MULTI-LEVEL ENERGY FOCUSED INTEGRATION OF SECTORS FOR RURAL DEVELOPMENT

AN INDIAN CONTEXT

MASTER THESIS REPORT BY **SANAJ MEHTA**

Multi Level Energy Focused Integration of Sectors For Rural Development

An Indian Context

by

Sanaj Mehta

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This thesis is confidential and cannot be made public until December 31, 2017.

TU Delft

Preface

This thesis was conducted as a part of the Master of Science program in Sustainable Energy Technology at the Delft University of Technology. The thesis presented in the report is the final step in obtaining the Degree and thus concludes the program. My passion for sustainable development especially energy in a world grappling with an uncertain future with respect to energy sources, took me from my bachelors degree in Mechanical Engineering to pursue a masters degree in Sustainable Energy Technology at Technische Universiteit Delft.

My interests lay in providing techno-economic solutions to traditional power approaches to help tackle the existing problems faced by renewables in the power sector and thus help renewables play a more significant role in power generation in a world which is in constant struggles of meeting our ever-growing energy demands with aspirations of attaining widespread sustainability. My interest in renewable energy solutions made me take on a focus on Energy System Integration and Optimization during my masters.

The seeds for my passion and understanding of the need for sustainable energy were sown during my bachelors in India, where I took up Energy management as a track elective. The energy issues that our world faces, particularly shortage and efficiency, got me thinking, and I felt the need to understand technical concepts in a practical environment. These beliefs I carried through my masters pursuing courses and electives which would drive me towards working on a thesis in the similar area of research.

In June 2016, I met Dr. Kas Hemmes who was interested in supervising me on topics related to Energy Integration, thus guiding me not only through the thesis but also my intern-ship which preceded the thesis chronologically. Together we embarked on a journey to provide solution directions for rural development in India using an Integrative Approach. Due to my educational background the primary focus of the approach was to target sustainable energy while mutually benefiting the water and waste sectors.During the initial phase of my research, I started believing in the need for applying sustainability in a broader sense, the need for integration and systems thinking, all of which is explained in my report. To not be focused on any particular segment of sustainability but to have a broad outlook and design a methodology for producing multi-purpose systems was a challenging as well as an enjoyable task.

This thesis report is a result of my work done for the period of December 2016-October 2017. Hope my work paves a way for a better tomorrow and helps bring in more effective practices in the future.

Sanaj Mehta
Delft, 16 October 2017

Acknowledgement

I would first like to thank my thesis first supervisor Dr. Kas Hemmes of the Technology, Policy and Management Faculty at the Delft University of Technology. The door to Dr. Kas's office was always open whenever I ran into a troubled spot or had a question regarding my research or writing. He consistently allowed this paper to be my own work, but steered me in the right the direction whenever he thought I needed it.

I would also like to express my gratitude to Dr. Otto Kroesen and Dr. Bartel Van De Walle from Technology, policy and Management Faculty of TU Delft for being members of the thesis committee. I am greatly indebted for your valuable time and the comments for the thesis.

Further on, I would like to thank all the stakeholders interviewed for the purpose of the thesis which includes Dr. G. Prasad and Mr. Tarun Kapoor from the Ministry of New and Renewable Energy, Mr. Dinesh Arora and R.k Gupta from Rural Electrification Corporation of India, Mr. Aklavya Sharma from DESI Power, Mr. Bhushan Trivedi from Piconergy, Dr. Amit Kumar and Dr. Shirish Garud from TERI India, Vrinda Chopra from University of Cape town and finally but specially Dr. Priti Malhotra from University of Delhi who provided me with not only guidance but with any kind of help regarding the thesis.

I would also like to thank all those who helped with their distinct educational and professional background to work on the local case study and contributed with identification of various I-neffs, the list Includes Abhishek Agrawal, Vanshika Bharaj, Meghana Biswas, Chahat Arora, Prashant Mewani, Chinmaya Anegundi, Nilofer Afza and Rushabh Chheda. Meghana deserves my special grattitude for her repeated help with my report and being my go to person for help with structuring my thesis.

I would also like to thank my friends for being my constant support and pillar of strength. Thank you for always pulling me back up when I was low. A special thanks to Rauniq Amla, Lakshya Dev Mudgil, Ahmed Gharib, Jasper Merks and Vibha Kothari for always being there and helping me stay on the path.

Finally but most importantly I would like to thank my family back in India, Mom, Dad and Sunayna thank you for showing me your constant support. My grand parents who always believed in me and made the initial step of this journey at TU Delft possible. A special thanks to my sister Vrinda Chopra, the scholar of the family, for being my guide through the thesis.

Summary

There are a variety of factors affecting the personal and economic well being of those living in rural areas of the world: energy, water, sanitation, health, food, employment and local economy are some of these factors. India, one of the most populated country in the world has been tackling impeded rural development since its independence in 1947. This thesis report aims at providing multi purpose systems as a result of energy focused integration of sectors for augmenting rural development in India. The main research question of the thesis was 'Having recognized the importance of systems thinking, how can energy focussed Integration of Sectors provide directions to overcome the problem of impeded rural development in India?'. Main criteria of answering the research question has a core around marking out potential barriers which could be faced by such sector integrated techniques to break into the Indian market and policy while discussing the obstacles to implementation of such solutions. Furthermore another important aspect of the thesis lays out some plausible solutions to these barriers and obstacles.

The multi purpose integration of sectors have a prime focus on energy. Energy is of paramount importance when it comes to the growth of a nation especially because of its close relationship with GDP. Insufficiency of energy brings economic stagnation and reduction in optimum productivity. Energy security therefore becomes a crucial aspect, which needs to be catered to, to help maintain and accelerate economic growth of a nation and thus overall development.

Due to no access to energy, the rural regions of India are very backward and hence are devoid of economic and social development impeding the nations development as a whole. The solution directions considered in this thesis are based on an integrative approach which tends to create multi purpose energy systems with cross sectoral branching for overall development. For the same purpose, consideration of rural water and waste sectors was done. Inclusion of water and waste in the above mentioned solution directions have manifold benefits to achieve a broader prospect of rural development. Presently the two considered sectors have faced large scale issues in rural regions which have lead to impedance in development. Solving these issues have manifold underlying benefits, both socially and economically, targeting larger aspects of the Sustainable Development Goals set by the United Nations.

The approach followed for the purpose of the thesis was given a terminology of TopDown-BottomUp. A Bottom-Up case study was performed to provide sector integrated solution directions for the selected rural region. The approach followed for the Bottom-Up case was based on I-neffs and E-nabes, I-neffs are the highest order factors which need to be catered to make integration possible, while E-nabes are technologies in existance or in development which makes this integration process possible by trgetting the specified I-neffs . I-neffs are not traditional system inefficiencies or engineering and design defects but need catering to for making integration a reality. The Bottom-Up case study was performed on a sample site, knowledge gained from performing the case study was extrapolated to provide certain aspects which would be required for integration process to be a success and thus the barriers and their identified solutions were defined on the basis of these identified aspects in the Top-Down case study.

The Top-Down case study was performed as well, where stakeholders and experts from various sectors of the institutional structure were interviewed to get a better overview of the aspects associated to the Integrative Approach defined in the Bottom-Up case study ,for creating multi purpose energy systems for rural development in an Indian context. it is this aspect if the thesis which provides detailed information regarding the barriers and obstacles expected to be faced while implementing such highly integrated solutions while laying out certain possible solutions to those barriers.

The thesis thus lays down certain aspects associated to energy focused integration of sectors, for the policy makers to make integration a reality for exponentially accelerated rural development in India.

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Acronyms

Table 1: List of Acronyms Used

Acronym	Full Form
GDP	Gross Domestic Product
PV	Photovoltaic
MSMP	Multi Source Multi Product
PHEV	Plug in Hybrid Electric Vehicle
AC	Alternating Current
DC	Direct Current
SHS	Solar Home System
BMS	Battery Management System
V2G	Vehicle To Grid
R&D	Research and Development
REC India	Rural Electrification Corporation Of India
SDGs	Sustainable Development Goals
MOP	Ministry of Power
MNRE	Ministry of New and Renewable Enerrgy
CEA	Central Electricity Authority India
CERC	Central Electricity Regulatory Commission
PC	Partially Covered
FC	Fully Covered
SERC	State Regulatory Electricity Commission
OECD	The Organisation for Economic Co-operation and Development
PPP	Public Private Partnership
DSO	Distribution System Operator
TSO	Transmission System Operator
RGGVY	Rajiv Gandhi Grameen Vidhyuta Yojana
DDUGJY	Deen Dayalan Upadhyay Gram Jyoti Yojana
RVE	Remote Village Electrification

Contents

1
Introduction

"Rural development is the process of improving the quality of life and economic well-being of people living in rural areas, often relatively isolated and sparsely populated areas" (Moseley, 2003). There are a variety of factors affecting the personal and economic well being of those living in rural areas of the world, energy, water, sanitation, health, food, employment and local economy are some of these factors.

The United Nations in 2015, passed the Sustainable Development Goals as a successor to the existing Millennium Development Goals;achieving these goals was believed to lead to rural development. The Sustainable Development Goals lay out 17 goals with 169 targets among them which was to be spearheaded by the United Nations in its 193 member states. These goals are also known as "Transforming our world: the 2030 Agenda for Sustainable Development" (Sachs, 2012), depicted inFigure 1.1. India one of the key members of the United Nations and the second most populated country in the world with a population of 1.21 billion people has one of the largest rural populations in the world with 70% of the country's population living in rural regions (Bank). Majority of those living in these regions are devoid of basic needs and thus heavily impeding national economic development. The potential of rural development is immense with the right technologies, strategies, policies and government support rural development could be achieved with ease. This thesis will majorly focus on providing solutions directions for achieving rural development through an integrative approach primarily benefiting the energy sector (majorly electricity) while at the same time, mutually benefiting the water and waste sectors. The thesis has been restricted to the consideration of three sectors due to time limitations. (United Nations, 2001).

Figure 1.1: Sustainable Development Goals (Remsol, 2016)

Why Primary Focus on Energy?

Energy and GDP are deeply knit phenomenon with a proportional relationship. Energy is of paramount importance when it comes to the growth of a nation especially because of its direct relationship with GDP. Figure 1.2 depicts the close relationship of Energy and GDP. Insufficiency of energy brings economic stagnation and reduction in optimum productivity. Energy availability, reliability and security therefore becomes a crucial aspect, which needs to be catered to, to help maintain and accelerate economic growth of a nation. Improved energy availability has many underlying benefits for development as well, improvements in energ availability and reliability is also said to be linked to all the remaining development goals set under the SDGs (Lu, 2017), as depicted in Figure 1.3.

(Bikramjit and Indranil, 2008).

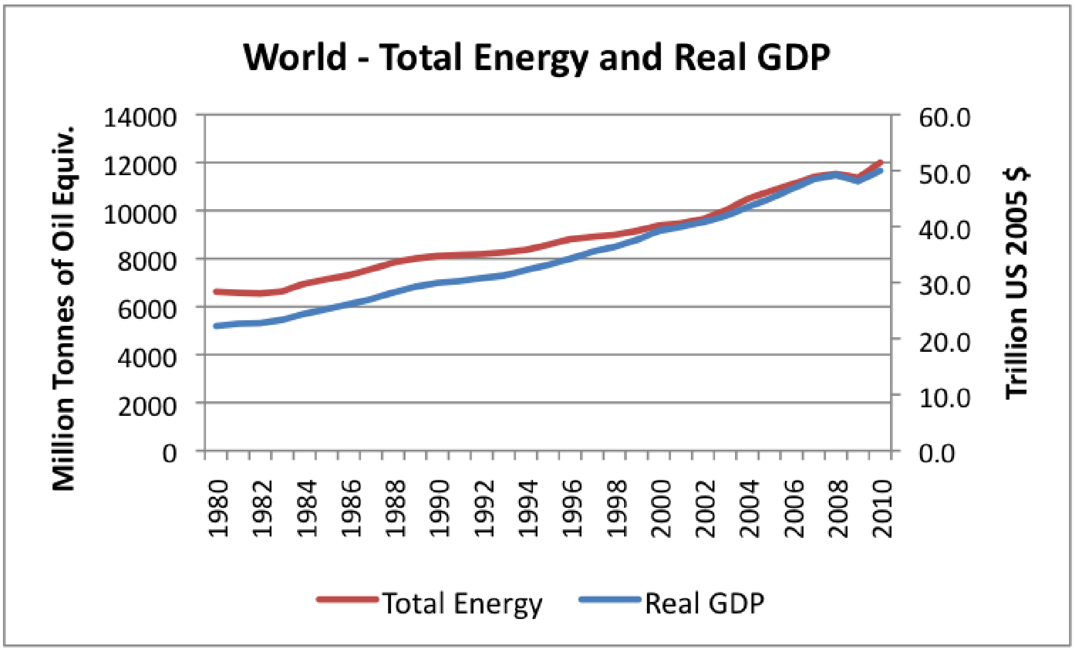

Figure 1.2: Relationship Between World Total Energy and Real GDP (Tverberg, 2011)

India has one of the largest un-electrified population ratios globally. Due to a low access to energy, the rural regions are very backward and thus are devoid of economic and social development. These regions lack proper connection to the grid and therefore sectors such as healthcare, communication, transportation, water, sanitation, lighting etc. experience impeded growth, leading to reduced quality of life. The consequences of the above mentioned issues are not only observed on an elemental level, but the effects are widespread, experienced at a national level. The approach to be taken in this thesis has been inspired by Amory Lovins, a leading physicist, environmental scientist, writer, and Chairman/Chief Scientist of the Rocky Mountain Institute. In his book- Natural Capitalism he stated (Hawken et al., 2013):

> "Designing a window without the building, a light without the room, or a motor without the machine it drives works as badly as designing a pelican without the fish. Optimizing components in isolation tends to pessimize the whole system—and hence the bottom line. You can actually make a system less efficient while making each of its parts more efficient, simply by not properly linking up those components. If they're not designed to work with one another, they'll tend to work against one another" - Amory B. Lovins.

. In this thesis we try to augment rural development by targeting to achieve the above mentioned Sustainable Development Goals. To do so we consider the aspect of system thinking and expand the boundaries of traditional systems to have a perspective of integrated energy focussed rural development.

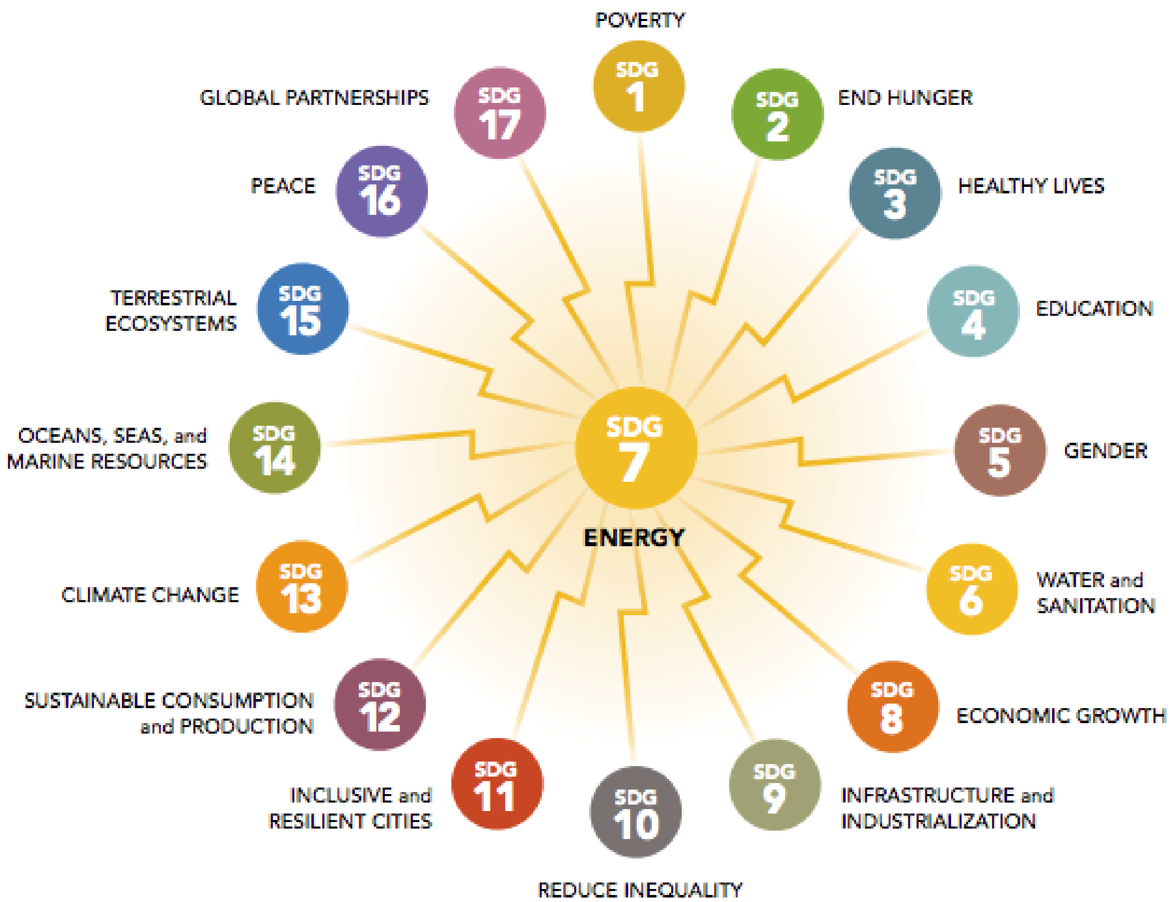

Figure 1.3: Energy related to all SDGs (Lu, 2017)

The problem of rural development in essence is highly complex, can be termed as a wicked problem. "The term 'wicked' in this context is used, not in the sense of evil, but as a crossword puzzle addict or mathematician would use it—an issue highly resistant to resolution". Social problems fall under the category of wicked problems since they cannot be treated with traditional: linear and analytical approaches. Wicked problems have high levels of interdependency between all its elements showing systemic properties, i.e. a problem cannot be isolated (Government of Australia, 2015). Thus solving the problem of rural development require a view point of a broader prospective. Any solution put forth should take into consideration these aspects, thus in the thesis integrative development is looked at. Wicked problems are different from 'Tame Problems' which though could be very complicated in nature are still not complex, in other terms tame problems can be solved by traditional approaches with its solution fairly readily identified (Government of Australia, 2015).

Integrative Approach

In this project, an integrative approach will be applied to augment rural development. The foresight committee on renewable energy conversions of the Dutch Royal Academy of Science proposed new alternatives- "An Integrative Approach". New solutions are brought up with this approach such as flexible co-production and storage in fuels (Hemmes et al., 2012). The following are the different type of integration techniques which could be applied for the betterment of energy systems(Hemmes et al., 2007):

- Integration of components into a system
- Integration of energy sources into multi-source multi-product systems
- Integration of industries into Eco-parks
- Integration of sectors
- Integration of new technology into existing

- Integration of Functions
- Integration of sustainability into energy systems

Other forms of integration techniques have been identified as well:

- Integration of Sites (Bandyopadhyay and Varghese, 2010)
- Integration of Goals and Multiple Objectives (Gianfranco and Mancarella, 2009)

Creating multi-purpose integrated systems targeting the energy, waste and water sectors has manifold benefits, in one way or the other these potential benefits help target majority of the above mentioned UN Sustainable Development Goals and thus have the potential for rural development. These potential benefits have been stated below:

- **New Revenue Sources For Public Services and Infrastructure:** Developers of energy systems pay taxes to the communities hosting their systems. These taxes are either paid at once (Land or Building Taxes) or on a periodic basis. Collected taxes can be used as revenue to provide public services such as schools and senior residences. landowners can lease or rent out land for the same purpose as an additional source of income. They have the option to diversify and increase their income(OECD, 2012).
- **Job and Business Opportunities:**Electrifying rural communities would definitely improve the whole economic scenario of the nation, as with an increase in demand of renewable energy systems will lead to employment opportunities in the field of renewable energy leading to job and income generation in the field of renewable energy supply chain, i.e. Manufacturing, construction and specialized services.A stable supply of electricity to a region would also give opportunities for industries to develop in those regions. Residents or business owners can themselves deploy technologies to generate extra income(OECD, 2012).
- **Innovations and Testing Ground for Services, Technology and Policies:** Rural regions are of paramount importance when it comes to development of new renewable techniques and technologies as these technologies are put to test in these regions, Once a technology is deployed, challenges appear over a period of time and then solutions to challenges are developed before applying the technologies to large scale. New policy implementations are also put to the test in the rural scenario(OECD, 2012).
- **Energy Security for The Remote Rural Communities:** Renewable energy could be a supreme player at the forefront to solve the problem of energy poverty, which is majorly prevalent in the rural regions of India. Instead of importing expensive fossil fuels for energy, the rural communities could produce and use their own energy through electrification with renewables. It lastly would provide the rural communities with energy security at affordable prices(OECD, 2012).
- **Lifestyle Improvement:** Those living in electrified rural regions would experience improvement in lifestyle and living conditions, as they would have better access to lighting, improved healthcare, better education, better communication, sanitation etc(OECD, 2012). Lack of access to safe drinking water and sanitation is third in line as risks to rural health in developing countries. Provision of clean water improves overall health of locals (World Health Organisation, 2015). In the long run, experiences have shown that improved rural health contributes to higher education rates (World Health Organisation, 2015).
- **Prevelant Synergies:** The waste and water sector have a highly synergistic relationship with the energy sector. Not only large quantities of water supply is required for energy generation but large amount of energy is required to treat and supply water. Waste on the other hand can be seen as a potential energy source, thus holding economic value. Using waste for energy prevents losing out on the economic benefits of waste at the same tine contributing to environmental sustainability.

In the past when solutions to the problems of energy supply have been looked into,we have tend to narrow our scope to distributed generation. This report will intend to enlarge the problem as such, first, looking at the possible integration of the rural electricity sector with other rural sectors with the application of distributed generation technologies to improve overall performance. This will be done to get a broader prospect of the situation, identify underlying potential benefits for the energy sector, primarily and mutually for the other considered sectors.

Thesis Outline

In order achieve the goal, the project will be executed as follows: Chapter 2 defines the problem. The goal of the research is discussed in depth. The objectives and deliverables are defined based on the goal. Furthermore, the main and sub research questions are discussed. A methodology to be followed to execute the dissertation is mentioned. Chapter 3 dives into discussion of Integration. Integrative concepts are introduced and I-neffs and Enablers explained. Chapter 4 introduces the electricity sector in rural India which is the core sector considered for the integrative approach in this thesis.The current scenario of rural electrification in India will be given, with its shortfalls and barriers. Chapter 5 will focus on the water sector of rural India. Will mention the same details as for the electricity sector.The chapter will also discuss the interrelations between the considered sector with the energy sector, for the purpose of potential performance improvement. Chapter 6 dives into the problems of rural waste sector and potential synergies with the energy sector. Chapter 7 presents the use of distributed generation as an alternative to grid electrification for rural India. Chapter 8 will give an introduction to the research methodology to be applied .Chapter 9 would involve a Bottom-Up case study, where the integrative approach for multi-purpose energy systems is applied to a rural case in India, to sho the scale of rural integratibility of the considered sectors and extrapolate this information for a Top-Down case study . Chapter 10 is to present a Top-Down case study to mark out barriers to energy focussed integrated development in rural India and put forth some plausible solutions . Chapter 11 would conclude the thesis and provide results. Chapter 12 will reflect on the relevance of the thesis while providing information on future research prospects.

2
Problem Definition

2.1. Goal of the Project

The goal of the project is to provide directions for energy focused integration of sectors to augment rural development in India, through targeting the sustainable development goals set forth by the U.N. The thesis aims at reducing the Top-Down knowledge gap prevelant in India with regard to integration, to do so barriers associated to such integration are intended on being identified in an Indian context and thus plausibe solutions for such barriers are set to be put forth to reduce the Top-Down knowledge gap thus providing directions of rural development augmentation through energy focused integration of sectors.

2.2. Research Question

Main Question:

Having recognized the importance of systems thinking, how can energy focused Integration of Sectors provide directions to overcome the problem of impeded rural development in India?

Sub-questions:

- How is rural electrification related to rural development?
- How is the application of integrative approach inclined with the objectives of Sustainable Development Goals for rural development?
- What are the concepts associated to integration?
- What is the present state of art of the rural electricity sector in India?
- What are the shortfalls being faced by the electricity sector in rural India?
- What efforts have been made by the Government of India to improve the shortfalls associated with the rural electricity sector?
- What are the potential benefits for consideration of water and waste sectors?
- What are the present alternatives to solve problems associated with rural electrification shortfalls in India?
- What methodology will be followed for energy focused integration of sectors for augmented rural development?
- How can gained knowledge of the Bottom-Up case study be extrapolated for India ?
- What are the benefits and limitations associated with such energy focused integration of sectors?

- What are the potential barriers to implementation of such energy focused integration of sectors in an Indian context?
- What are plausible solutions to overcome these barriers in an Indian context?

