there in number of states but households are unaware about the concept of net-metering. In net-metering, the surplus electricity generated by rooftop solar PV during the day is fed back into the distribution system and the amount for the power fed in the system is deducted from the household's monthly electricity bill.

f) **Quality –** With no industry wide standards and benchmarks for solar PV, the quality has indeed become a major issue as people are conscious about sub-standard products flooding in the market which are relatively cheaper but are also less efficient. The households are sceptical towards the chances that they might be duped off by a dealer who sells a sub-standard product for a full price and later refuses to give service if needed.

The above mentioned barriers such as the high capital investment, a lack of information about the future government policy, undefined or under-defined technical standards and benchmarks make people reluctant towards adopting solar technologies. Therefore, it becomes imperative for the government and private sector to address the above mentioned barriers and allow access to every household to rooftop solar PV technology. This would in return ensures energy access and security to each and every household in the country, while also at the same time is clean and eco-friendly.

5.2) RECOMMENDATIONS

In the section above, we have discussed in detail the challenges and barriers encountered by the rural and urban households in order to install rooftop solar PV. Having established a basic understanding and during the course of interviews and review of articles by various academic researchers, there have been an unanimous demand for having two different approaches for reaching rural and urban households for the differences in socioeconomic backgrounds of rural and urban households, access to information, financial capacity and other factors. Several suggestions and recommendations made which we try to now list. In this section the research attempts to identify some possible solution to address these challenges.

1) **Policy Paradigm shift –** The renewable energy policy of India is currently biased towards large scale solar PV farms at the expense of concentrated solar power (CSP) technology. The Solar PV technology is less efficient against CSP (Ghosh & Hairat, 2017). As a consequence of this policy bias, industry completely ignores the domestic rooftop market. Thus a more balanced approach is needed in order to shift the focus towards the currently neglected area of rooftop solar power.
2) **Institutional Finance –** The cost of the solar PV is major challenge for all households be it urban or rural. Currently, there is no existing national scheme for purchase of solar PV for a capacity less than 1,000 kwp (MNRE, 2015). This means that people who are willing to buy rooftop solar PV are left out because of their lack of finances. What is necessary is a national policy directing banks to provide loans at concessional rates. This will initially result in a scenario where the savings on electricity bills are used to pay back the loan in the short term whereas in long term it is still a net saver on cost of electricity. For rural areas, loans can be disbursed through regional and rural banks, microfinance institutions or National Bank for Agriculture and Rural Development (NABARD) as solar PV has potential to bring socioeconomic development by improving healthcare and education conditions while also improving household income.
3) **Financial Incentives –** Currently, majority of government's financial instruments such as tax breaks, accelerated depreciation, long term tenure – debt, preferential tariffs etc. are targeted towards large institutional power producers and not individual households. For households, currently only two financial instruments exist, subsidy and generation based incentives. While as discussed earlier there is lack of clarity on quantum of subsidy and other specifications, generation based

incentives are provided by state governments and currently not all state governments provide. Thus a few more financial incentives can work in public favour promoting solar PV uptake. Since, farm incomes are exempted from taxation in India so tax breaks or credits may not be viable but providing government backed securities with extended tenure for payments at lower interest rates can also work in rural areas. As for urban areas where majority households are in the ambit of tax next and pay their taxes regularly can certainly be provided with tax credits, concessions or exemptions to a certain limit.

4) **Promoting Standards –** As argued in the previous section, most local solar manufacturers follow their own technological specifications and standards leading to products having different efficiency and life span, government in collaboration with manufacturers should release a guideline specifying certain minimum conditions for the manufacturers to follow for making it easy for the buyers to pick and choose products without much confusion.
5) **Higher incentives for solar companies and businesses to enter rural markets –** As highlighted, there is a lack of dealers and trained manpower to sell, install and repair solar PV in rural markets. The government can incentivise the companies through tax breaks, discounts on duties etc. to improve their supply chain in rural areas while also to create a skill workforce locally. Additionally, the government can provide a push through the already existing Corporate Social Responsibility Act to companies that are voluntarily providing courses to teach skills to people who can work in partnership with solar companies to create a skilled workforce base in rural areas.
6) **Linking solar schemes with housing schemes –** The central and state governments already have an existing policy where they have identified preferred establishments for installing rooftop solar power plants. These establishments include all central and state government office buildings, offices of public sector enterprises, all commercial and social institutions, charitable trusts, schools and colleges, hospitals and residential buildings. In addition, it is compulsory for new residential buildings to install rooftop solar panels but for existing residential building this is a voluntary choice. However, the policy does not include measures for the owners of flats and independent house owners.