2.3. Research Methodology

Literature Study: Literature review is fundamental for any explorations contemplate as it aids in developing the problem definition. In our review, we would allude to literature pertaining to integration , which discusses the boundaries and specialty procedures to inculcate these techniques in energy systems. We would likewise concentrate on other sources such as distributed generation and energy system and sector integration which would help in distinguishing hindrances and procedures especially to implement renewable energy innovations in developing nations from the perspective of a multi-purpose system. Comparative contextual analyses and undertakings are in reality highly beneficial in investigating the hindrances and methodologies for above-mentioned technologies. In context to the project the literature study is performed define the problem and to perform a background study on the solutions being considered to solve these problems.

Interview of Experts: It is important to acquire master opinions and therefore identification of hindrances and related techniques. Their view points can help in recognizing hindrances for renewable energy innovations especially in rural energy systems (Painuly, 2001). Experts in the field of rural electrification from different strata of the institutional structure pertaining to the issues of rural electrification and energy supply are to be interviewed to get further insights on the real problems being faced by the organisations in implementation, management, policy and operation of systems in these rural regions.

Case Studies: This exploration strategy is vital for investigating and understanding complex issues which alone can't be settled by factual methodologies. It is thought to be a strong research technique when a far-reaching and significant examination is required (Zainal, 2017). In this review, a few contextual analyses would be analysed and worked out through desk research. Cases considered would be integrated with the findings of the interviews.

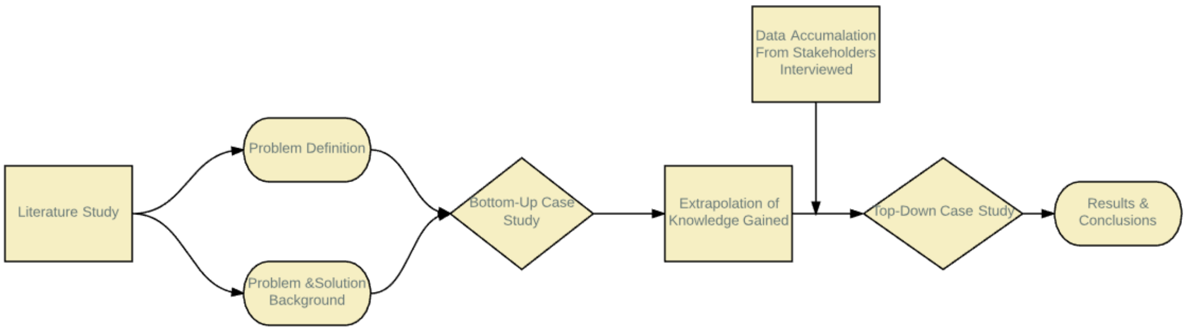

Figure 2.1: Research Methodology

The figure above describes the methodology to be followed for the purpose of the project. It depicts the procedure and interlinks between various steps, which are to be performed to obtain results for the entire study.

3

Why Integration and Associated Concepts

3.1. Wicked Problems

As discussed in the previous section "The term ‘wicked’ in this context is used, not in the sense of evil, but as a crossword puzzle addict or mathematician would use it—an issue highly resistant to resolution". Social problems fall under the category of wicked problems since they cannot be treated with traditional: linear and analytical approaches. Wicked problems have high levels of interdependency between all its elements showing systemic properties, i.e. a problem cannot be isolated . Wicked problems do not have any formal definition and thus are difficult to specify or describe. Perception of wicked problems change with the involved stakeholders with every stakeholder perceiving the problem in their own way. Some features of wicked problems have been discussed below (Government of Australia, 2015):

- **Systemic**
  Wicked problems are heavily and deeply knit in the system, in other words the problems of integrated systems cannot be isolated or separated from the system, wicked problems are usually systemic in nature, these problems are relating to system dynamics rather than to particular parts and can be understood as an emergent phenomena of how components interact and how the whole system works not a part of it.

- **Multi-Dimensional and Planar**
  Wicked problems are multi-dimensional in nature. Directly or in-directly expanding to or depending on social factors, political issues, technical issues, cultural factors, design capabilities, economics. The associated factors or effects from one aspect need not even be in the same sphere of plain, in other terms they could be expanding over international level, national level, state level as well as local level with high interconnectivity between all the elements spread over different spheres of plane. They are highly interconnected from the micro to the macro spheres.

- **No Single Solution and Evolving Problem Set**
  Wicked problems do not have a single solution. The complexity of the situation prevents any single solution from behaving as the final or ultimate solution. Over a period of time the problems and the solutions to those problems keep evolving with the definition of the problem itself evolving. No single solution thus can be termed as the final solution and needs to evolve over a period of time with performance of the entire system with multiple feedback loops in place linking various elements of the system with the emergent new levels of different scales. Solutions to wicked problems are not verify-ably right or wrong rather good or bad, the problems is so complex that the solution ends not with the end of the problem but with other parameters like resource constraints, change of stakeholder’s goals etc.

- **Highly Interconnected**
  Deep interconnections and interconnectivities. System boundaries considered for wicked problems have intricately interconnected, interdependent and non linear elements. With these highly interconnected problems when you try to pull on one part you end up getting the who thing. The elements of wicked problems are highly interdependent or their combined performance depends on their interdependence or inter linking, leading to non-linearity in their relations. When two or more elements

are put together, the combined effect is usually not the expected effect from their operation in isolation it usually improves overall performance in combined operation or makes it worse, thus designing integrated systems we need to take the aspect of non-linearity into consideration aiming at obtaining positive exponential outputs due to non-linearity.

Concluding it can be stated that solutions for wicked problems are hard to draw out, design and implement reasons (Government of Australia, 2015)

- Incomplete or contradictory Knowledge
- Number of stakeholders or opinions involved
- Large economic burden
- High Interlinking

Thus solving the problem of rural development require a view point of a broader prospective, in other terms rural developmet can be observed through the lens of wicked problems, due to the fact of rural development showing above mentioned characteristics. Any solution put forth should take into consideration these aspects, as a result in the thesis an integrative approach is looked at which broadens the boundaries of the system in consideration. The Figure 3.1 depicts the system boundaries of rural development in India also depicting certain interacting elements , which show interaction on different planes.

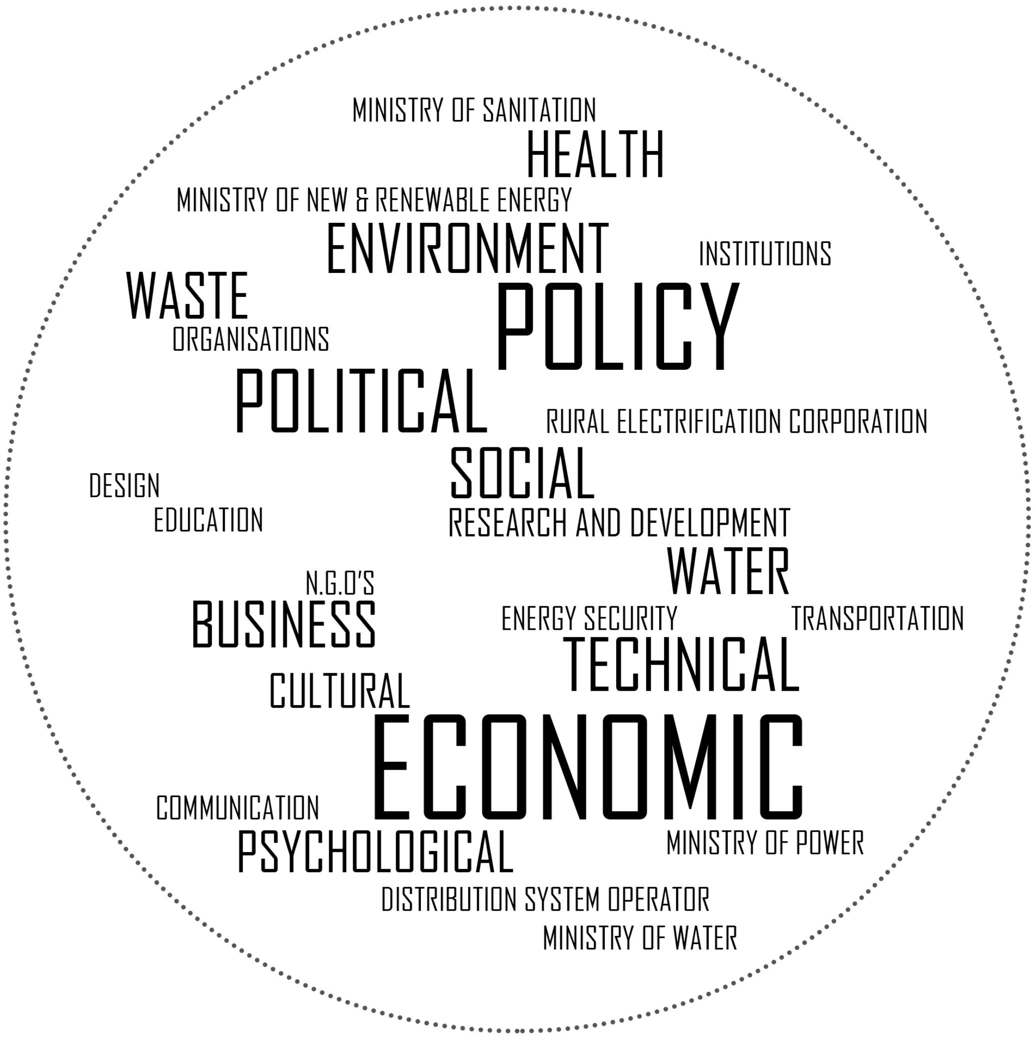

Figure 3.1: Schematic Representation of System Boundaries and Some Elements of Rural Development in India

3.2. Systems Thinking

The sectors of energy, waste and water have various entwined concerns going from guaranteeing access to services to environmental impacts to policy formulation. The impacts of these issues though in the three sectors are closely related but the effects of the issues manifest in distinctly different ways. The identification of the inter-relations is of paramount importance to identify the synergies. For such levels of integration to work successfully 'Systems Thinking' has to be inculcated into the policy making as well as operational processes (Bazilian et al., 2011) else the interlinking between the sectors still remains relatively unexplored.

Amory Lovins states- "Designers and decision-makers too often define problems narrowly, without identifying their causes or connections.This merely shifts or even multiplies problems" .He also stated that such issues faced by the modern era can be tackled by a greater integration of systems thinking into our design and research process. Ross Arnold and Jon Wade define systems thinking as "a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviours, and devising modifications to them in order to produce desired effects. These skills work together as a system" (Arnold and Wade, 2015). In other words, as our research and development structure is set up we look at systems by the elemental function of their components. Research is done on improving each component's individual performance and efficiency.In today's world with highly complex and entwined systems this is no longer enough. For systems to operate more efficiently a new approach has to be applied, where the function of the component in the functioning of the system is focussed on rather than it's individual characteristics, this is systems thinking.

Experts have led the scientific community to believe that integration of systems thinking into the design process of systems can lead to optimised and innovative solutions with greater performance efficiencies. Involvement of more stakeholders, decision makers and views could help broaden the adaptability and flexibility of the solution. On these lines of reasoning the thesis looks to broaden the solution scope for rural electricity shortfalls in India by integrating the water and waste sectors.

3.3. Integration Options for Energy Systems

Integration is defined as bringing together the best of technology, energy sources, generation technology, infrastructure, policies and stakeholders to improve the performance of the whole system. Different forms of integration have been analysed and explained in this thesis, these different possible integration options have been explained below with some examples to help better understand the concepts.

3.3.1. Integration of components into a system

At present we majorly focus our research of energy systems to the component level, which is an obvious choice as well performing energy systems require parts which are highly durable, enduring and efficient. However the observation and relative significance of the issues on the component level is not the same as those from a system or framework point of view. Moreover, one ought to recognize hypothesis and simulation and genuine operation of energy frameworks in a complex financial setting of daily practice. In daily practice, totally unique issues might decide performance of the system that can bring about a change in the component segment priority. Thus, it is imperative to couple R&D, and furthermore long term R&D to direct usage as quick as conceivable without losing a long-term vision depending on the specific development phase of the technology. A very important concept, which is to be mentioned when considering the component level, is flexibility of operation. To match the demand and supply the traditionally considered solution is storage, which is inefficient and cost intensive. Flexible co-production is a solution direction, which could replace storage, as with flexible co-production the system maintains high efficiencies in part load or full(Hemmes et al., 2007).

Power Windows: Scientists at the US department of energy have made glass capable of generating power, the thin transparent films are composed of semiconducting polymer material doped with carbon rich fullerenes (US Department of Energy , 2010).

3.3.2. Integration of energy sources into multi source multi product systems

Energy systems are of different types and can be catagorised based on the input and output possibilities on the basis of co-generation,tri-generation and MSMPs. Co-generation systems are known to produce electricity and heat, tri-generation systems go a step ahead and produce cooling as well, whereas MSMP systems involve multiple output and can store energy in the form of useful chemicals as well. The improvement of performance and operational efficiencies of distributed generation technologies has brought the attention of scientific communities on the application and thus further development of the distributed generation scenario. Studies are being focused on certain aspects such as technical, environmental, economic and social issues of the energy systems. One such system capable of tackling these issues with high levels of efficiency are multi source multi product systems. MSMP systems are highly flexible systems capable of producing various outputs such as electricity, heat, cooling and storage in chemicals and fuels. Adoption of MSMPs potentially has noteworthy advantages as far as higher efficiencies, decreased CO2 emanations, and economic benefits are confirmed. (Gianfranco and Mancarella, 2009).

A multi source multi product system is an energy system with multiple inputs and outputs, the inputs to a MSMP system can either be conventional or non-conventional. The interface between the inputs of the energy system and outputs is called energy hub (Hemmes et al., 2007), Figure 3.2 is a representation of a MSMP system.

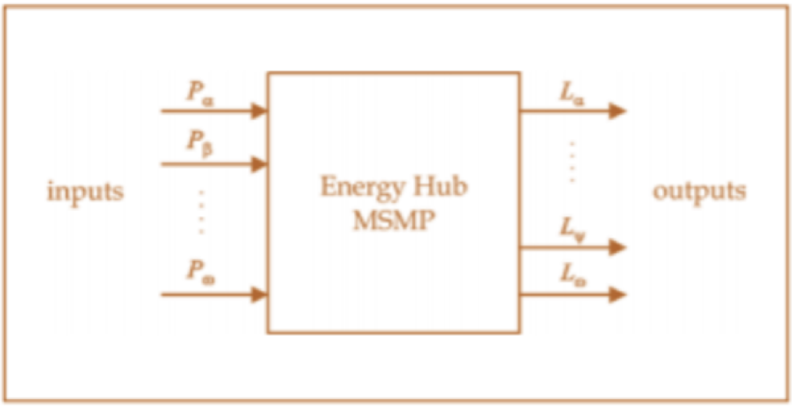

Figure 3.2: Schematic Representation of a MSMP Energy System (Hemmes et al., 2007)

3.3.3. Integration of Industries into Eco-Parks

This form of integration follows the principles of industrial ecology. The effort is to develop industries which are a part of the eco park economically while minimally polluting or harming the environment (Heeres et al., 2004).

A widely accepted definition of eco-parks was given by Lowe in 2001, "An eco-industrial park is a community of manufacturing and service businesses seeking enhanced environmental and economic performance through collaboration in managing environmental and resource issues, including energy, water, and materials. By working together, the community of businesses seeks a collective benefit that is greater than the sum of the individual benefits each company would realize if it optimized its individual performance only. The goal of an EIP is to improve the economic performance of the participating companies while minimizing their environmental impact." (Ernest, 2001)

The benefits of eco-park integration are manifold, those who are a part of these eco-parks can be sharing services, material, costs etc increasing the overall efficiency of the eco-park. By-products of a company which are usually disposed could be used as a resource for another, such a relationship of industries or collaboration of players for a synergistic performance of the collaboration is called industrial symbiosis and is related to industrial ecology. The figure below shows an example of an eco-park with a potential for the algal bio fuel industry for the United States, the park has potential of integrating solar energy, wind energy and other resources (Subhadra, 2010).

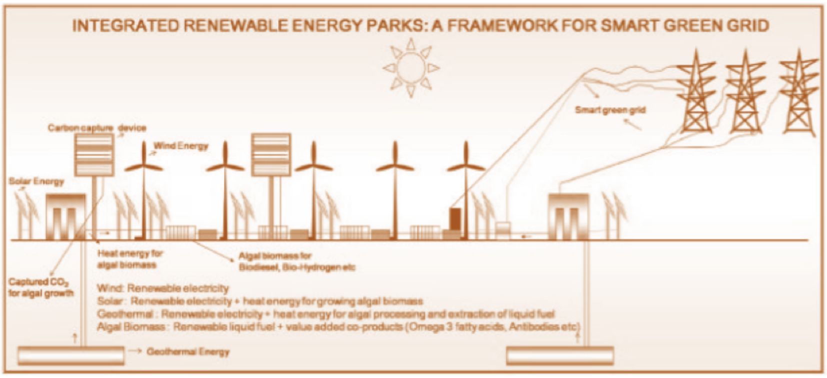

Figure 3.3: Example of an Integrated Eco-Park (Subhadra, 2010)

3.3.4. Integration of sectors

Integration of sectors is another efficient technique, which could be applied for improving system performance, which could be achieved on a large scale. Energy largely affects the improvement of transportation, horticulture, mining, and so forth. Sectorial coordinated energy ventures have endeavored to research how energy identifies with a particular area and to distinguish speculation activities and arrangement changes that can bring about enhanced energy use by integrating sectors. The integration of the waste industry and the energy industry is a good example of such a type of integration, which has been achieved successfully through waste incineration plants. On a smaller scale sector integration has been achieved through combi-boilers for domestic purposes, which provides heat though the central heating system as well as hot water for use. One aspect of sectorial integration, which has been receiving the attention it deserves lately, has been the integration of the water and the energy industries but to achieve high levels of integration between these two industries the policies and economics of the sectors need integration as well (Hemmes et al., 2007).

IT Sector & Energy: The best example for the integration of these two sectors is smart grids, where ICTs and energy systems have been integrated to improve the performance of the energy system. ICT have proven to play a crucial role in the conversation of energy. Sensors and dynamic communication has also led to optimise the whole system.

3.3.5. Integration of new technologies into existing technologies

New technologies could be integrated into existing systems to improve the operational credentials of the existing system. The existing systems can be supplemented by placing add ons rather then opting for complete replacement of the system. Complete replacement of old technology can be tedious and expensive, thus opting for gradual replacement of old technology with integration with new technology can be seen as a more economical as well as efficient option. Such a scenario would add flexibility and efficiency to the system. Examples of add on technologies are PV modules, plug in hybrids, electric cars, micro reactors etc. (Hemmes et al., 2012).

Osmotic Power: Osmotic power production can be seen as an existing example of this kind pf integration. Though osmosis can be seen as a phenomena known to the scientific community for years, using this phenomena for power generation is relatively new. This concept is observed when salt water meets fresh water, points where fresh water rivers and the sea or ocean meet each other can be seen as energy generation potential sites. Salt water and fresh water are driven through separate chambers separated by semi permeable membrane, salt molecules attract and thus pull fresh water molecules through the membrane drasticaly increasing the pressure in the chamber of the salt water, this rise in pressure can be used to drive turbines to produce electricity (Ramon and Feinberg, 2011). Figure 3.4 depicts the performance of such an Osmotic System.

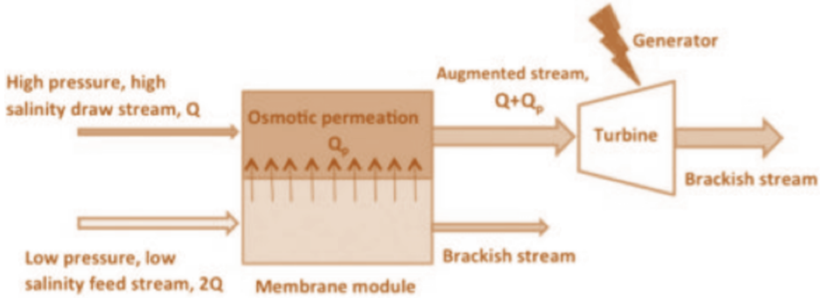

Figure 3.4: Representation of an Osmosis Generator (Ramon and Feinberg, 2011)

3.3.6. Integration of functions

Further penetration of distributed energy systems could be made easier by the integration of functions, to achieve so synergy between various sectors of the energy system need to be prevalent. Integration of various functions into a single component or system could lead to flexibility of systems as well as cost effective solutions to multiple problems. A good example of functional integration is the use of solar panel to solve the purpose of roofs as well along with electricity generation (Hemmes et al., 2012).

Solar Roof Tiles: Scientists have come up with an ingenious solution which is a great example of integration of functions,scientists have designed roof tiles capable of generating electricity on the principles of photovoltaic technology.These tiles not only serve the purpose of traditional roof tiles but also can generating electricity reducing costs involved when the process has to be carried out considering both separately. Figure 3.5 is an example of integration of PV technology with rooftops.

Figure 3.5: Representation of an Elecrticity Generating Roof Tiles

3.3.7. Integration of Sites

The integration of sites rests on the same principles as integration of industries into eco parks, the difference being industrial ecology is a way broader concept whereas integration of sites aims at heat recovery and conserving energy. Integration of sites can be achieved either directly or indirectly. Indirect site integration requires a medium to transfer heat from one site or process to the other one, in terms of control and flexibility indirect integration turns out to be more advantageous but for the case of energy conservation and economics of operation and capital direct integration turns out to be more advantageous (Bandyopadhyay and Varghese, 2010). Depicted in Figure 3.6

Small scale industries, residential complexes and residential dwellings can be seen as a few exapmles of 'Sites' for integration. These sites can be seen as sites of either heat sources or heat sinks, the energy demands for the users are considered. These demands for energy for users can be satisfied in various ways: renewable energy technologies, boilers, heat recovery, dynamic power transfer and balancing, biomass etc. When in excess heat and power is fed into the integrated grid, which makes use of these excesses and distributes it amongst the users as steam or hot water (Perry et al., 2008).

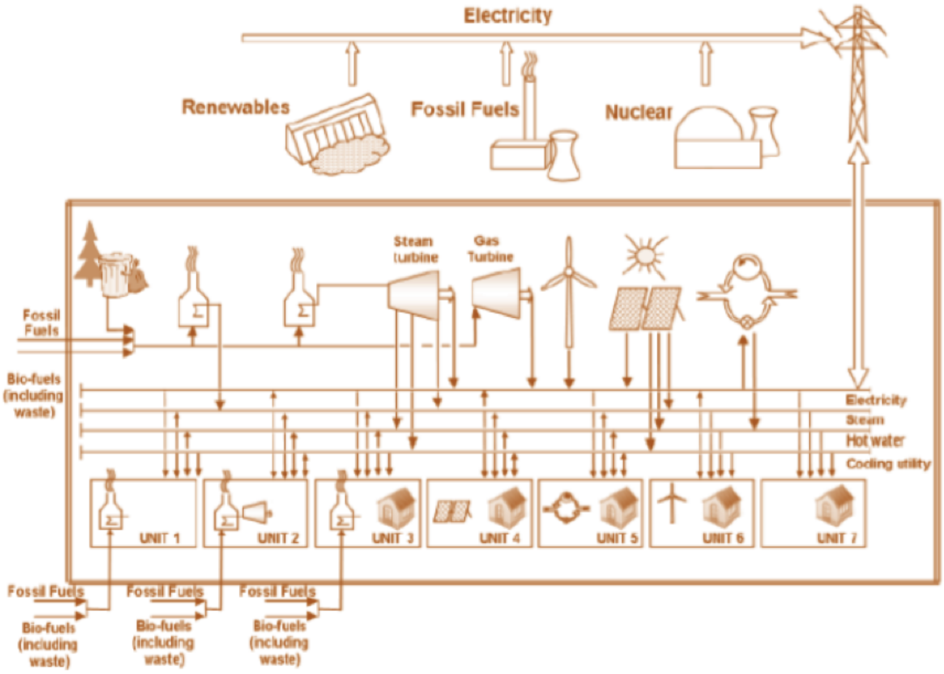

Figure 3.6: Example of Site Integration (Perry et al., 2008)

3.3.8. Integration of sustainability into energy systems

While designing any energy system we need to take Brundtland's definition of sustainability into account. The system should not compromise the needs of the future, and should take sustainability, global warming, finite resources, etc. into account. The system should be able to provide employment and income for the local community (Hemmes et al., 2007).

Sustainability when looked at in a broader sense has three main aspects: social, economic and environmental. Synergies are highly prevelant between these aspects across the spheres of sustainability. While designing any energy system these aspects need to be taken into consideration and it has to be made sure to not disturb the stability between the three aspects and the system should be beneficial for all three aspects and cannot be biased towards any one of them.

3.3.9. Integration of Goals and Multiple Objectives

For better performing highly integrated solutions of technologies a better application or implementation is required, such implementations require a better policy instrument. Overall goals of economic effectiveness, technical efficiency and barrier removal cannot be achieved without proper policy interventions. At present, support for such projects is provided by corporations with international expertise in technical and financial resources, but in the future energy policies need to address these issues for the integration concept to hold greater significant value (Gianfranco and Mancarella, 2009).

A policy approach of this nature, has a larger field of problems which could be catered to under its scope. Such an integrated approach avoids fallouts faced by another sector when formulating policies to solve issues faced by the considered sector. Multiple goals and objectives could be attained by implementing such an approach. Synergies prevelant between various sectors could be analysed and thus these synergies could be used as a policy instrument to solve multiple issues faced across the considered sectors (Hemmes et al., 2007).

3.4. I-neffs and E-nabes

3.4.1. Introducing I-neffs

When looking at a system from a system's thinking point of view and trying to improve its performance, it could be highly beneficial to identify aspects which at present hinder the integration process. Identifying factors holding potential integrative benefits for the system which are usually overlooked in a traditional system design approach. I-neffs essentially are higher order factors for any system which provide an answer to: "What is the one most important higher order factor without which the integration of sectors for this integrated energy system cannot occur". (Elango, 2012).

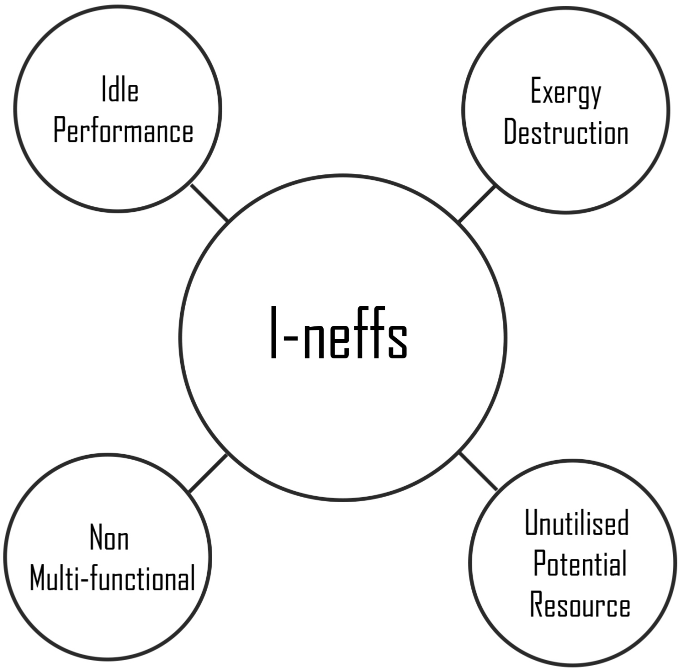

Figure 3.7: The Four I-neffs for System Analysis

I-neffs are defined as higher order inefficiencies or factors without whose identification integrated multi-purpose energy systems would not be possible. I-neffs are not traditional system or component inefficiencies or engineering defects, but factors if catered to hold potential integrative benefits which have been overlooked in the system. These I-neffs are a critical factor in impeding the integrability of the system. Addressing these I-neffs thus for the purpose of this report holds paramount significance to improve system performance, which leads to a tendency of new directions for innovative integrated systems (Elango, 2012). I-neffs are depicted in Figure 3.7

The literature followed for the thesis presented three I-neffs, which are presented below (Elango, 2012):

- Device or component is not operated all the time i.e. performance or operation time is not 100%. In other words the system or component is standing idle (for a significant fraction of the time).
- The system is designed as such for the component or device to have only one function.
- Exergy destruction is overlooked. Exergy destruction is said to occur only when a process is irreversible, holding value especially for the energy sector. This concept is best understood with an example discussed further in this section.

For the purpose of this thesis, a fourth I-neff was identified as a consequence of a focus on energy sector improvement:

- A potential locally available resource in essence is not utilised or in other terms a potential economically beneficial resource source stands idle. Specially for the case of an energy prospective.

The reason behind categorizing critical integration factors into the considered high order factors impeding integration or I-neffs and not looking at lower order inefficiencies is that in most cases catering to a single lower order inefficiency can organically lead to catering to multiple interconnected inefficiencies. This becomes cumbersome and does not lead to understanding of how multi-purpose energy systems can be defined. Identification of distinct higher order factors is important for the innovation aspect of integration to evolve .

3.4.2. Introducing E-nabes

To address I-neffs in a system 'E-nabes' are needed. E-nabes are essentially Enablers which are defined as technology either existent or in development which could address and thus target the I-neffs in the system. In other terms E-nabes can be defined as technology or factors catering to the highest order factors making the integration process possible. I-neffs and Enablers can be viewed as building blocks which could be incorporated into technology leading to innovative multipurpose energy systems. In other words E-nabes provide solutions to I-neffs resulting in multi source multi product energy systems (Elango, 2012).

The above mentioned concepts of I-neffs and E-nabes can be better understood with some examples before being applied to the Indian Rural Scenario. Table 3.1 provides some examples for better understanding.

Table 3.1: List of analysed integrated energy system solutions, their I-neffs and Enablers

Solution	Integration Type	I-neff	Enabler
Building Integrated PV	Integration of Functions	Non-Multi Functional Rooftops	PV Technology
Solar Hybrid System	Multi Source Multi Product Systems	Exergy Destruction by PV Panels	Combination of heat and chemical existent technologies
Super wind Concept	Multi Source Multi Product Systems	Exergy Destruction by Windmill	Combination of heat and chemical existent technologies
PV Panels Laid on Canal Face	Integration of Functions	Exergy Destruction on Canal face	Photovoltaic Technology
Implementation of Piezoelectric Material on Floors	Integration of Functions	Non-Multi Functional Nature of Floors	Piezoelectric Conversion Technology
Waste Utilisation for Energy	Integration of Sectors (Waste & Energy)	Idle Waste	Anaerobic Digestion Techniques
Vehicle to Grid	Integration of Sectors (Building, Energy, Transport)	Idle State of Vehicles	Electric Vehicle Technique

- **Vehicle to Grid (V2G)**
  The vehicle to grid concept also involves the integration concept of vehicle to building, thus in turn involving integration of the transport, building and power sectors. To understand the I-neffs associated with V2G we first need to provide an answer to "What is the one most important higher order factor without which the integration of sectors for this integrated energy system cannot occur".

  The I-neff prevelant in vehicles which was identified was the Idle nature of vehicles in a day. In the United States on average the cars stand Idle for 93% of the time on a weekday (Haaren, 2011) depicted in Figure 3.8. This aspect of standing Idle is not a traditional inefficiency or an engineering or design defect yet can be identified as an I-neff.

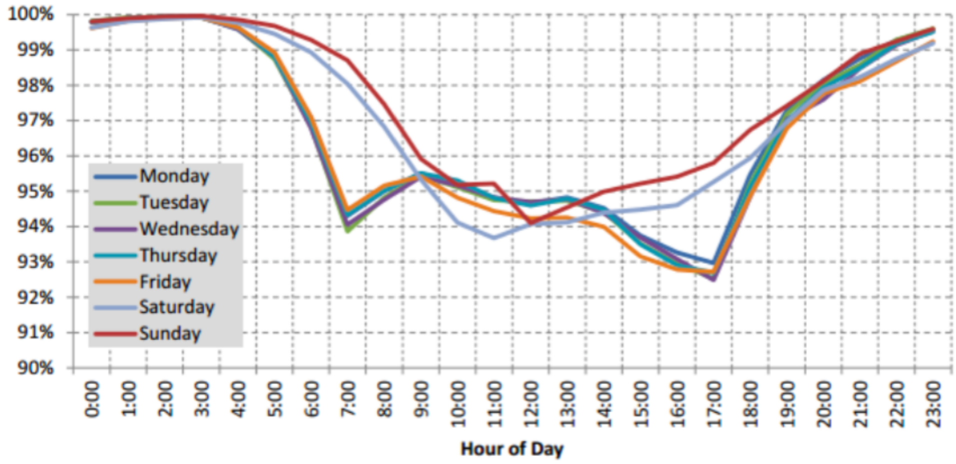

Figure 3.8: Representation of Car Usage Pattern in The United States (Haaren, 2011)

Firstly, an answer to what makes the V2G concept possible is analysed. As already discussed, the plug useful in recharging a PHEV facilitates the PHEV to become a load to power system. Therefore, it is due to the availability of a plug that the vehicle to grid and vehicle to building concepts take place. Secondly, the question on when the plug becomes useful is answered. The availability of a plug does not hold value unless the vehicle is in idle state. This means that the vehicle should be parked in order to be plugged in and this in turn completes the V2G concept. The entire integration in this energy system therefore revolves around the vehicle being idle. When a vehicle does not remain idle, it is impossible to achieve this particular integration (Elango, 2012). Thus the E-nabe for the Idle state of electric vehicles I-neff becomes the bi directional nature of power flow capabilities of the charging plug as well as the grid.

- **Solar Hybrid System**
  The solar hybrid system is an example of a multi-source multi-product system. There are multiple inputs as well as multiple outputs of the system. The solar hybrid system tries to solve the I-neff of exergy destruction by PV technology. Although PV panels applied on roofs tend to solve the unifunctional nature of rooftops but yet the PV panels are not highly efficient and thus are unable to utilise the incident energy completely.As a result solar hybrid systems cater to multiple I-neffs.

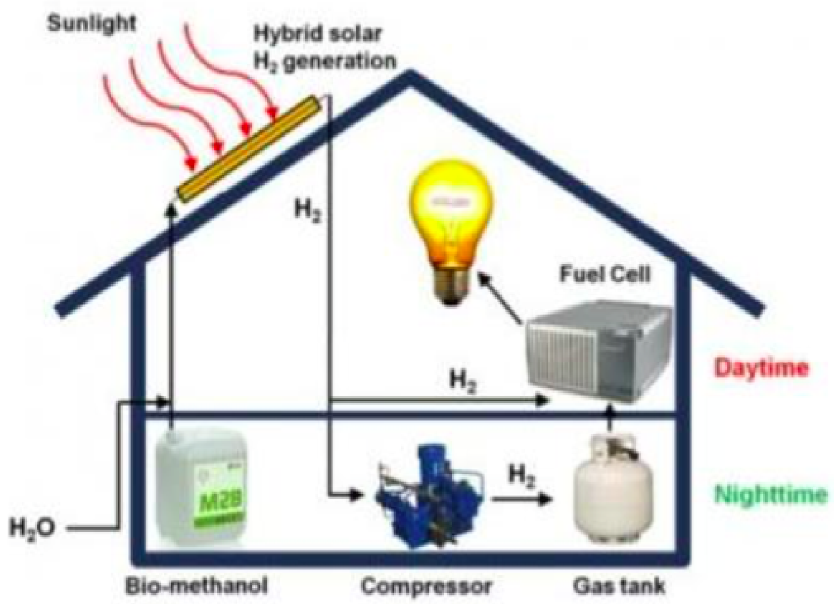

Figure 3.9: Representation of a Solar Hybrid System (Elango, 2012)

"The exergy of a system with respect to a reservoir is the maximum work done by the system during a transformation which brings it into equilibrium with the surrounding. It is defined as a measure of the actual potential of a system to do work" (Fischer et al., 2008)

When a system does not provide maximum useful work, it is said to be exergy inefficient or destruction of exergy is said to occur. Solar panels by not utilizing the sun's rays to the maximum can be rendered as exergy destruction by panels. Thus the E-nabes solving the Exergy destruction I-neff of PV panels was existing knowledge of MSMP Systems. Figure 3.9 depicts a solar hybrid MSMP system. Using sunlight to heat a combination of water and methanol in a maze of glass tubes on the rooftop, hydrogen is produced. Two catalytic reactions result in the production of hydrogen which can be stored and used on demand in fuel cells. A novel hybrid system such as this is capable of utilizing more energy from sunrays than when installing solar panels on rooftops.

4

Rural India-Electricity Sector

In this section, the problem of the acute rural energy poverty in India is addressed. The section discusses the rural electricity sector in India in detail. The governmental efforts, present state of the art, shortfalls in electrification and their causes are discussed.

4.1. Present State of Electrification

To have an effective approach in addressing the energy scenario of the nation we need to address the problem of energy insufficiency or energy poverty in the rural regions of India (United Nations, 2014). People in Rural India have very limited access to energy and thus electricity. Majority of rural households depend on traditional sources of fuel like fuel wood, kerosene, cow dung cakes etc. to meet most of their daily energy requirements (Cecelski et al., 2015).

According to the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), If 10% of the village households were electrified and electricity access was provided to public spaces such as schools, panchayat offices, health centres, community centres and dispensaries, the village was deemed electrified (Ministry of Power, Government of India , 2015).

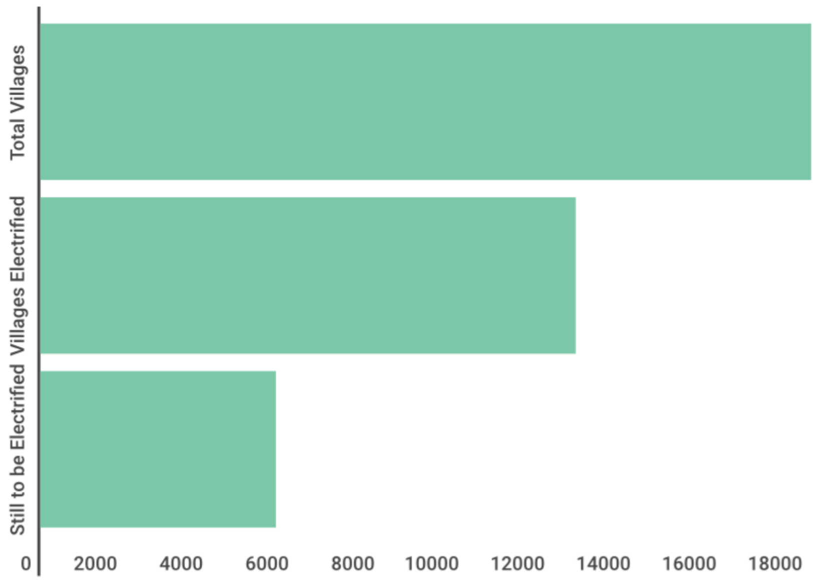

Figure 4.1: Electrification Penetration, Showing Number of Rural Settings Electrified Under New Scheme (Rural Electrification Corporation of India, 2017)

After coming to power, Prime Minister Narendra Modi, on India's Independence Day i.e. 15th August 2015 announced that the remaining villages would be electrified within 1,000 days. After this announcement the Government of India launched the Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY) to layout the policies for the electrification of the remaining villages within the described timeframe. The state governments provided a list of unelectrified villages to the central government. According to the policy these villages are supposed to be electrified within a 1000 day time frame from 31t December 2015 (Ministry of Power, Government of India , 2015). To bring transparency into the electrification process the central government appointed 309 Grameen Vidyut Abhiyantas who are the rural electrification engineers, to overlook the electrification process and post the progress on the GARV application (Rural Electrification Corporation of India, 2015), which is a open platform to public viewing thus encouraging transparency inturn , putting pressure on the state governments to deliver on time (Arora, 2016)The new policy guidelines not only aim at electrifying these villages according to the old standards (i.e. 10% of households) but also in the long-term aim at electrifying all the remaining households. 27% of the rural households in the country are yet to be electrified (Rural Electrification Corporation of India, 2015)..

Table 4.1 provides information on the electricity scenario in the rural regions of the eight large and highly populated states of India namely Bihar, Uttar Pradesh, Assam, Jharkhand, Odisha, Meghalaya, Manipur and Madhya Pradesh out of the 29 states in total of the country. The following figure also gives an idea of the disparity in terms of access to resources between the rural and urban regions of these states.

Table 4.1: Households with no electricity connection in major states of India, Rural Versus Urban (Rural Electrification Corporation of India, 2015)

States	Rural	Urban
Bihar	87%	33%
Uttar Pradesh	71%	19%
Assam	66%	16%
Jharkhand	63%	12%
Odisha	52%	17%
Meghalaya	46%	5%
Manipur	45%	18%
Madhya Pradesh	43%	7%

India's existing electricity policies and missions have focussed majorly on grid extensions. Extensions are set up next to the existing central grids (Ministry of Power, Government of India , 2015). As for the cases where grid extension was not feasible or foreseen in the next seven years, the policy laid out guidelines for distributed decentralised generation, for which the government provided substantial capital and operating subsidy (World Bank, 2010)

4.1.1. The Issue of The Underserved

According to the RGGVY policy, a village is deemed as electrified if the basic infrastructure required for electrification is set up i.e. transformers and distribution lines and if 10% of the households have electricity access (Ministry of Power, Government of India , 2015). The drawback of RGGVY policy is such that even though the government claims to have electrified majority of the villages the truth is that 36% of the households in the villages registered under this scheme still have no access to electricity (Ministry of Power, Government of India , 2015) The Villages, which even have been given grid access, face major issues of electrification. These Villages are underserved and have very limited access to the grid i.e. less than four hours a day (Goldmansachs, 2015), Figure 8.2 sheds some more upon the level of under-electrification in the rural regions of India.

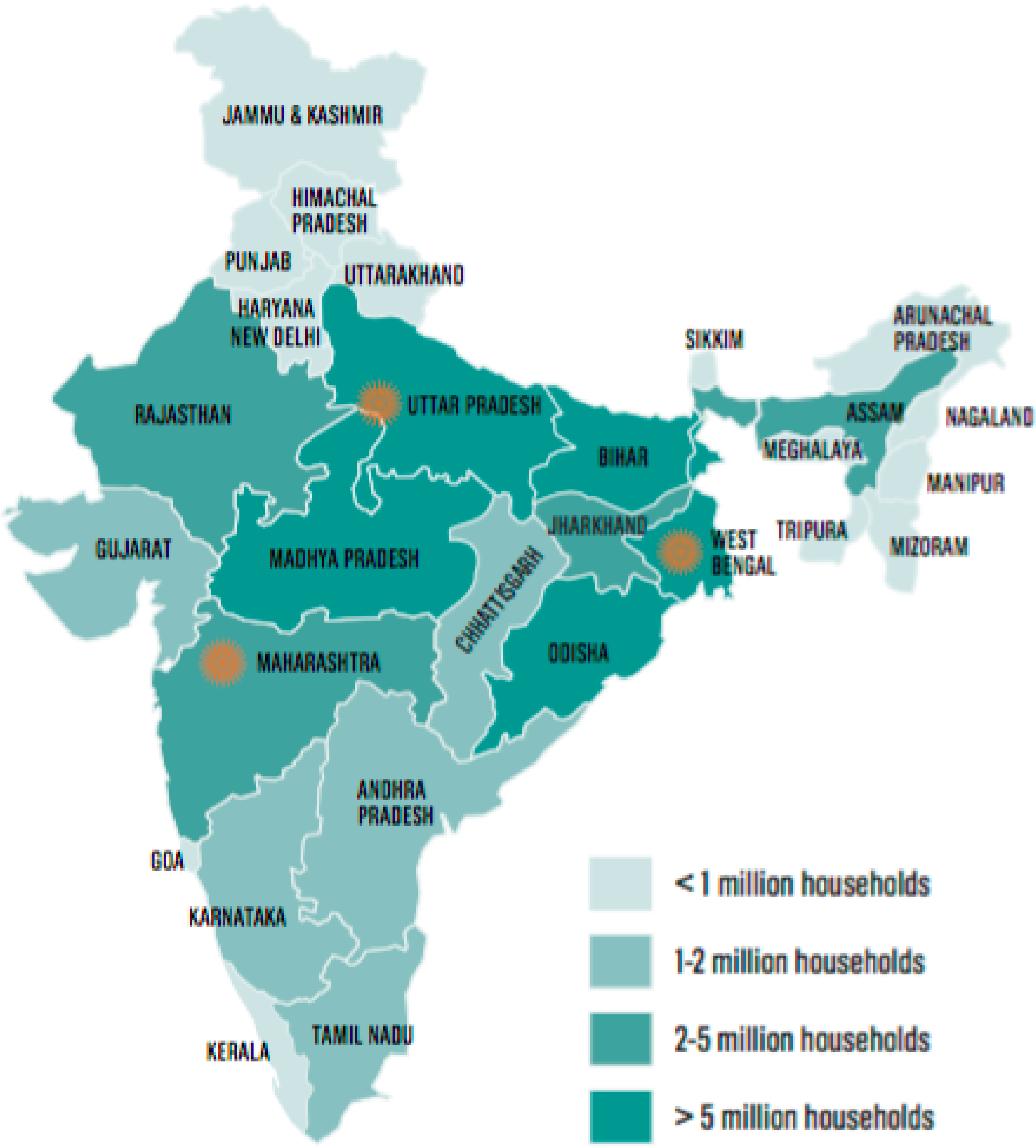

Figure 4.2: number of Under Served or Under Electrified Households as per state (Goldmansachs, 2015)

Figure 4.3 and Figure 4.4 depict the state of underserved villages in six of the large and densely populated states of India. Figure 4.3 depicts the percentage of households getting electricity for 20 hours or more in a day and Figure 4.4 depicts the percentage of households getting electricity for 4 hours or more in a day. The solution of grid connection is deceptive, the problem doesnt end at connecting a village or house hold to a grid, even with a grid connection majority of the rural households are classified under the lowest level of energy access or are deemed as under served due to the bad quality, unreliability and low duration of supply (Urpelainen and Johannes, 2015).

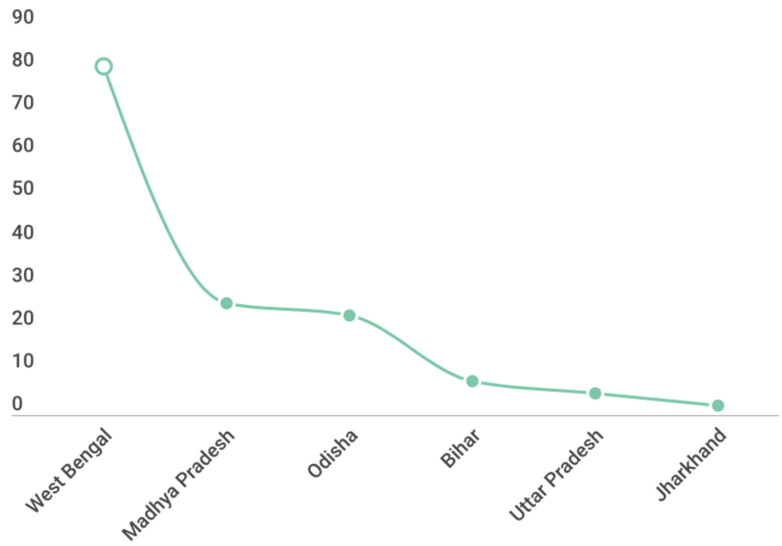

Figure 4.3: Percentage households receiving 20 or more hours of electricity in a day, for major states of India (Urpelainen and Johannes, 2015)

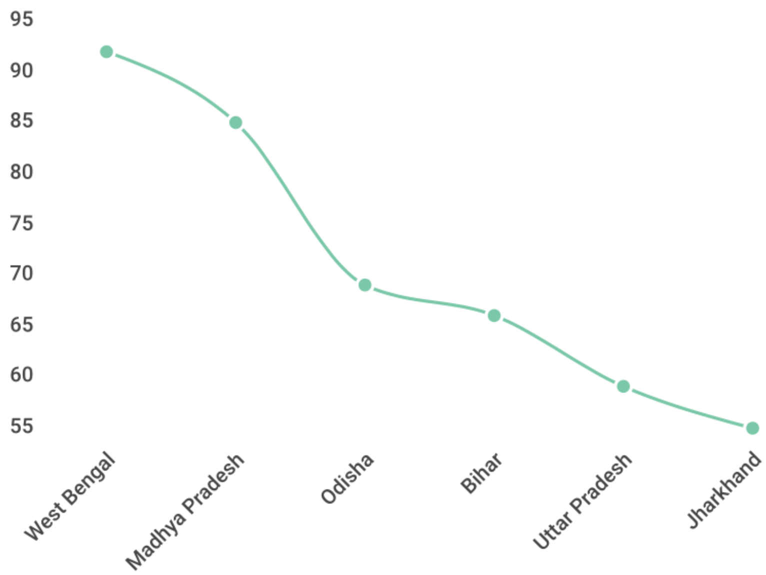

Figure 4.4: Percentage households receiving 4 or more hours of electricity in a day, for major states of India (Urpelainen and Johannes, 2015)

4.2. Rural Electricfication Shortfalls

Before jumping into the details of the shortfalls in rural electrification in India, it is important to understand what is an energy system and what leads to shortfalls in energy systems from a general outlook, these aspects are discussed in detail in Appendix A.

4.2.1. Shortfalls with the Grid Extension Senario

As mentioned earlier, India's electrification mission presently focuses on centralised grid extensions. Under the specifications of the policy, the Government has and will continue to connect the un-served villages of the country to the grid. In doing so the government has been facing a large number of shortfalls and barriers while new ones have come up over the course of the period. Figure 4.5 depicts issues generally experienced with central grid electrification, which have been discussed in detail in Appendix B.