   To address these shortcomings, the government can take a leaf out from its own policy where they have integrated the Swachh Bharat Mission, a mission where the government shares the cost of constructing toilets in homes by providing cash benefits to rural households, with its Housing for All mission, under which government plans to provide affordable housing for all by 2022 and share the costs of constructing a home. Similarly, government can provide a direct cash benefit to rural households to install rooftop solar in their homes of a capacity of 500 W to 1kWh. Thus resulting in a more sustainable household at a lower cost for both government and the family.
7) **Marketing –** To address the issue of lack of information, central government along with state governments and their renewable energy ministries and departments can create authorized solar dealerships, and dedicated portals where citizens can get all the relevant information about solar such as technological standards, solar radiation

data, capacity requirements, information about subsidies and other benefits/incentives, and dealer information. This one-stop information portal will not only improve information dissemination among the public but will also reduce the complexity of the process and the amount of wrong information that is currently provided.

5.3) CONCLUSION

An underlying and undefined question of the research was whether households are really free to choose the energy carrier of their choice or are bound by their physical and economic environment. The majority of studies done have maintained that economic conditions of the households are the single biggest factor governing the choice of fuel for the household and rural families and households are generally so poor that they are not able to afford modern energy carriers while even if they can, the lack of access and stable supply of modern fuels do not allow them to use these fuels leaving them to use traditional fuels which are inefficient, polluting, unsafe.

The energy consumption pattern of families in urban households has largely followed the assumptions made by the energy ladder theory and energy transition theory as they moved from one energy carrier to another in a clean and swift manner. Increasingly, urban people are using modern energy carriers of gas and electricity for meeting their daily energy requirements due to increase in household income, superior quality and efficiency of the modern commercial fuels leading to higher productivity and reduced health and environmental risks. While rural households have been observed to use a variety of energy carriers for meeting their energy requirements and are also in a process of making a transition from least efficient, highly polluting low ranked energy carriers such as cow dung and firewood to more modern and commercial energy carriers such as gas and electricity while skipping intermediate fuels such as coal and kerosene. The transition has been facilitated by not only improvement in income but because of increased awareness towards health, economic benefits of using time for other productive activities, access to modern fuels and incentives such as subsidies provided by the government which has led to the adoption of modern and commercial fuels by even low income households in rural areas. The higher socioeconomic status attached with using more modern and expensive fuels may too have played its part in transition.

However, the danger towards transition to renewable energy carriers also comes from government’s own policy choices. Despite government’s own reports confirming that there is no need of building any more of coal based power plants in the country till year 2027 while 75 GW of coal based power plant are already under construction and another 214 GW of coal based power plants are at planning stage. Though the government wants to provide all the citizens with 24*7 access to electricity, the same can also be achieved by the help of renewables such as solar and wind. The step of building coal based power plants seems a rather short sighted arising from the political myopia and instead of creating lock-ins in investment in infrastructure projects which may not be required in future, the government should create policies to direct the investment towards clean and renewable energy.

No doubt, the target of achieving 100 GW of grid connected solar energy, with 40 GW from grid connected rooftop solar, by 2022 is a highly ambitious target and the government and the citizens should be appreciated for making a concerted approach to achieve the targets with their current limitations. After having done an extensive review of several reports from various intuitions, government bodies and interviews with solar energy consultants, solar entrepreneurs and academic researchers working on solar and renewable energy policies, the research has pointed towards the fact that achieving the target of 40GW of grid connected rooftop solar energy by 2022 will be difficult though India may still achieve its target of 100 GW of solar energy, thanks mainly to large scale solar farms.

However, there is still time and with correct policy measures, support from government and industry and the emerging trends regarding energy transition among rural households, leap frogging to renewables in rural areas cannot be ruled out. If such a scenarios shapes up the nation may not achieve its target of 40 GW of grid connected rooftop solar energy but may also exceed it and at the same time providing energy access to 300 million people who currently lack access to electricity and energy security to 700 million people who experiences regular black outs and brown outs.

India being an emerging country with a majority of its population still residing in rural areas, the findings of the research may be applicable to other emerging and developing countries particularly countries from South Asia including Nepal, Pakistan, Bangladesh and Sri Lanka.