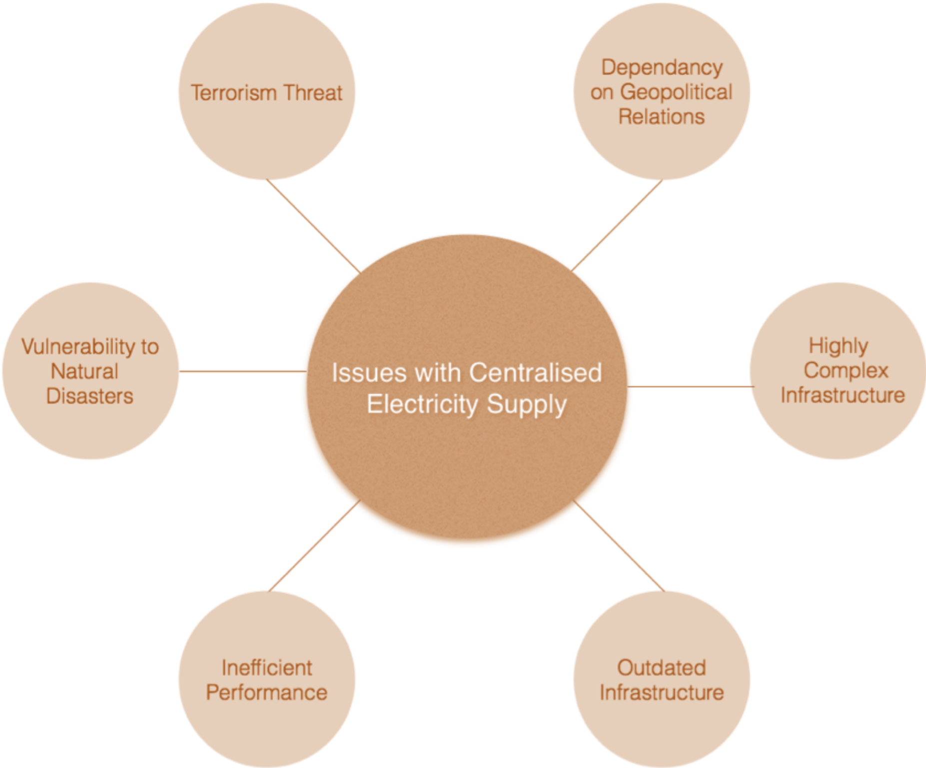

Figure 4.5: Issues Associated with Centralised Electricity Supply

Further on, the problems associated with centralised grid supply in India are duscussed below, to understand the depth of the problem the shortfalls will be divided into the four categories, Technical, Economic, Social and Political. The shortfalls pertaining to centralised grid supply in India were looked at through literature as well as through a set of Interviews of stakeholders from the strata of policy and implementation of the electricity sector in the country, which have been presented in Appendix-C.

4.2.2. Technical Issues

Considering the scale and complexity of the rural electrification in India it is but obvious that large technical barriers and shortfalls have been experienced. There are a variety of reasons as to why technical issues crop up, depicted in Figure 4.8, which have been explained in a bit more detail below:

- **Absence or Outdation of Infrastructure:**The shortfalls in supply of electricity are observed due to a variety of reasons, but in easier terms could be categorised into (Aggarwal and Alison, 2014).:
  - Absence of Infrastructure
  - Presence of Infrastructure but with highly prevalent discrepancies.

  Shortfalls in supply for the case of absence of infrastructure are more or less self explanatory,In hilly and remote regions, the major constraints related to grid extension are logistics and high costs and thus the infrastructure has been missing in these regions. Nuoni et al stated that for such locations decentralisation is a logical option due to its cost efficiency and ease of set up and operation (Nouni and Malik, 2009). whereas for latter a variety of reasons have been experienced which have led to the shortfalls such as: outdated, capacity losses, skill shortages, substation losses, voltage imbalances, frequency fluctuations etc (Appendix C.6).

  Figure 4.6 gives a more in depth idea of the reasons for discrepancy in the supply of electricity on the basis of unavailability of infrastructure. Shows the comparison of performance of the majorly populated states of the country. We observe that the richer states are performing better than poorer states.

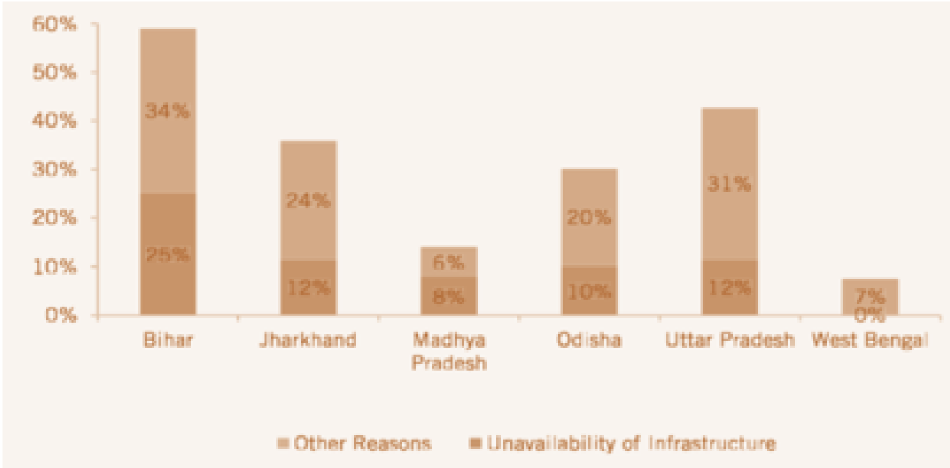

Figure 4.6: Reasons for -unavailability of rural electricity in the major states(Urpelainen and Johannes, 2015)

- **Reliability:** The reliability of grid-based electricity in India is questionable. The central grid in the lesser developed states find it hard to meet the minimal goal of supplying at least 6 hours of power a day(Harish et al., 2013). According to a survey conducted in Bihar in 2008-2009, it was found that villages received electricity anywhere between 1.3 hours to 6 hours a day. Moreover, there was no correlation between the number of years a village had been electrified, the proportion of households electrified, and the hours of power available (Oda and Tsujita, 2011). These results show that grid power reliability is a major concern and the grid has not necessarily stabilized with time. The scenario is not expected to improve in the near future say in the next 10 years (Appendix C.4). Thus Grid reliability is a major issue which needs to be catered to the following sub-parts further describe the reasons for low reliability of the grid.

- **Loads:** In general, the central grid in India is highly strained. The demand due to the grid extensions is constantly increasing whereas the supply is not. Even though India has enough generation capacity to serve base load upto 2027 (Appendix C.2) power outages and shortages are experienced especially during the peak demand hours. India is facing shortages of power of about 3000 MW out of 150,000MW which is required during peak demand (Central Electricity Authority, 2013).
  However, Uttar Pradesh is the worst performing state in terms of supply during peak demand as in Uttar Pradesh on average a deficit of 19.4% of entire peak demand is observed during peak time.

- **Losses:** The Central Grid experiences large losses, in 2010-2011, India lost 27.97% of its produced power due to grid losses (Central Electricity Authority, 2012). The main causes of grid losses in India boil down to the following causes (Wadia and Deorah, 2015) Electricity Theft, Over due payments and Discrepancies in billing by distribution companies. Bihar was observed to be the worst performing state in term of losses, where losses in the range of 46.4% were observed (Udupa et al., 2011).

  Electricity theft being one of the main reasons leading to shortfalls in electricity supply. Since the scale of the theft is so large distribution companies face heavy losses and thus to curb losses they cut power. Distribution companies tend to provide electricity only when it is profitable leading to underserving of rural regions (Appendix C.1).

- **Generation Sources:** In India, at present, coal adds 56% to the generation mix, hydropower adds 20%, 2% comes from nuclear and the rest is divided between renewables and gas. Thus to cater to the shortages in grid supply the government aims at adding more decentralized renewables to the mix (Central Electricity Authority, 2012).

- **Power Supply Discrepancy:** Major discrepancies are observed in the distribution sector of the electricity supply chain .The main reason why heavy imbalances of power are faced are power theft or illegal connections. This is also why the viability of the government's grid extension policy described under the DDUGY is being questioned.(Appendix C.2)

Looking at the electricity supply chain we observe that 'Generation' of electricity happens in a protected, highly monitored and closed environment and thus power discrepancies are rarely observed, similarly the high voltages of electricity during the 'Transmission' part of the supply chain protects the sector from thefts, but when we look at the 'Distribution' sector the voltages are low also there is no protective environment making the sector highly vulnerable to theft and other discrepancies (Appendix C.1).

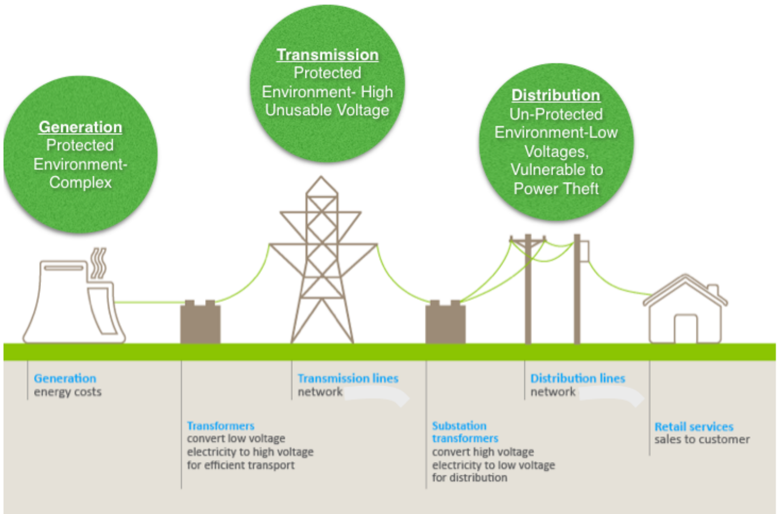

Figure 4.7: Electricity Supply Chain: Sector Comparison on the basis of Protectiveness

- **Operation and maintenance:** Operation and maintenance is a long-term issue experts in India have been in a constant tussle with. There is a shortage of skilled labor in India dealing with grid maintenance (Udupa et al., 2011). The large transmission and distribution losses make it harder for experts to manage the grid (Oda and Tsujita, 2011).

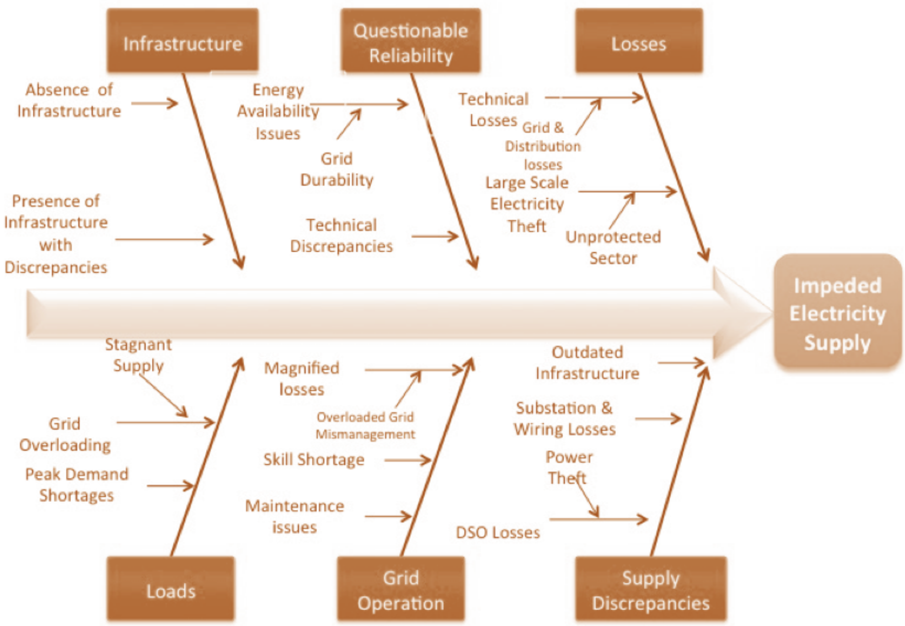

Figure 4.8: Technical Issues Associated with Rural Electricity Supply-India

4.2.3. Economic Issues

In the following section the economic consequences of large scale electricity theft have been discussed and also how economic issues have to lead to shortfalls in the electricity distribution sector creating large scale discrepancies in power supply for the rural regions. Figure 4.9 depicts Economic Issues leading to shortfalls in the performance of the electricity sector in India.

- **DSO's Dilemma:**
  - **Un-Favourable Market:**Electricity providers in rural regions for long have been tackling with the issue of large scale power theft. Power theft thus leads to imbalances in supply of electricity and thus the affected party are the local distribution companies (Appendix C.5). As a result large economic losses are observed by the DSOs and thus the rural supply of electricity becomes highly un-profitable and un favourable. With a natural tendency To cut losses the DSOs tend to buy less power and inturn supply less power(Appendix C.6).
  - **Mentality:** 'The DSO's Dilemma' can also be described as a mentality problem, since the distribution companies are privately owned and run, they're sole motive is to make profits, the companies do not believe that its their duty to supply reliable electricity. As a result to cut losses DSOs tend to cut power (Appendix C.6).
  - **Skill Shortage:** There is a shortage of skilled labour in India when it comes to dealing with grid maintenance and operations (Udupa et al., 2011), this has added to the problems of the DSOs as grid management becomes even harder when large scale electricity theft comes into the picture. Large transmission and distribution losses get added up with skill shortage leading to absolute chaos in the grid (Oda and Tsujita, 2011).

- **Agricultural Load Dilemma:** Agricultural electricity is highly subsidised and in some states absolutely free. As a result large scale misuse of agricultural load is observed in majority of the rural regions, domestic loads are also connected to the same feeder and deemed as agri loads (Appendix C.6). Agriculture load accounts for 20% of total energy consumed but the revenue generated in just 5% of total revenue generated from by the electricity sector. Thus to deal with this issue the government is expected to put forth a scheme of electricity distribution based on the Gujrat model, where two different feeders would be used, one feeder with subsidised nominal tariff for agri loads, only to supply energy for a fixed number of hours a day based on the working hours for farmers in the state and the other feeder with normal tariff for domestic loads (Appendix C.2).

- **Overshadowing by Urban Potential:** Rural regions do not form the most appealing of the markets for the electricity distribution companies. Since the number of users is low and their load demands are also low the electricity distribution business does not turn out to be very profitable in these rural regions whereas in comparison urban regions have densely populated high energy consuming pockets of civilisation which act as the perfect market for the distributions companies. Large number of consumers with heavy load demands equals more profits in monetary terms for the DSOs, thus the natural tendency of DSOs is to try entering the urban market rather than rural (Appendix C.6).

- **Major Book Keeping Discrepancies:** As mentioned before the grid losses experienced in India are of a mammoth scale, in 2010-2011 India lost 27.97% of grid power due to transmission and distribution losses (Central Electricity Authority, 2012). The main causes of these losses are payment defaulters and electricity thefts (Wadia and Deorah, 2015). As a result major discrepancies are experienced in the book keeping of the DSOs. The costs of electricity provision and the bills received from the sectoral customers don't add up. Large scale theft leads to economically non efficient performance of the distribution sector and thus they tend to cut losses by cutting power. Say there are 'X' houses in a village with 'Y' paying customers, DSO tends to provide electricity only when the cost price of electricity for he DSO is so low that the paying 'Y' customers can make up for the remaining non-paying 'X' customers as well (Appendix C.3).

  The regulatory policies further add to the woes of the distribution companies, as the regulator does not permit power cuts beyond a particular point thus increasing the losses of the DSOs overtime (Appendix C.6).

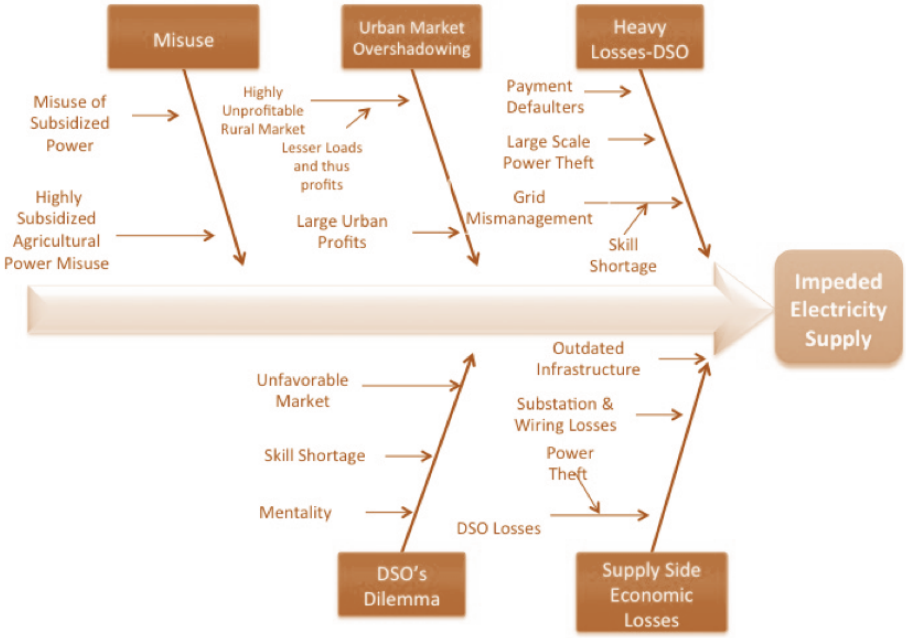

Figure 4.9: Economic Issues Associated with Rural Electricity Supply-India

4.2.4. Social Issues

The following section discusses how certain social aspects of rural society in India have added to the shortfalls of electricity sector experienced in such regions. Social reasons for electricity theft, illegal connections and payment defaulters being the major topic of discussion. The social aspects of electricity shortfall can also be seen as a 'mentality issue', the following section will throw more light on as to why social aspects have been deemed as mentality issues.

- **No Willingness to Take legal Connections:** Majority of rural households are not willing to take connections, the fear of high utility costs and bills has lead to this circumstance (Appendix C.1).
- **Free Electricity Perception:** For years now the government of India has been in a constant tussle of dealing with large scale electricity theft especially in the rural regions. Locals living in these regions exhibit what has been termed as the 'Free Electricity Perception'.

  Rural locals in India believe that free electricity is their birth right and thus tend to either not pay for grid utilities or engage in theft of electricity. The reason being, a long history of electricity theft spread over multi generations of rural families (Appendix C.3). Since those born in such families experience electricity theft since a very young age they tend to believe it is their birth right to attain free electricity (Appendix C.2).
- **Violent Conduct Towards Intervention:** Distribution company intervention to prevent theft or to punish offenders is not taken well by the locals, they usually tend to greet correction officials with violence and threats due to their strong belief of their right to free electricity. As a result most of the efforts to prevent pilfering of power have been futile (Appendix C.1).

4.2.5. Political Issues

The following section discusses the political aspects leading to rural electricity shortfalls in India.Though the central and state government play the blame game over the accountability and responsibility of the electricity shortfalls in the rural regions, the truth is both should be sharing the blame for the issue (Appendix C.2).

Local political parties in power tend to add to the woes of the distribution companies. To retain power, the local parties need votes and to do so need to keep the locals happy thus highly subsidised power and political support is provided to offenders for the purpose of potential vote extraction (Appendix C.1)

- **Free electricity to draw votes:** The equation is straightforward. Indian voters, 70 percent of whom live in rural provincial ranges and half of whom are occupied with agricultural interests, have a sound (and developing) craving for energy. Government officials, thus, have a continuing hunger for winning elections. For years, politicians have been very upbeat to give free or vigorously subsidised power to rural locals with the expectation of receiving the benefits at the votes tallying station (Vaishnav, 2012).

- **Fragility of the Coalation Government:** Political issues additionally assumes a part in enabling states to draw more power than they are entitled for. With the formation of coalition government, the central authority is frail to discipline those that damage "grid discipline"— punishing wayward state politicians whose bolster you depend on is a surefire method for sending into the arms of your adversaries and thus losing political support (Vaishnav, 2012).

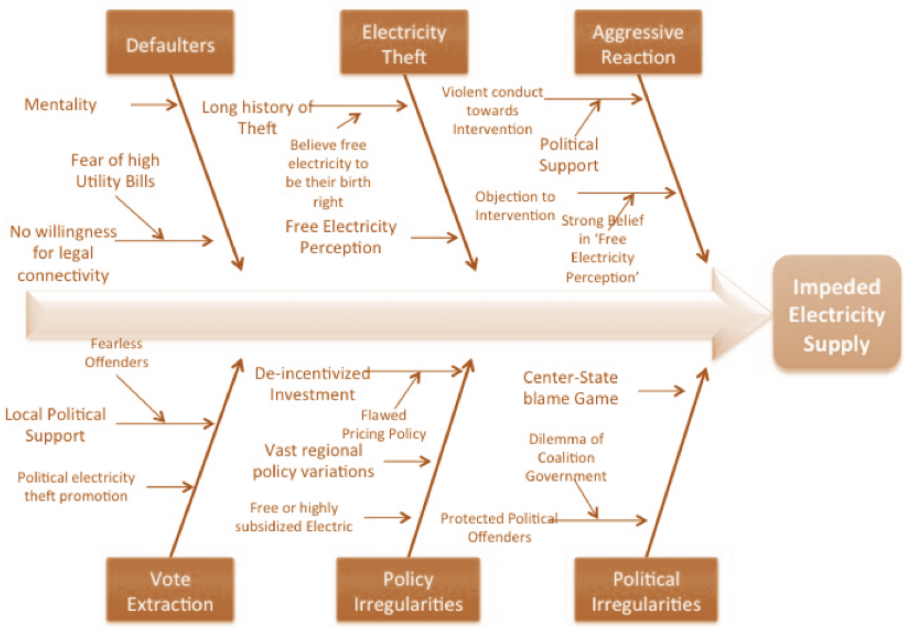

Figure 4.10: Social and Political Issues Associated with Rural Electricity Supply-India

- **Political Support to Offenders:** Governmental issues, be that as it may, plays out in considerably more unreasonable courses than what has been mentioned above. Take, for example, the way that India routinely loses around 30 percent of the power it delivers because of "line losses"— the specialized term for waste, mismanagement, theft and mishandle, many trust that politicias participate in "politically-motivated theft." A current review by analysts at the University of California, Los Angeles and University of Michigan demonstrates that line losses work on a electoral cycle in Uttar Pradesh, the nation's most populous state, with more than 200 million inhabitants. Put just,to keep voters satisfied, government officials promote greater power theft around elections (Vaishnav, 2012).

  For the same purpose of luring votes from the locals living in these rural regions the politicians tend to keep them happy by providing political support even to the offenders and power thieves, adding to the voes of the local distribution companies (Appendix C.1).

- **Flawed Subsidy Policy:** Subsidised (or free) power implies consumer costs are lower than market rates, and thus distribution companies are compelled to work at a loss, disincentivizing private investment. On the generation side, India remains intensely dependent on coal for energizing its energy supply and the state-owned endeavour, Coal India, commands the commercial centre. With a virtual monopoly on coal supply, and confronted with high costs for imported coal, private firms are hesitant to draw in on the generation side. Coal India itself is required to offer coal at a vigorously marked down value, so it too has next to no liquidity to put resources into new ventures or in R&D (Vaishnav, 2012).

4.3. Government Efforts

The following section describes the role of the government in the rural electricity sector in India. The policies laid out by the government have been discussed with their aims and objectives. First Figure 4.11 displays the institutional structure and the top down nature on the electricity sector.

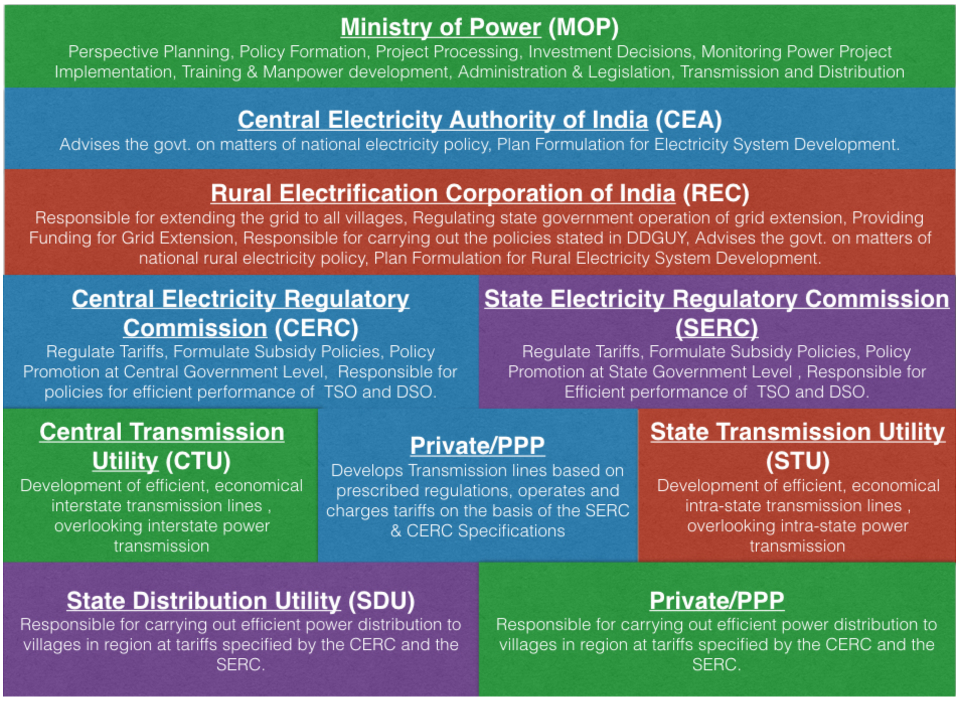

Figure 4.11: Institutional Structure of the Indian Electricity Sector

- **Electricity Act of 2003**
  From 1947-1952, obligation regarding the power allocation lay in the hands of State Utilities Boards. While the central administration held certain general administration, the vertically incorporated boards were to a great extent in charge of energy production, transmission, and distribution. However, the utility boards as often as possible worked in losses. By 1990s, the Indian administration had started looking for option structures to advance development of the power segment. The highlight of this act was to change the power sector.

  The act included features like, the unbundling of these boards into discrete bodies , diffusion, and circulation; de-licensing of energy with the goal that it was interested in financing and competition from the private division; permission to open sector to diffusion and dissemination; endeavours to enhance the economic circumstances of distribution organizations through an expanded accentuation on metering and losses through robbery; and foundation of the Central Electricity Regulatory Commission (CERC) and the State Electricity Regulatory Commissions (SERCs).

  The Act likewise permitted non-legislative features to set up rural administration concurrences with remote groups that were not anticipated that would pick up lattice access within a reasonable time frame.

- **Remote Village Electrification Program**
  In 2003, the Ministry of New and Renewable Energy presented the Remote Village Electrification (RVE) program with the goal of conveying essential lighting and electricity to un-energized remote towns and

furthermore to un-electrified remote habitations of remote towns through renewable energy innovations. The objective of the program was to electrify every single remote village by 2007 and all households by 2012. In any case, taking after the dispatch in 2005 of Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), depicted in more prominent feature underneath, the RVE project was altered to concentrate just on those towns and villages where grid expansion was inefficient or infeasible. Specifically, it concentrated on towns of more than 300 locals that were more than 3 km from the closest grid access. RVE gives sponsorships to almost 90% of the establishment expenses of renewable energy ventures, with the specific renewable energy innovation picked by the pertinent state-level organization after a valuation of renewable asset accessibility. By December 2010, the project had achieved more than 7,000 villages and 2,100 hamlets.

- **Village Energy Security Program**
  The Ministry of New and Renewable Energy propelled the Village Energy Security Program (VESP) in 2004 with the point of meeting the aggregate energy needs of remote towns through locally accessible renewable energy. MNRE gave a one-time funding to conceal to 90% of the investment expenses of power generators utilizing biomass gasifiers and additionally herbal oil in blend to disseminate the electricity for all program. The project likewise advanced the utilization of clean cooking fuels through the circulation of enhanced cook stoves and biogas powered technology. In all circumstances, community individuals were in charge of giving "no less than 10% of a value commitment with either money or different commitments, for example, land and labor."

  Community proprietorship was an essential element of VESP, and every group was in charge of arranging and the execution of the project. This was implemented through the formation of Village Electrification Committees (VECs) that united town councils and local administration bodies. The VECs were additionally in charge of the setting of levies, bill accumulation, and progressing operations and upkeep, including the obtainment of biomass fuel.

  A similar review found that VESP ventures went up against difficulties that included chaotic supply chains for biomass, lacking specialized learning about how to work generators, insufficient technical knowledge, disarray about the division of obligations among partners, and low interest for power. Subsequently, VESP was stopped in 2012.

- **Rajiv Gandhi Grameen Vidyutikaran Yojana (RRGVY)**
  In 2005, Prime Minister Manmohan Singh propelled the rural electrification program RGGVY. The project was made by "basically joining existing rural electrification programs under another symbol and raising the prevalent issues. The plan was executed via the Rural Electrification Corporation, which is a public undertaking that funds and advances rural electrification projects all through the nation. RGGVY finances ninety percent of the investment expenses for network augmentation to actors who embrace rural electrification programs. The rest 10% is secured through advances from Rural Electrification Corporation. Also, family units beneath the poverty mark are sans given free electricity network.

  In 2009, the Ministry of Power reported rules for the Dispersed Disseminated Generation (DDG) project inside RGGVY. Where network expansion is not practical or predicted in the following five to seven years, RGGVY suggests off-grid arrangements and gives generous investment and working sponsorships via DDG.

  By September 2013, the Ministry of Power detailed that RGGVY had finished electrification endeavors in 100,000 Un-electrified villages and concentrated electrification efforts in 300,000 halfway electrified villages. Moreover, it had given free power access to 2.1 million families underneath the poverty line. There are drawbacks associated to the program, some believe that the definition of electrification under the policy is flawed. Only 10% households connection to the grid deems the villages as electrified. Another aspect if the lack of electricity availability through the grid connection provided.

- **Deen Dayalan Upadhyay Gram Jyoti Yojana**
  The Deen Dayalan Upadhyay Gram Jyoti Yojana was launched as an updation of RGGVY to augment provision of continuos power supply to remote and rural villages. For the same purpose Ministry of Power sactioned funds for the scheme in approximation of 10.7 billion euros. The scheme aimed at achieving the follwing objectives (Ministry of Power, Government of India , 2015):

- Provision of electricity on to all villages
- A feeder system, to separate and ensure sufficient power to agricultural sector as well as other consumers.
- Improvements in distribution networks and sub transmission to cut down losses and thus improve quality and reliability of supply.
- Metering for all, to lessen the number of defaulters to cut down losses. What is suprising is the fact that the costs of meters, cabling, local transmission lines, salaries and other IT costs were not included in the released funds. The question of what really are the funds released for arisies when observing the objectives of the scheme.

5

Rural India- Water Sector

India has a rural population of approx. 700 million living in 1.42 million various habitations, which is spread over 15 different biological locales therefore providing drinking water is highly difficult task. India also differs region-to-region in terms of development, education and awareness and also cultural and religious beliefs add to the problem (Khurana and Sen, 2008).India faces a great shortage in terms access of quality of water for consumption. Various factors such as un-organised industrialisation and development, financial and technical constraint have been responsible for a lot of un-needed pollution and wastage of water resources. Another reason also is that rainfall in India is also not equally distributed. Non enforcement of laws relating to misuse is also an important factor. Figure 5.3 depicts the water stressed rural regions of India to lay stress on the urgency of the matter.

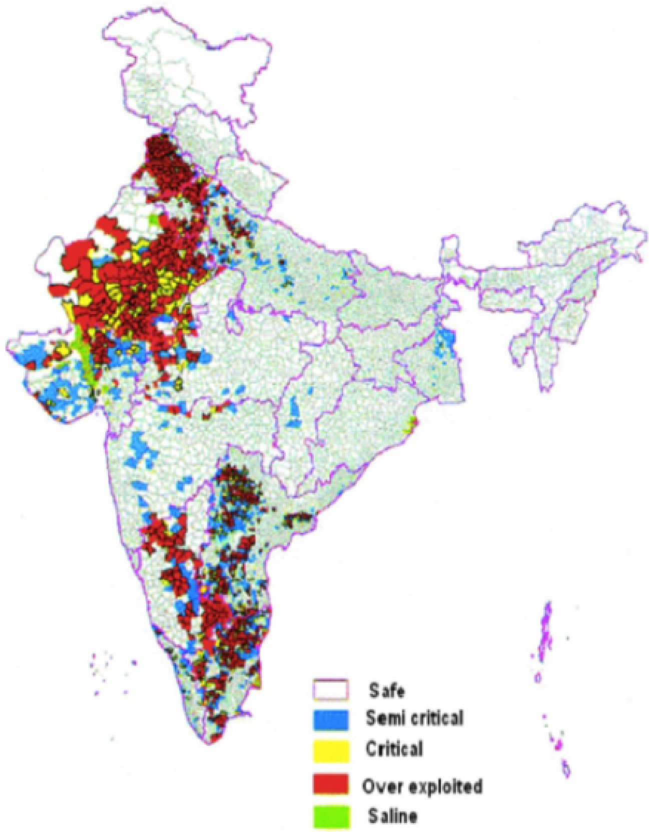

Figure 5.1: Groudwater stressed areas of India

5.1. Problems of Water Scarcity

The annual rainfall in the country is well distributed. India receives 1176mm average rainfall in a year spread over a period of 5 to 6 months. The rainfall is very unevenly distributed with 100mm of rainfall in Rajasthan desert and 10000mm in Cherapunji in Meghalaya. India annually receives 4000 billion m3 amount of fresh water but large amount is wasted because of runoffs, evaporation and transpiration causing a loss of 1057 billion m3 of usablewater, and hence the available is reduced to 1953 billion m3 of this 1123 billion m3 is available for usage. The ratio of usable water provided by surface water is 728 billion m3 and 395 billion m3 is replenishable underground water. Ironically India merely uses 18% of the rain water effectively while 48% is lost by entering into the rivers and mostly flowing into the oceans. The estimated water consumption in the country in 2006 was 829 billion m3 with will substantially increase to 1093 billion m3 in year 2025 and by 2050 the requirement will be about 1047 billion m3 as per Government of India report 2009. The potentiality of increasing the volume of water utilisation is mere 5-10% which gravely will create severe scarcity of fresh water in the future (Hegde, 2012).

The statistics show that the water available per capita in the year 1951 was 5177 m3 when the population was 361 million, with the increase in population over the years, in the year 2001 with the population increasing to 1027 million water available per capita fell drastically to 1820 m3 per capita and as per analysis it will further reduce to 1341 m3 by 2025 and will be 1140 m3 by year 2050 as shown in the table below. Besides providing water for consumption for a growing population in India there is a also a ever growing need to provide water for irrigation and livestock husbandry so that that the demand for the growing Indian population can be met. When ever the water availability per capita for various purposes falls in the range of 1000 to 1700 m3 it is considered a stress zone and as and when it falls bellow 1000 m3 per year it is defined as water scarcity. Various states in India differ in terms of rainfall, proximity to the rivers and also in respect of ground water reserves and hence most of them will reach water stress level by year 2025 and scarcity by 2050. This will also effect food security in the country as water scarcity directly effects agricultural production (Hegde, 2012).

Table 5.1: Per capita Water Availability-India

Year	Population (Million)	Per Capita Water Availability (m3/year)
1951	361	5177
1955	395	4732
1991	846	2209
2001	1027	1820
2025	1394	1341
2050	1640	1140

A census done in year 2001 reported that 68.2 percent of the population has access to safe drinking water. The latest estimates show safe drinking water is available to 94 percent of the rural population. As per Department of Drinking water supply that out of the 1.6 million rural settlements in the country 1.06 of them are fully covered (FC), 0.34 are partially covered (PC) and .019 do not have access to safe drinking water. This census is unfortunately based on the installed capacity and not on the actual supply or quality of water being provided (Khurana and Sen, 2008). There has been improvement over the years in this respect but still there is a vacuum in availability of fresh drinking water for consumption and domestic usage. The unfortunate part is that though on paper basic infrastructures show their presence but substantial number of these facilities are either dysfunctional or available for a limited period per day and this results in a the poor population finding other sources with are mostly polluted. As per a report by World Health organization and UNICEF besides scarcity in availability of drinking water in rural India there is also a imbalance in the quantum of water available across the country, ranging in some areas as low as 9 lpcd and in a few as high as 584 lpcd. As per the table given below it shows the average time taken by the rural population to collect water for drinking/domestic purposes (Mandal, 2008).

Table 5.2: Time for water collection in rural India (Government of India 2009)

Collection Time	Percentage of Rural Households
Water on Premises	42%
Less Than 30 Minutes	43%
Thirty Minutes or Longer	14%

Table 5.3: Age Distribution Water Collection Rural India (Government of INdia 2009)

Gender & Age	Percentage of Rural Households
Adult Females (Over 15 Years)	83%
Adult Males (Over 15 Years)	11%
Young Females (Under 15 Years)	5%
Young Males (Under 15 Years)	1%

5.2. Reasons for Shortfalls

5.2.1. Agriculture

Agriculture contributes to water issues in India in a major way, both pollution and shortage issues.

- **Ever Increasing Irrigated Area:** Presently, in spite of good rainfall distribution, the country is unable to make good use of rain water, because of lack of awareness and poor infrastructure to construct dams and reservoirs. As a result, only about 35-40% of the cropping area receives irrigation to take 1-2 crops in a year. Out of the total cultivable area of 182 m ha, only 140 m ha are under net cultivation and of this, 62 m ha are under irrigation. There is further potential to increase the area under irrigation to 140 m ha, 76 m ha through surface water and 64 m ha by using ground water. So far, the irrigation potentials have already been created to cover 107 m ha, although they are not utilised effectively. It is estimated that effective area under irrigation by 2025 will be 76 million ha, although the Government of India is estimating to cover 104 million ha. Ground water is the major source of irrigation and this trend will continue. By 2025, 60 million ha will be irrigated by using ground water and by 2050, the area under ground water will increase to 70 million ha. In 2000, the area under canal irrigation was 17 million ha, which will increase to 27 million ha by 2050. There is further scope to increase the potential by 35 million ha, by inter-linking the rivers and harnessing 36 billion m3 through artificial recharging of ground water (Hegde, 2012).

- **Groundwater Exploitation:** The study shows agricultural sectors uses 80 to 90 percent of the ground water. Majority of the farming community relies on ground water resources other than seasonal rainfall to meet the shortfall, as such there are 25 million ground water blocks in the country. Week policies and legislations by the Government has allowed the farmers exploit the ground water faster than its replenishment causing the water table falling to a unsafe level which has led to the water becoming unsafe for agricultural consumption, reason being it is too saline or polluted for the purpose. The Farming community in India forms a large portion of the voting population and as most of the attempts to regulate the usage so that the ground water gets renewed have failed. To keep the farmers happy water pumps and energy are provided to them at a subsidized rate and in the process any law or regulation to control the exploitation of ground water resources is totally ineffective. Any law or ruling is mostly on paper and there is generally no enforcement of the same (Rajawat, 2016).

- **Inefficient Water Usage:** Lack of education has led to inefficient usage of water in agricultural sector. Majority of the farmers due to lack of education and financial resources are not willing to change and use the more effective modern irrigation methods. The concept of drip irrigation or other techniques to obtain ‘more crop per drop’ is non existent and India continues to rely mostly on traditional methods which in turn have resulted in huge wastage of precious water resources e.g the sugar cane belt in

Maharashtra covers only 4 percent of the area but uses 70 percent of the irrigation water of the state. India due to such factors operates at 38 percent efficiency in agricultural water consumption (Rajawat, 2016).

- **Agricultural Run-off and Impropoer Practices:** India faces multiple challenges in respect to food production due to its ever increasing population. In order to meet the demand and have a higher yield the trend in the agricultural community in India has been intensive and ever increasing usage of chemical fertilizers, pesticides, weedicides and other chemicals and when used in excess to the recommended dosage it leads to polluting the environment. There is no exact estimate available about the extent of safe water being polluted by excessive usage of chemical fertilisers and pesticides, for example it is estimated that in Haryana, a 40 km long drain pours approximately 250,000 kg/day of chlorides into the Yamuna and this causes the chloride concentration in the river to increase from 32 mg per litre to 150 mg per litre just upstream where the drain meets the river and most of these chlorides are from agricultural return flows. Along with higher doses of fertilisers excessive use of water for irrigation also results in polluting the wells, canals, rivers etc . The end result is that a large percentage of the water which is around the irrigated lands have become unsafe for consumption. Excessive irrigation also results in the water reaching lower soil layers which have high content of salts and due to capillary action these salts with time come to the surface and result in creating lot of wastelands unfit for agricultural use. Presently, over 9 million ha fertile irrigated lands have turned into sodic wastelands and the water in most of these areas have high salt concentration, unfortunately most of the population in these areas due to lack of facilities and awareness are consuming this unsafe water which has resulted in high incidences of illnesses (Rajawat, 2016).

5.2.2. Non-Revenue Water

The difference in the volume of water supplied and what is actually received by the legitimate consumer is referred to as Non revenue water. India on an average looses about 20 percent of the supply mainly thru leakages, poor infrastructure, theft and faulty metering. Normally the data available in this regards is questionable because the NRW of cosmopolitan cities like Delhi or even Goa for that matter show a higher NRW that the entire national data available. The major factors that contribute to this loss in India are basically aging and poor infrastructure although theft and corrupting also play a significant role in NRW. In the case of water theft most of the water sold in the black market is from the public water grid which tend to add to the water scarcity normally amongst the poor population (Rajawat, 2016).

5.2.3. Water Pollution

Water pollutions in the country is cause number of factors such as Industrial and sewage discharge, agricultural and Urban run offs. To make things worse there is total lack of awareness and education in this regards. The following factors that contribute towards water pollution are discussed below :

- **Sewage Disposal:** Approximately 80 percent of the ground water in India is polluted. Poor sewage treatment facility is a one of the main causes for this pollution. India lacks total environmental awareness in this respect and even though efforts are being done by government and non government organizations yet because of the enormity of the population the problem is simply escalating with each year. Sadly the Slogan “Incredible India” has drowned in its on excreta is how environment activists define the magnitude of the sewage problem in the country. Only 30% of the rural population and 65% of urban population has excess to proper toilets other than that the human waste either seeps into open wells or water tanks contaminating the water with nitrates and harmful germs arising from the human excreta further reducing the available safe water. Delhi on an average generates 36 million tons of sewage per day of which only 50% is treated and the rest flows into the Yamuna river. The situation is grave in 23 other major cities also where only 31% of the sewage is treated and the rest pollutes 18 major rivers of the country (Hegde, 2012).

- **Indusrtial Discharge & Fertiliser Use:** India is a developing nation where in order to achieve economic growth the ecosystem has been overlooked to a point of collapse. Short-term economic prosperity has caused irreparable ecological harm to the environment. Lack of implementation of policies and control methods in the organized and un-organised industrial zones lack waste management and allow their industrial discharge of untreated effluents flow or seep into rivers, lakes and other water bodies leading to contaminating of water sources and making it unsafe for consumption. It is estimated that the wastewater generated from all major industrial sources is estimated at 83,048 MId of which 66,700 Mid is from cooling water generated from thermal power plants and out of the balance 16,348 Mid another 7,275 Mid is generated from boiler blow down water and overflow from ash ponds. Engineering industries comprise the second largest generator of wastewater in terms of volume. Under this category the major polluting industries are electroplating units.The other significant contributors of wastewater are paper mills, steel plants, textile and sugar industries. The major contributors of pollution in terms of organic load are distilleries followed by paper mills. Graph below shows the volume of wastewater from different industries in India (Hegde, 2012). Installation of costly treatment and disposal equipment's in many of the large scale industries are often not in proper working order. Several examples of pollution can be quoted such as oil wastes present in the storm-water channel along Haldia Refinery and ammonia pollution in ground water around urea factories of Kanpur and a pollution of natural spring close to Zuari Agro Urea plant in Goa. Both large and small-scale industries are responsible for water pollution. There are approximately 3 million small scale and cottage industries in the country. Majority of these small scale industries do not have or cannot afford proper pollutant disposable systems for there highly polluting production technologies. For example tanning of leather, use of azo-dyes in fabrics, use of cadmium in ornaments or silver-ware, electroplating with cyanide baths, production of dye-intermediates and other refractory and toxic chemicals, etc. The solid wastes and sewage sediment containing heavy growth of microorganisms from such industries get scattered around or dumped in unlined pits and effluents tend to flow to ponds, lakes or streams through drains or gets stagnated in areas of depressions and thereof seeping into the ground and contaminating the ground water (Mandal, 2008).

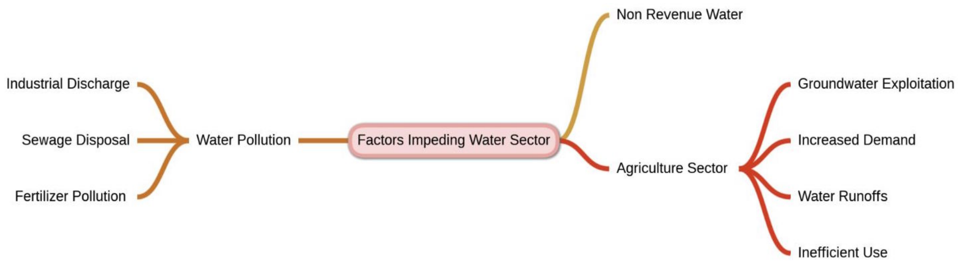

Figure 5.2: Factors leading to impeded performance of rural water sector

5.3. Water Quality and its Health Impacts

India ranks 120th out of 122 countries, in poor potable water-quality. Groundwater is the major source of water in our country with 85% of the population dependent on it. Though ground water is less susceptible to pollution as compared to surface water, the nature of quality problem in ground water is of two types: (i) It is inherent in the form of contamination caused by the very nature of geological formation, viz. excess fluoride, arsenic, brackishness, iron, etc. (ii) Ground water pollution caused by human intervention (anthropogenic) e.g. nitrates. 15 per cent of the rural water supply comes from surface water sources. Major quality problem for surface water is seasonal turbidity. Water also suffers from bacteriological contamination, reasons being anthropogenic. The reasons for chemical and bacteriological contamination are: poor hygienic conditions around the water sources, improper disposal of sewage and industrial waste water, callous disposal of solid waste, indiscriminate use of chemical fertilizers having high quantity of nitrates used in the agricultural sector, pollution from industrial effluents (untreated), over-exploitation leading to quality degradation, pollution of the source due to ignorance of the people, over-population and lack of public awareness (Khurana and Sen, 2008).

The Central Pollution Board conducted a survey in 2005, which found samples containing high values of organic values (upto66%), the samples also contained unacceptable levels of coliform bacteria generally occurring due to feces (44%). The survey also found high heavy metal contamination of samples, with widespread contamination by iron, lead, arsenic, flourides and nitrates. High fluoride levels were found in majorly populated states of Uttar Pradesh, Madhya Pradesh and Jharkhand leading to widespread deformities in children.

Flourides are said to contaminate drinking water of 20 out of 28 states in the country. An approximate of 200,000 habitations are said to be affected by high levels of fluoride contamination (Khurana and Sen, 2008). The figure below depicts the immediate issue of drinking water quality in India.

The health burden due to poor water quality is enormous. An approximate of 38 million Indians are affected by water borne illnesses annually. Cholera, diarrhea and meningitis are the most widespread of water bourne diseases observed in India. On average 1.5 million children die of diarrhea annually. Economic losses due to water borne disesases are immense, 73 million working days are lost annually resuting in a $600 million loss to the national economy. 10 million people in the country are cancer vulnerable due to arsenic contamination and 66 million vulnerable to the issue of fluorosis. Fluorosis is influencing future generations too through pregnant women who are suffering from fluorosis inflicted anaemia. Mothers suffering from anaemia give low birth-weight babies who thusly show their moms' wholesome defficiencies through physical and mental distortions. The figure below depicts the urgency of the matter through depiction of water borne Cholera and Diarrhea in various states of the country (Khurana and Sen, 2008)

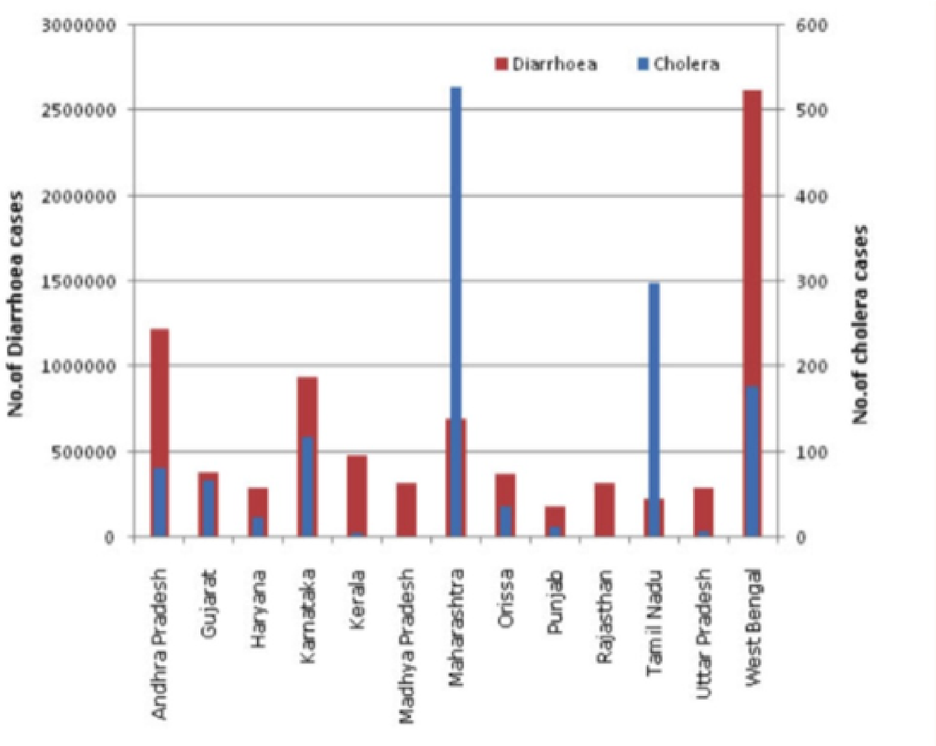

Figure 5.3: Cases of Acute Water Borne Diarrhoeal Diseases and Cholera in India in 2007 (Tripathi et al., 2015)

5.4. Government Involvement

Water quality and management of drinking water supply to the rural regions of the nation have always been major concerns for the government of India. In February 2006 , the government launched the National Rural Drinking Water Quality Monitoring and Surveillance Program, aimed at institutionalizing community participation monitor ad for surveillance of resources of drinking water by the local governing body at grassroots levels (Mandal, 2008)

Under the Accelerated Rural Water Supply Program (ARWSP), the central government provides financial aid to state governments to implement projects and efforts for improvement of water quality and supply. In 1986, the National Drinking Water Mission (NDWM) was introduced with ARWSP as an integral part of the mission. NDWM was tweaked and thus renamed in 1991 as Rajiv Gandhi National Drinking Water Mission (RGNDWM). The main motives of this project are (Khurana and Sen, 2008):

- Providing safe drinking water to all those who lack access.