REFERENCES

- Bajracharya, D (1983). Deforestation in the food/fuel context: historical and political perspectives from Nepal. Mountain Research and Development, 3 (3), pp. 227-240. DOI: 10.2307/3673017

- Bandyopadhyay S (2017), Renewable targets for India. Clean Technologies and Environmental Policy, 19 (2), pp. 293-294. DOI: 10.1007/s10098-017-1335-z
- Bashmakov, I (2007). Three laws of energy transitions. Energy Policy, 35 (7), pp.3583-3594. https://doi.org/10.1016/j.enpol.2006.12.023
- Bernard, H.R. (2011). *Research methods in anthropology: Qualitative and quantitative approaches*. Maryland: Rowman Altamira, pp. 1-666.
- Bryman, A (2004). Social research methods. Hampshire: Oxford university press, pp. 1-575.
- De Vaus, D. (2013). *Surveys in social research*. Abingdon: Routledge, pp. 3-381.
- Goddard, W. and Melville, S (2004). *Research methodology: An introduction*. Lansdowne: Juta and Company Ltd., pp. 1-149
- Goel, M (2016). Solar Rooftop in India: Policies, challenges and outlook. Green Energy & Environment, 1 (2), pp. 129-137. https://doi.org/10.1016/j.gee.2016.08.003.
- Gulati M. (2012), Developing solar power lessons from India's national solar mission. WWF South Africa.
- Hairat M.K. & Ghosh S (2017). 100GW of Solar Power in India by 2022 – A critical review. Renewable and Sustainable Energy Review, 73, pp. 1041-1050. http://dx.doi.org/10.1016/j.rser.2017.02.012
- Hall P.A. & Soskice (2003). Varieties of Capitalism and Institutional Complementarities. In Franzese R. & Mooslechner P. ed. Intitutional Conflicts and Complementarities: Monetary Policy and Wage Bargaining Institutions in EMU, Boston: Springer, pp. 43-76. DOI 10.1007/978-1-4757-4062-2
- Hosier, R.H. and Dowd, J (1988). Household energy use in Zimbabwe: an analysis of consumption patterns and fuel choice. Scandinavian Institute of African Studies, pp.83-109. ISBN: 9171062785
- Kapoor, K., Pandey, K.K., Jain, A.K. and Nandan, A (2014). Evolution of solar energy in India: A review. Renewable and Sustainable Energy Reviews, 40, pp.475-487. http://dx.doi.org/10.1016/j.rser.2014.07.118
- Loorbach, D. and Rotmans, J. (2010). The practice of transition management: Examples and lessons from four distinct cases. Futures, 42 (3), pp.237-246. https://doi.org/10.1016/j.futures.2009.11.009
- Masera, O.R., Saatkamp, B.D. and Kammen, D.M. (2000). From linear fuel switching to multiple cooking strategies: a critique and alternative to the energy ladder model. World development, 28 (12), pp.2083-2103. https://doi.org/10.1016/S0305-750X(00)00076-0
- Moallemi E. & Aye L. et al (2017), India's on-grid solar power development: Historical transitions, present status and future driving forces. Renewable and Sustainable Energy Reviews, 69, pp. 239-247. http://dx.doi.org/10.1016/j.rser.2016.11.032
- Mukherjee, S., Dhingra, T. and Sengupta, A (2017). Status of Electricity Act, 2003: A systematic review of literature. Energy Policy, 102, pp.237-248. https://doi.org/10.1016/j.enpol.2016.12.001
- René Kemp, Derk Loorbach & Jan Rotmans (2007). Transition management as a model for managing processes of co-evolution towards sustainable development. International Journal of Sustainable Development & World Ecology, 1 (1), pp. 78-91. http://dx.doi.org/10.1080/13504500709469709
- Saran, S. and Sharan, V., 2012. Identity and energy access in India-setting contexts for Rio+ 20. *Energy Security Insights*, *7*, pp.14-9.

- Sawhney, A (2013). Renewable energy policy in India: addressing energy poverty and climate mitigation. Review of Environmental Economics and Policy, 7 (2), pp.296-312. DOI:https://doi.org/10.1093/reep/ret010
- Sharma, N.K., Tiwari, P.K. and Sood, Y.R (2012). Solar energy in India: Strategies, policies, perspectives and future potential. Renewable and Sustainable Energy Reviews, 16(1), pp.933-941. https://doi.org/10.1016/j.rser.2011.09.014
- Shrimali G. & Srinivasan S. et al (2017). The Effectiveness of Federal Renewable Policies in India. Renewable and Sustainable Energy Reviews, 70, pp. 538-550, http://dx.doi.org/10.1016/j.rser.2016.10.075
- Shrimali G, Rohra S (2012). India's Solar Mission: A Review. Renewable and Sustainable Energy Review, Vol. 16 (8), pp. 6317-6332. http://dx.doi.org/10.1016/j.rser.2012.06.018
- Thapar, S., Sharma, S. and Verma, A., 2016. Economic and environmental effectiveness of renewable energy policy instruments: Best practices from India. Renewable and Sustainable Energy Reviews, 66, pp.487-498. https://doi.org/10.1016/j.rser.2016.08.025
- van der Kroon, B., Brouwer, R. and van Beukering, P.J (2013). The energy ladder: Theoretical myth or empirical truth? Results from a meta-analysis. Renewable and Sustainable Energy Reviews, 20, pp.504-513. https://doi.org/10.1016/j.rser.2012.11.045
- Veer, C. and Enevoldsen, K. (1993). Wood in rural energy planning: issues and strategies for discussion. TIDE, 3, pp.323-337.
- Victor DG, Heller TC, Hope E (2008). The political economy of power sector reform: the experiences of five major developing countries. The Energy Journal, Vol. 29 (2), pp. 186-188
- Wilson, J. (2010) “Essentials of Business Research: A Guide to Doing Your Research Project” SAGE Publications, p.7
- Wacker, J.G. (1998). A definition of theory: research guidelines for different theory-building research methods in operations management. Journal of operations management, Vol. 16 (4), pp.361-385. https://doi.org/10.1016/S0272-6963(98)00019-9
- Baroni M. & Cozzi L. et al (2015), World Energy Outlook Special Report: India Energy Outlook. International Energy Agency (IEA) Paris, pp. 19, Available at https://www.iea.org/publications/freepublications/publication/IndiaEnergyOutlook_WEO2015.pdf, Accessed on 17th March, 2017.
- Ebinger C.K. (2016), India’s Energy and Climate Policy: Can India Meet the challenge of Industrialization and Climate Change. Brookings Energy and Climate Initiative.
- Gaye, A. (2007). Access to energy and human development. *Human development report*, *2008*.
- Draft National Electricity Plan (2016), Central Electricity Authority, Ministry of Power, Government of India. Available at http://www.cea.nic.in/reports/committee/nep/nep_dec.pdf. [Accessed on 1st June, 2017].
- Mukherjee, Mohua. 2014. Private Participation in the Indian Power Sector: Lessons from Two Decades of Experience. Directions in Development--Energy and Mining. Washington, DC: World Bank. World Bank. https://openknowledge.worldbank.org/handle/10986/20410 License: CC BY 3.0 IGO.