- Sustainability of environment, systems and sources
- Improve water quality

Figure 5.4: Rural Water Sector: Institutional Structure

The government has invested over 1 billion rupees up-till the tenth plan, despite large-scale invested the issues of impeded water supply and questionable water quality have continued to be a prevalent, being a major national economic hurdle (Khurana and Sen, 2008).

Bharat Nirman, a rural development scheme launched by the government to aid rural development from 2005-2009 had drinking water supply and quality at the core of the motives of the mission for building rural infrastructure. During this period the government had aimed to cover 55,000 habitations which had no supply till the point and 200,000 habitations which were affected by poor water quality were to be targeted as well. Solving issues related to arsenic and fluoride contamination were prioritized. Bharat Nirman was to target issues prevelant in lagging states to augment economic growth through rural infrastructure development (Khurana and Sen, 2008).

Policies have been put forth which led to creation of Water Quality Review Committees, these committees improved synergy of performance between the central and state governing bodies. Issues related to water supply and quality are reviewed by these committees, they gather data to be analysed, asses schemes put forth by the government, These committees are responsible for the un impeded performance of the entire supply chain of water.

5.5. Energy-Water Inter-relations

Energy and water are mutually dependant assets. Water is an integral part of energy resource supply chain which includes extraction, refining, processing and transportation. Water use in the electricity sector is usually substantial in large scale thermal power plants, where water is used as steam to run turbines, though this water is reused still a large chunks is lost as steam losses.Large scale economic and population growth have led to increased energy demands in turn leading to increased pressure on the water supply system. Thus, present trend of events show signs of increased water demand by the energy sector and thus provides incentives for reducing the water consumption of the sector (Tripathi et al., 2015).

5.5.1. Energy Sector's Water Dependence

Table 5.4: Sector Wise Water Consumption in Billion Cubic Meter- Indian Scenario Sinha (2014)

Sector	**Probable Water Demand as Projected by NCIWRD (1999) (High Demand)**		
	2010	2025	2050
Irrigation	557	611	807
Domestic	43	62	111
Industry	37	67	81
Energy	19	33	70
Others	54	70	111
Total	710	843	1180

Table 5.4 depicts the water intensity for the major sectors of India, shows the expected rise in water consumption for the sectors up till the year 2050. The water demand of the energy sector is expected to grow 3-8 times in the near future due to rapidly increasing demand (Tripathi et al., 2015).

The water dependance of electricity generation is highly fuel and technology dependant. The kind of applied tech defines the water intensity of power generation.

- **Thermal Power Production:** Thermal power units are highly water intensive, not only does the fuel required for the plant require water but the electricity generation from these fuels require large quantities of water as well. A coal powered generation unit requires water in the range of 0.005-0.18 m3/kWh, though with the application of ash pond treatment facility this demand has been reduced from 0.18m3/kWh to 0.15m3/kWh (Pokale, 2012).One MWh of electricity produced from a coal power station typically requires 1,200-2,500 litres of water, where 20-270 litres is required at the fuel extraction and processing stage and 1,200-,2000 additional litres for power production.

- **Nuclear Power Production:** Nuclear power stations utilise water for twofold applications: to convert water to steam to drive turbines and produce electricity and to cool the core of the plant . Water consumption for nuclear power plants is enormous, consuming 13-24 billion litres of water per year or 35-65 million litres of water in a day depending on the scale of the plant. Typically a total of 2,870-3270 litres of water per MWh are required for nuclear power production, where 170-570 litres is required for uranium extraction and processing and the remainder for power production (Tripathi et al., 2015).

- **Renewable Power Production:** In India, wind energy, hydropower, solar energy and energy from biomass are the major energy sources for the renewable energy sector. The water intensity of renewables is highly technology dependant, ranging from negligible to water demand comparable to large scale conventional power. Solar PV and wind energy have negligible water consumption, water usage only during the manufacturing process. Whereas solar thermal plants with wet recirculating cooling technology require 2,200-2,500 litres of water per MWh, for those plants with dry technology for cooling this water demand could be reduced by 90% (Macknick et al., 2011).

  Hydro power is heavily reliant on water for power production. Usually hydro is not a consumer of water only uses water to generate electricity by running water over its turbines yet there is still some consumed due to losses, seepages and evaporation. Water consumed is determined by various factors which are site specific, climate dependant and thus are variable(Torcellini et al., 2003).

Energy from biomass usually depends on technology applied for primary energy source utilisation. Power plants consume water comparable to coal, ranging from 1,800 litres to 3,400 litres for each MWh of electricity generated (Macknick et al., 2011).

As of the 31st of March 2017, out of a total 330,261 MW of intsalled generation capacity, the total installed capacity of thermal power plants in India was 221,626 MW or 67.1% of total capacity. These plants include coal(59.2%),oil(0.3%) and gas(7.6%) powered generation units, Nuclear power comprised of 2.1% which totals to 6,780 MW, Renewables as 17.3% or 57,260 MW and hydro power 13.5% or 44,594 MW (Ministry of Power, Government of India, , 2017) depicted in Figure 5.5. Whereas Figure 5.6 depicts the water intensity of various generation technologies in litres to produce one kilo-watt hour of electrical output. The figure could be used to re-iterate the arguement for improving the water efficiency for the energy sector, as energy sector is one of the largest consumers of water in the Indian market.

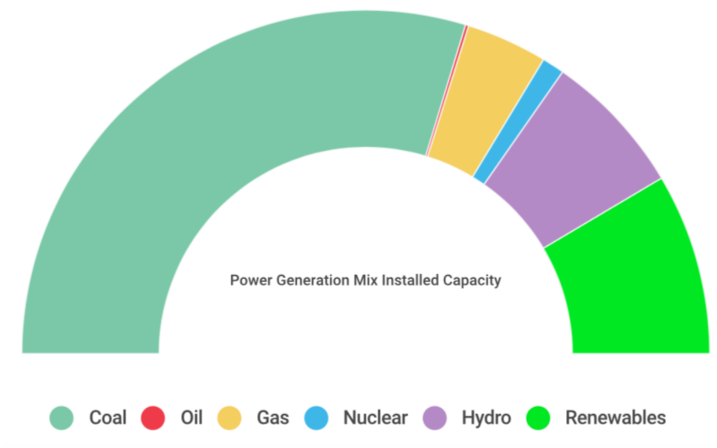

Figure 5.5: Power Generation Capacity Distribution-India

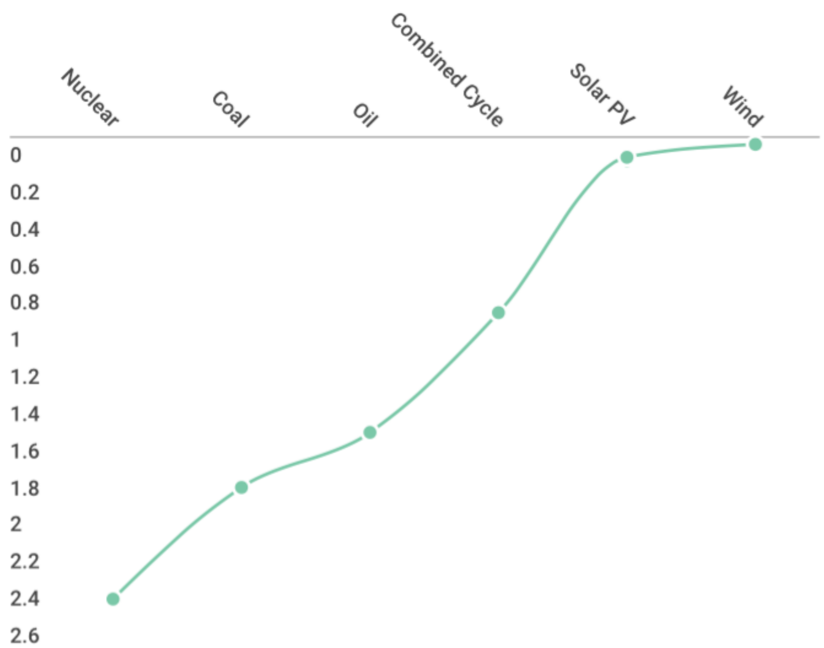

Figure 5.6: Water Consumption for Different Generation Technologies to Obtain kWh Electrical Output (Tripathi et al., 2015)

5.5.2. Water Sector's Energy Dependence

Vice versa energy has always been an integral part of the water sector. Every step of the water supply chain is highly energy intensive, pumping,purification, transportation and distribution, all aspects are heavily dependent on a stable energy supply to keep the sector operational (Hussey and Pittock, 2012).
Municipal water facilities in India consume as much as 12,000 MUs of electricity for water provision Rudra-Narsimha and Sharma (2013). Almost 80% of this electricity is use for transporting water. The entire water supply chain requires energy at each stage. The energy dependence of water supply has been discussed below:

- **Energy for Water Treatment:** Electricity is used to run the equipment such as blowers, centrifuges, UV radiation, fans, ozone generators and mixers.Almost 80% of energy in treatment plants is used for water pumping and the rest is used for treatment processes. Energy costs could account for 15%-40% of total water treatment O&M. (Pabi et al., 2013). The figure below throws some light on th energy usage in water treatment plants.

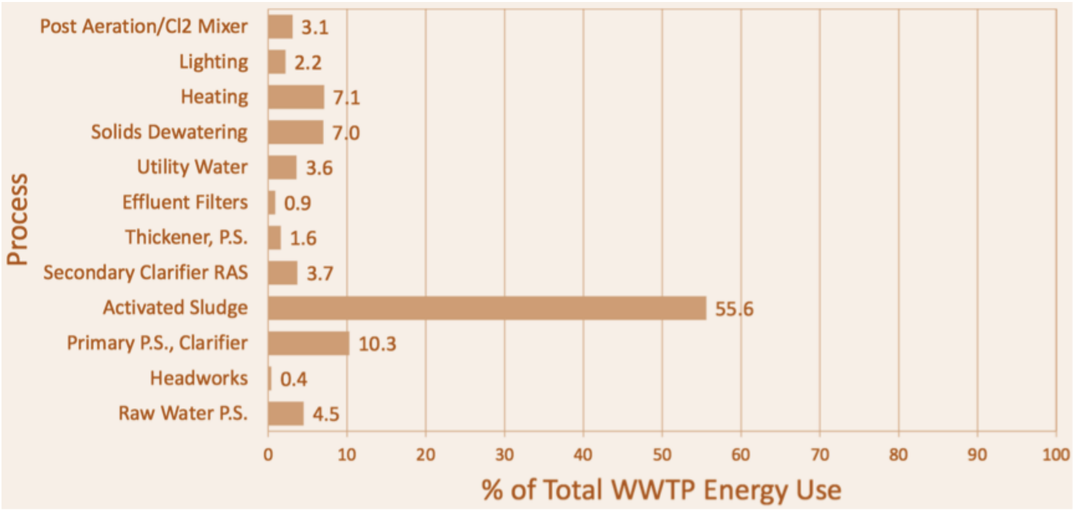

Figure 5.7: Energy Usage Distribution of Water Treatment (Larry, 2012)

- **Water Transportation:** The water system in todays world has a centralised framework. As a result the water supply chain has a source, a treatment unit, a distribution channel and end consumer. For the water system to be continuously running round the clock, high energy intensive pumps are required to transport water to the end consumers. Typically the entire surface water supply chain require 1500 kWh per million gallons of water from water extraction from source to delivery to the end consumer, broken down, 100 kWh per million gallon is required from water conveyance from source, 250 kWh per million gallons is required for treatment and another 1,150 kWh per million gallons for water distribution. Whereas water supply chains with ground water usage require around 1,800 kWh per million gallons (Agency, 2013).

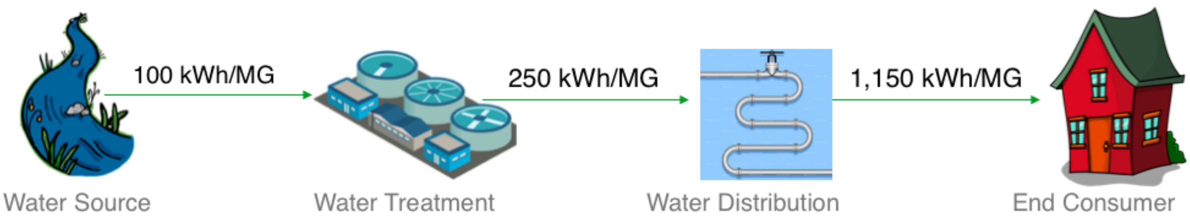

Figure 5.8: Energy Usage for Water Transport

Concluding, the highly synergistic sectors of water and energy sector could be considered as the backbone of the Indian economy.Identifying synergies between the two sectors holds paramount significance to help provide the directions for integrated solutions for the two sectors.

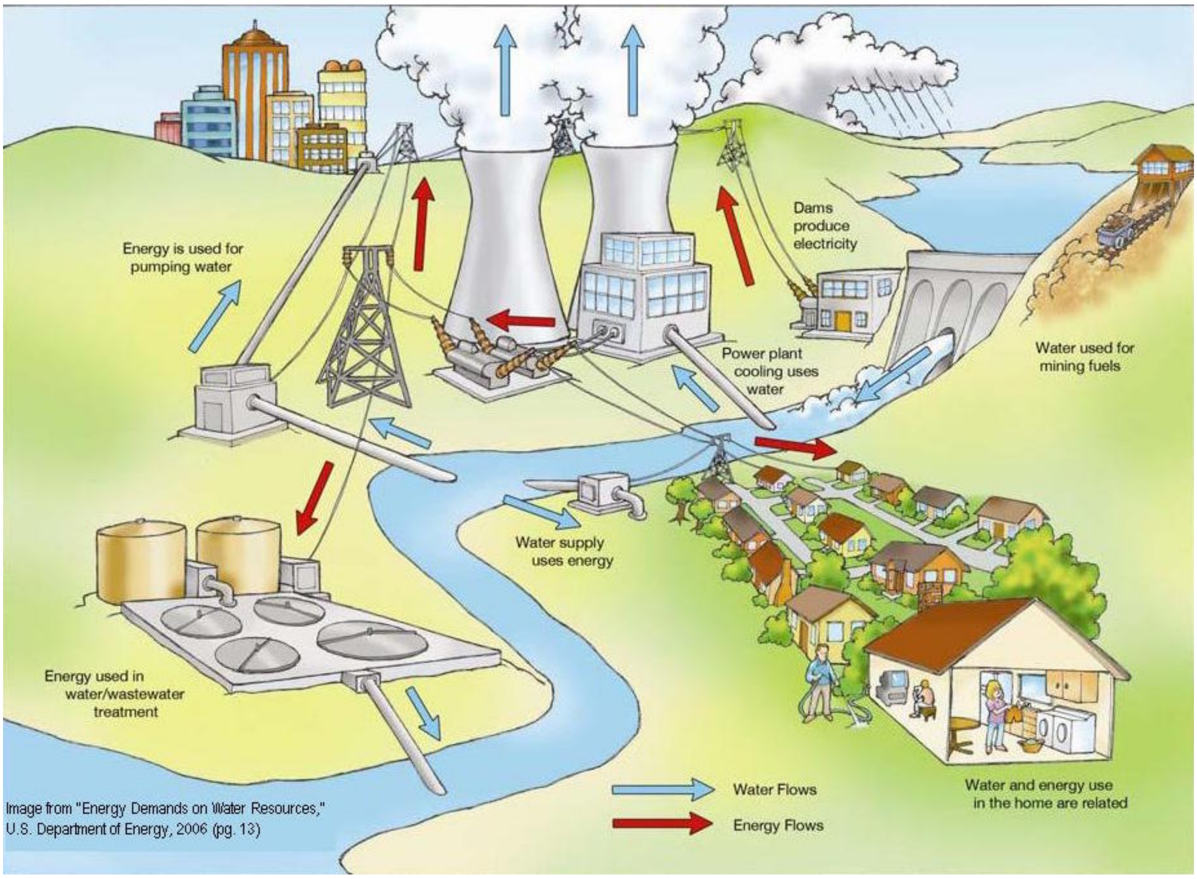

Figure 5.9: Interlinks Between the Water and Energy Sectors

6

Rural India-Waste Sector

Efficient Rural waste management solutions has always been a significant issue for India. With the increase in the amount of waste, both solid and liquid, being produced in rural regions, waste management become one of the key focus of sustainable development policies. Improvement of rural sanitation which is one of the major goals of the government would also involve proper collection, transportation and disposal of rural waste (Unicef, 2006).

The large quantities of rural waste generated in India is not only seen as a threat to the environment but also to public health and cleanliness. Though the waste generated in rural India is predominantly organic and biodegradable, it still affects the stability of the ecological balance. Rural India generates around 0.3-0.4 million metric tons of organic waste every day, a daily average of 312 Mt of crop residue waste from just the ten major crops produced in the country. The rural part of the country is also generating 15,000-18,000 million Liters of liquid waste daily (Moharana, 2012).

6.1. Types of Solid Waste

Solid waste is defined as waste material produced, including both organic and inorganic material which has no value in economic terms to the owner(Moharana, 2012). Rural areas usually generate solid wastes from household activities, agricultural wastes, cattle waste, etc. Based on the biodegradability the waste can be categorized into the following:

- **Biodegradable Waste:** Waste which can be broken down or decomposed naturally through biological processes either in the presence or absence of air. For example food waste, dung, crop residues etc (Unicef, 2006).
- **Non-Biodegradable Waste:** Waste which cannot be decomposed naturally or biologically is termed as non-biodegradable waste (Unicef, 2006). For example plastic waste, metal scraps, etc. Usually non-biodegradable wastes can be categorized as:
  - **Recyclable:** Waste destined for disposal which has no further value for the owner but still has some economic value can be recovered and thus reused. Such wastes are termed as recyclable wastes. For example paper, cloth etc (Moharana, 2012).
  - **Non-Recyclable:** Waste whose recovery does not involve any significant use or economic value is termed as non-recyclable. For example Tetra Packs, carbon paper, Thermocoal etc (Moharana, 2012).

6.2. Problems of Solid Waste Management

The total absence of waste management and administration in rural parts of India has been the main reason of failure of the waste sector. It has led to stockpiling of waste, including large quantities of plastic in and around villages and state highways. These stockpiles have been breeding grounds of diseases and apart from the environmental consequences it has even led to major health drawbacks (Venkatesh, 2013). In the following subsection the reasons which have led to the failure of the sector have and their drawbacks have been discussed based on elemental level failures of the supply chain of the rural waste management sector, which has been depicted by Figure 6.1

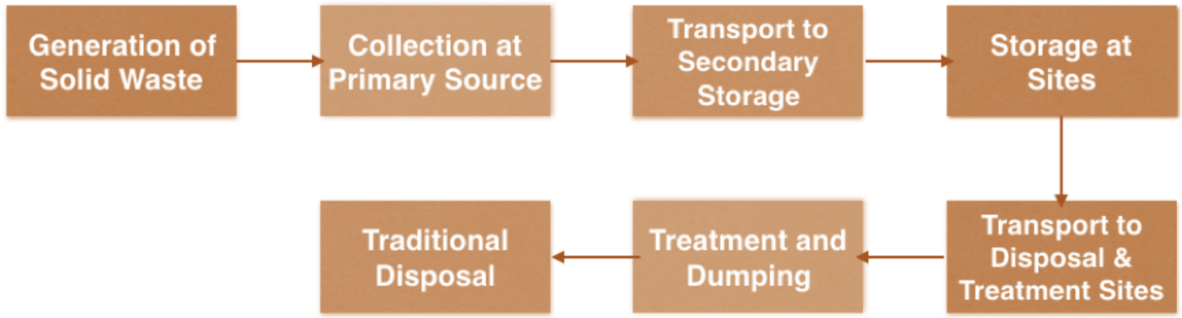

Figure 6.1: Solid Waste Management Supply Chain- Rural India (Kumar and Pandit, 2013)

6.2.1. Problems of Storage of Solid Waste at the Source of Generation

The major problems associated with collection, segregation and storage of rural solid waste at the source of generation have been discussed below (Kumar and Pandit, 2013):

- Majority of the localities or districts lack systematic and scientific storage or collection of solid waste. Usually waste is either not dumped in the alloted locations or segregation is not followed.
- Vacant barren lands are seen as waste sites, vacant streets, lands, drains etc have evolved as primary dumping sites in rural regions.
- The streets being stocked with wastes has led to unhygenic and unsanitary conditions, the municipal provisions for cleaning streets are also not enough.
- No proper garbage bins are usually provided in residential or public spaces.
- Drains passing through the vicinity have been clogged with garbage leading to reduction in draining capabilities thus leading to overflows creating unsanitary conditions.
- The density of municipal waste collection points is not enough as a result civilians prefer dumping garbage the easy way.
- Rainfall over these open disposal sites makes matters worse,spreading the garbage around with a foul smell and clogging water which act as breeding grounds of disease spreading mosquitoes.

6.2.2. Service Provisions for Waste collection at Generation Sites

The major issues observed by administration, service provision and implementation of waste management techniques at primary waste generation sites have been discussed below (Kumar and Pandit, 2013):

- Municipal street cleaners or sweepers usually restrict themselves to just street cleaning that too in an inefficient manner, waste in drains is usually overlooked.
- Door to door waste collection facility provided by the government has proven to be inefficient and thus has to be handled privately. According to the state Municipality act sweepers are supposed to collect household waste going from door to door.
- No initiative is generally taken in community monitoring to make sure the waste is collected in a proper described manner or is brought to its desired point.
- Municipal manpower and resources are not enough to manage the large scale waste generation in these regions, also the improper use and distribution of finances has added to the depth of the issue.

6.2.3. Processing & Recovery of Solid Waste

The following subsection discusses the shortfalls observed in rural India associated to the treatment, processing and thus recovery of solid waste (Kumar and Pandit, 2013):

- Indian states lack established waste recovery and processing units.
- Recycling and thus recovery of waste holding economic value is restricted to small scale business holders, no utility facility has been established for the same.
- Financial Implications of waste recovery and recycling are overlooked, lack of proper awareness about the same has been observed.

Summarizing the issues observed by the solid waste management sector in rural India, the factors leading to impeded performance of the sector have been depicted in Figure 6.2

Figure 6.2: Factors Leading to Failure of Rural Solid Waste Management- Indian Scenario

- **Social:** Social Issues leading to failure of waste management in rural India can be seen as :
  - **Mentality Issue:** The locals living in these regions donot beleive its their duty to their bit in keeping their locality clean, they tend refrain from engagement in proper, hygenic and sanitary waste disposal practices.
  - **Lack of Awareness:** Rural regions lack the awareness amongst the residents about the benefits of proper waste disposal and the consequences of flawed waste disposal practices.
- **Administration:** The issue of administration of waste management in rural regions can be seen as a consequence of improper implementation of policies, Insufficient Practices, Flawed Policies and Financial Issues.
  - **Improper Implementation:** Rural India has observed large scale failures in implementation of waste management practices, this is due to lack of intent and knowledge gap prevalent in the labor of the sector.
  - **Insufficient Practices:** The practices of rural waste management have proven to be insufficient in tackling the gravity of the issue, basic amenities and thus awareness is absent leading to large scale waste disposal issues.
  - **Flawed Policies:** The policies laid forth by the government and municipalities are obsolete and need to be changed, it does not lay the required gravity of stress on recycling and reuse, thus not aiming at making use of the economic value of waste.
  - **Financial Issues:** The municipalities face major financial constraints in relation to resources and manpower, thus not being able to cater to the problem with the intent or force required, the allocation of resources within the sector is also improper.

6.3. Implications of the Failure of Rural Solid Waste Management

With an ever increasing rural population, the generation of municipal solid waste has been on the rise. Not only the failure of waste management cause widespread environmental pollution but also is the cause of widespread illnesses and diseases. Some of the health and environmental hazards caused by the present scenario of waste disposal i rural India have been discussed below:

- Stagnant water in drains clogged by waste disposalact as breeding sites for disease spreading mosquitoes and insects. Mosquitoes in particular have been responsible for spreading malaria and dengue epidemics in the country (Moharana, 2012).

- Decomposing waste usually has bad odor and attracts flies and scavengers, creating a nuisance for the residents. Scavengers are responsible for spreading the waste around thus spreading diseases (Moharana, 2012).
- Agricultural wastes potentially could consist of chemicals and fertilizers leading to deep damage to the environment and soil (Puri et al., 2008).
- Disposal of waste i drains leads not only to pollution of the water body the drain is connected to but also water borne diseases, which in turn could be widespread depending on the dynamic nature of the water body and the population dependence on it (Puri et al., 2008).
- If these rural regions involve industries then the treatment of solid waste holds all the more importance, industrial waste is known to hold cyanides, mercury and polychlorinated biphenyls which are super hazardous not only to help but also to the environment. For example mercury from waste can seep into the ground heavily contaminating ground water, having large scale wide spread health implications. Plastics, especially coloured plastics are known to show the same effects as they contain heavy metals (Puri et al., 2008).
- The health of the personnel providing garbage collection services such as the door to door services are easily exposed to diseases, thus reiterating on the flawed existing practises and policies (Puri et al., 2008).

Figure 6.3: Institutional Structure for Rural Waste Management Sector- India

6.4. Energy-Waste Inter-relations

India a country grappling with the environmental affects of waste disposal could see energy recovery from waste as a potential stratergy to curb the environmental damage through landfills. Waste and energy are highly interlinked phenomenas and thus it is important to find these synergies for mutual benefits to both the sectors.

Waste to energy is technique working on the principal of energy recovery. Involving primary treatment of waste to generate energy in either of the forms, electricity or heat. This process is carried out either through direct combustion of waste or by coversion to useful combustible fuel first. This process can potentially lead to reductions in community landfills by upto 90% and save major carbon dioxide emissions into the atmosphere. For every 1000 kilograms of waste incinerated, 1000 kilograms of carbon dioxide release is potentially curbed along with the methane which is released in landfills (Deltaway Energy, 2017). The potentials of Biogas generation from rural waste in India has been depicted by Figure 6.4

- **Rural Municipal Solid Waste:** Municipal solid waste consists of both organic and inorganic components. However, post segregation the inorganic components can be recycled and the organic fractions digested to produce biogas. On average, for small towns and rural regions the compostable matter in India is in the order of 56% of the entire waste generated. Biogas generation capabilities of organic solid waste are 95m3/t. (Rao et al., 2010).Rural India generates about 0.5-0.6 million tons of municipal solid waste everyday, 0.3-0.4 million tons of which is organic and compostable (Moharana, 2012). 3Mm3/day is the potential of generating biogas from rural solid waste per day.

- **Agricultural Waste:** India is an agrarian country, the agricultural sector produces large amounts of organic compostable waste everyday. Traditionally farmers dispose agricultural waste by burning it or dumping in fields to serve as manure. The collected crop residue and agricultural waste is also used as fodder for domestic and farm animals. The remainder of the waste could be used for bio energy and is in the order of 278.71Mt/day, having a biogas generation potential of 46Mm3/day (Rao et al., 2010).

Figure 6.4: Daily Biogas Production Potential from Various Rural Waste in Inida (Mm3/day)(Rao et al., 2010)

- **Animal Manure:** India is home to one of the largest deomsticated livestock populations in the world, 300 million livestock animals (cows, buffaloes,calves and bulls) were existent in the country till the beginning of this decade, out of which 224 million were cattle and 97 were buffaloes (Ravindranath et al., 2005). Dung generation and then biogas generation depends on animal type and sex of the animal. Though cattle in India are used for rural transport as well as in farmlands to carry out agricultural operations, thus dung collection is only possible from livestock sheds. The annual dung production is projected at 659 Mt annually and the recoverable quantity for biogas production is 510Mt. Biogas production potential from animal dung in India at the beginning of the decade was projected at 17,850 Mm3 annually or 49Mm3/day (Rao et al., 2010).

- **Waste Water:** Waste water could also be used for biogas production. Waste water involves large quantities of organic compostible matter usually in the form of excreta. Waste water sludge could be anaerobically digested to produce biogas. Apart from biogas production the digested sludge could also be used as manure for the farmlands (Gupta, 1988).

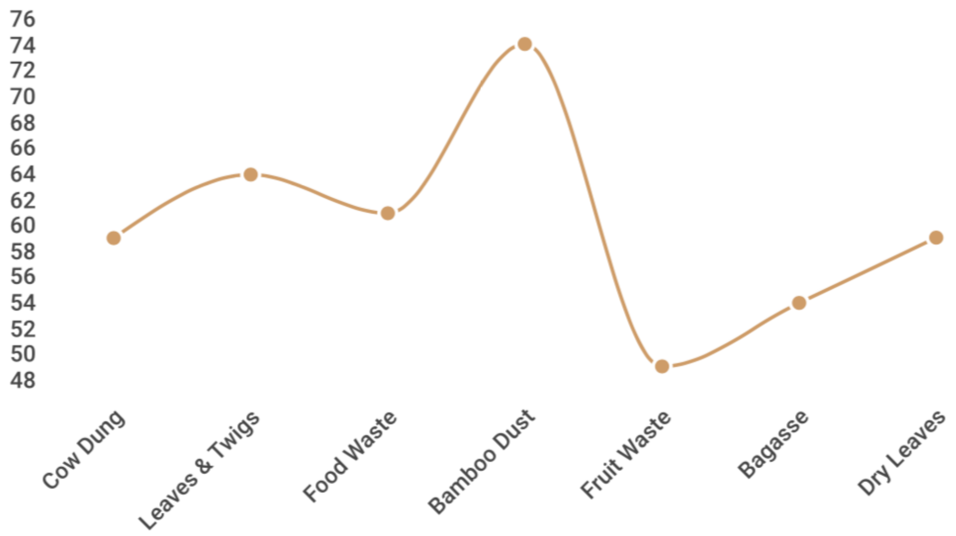

Figure 6.5: Methane content for Various Rural Wastes (Gupta, 1988)

Biogas primarily is composed of Methane, carbon dioxide and small quantities of hydrogen sulphide and water vapour.It is methane out of the contents which can be burnt with the provision and air and oxygen. Methane content for biogas produced from different rural organic waste has been depicted in Figure 6.5 Biogas also prevents the release of methane into the atmosphere which has a much higher global warming potential than CO2, on combustion methane is turned to CO2 and water vapour (Venkateswara and Baral, 2013). The methane content of biogas varies with the primary source of biomass which can be easily observed in figure **??**. Biogas with 50%-60% methane content has an energy yield of 6kWh/m3 Reklambyra and Malmo (2007).

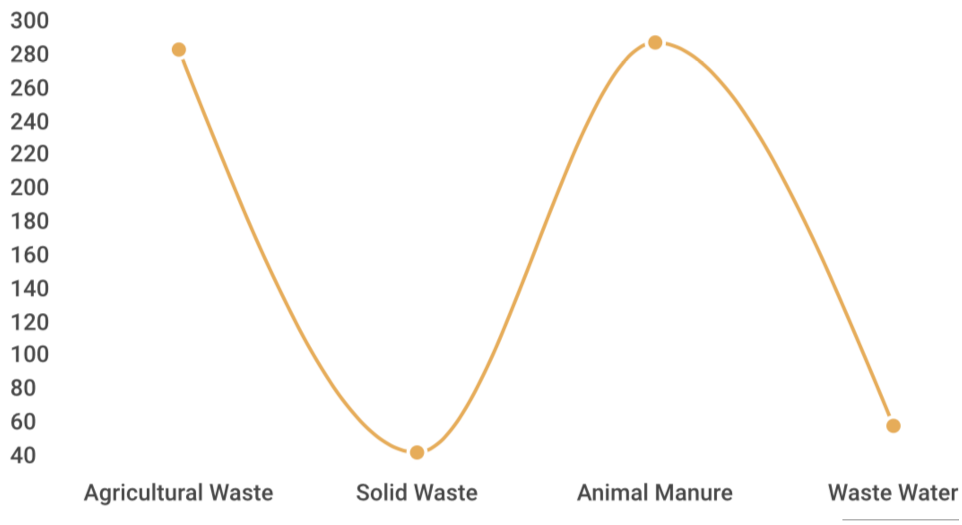

Figure 6.6: Potential Energy from Biogas produced from Rural Waste (MkWh/day)

7

Distributed Generation as an Alternative to Electrification

With the ever-increasing energy demand and depletion of conventional sources of energy we are forced to turn to sustainable and more renewable sources of energy to satisfy this globally growing hunger for power. With a large-scale issue of impeded electricity supply through the central grid, the government of India aims at decentralized integration of renewables as an alternative to grid electrification to improve the reliability of the power system (Aggarwal and Alison, 2014).

7.1. Distributed Generation

The reaction to the maturing, wasteful power systems has been an ascent in dispersed or distributed energy generation. Dispersed Energy is the usage of smaller energy generation and storage frameworks used to power homes, organizations and communities. Most dispersed energy frameworks exploit renewable sources, for example, sun based, wind, and hydro.

Decentralization is dispersed production of power. The energy is produced close to the locality of use. Decentralization helps enhance unwavering quality and security of supply through utilizing a mix of energy sources. It would enhance energy efficiency thus bringing down the national carbon impression through a decrease in transportation and production losses. It would likewise make plant ventures less risky in light of the fact that decentralized systems have a tendency to be smaller and less modular (Lovins, 2005). Decen-

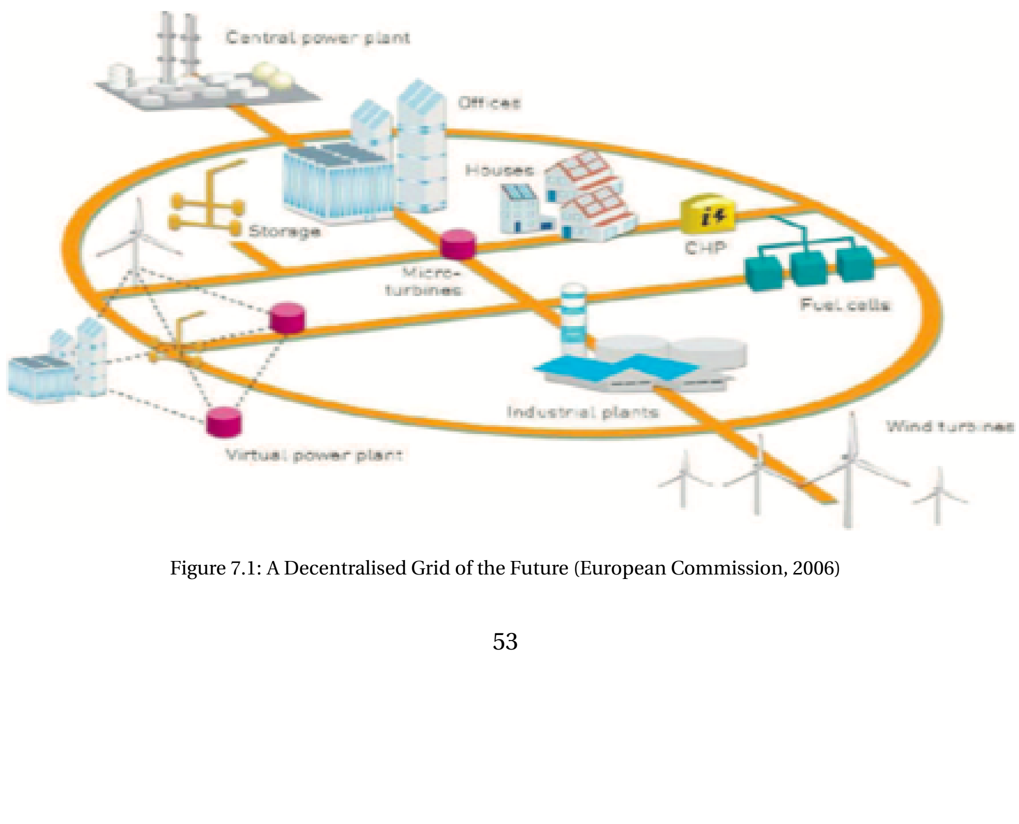

Figure 7.1: A Decentralised Grid of the Future (European Commission, 2006)

tralized frameworks (depicted by Figure 7.1) are less sensitive to unsettling influences in the power network when contrasted with centralised systems and thus have manifold advantages:

- **Improved Efficiency:** Decentralized frameworks are additionally more efficient than centralised power networks in light of the fact that as power streams through an electrical cable, a portion of it is lost to different variables. The larger the separation from the production site the more noteworthy the loss (Davidson, 2009). Savings that are acknowledged by having shorter transmission lines could be utilized to introduce the renewable energy sources near homes and businesses. The reduction of transmission expenses and the improvement in efficiency would bring about lower power utilization in general.

- **Improved Energy Security:** At present, the central power grid is dependant on fossil fuels for power. These fossils are usually imported from fuel rich countries, thus compromising the energy security factor of the importing country. Those who import these resources are at the mercy of the producing nations as well as of the transit countries. Decentralisation reduces the amount of grid electricity required thus allowing the local communities to produce their own energy locally. This aids in improving the energy security of the region, as any disturbances in the energy supply chain would have lesser profound effects in a dispersed energy scenario as compared to a centralised grid (Bouffard and Kirschen, 2008) Security advantages of decentralized frameworks are tremendous, as a result of the redundancies in supply. These redundancies are required if the central grid gets to be distinctly inoperable because of a cataclysmic event. Communities or individual houses can then depend on microgrids with disseminated power production for their energy supply. Besides, having a dispersed power frameworks and lesser dependence on long-scale transmission lines decreases potential targets for terrorist assaults. Fewer individuals would then be affected by resulting power blackouts. Moreover, decentralized power diminishes the impediments to fiasco recuperation by permitting the concentration to move first to basic framework and after that to stream outward to less coordinated outlets (Warner, 2011).

- **Improved Reliability:** The following reliability benefits can arise by application of distributed energy systems-

  - **Increased power quality:** As the intricacy of today's innovation expands, so does the affectability of a centralised grid to voltage variances. These changes can bring about expensive shutdowns. Integration of decentralised micro grid systems improves power quality by reducing the fluctuations and variances in voltage. It is a source of stabilised power supply providing stable voltage as well as in centralised systems voltage and frequency fluctuations are usually due to impedances in management of power flows, which is comparatively easier in decentralised systems (Virginia Polytechnic, 2007)

  - **Increased power quality:** As the intricacy of today's innovation expands, so does the affectability of a centralised grid to voltage variances. These changes can bring about expensive shutdowns. Integration of decentralised micro grid systems improves power quality by reducing the fluctuations and variances in voltage. It is a source of stabilised power supply providing stable voltage as well as in centralised systems voltage and frequency fluctuations are usually due to impedances in management of power flows, which is comparatively easier in decentralised systems (Virginia Polytechnic, 2007)

  - **Reduced vulnerability:** A centralised power framework in view of broad T&D is vulnerable against human and natural dangers. A particular danger to power systems is outrageous climate. Integrated distributed energy systems reduce the vulnerability of the energy system users to the effects of natural disasters, which might take the central grid out of action. It is presently normally perceived that a more distributed energy generation framework makes differing qualities, bringing about a more powerful and dependable power framework (for Decentralised Energy, 2017).

  - **Flexibility:** Decentralised generation provide more flexibility in the power supply and demand. As the networks become more decentralised they are becoming highly interactive and smart. There is better communication within the elements of the micro-grid framework. This provides for options of load shifting and demand side management. Decentralised systems also provide flexibility when it comes to energy use, if the renewable micro-grid is falling short to meet the demand the shortfall can be met from electricity from the main central grid, also if the micro grid produces more than the demand the excess can be exported to the grid, thus integrating dispersed energy systems into the main central grid provides flexibility to the users and thus improves the reliability of operation (Bouffard and Kirschen, 2008).

Figure 7.2: Advantages of Distributed Generation

Better integration of Distributed Generation can be better achieved through an involvement and evolution of active management. Which is Described as follows (European Commission, 2006):

- **Initial Stage:** Expansion of Dispersed Generation and Renewable Energy Systems remote control to encourage more prominent association action. A few associations will depend on two-sided contracts with circulated generators for auxiliary administrations. Standards should be characterized to layout physical and geological limits of contracting.

- **Intermediate Stage:** An administration equipped for pleasing noteworthy measures of DG and RES must be characterized: nearby and worldwide administrations and trading issues, versatility without data over-burden.

- **Final Stage:** The final stage would be inculcating a completely dynamic power administration mechanism. A circulation administration utilizing constant real time correspondence and remote control to meet most of the system administration's necessity. With the transmission and distribution frameworks both being dynamic, with blended and on-going interface control capabilities and efficient power flows.

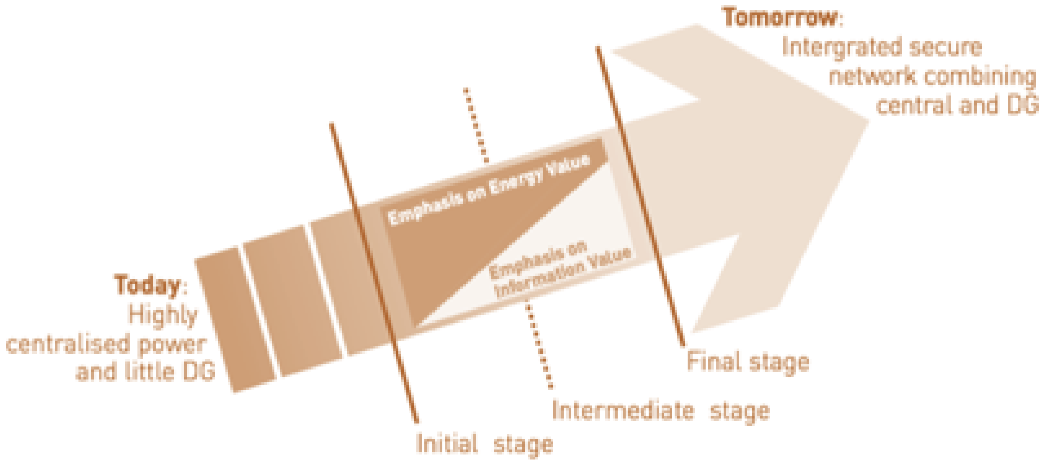

Figure 7.3: Stages to successfully integrated DG Systems (European Commission, 2006)

As mentioned above, for decentralisation to have a positive impact on the grid improvement and stabilisation process, a highly bidirectional yet interactive system is to be applied, which is the ultimate goal. Such systems are made possible when the local micro-grids are 'smart'. There are two types of decentralised micro-grids:

- **Grid Connected:** The local micro-grid is connected to the central grid. Allowing exchange of energy and information between the main power framework and the local micro-grid. When demand of locality is more than the supply of the decentralised production the remainder can be satisfied using power from the grid and when lower then the excess power can be sold back to the grid (Koirala et al., 2016).
- **Grid Defected:** Grid defected micro grids are stand alone systems. The localities energy needs are satisfied by the locally produced energy itself. Reliability is compromised in the sense that, during any break down the grid is shut down and the local micro-grid is the only source of electricity (Koirala et al., 2016).

Completely dispersed power supply or grid defected micro-grid systems, at present are not conceivable or even really alluring. The safe and clean energy frameworks without bounds will be those which are sufficiently adaptable and are able to bring to the table efficient hybrid modes of operation between the central grid and local micro-grid in other words grid connected micro-grids. A huge piece of this adaptability will originate from the systems that make it conceivable to join these two sorts of foundations and acquire the advantages of both methodologies (Bouffard and Kirschen, 2008). Such high levels of advancement with higher component interaction, improved reliability and higher efficiency would be achievable when the central grid is a smarter more interactive framework. "A smart grid is defined as the electricity networks that intelligently integrate generators and consumers to efficiently deliver electricity which is sufficient capacity and coverage area which is accessible, safe, economic, reliable, efficient, and sustainable" (W., 2011). Smart grids are highly interactive electricity networks with high level of communication between the components of the grid thus improving the overall operational efficiency of the power system leading to overall savings in fuel and costs.

The following are the benefits associated with application of smart grids (Phuangpornpitak and Tia, 2013)

- To start with, empowering renewable energy assets to suit higher infiltration with financial effectiveness, while enhancing power quality, grid stability and reliability.
- Second, a highly dynamic role of customers in the power framework; System observes higher savings which are accomplished by diminishing demand peaks and thus enhancing system proficiency, and in addition cutting green house gas emanations. In other terms high integration of demand response.
- Lastly, reduction in marginal operation costs by voltage regulation and optimal power flow.

Grids of the future look at achieving high levels of integration of local micro grids with the centralised grid for hybridised operation between the both. Thus it is expected that an overall smarter central grid will make integration of decentralised micro-grids more alluring or profitable.

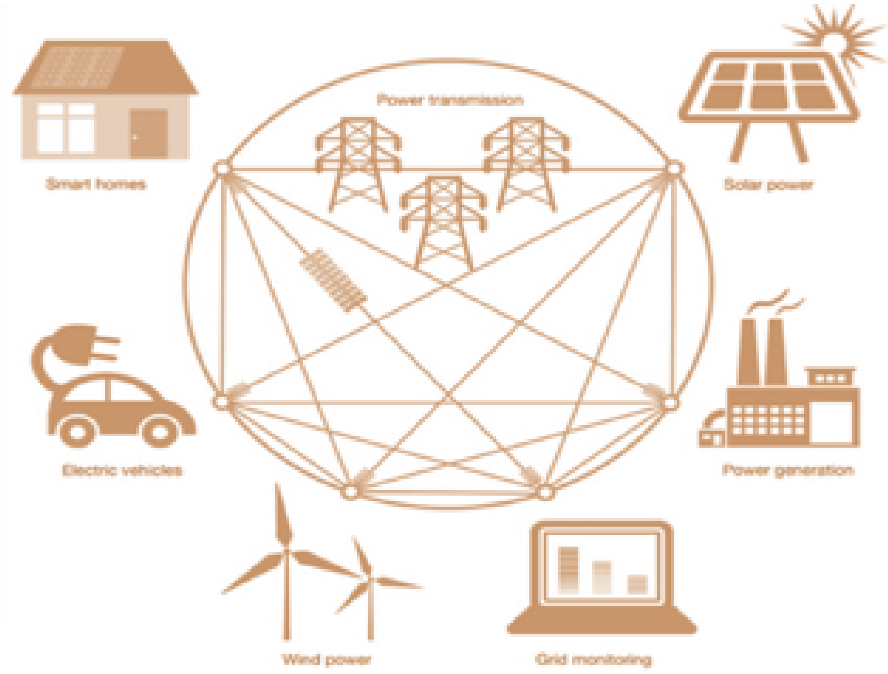

Figure 7.4: Smart Grid Layout

The following are the value chains associated with the grids of the future (Michael and T., 2015):

- **Demand Response:** Load control, balancing and shifting in a micro-grid framework to ease the load on the supply. Central utility controls the demand, over all incentive is to control consumption and thus easing the operational demand of the central framework.
- **Electricity Export:** Excess electricity produced within the micro-grid can be exported to the main grid thus stabilising the operation of the main grid as well. The electricity sold back to the main grid depends upon agreements made with the utility.
- **Blackout Resiliency:** Higher reliability due to redundancy created by onsite generation and energy storage. Also serves as back up power to satisfy demand in the period of outages.
- **Local Energy Markets:** Expected emergence of local energy markets with interactive micro-grids. Possible when large numbers of decentralised micro grids are connected to the grid. This would provide added benefits to micro-grid owners and make decentralised micro-grids alluring.

The following two are the most accepted decentralised energy solutions:
Solar Home Systems
Microgrids

7.2. Solar Home Systems

Solar home systems are distributed renewable energy frameworks, which are used in rural India to provide lighting solutions. These SHS are independent power frameworks that incorporate an arrangement of sunlight based PV modules, battery storage unit, a battery management system, a discretionary and different end-use hardware, for example, fluorescent lighting (Martinot et al., 2001). Because sun based PV modules produce DC power, the end-utilize equipment is constrained to DC apparatuses, for example, lights, unless an inverter is incorporated into the setup (Chaurey and Kandpal, 2010). In the 1990s, the World Bank recognized SHS as the most cost effective solution for the issue of rural elecrtification and upheld numerous SHS programs in the developing nations. In India, by 2012, there were 500,000 SHS and 700,000 sun powered lamps dispersed over the country (Raman et al., 2012).

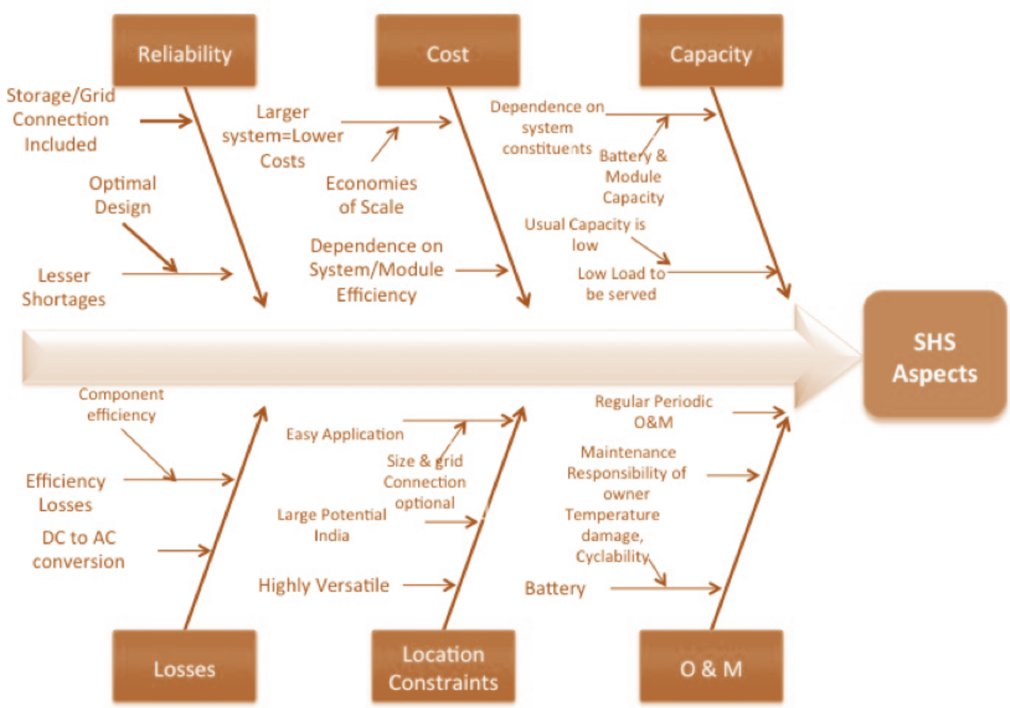

Figure 7.5: Aspects Associated to Solar Home Systems

- **Reliability:** SHS are designed to serve pre defined loads as the SHS are applied according to the loads of the households, as the incoming solar irradiation does not experience much variations the SHS are not expected to experience many power shortages (Chaurey and Kandpal, 2010). Moreover, to guarantee that the load does not surpass the supply limit, consumers must have a basic idea of the operation of the SHS and the capacity limits involved, this would help maintain reliability of operation (Gustavsson and Ellegård, 2004). Sub optimal operation and maintenance of the systems has a drastic impact on the reliability of the system especially affecting the battery storage unit.