- Tim Buckley (2015), India's Electricity Sector Transformation. Institute for Energy Economics and Finance Analysis, available at http://ieefa.org/wp-content/uploads/2015/08/IEEFA-Indian-Electricity-Sector-Transformation-11-August-2015.pdf. [Accessed on 1st June 2017].
- Trudeau N., Tam C. et al (2011), Energy Transition for Industry: India and The Global Context. International Energy Agency (IEA) Paris, pp. 14-26, Available at https://www.iea.org/publications/freepublications/publication/energy-transition-for-industry--india-and-the-global-context.html, Accessed on 16th March, 2017.
- Arvind Panagariya (2016). National Institute for Transforming India (NITI Aayog), Government of India. Available on http://niti.gov.in/content/indias-generous-indics. [Accessed on 8th June, 2-17]
- Bloomberg (2017). Cheaper solar in India prompts rethink for more coal projects. Available at https://www.bloomberg.com/news/articles/2017-06-01/cheaper-solar-in-india-prompts-rethink-for-more-coal-projects. [Accessed on 28th June, 2017]
- Business Standards (2016), Jat Stir Shakes India Inc. Available at http://www.business-standard.com/article/current-affairs/jat-stir-shakes-india-inc-116022000835_1.html. [Accessed on 21st June, 2017].
- CEA (2016). National Electricity policy 2016. Available at http://www.cea.nic.in/reports/committee/nep/nep_dec.pdf. [Accessed on28th June, 2017]
- Enerdata (2015). Total Energy Consumption (2015), Global Energy Statistical Yearbook 2016. Available at https://yearbook.enerdata.net/#energy-consumption-data.html. [Accessed on 20th June, 2017]
- Government of Haryana, District Gurugram (2016). Available at http://gurgaon.nic.in/pdf/about-gurgaon.pdf. [Accessed on 22nd June, 2017].
- Institute for Human Development (2008). A baseline survey of minority concentration districts of India (2008), Available on http://icssr.org/Mewat[1].pdf. [Accessed on 22nd June, 2017].
- Institute of Energy Research (2015). China: World's largest energy consumer and greenhouse gas emitter (2015), Institute for Energy research (IER). Available at http://instituteforenergyresearch.org/analysis/china-worlds-largest-energy-consumer-and-greenhouse-gas-emitter/. [Accessed on 20th June, 2017]
- International Solar Alliance (2016), available at http://intsolaralliance.org/Contactus.html. [Accessed on 22nd June 2017].
- Make in India, 2017, Govt. of India. http://www.makeinindia.com/sector/renewable-energy. [Accessed on 17 March 2017]
- Ministry of Power, Govt. of India, http://www.powermin.nic.in/en/content/power-sector-glance-all-india [Accessed 17 March 2017]
- Rakesh Dubbudu (2016). India's per capita electricity consumption lowest among BRICS nations. https://factly.in/indias-per-capita-electricity-consumption-lowest-among-brics-nations/. [Accessed on 18th June, 2017].
- S M Sehgal Foundation Gurgaon (2015), Identifying backwardness of Mewat Region in Haryana: A block level analysis. Available at http://niti.gov.in/writereaddata/files/document_publication/Identifying%20Backw

ardness%20of%20Mewat%20Region%20in%20Haryana-%20A%20Block%20Level%20Analysis_final_0.pdf. [Accessed on 22nd June, 2017].

- Solar Corporation of India, Government of India (2016). An Overview of Solar Energy Program and Potential in North East. Available at http://www.cseindia.org/userfiles/rakesh-kumar_SECI.pdf. [Accessed on 20th June 2017].
- The Economic Times, 2017. Barring 6 states and Chandigarh, India to turn power surplus this fiscal. Available at http://economictimes.indiatimes.com/industry/energy/power/barring-6-states-and-chandigarh-india-to-turn-power-surplus-this-fiscal/articleshow/58900457.cms?utm_source=facebook.com&utm_medium=referral&utm_campaign=ETFBMain. [Accessed on 29th May, 2017].
- The Economic Times, 2016. Delhi government to provide generation-based incentive for power from rooftop solar system. Available at http://economictimes.indiatimes.com/industry/energy/power/delhi-government-to-provide-generation-based-incentive-for-power-from-rooftop-solar-system/articleshow/51007030.cms. [Accessed on 29th May, 2017].
- The Independent (2017). India cancels plans for huge coal power stations as solar energy process hit record low. http://www.independent.co.uk/environment/india-solar-power-electricity-cancels-coal-fired-power-stations-record-low-a7751916.html. [Accessed on 28th June, 2017]
- The Carbon Brief (2016), Analysis: What global emissions in 2016 mean for climate change goal. Available at https://www.carbonbrief.org/what-global-co2-emissions-2016-mean-climate-change. [Accessed on 18th June 2017].
- The Indian Express (2014). http://indianexpress.com/article/india/india-others/66-per-cent-of-india-still-relies-on-dung-based-fuel-to-cook-un/. [Accessed on 13th June]
- United Nations Sustainable Development Goals (2015), https://sustainabledevelopment.un.org/sdg7. [Accessed on 14th June, 2017].
- United Nations Sustainable Development Goals (2015). Available at https://sustainabledevelopment.un.org/sdg13. [Accessed on 14th June, 2017].
- United Nations Sustainable Development Goals (2015), http://www.un.org/sustainabledevelopment/wp-content/uploads/2016/08/7_Why-it-Matters_Goal-7_CleanEnergy_2p.pdf. [Accessed on 14th June, 2017].
- United States Environmental Protection Agency (2017). Global Greenhouse Gas Emissions Data (2017). Available at https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data. [Accessed on 20th June 2017]

SOCIAL WATCH

August 2017

www.saraswati-seva-foundation.org