- **Costs:** Installation costs depend on the SHS to be deployed, varying with the kind and rated power of the PV modules considered and consideration of storage units. Smaller SHS capable of powering a few basic household devices typically cost around Rs 45,000 whereas larger systems with rated capacities of around1kWh typically cost around Rs. 120,000 to Rs 180,000 (Aggarwal and Alison, 2014). Costs of generation of SHS are usually around Rs.37/kWh. The generation costs of the system depend majorly on the efficiency of the modules and the storage unit, larger SHS typically have higher efficiencies thus lower generation costs(Chaurey and Kandpal, 2010).

- **Capacity:** The capacity of a SHS framework is controlled by both the of the rated capacity of the PV modules and in addition the battery storage unit (Gustavsson and Ellegård, 2004). SHS ordinarily just bolster little loads, for example, a few family unit lights, a fan, and an outlet for charging cell phones. Including PV panels or obtaining a battery with a larger capacity can expand the framework's ability. Usually, the capacity of a common SHS is low, around 100 watts, so there is constrained capacity burdens to the framework or to deal with changing associated loads (**?**), what's more, SHS produces DC power, so ordinary frameworks might have the capacity to bolster DC-perfect machines, which are less-broadly accessible and more expensive (Chaurey and Kandpal, 2010). Installing an inverter to the framework can permit them to use regular AC-run apparatuses; nonetheless, as inverters are very costly, this is probably fundamentally going to drive up the expenses of system.

- **Losses:** SHS generate DC power thus usually losses occur from system component in-efficiencies such as DC to AC conversion using an inverter. Mentioned before, smaller systems have lower efficiencies compared to systems with larger components, this is why microgrids usually have higher efficiencies than SHS (Chaurey and Kandpal, 2010).

- **Location Based Constraints:** SHS display high levels of versatility among the considered alternatives. India, as a country receives ample amount of sunlight all over the country and thus huge potentials for solar electricity generation. Since the SHS do not need to be connected to any distribution network or infrastructures, the application of SHS is easier and less cumbersome (Wadia and Deorah, 2015)

- **Operation and Maintenance:** In spite of the fact that the setup of SHS is basic, the frameworks still regularly require legitimate operations and maintenance to be financially efficient. While low-quality PV modules are damage easily, Industrial grade PV solar modules are durable and don't require much maintenance. Be that as it may, the battery has a tendency to lose its storing capacity both because of ecological elements and operational elements and should be supplanted each 3–5 years (Raman et al., 2012). The majority of the natural factors identify with the temperature, in the sense that higher temperatures diminish the life expectancy of a battery. As to the operational elements, low and variable charge currents and deep discharge cycles of batteries without appropriate charging of the battery will diminish its lifespan (Gustavsson and Ellegård, 2004).To help address these operational elements, a battery management system (BMS) can help confine the battery charge within safe limits, thus avert over-charging or discharging of the battery. A BMS can naturally disengage the battery from the PV framework when the current accessible is higher than the higher limit of the charging current (Gustavsson and Ellegård, 2004). As for SHS,the owner of the household to which the SHS is applied is the sole owner of the system and thus is also in charge of its maintenance and operation, thus providing maintenance heavily depends on the location of the household, as the more remote the household with the SHS is the harder it is for technical support to access and thus provide maintenance services (Chaurey and Kandpal, 2010)

7.3. Decentralised Renewable Micro grids

The term micro-grid alludes to a solitary electric power subsystem connected to few appropriated generators that can be controlled by either renewable or conventional energy sources, alongside various load clusters (Mariam et al., April 2013). The key component of micro-grids is that they can work independently off the centralised electricity framework. This can help enhance the power quality and reliability. In addition micro-grids provide more energy security to the local community and thus more control of the power framework (Lasseter, 2007). Even if the applied micro-grid is tied to the central grid for back up the community would still hold majority of control of the entire system. The essential micro-grid design involves the accompanying parts: Distributed energy resources, a storage framework (discretionary), a distribution framework or network, and a correspondence and control system (Mariam et al., April 2013). The primary criteria for recognizing various types of micro-grids are: (a) In regard to its connection with a central grid; and (b) what sorts of energy sources are associated with the micro-grid (Lasseter, 2007). Figure 7.6 depicts various aspects associated to micro-grids in an Indian Rural context.

- **Reliability:** Micro-grids are usually powered by renewable resources and thus suffer from some reliability issues associated to the intermittency of the renewable source availability. Some micro-grids could also face voltage imbalances and flickering (Lasseter, 2007). Though compared to SHS micro-grids have higher reliability due to the fact of better quality of components used. Incorporating a battery storage system can further improve the power quality of micro-grids. Storage units can balance the variations in energy generation or demand to help maintain the reliability and availability of the energy system. Since the battery units are usually expensive in the Indian context due to the limitations in ability to pay of the general population the micro-grids could either be grid connected or backed up with diesel gensets in case of battery application issues (Mariam et al., April 2013).

- **Costs:** In the case of microgrids, typically costs of production are in the range of 23 to 33 Rs/kWh based on the generation technology used in the micro-grid, monthly operation costs range from Rs 100 to Rs 200 (Aggarwal and Alison, 2014). As the learning curve of the renewable technologies advances and economy of scales starts playing a part the prices fall thus making micro-grids more economically feasible. While comparing stand-alone micro-grids to grid extension it is believed that micro-grids become a more viable solution when the project location is close to 17 kms away from the central grid.

Thus micro-grids are considered to be a more viable option as the distance from the grid increases (Nouni and Malik, 2009)

- **Losses:** Micro-grids eliminate the need of extension of long transmission lines thus also eliminating the transmission and distribution losses associated with flow through longer cables. Micro-grids are also more easily deployed in remote villages as compared to the grid (Chaurey and Kandpal, 2010). In turn micro-grids have comparatively lower investment costs and time of construction due to the simpler infrastructure involved with the system in turn reducing the risks involved with the investment.

- **Geographic Constraints:** Usually micro-grids are highly flexible in their application when the geographic constraints come into play, those based on hydropower show high levels of geographic dependency though. Micro-grids have proven to be easier in installation especially in remote locations or hilly or forested regions (Nouni and Malik, 2009). Since micro-grids show large flexibility in the type of generating technologies, which can be employed, they usually are not highly constrained by geographic conditions.

- **Operation and Maintenance**: The maintenance of micro-grids highly depends on the type of generation technology employed. For example solar PV modules are highly robust and do not require much of maintenance apart from some dust cleaning, whereas batteries require operation and maintenance work. Wind turbines consist of a lot of moving parts and thus experience fatigue and other part failures requiring large amount of maintenance. Micro-hydro turbines are highly robust again and do not require much of maintenance (Nouni et al., 2006). Biomass gasification though on the other hand requires maximum maintenance especially with the involvement of an engine as the gasification process leaves behind residue, which requires constant cleaning Buragohain et al. (2010).

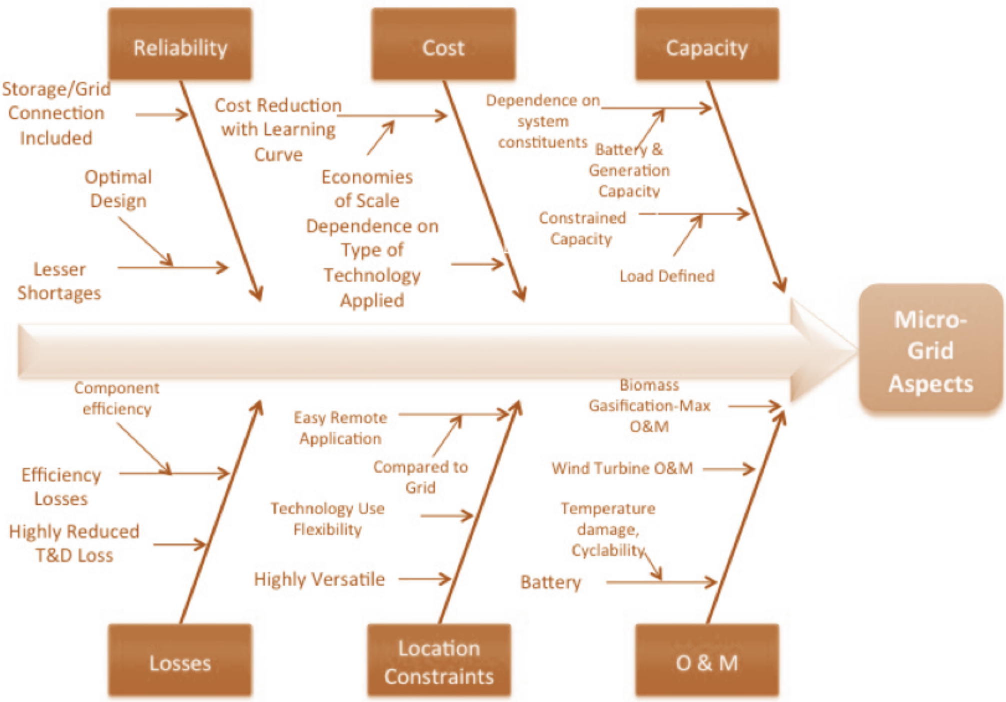

Figure 7.6: Aspects Associated to Micro-Grids

The following table compares various aspects of the three possible electrification scenarios for the Indian rural sector:

Characteristic	Grid Extension	Solar Home Systems	Microgrids
Reliability/ Power Quality	Low reliability, especially for rural areas that are not considered profitable because of low demand	Reliable power quality as long as the load is within the system's initial capacity. Low-quality end-use appliances, replacement parts, and lack of standards may negatively affect reliability of system overall	End-use appliances and replacement parts overall more reliable than those for SHS. Varies, though coupling generation sources and including energy storage device can improve power quality
Cost of Generation for Producers	For remote rural villages, can range from Rs. 3.18/kWh to Rs. 231/kWh, high range is mostly due to varying distances from central grid	About Rs. 37/kWh	Around Rs.23 to 33/kWh (varies by generation source, e.g., micro-hydro, biomass, solar PV, wind-solar)
Geographic- or Location-Based Constraints	Cost for supplier increases for more remote villages, difficult to extend power lines across hilly or forested areas	Most appropriate in areas with high levels of solar irradiation	Generation sources may depend on location, but microgrid location itself is flexible
O&M	Low O&M capacity, often takes days for the State distribution companies to fix a problem	Easy installation and relatively low amount of maintenance needed with proper battery use	Varies from low (solar PV) to high (biomass)
Price of Electricity for Consumers	Usually estimated to be Rs. 3/kWh, though this varies greatly by customer category; monthly costs increase with extent of usage	High per kWh costs; total upfront cost about Rs. 45,000 for a small home system	High per kWh cost, but typical weekly/monthly rates are of the order of Rs. 100 to 200/month
Load/Capacity	Unlimited capacity, although there is often load shedding during times of peak demand	Limited capacity; small loads only (e.g., lighting, cell phone charging).	Limited capacity but greater than that of SHS; currently most microgrids are limited to small loads
Losses	About 23.97% in 2012	Losses exhibited are based on inefficiencies of the components within the SHS (e.g. battery and inverter)	Overall fewer losses than with SHS; losses exhibited are still based on inefficiencies of the components within the microgrid; losses can also take place in distribution infrastructure of electricity
Generation Sources	Varies, e.g. nuclear, renewable sources, coal, gas, oil, hydro, etc.	Solar	Determined by local DG resources (e.g. micro-hydro, biomass, solar, wind)

Figure 7.7: : Comparison of Different Rural Electrification Alternatives Available . This caption will be on the right

8

Case Study Methodology

In the following section of the thesis integrated multi-purpose energy prospects for rural development are reflected over and analysed from a theoretical perspective, to help the reader understand the broadness of the aspects associated to such integrated solution directions better. The aim is to help the reader understand the complexity of the issues that lie in front of us. The approach intended to be used to provide solution directions for augmented rural development in India will be based on high levels of integration: technical, economic, social, sectoral, institutional, political and cultural integration are all to be a part of the directions. The herculean task of attaining rural development in India involves coordination between various elements on a national as well as local level, as a result it is legitimate to consider the entire structure of institutions involved as well as the local prospects.

In other terms rural development in India can be seen as a complex problem with large number of interacting elements.These elements have interactions on a micro as well as macro scale giving rise to new emergent levels of different scales which are continually evolving. Thus, two separate approaches are to be applied for the same. The first case study applies the integrative approach for multi-purpose energy systems in a micro manner or a Bottom-Up case approach and the second case analyses the approach in a Top-Down manner from a national perspective based on interviews of experts from government institutions and policy makers. The second case study aims at identifying aspects of the approach in context to the India as a whole while essentially marking out the barriers to implementation, hence forth providing some possible solutions to those barriers.

8.1. Bottom-Up-Top-Down

The approach followed for the purpose of both the case studies has been given a combined terminology of 'Bottom-Up-Top-Down'. This is done to get a perspective of the solution directions from experts and stakeholders as well as a potential prospective of integratibility of sectors in rural India by applying the integrative approach based on I-neffs and E-nabes to a real rural case in India. For such integrative considerations it is important to consider a methodology encapsulating both a Bottom-Up approach as well as a Top-Down approach to show the true essence of integration. The Bottom-Up approach is useful in pointing out the scale of integration possibilities while showing the broadness of sectors available to be integrated in the Indian scenario, whereas the Top-Down approach needs to be carried out to identify the existent knowledge gaps prevalent in India in terms of Integration with an energy focus. Though the non-versatility of Bottom-Up case will be taken into consideration, as the local dynamics of integration would change with the change in local problems due to the changes in geographical locations, weather, availability of resources as well as operating sectors it is considered essential to carry out a Bottom-Up study as Top-Down approach applied alone leads to loss of information and knowledge on many fronts. It is also essential to point out the essence of integration to the policy maker and that of associated concepts before conducting a Top-Down methodology. A Top-Down approach is essential due to the broadness of the problem on hand. As discussed in previous sections rural development can be viewed as wicked problems, thus a major associated aspect being interaction of associated elements on many levels and scales. Decisions of institutions and policy makers at the central government would have local effects in many seen and unseen ways, thus it is considered essential to first mark out the barriers to integration and lay out some possible solutions to these barriers from the Top-Down perspective or from a perspective of the influencing decision makers.

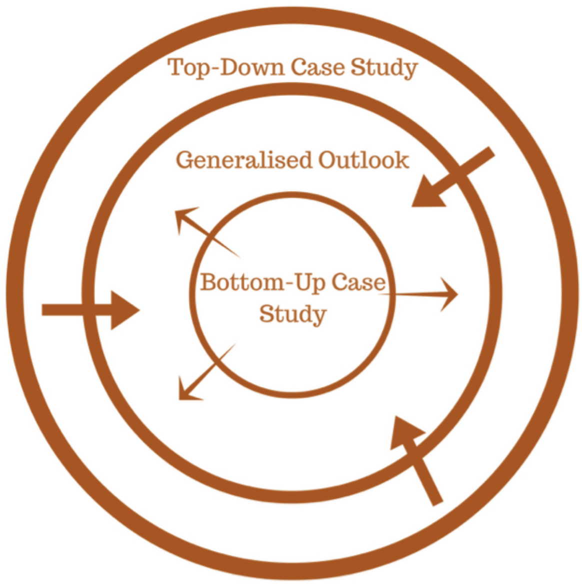

Figure 8.1: Schematic Representation of Considered Approach

8.2. Bottom-Up

The following section gives an introduction to Bottom-Up approach, introducing the advantages and disadvantages. As approach based on the Bottom-Up approach has been applied in the case study of chapter 9.

Bottom-Up approach is a methodology where process progression happens from micro elements upwards or outwards towards a macro or broader prospect. The bottom up approach recognizes the prospects obtained from actual ground work. "At the macro-implementation level, centrally located actors devise a government program; at the micro-implementation level local organisations react to the macro-level plans, develop their own programs and implement them"(Berman, 1978). As opposed to top-down theorists, bottom up theorists recognize the way that implementation on the smaller scale is carried out and opinions are framed giving the implementation a chance to adjust to local conditions. Bottom up theorists perceive that those involved with actual implementation and operation of a project have a better understanding of local conditions opposed to the superior policy makers. "If local implementation is not given the freedom to adapt the program to local conditions it is likely to fail " (Palumbo et al., 1984). Bottom up theorists are condemned for the over-valuation of the level of local independence and importance of practicality as the execution couldn't work without the assets, resources and institutional structure provided by the focal organizers. Finances and human resources may have an incredible effect on the local implementation as it can make it more proficient (Matland, 1995).

For the purpose of this thesis, a Bottom-Up approach has been applied in an unconventional manner to get an implementation point of view, Bottom-Up approach here would help view the integration prospects from a grass-root level.Throwing a critical light on the scale of integration possibilities for rural locations.

There are some advantages associated with looking at implementation of the solution directions considered for the purpose of this thesis from a bottom up point of view. These advantages help us reiterate the importance of the 'Bottom-Up' part of the methodology ,which have been stated below:

- The potential can be viewed from a critical point of view.
- With integrated systems, if the combined functions of low level modules are driven by other modules, it is legit enough to look at the prospects of the lower level module in a localised manner.

- Experiences from local case studies can lead to knowledge development; provides directions for future research to resolve shortfalls associated with the approach.

- From a macro point of view for policy makers, implementation of technology at a localised highly practical level could provide directions for policy improvement, through identification of dynamics of operations of technology, in our case integrated systems.

Prevalence of certain drawbacks associated to a bottom up approach are known to exist, these have been stated below.

- From a Bottom-Up approach we cannot observe or test system level functions from an integrated point of view, requirement of a top level test driver is important.

- Systems from a bottom up view are highly case specific, results from implementation of localised systems hold true only for that region.

8.3. Versatility In Question

India is a vast country with highly diverse climate, geography and economic conditions. The diversity is also known to exist when looking at rural problems prevalent in different states of the country. Such can be observed when observing problems of rural electricity shortfalls in the nation, the diversity can be observed with ease, the electricity supply between the states Bihar and Maharashtra differs by a factor of 4. In the state of Maharashtra rural households on average receive 20 hours of electricity in a day whereas in Bihar the daily average is 4 hours. The following figure throws more light on the diversity present in rural electricity problems in India. Figure 8.2 displays a map of India depicting the number of un-electrified households in the respective states.

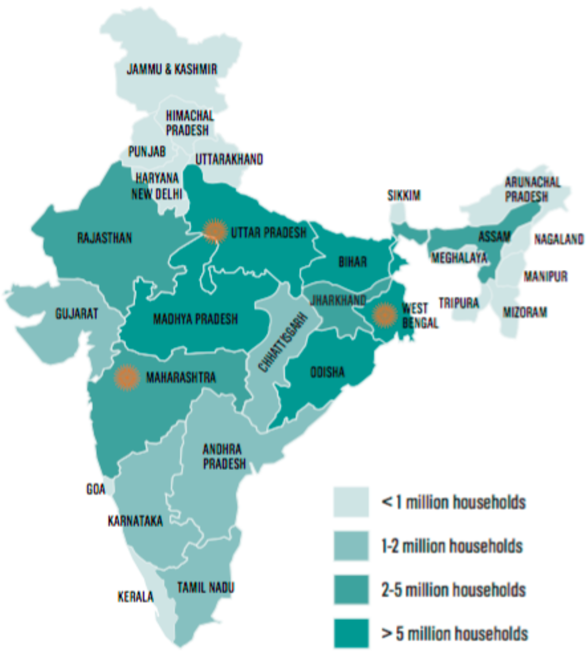

Figure 8.2: Number of Under Served or Under Electrified Households as per state (Goldmansachs, 2015)

This diversity in rural issues are not only pertained to the electricity sector, they branch to healthcare, education, water issues, etc. One common trend observed for the case of India is that economically backward states have known to perform worse than the richer states.

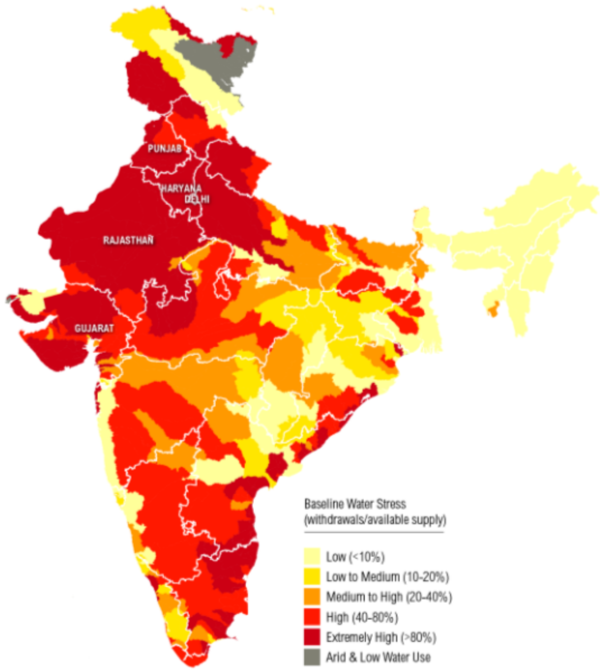

Figure 8.3: Water Stress Distribution in India (Shiao et al., 2015)

Observing from the figure above, the water stress level difference between the 'good' and the 'bad' regions of the nation has a factor difference of 8, such can be seen while comparing Kashmir to Rajashthan. As a result it can be concluded that the issues present in rural India are highly diverse and case specific. As a result integration prospects in these regions would differ with the available resources, operating sectors, local conditions and goals of local communities for development. Versatility of obtained results of a local case study would not hold true for the entire nation. To generalise outcomes of local cases it would only be legitimate to conduct multiple case studies in different parts of the nation facing different issues to legitimately extrapolate results. Such was the main driving factor behind carrying out a Top-Down case study.

8.4. Top Down

The following section gives an introduction to Top-Down approach, introducing the advantages and disadvantages of such an approach. A similar approach has been applied in the Top-Down case study in chapter 10. Top down approach is a method of study where process progression happens from a macro prospect inwards towards a micro prospect. The top down approach realises the opinions of the executives and the policy makers. "The starting point is the authoritative decision; as the term implies, centrally located actors are seen as most relevant to producing the desired effect" (Matland, 1995). Top Down theorists believe in the importance of policy for efficiency improvement for the functioning of the entire systems, along with minimising the number of involved actors and putting constraints on the extent of required change (Matland, 1995). Opposed to bottom up theorists top down believes in laying down a framework and constraints before implementation. Top down approach is viewed in a critical light due to its focus on creating or existing statutes. Top down approach fades out preferences and resource avalibility of regions and provides outcomes which are treated as sole outcomes disregarding case specificity of regions.

For the purpose of the thesis a Top-Down approach is carried out to identify barriers impeding energy focused integrated rural development and thus laying out policy recommendation to overcome these barriers.

There are some advantages associated with looking at implementation of the solution directions considered for the purpose of this thesis from a Top Down point of view. These advantages help us reiterate the importance of the 'Top-Down' part of the methodology ,which have been stated below:

- Versatility of outcomes.

- Isolation of interface issues and errors is easier due to the incremental nature of the approach.
- Outcomes of such an approach target a larger share of improvement possibilities.

Prevalence of certain drawbacks associated to a Top Down approach are known to exist, these have been stated below:

- Until a certain point in the progress, the lower level modules cannot be analysed. Which is required for policy making process.
- Top Down theorists tend to overlook ground level case specific realities.
- Overlooking of ground level prospects in many ways leads to loss of information and knowledge on many fronts.

9
Bottom-Up Case Study

The following section deals with the 'Bottom-Up' part of the research methodology. Application of the integrative approach based on I-neffs and E-nabes is to be carried out and applied to a local case, to identify aspects making the integration process possible for the case while, highlighting the methodology followed. Reiterating the methodology does not provide 'Final Integrated Solutions' but is a creative tool to identify aspects associated making the integration process possible. Again, I-neffs identify highest factors which need to be catered to make integration possible and E-nabes can be used to cater to these I-neffs making the integration process possible.

9.1. Case Methodology

The following section describes a methodology to be implemented for the local case in to identify how integration can be achieved in order to lead to multi-purpose energy systems. The methodology shown provides various steps giving description of their background and implementation procedures. The methodology followed has been obtained from the Thesis "Towards an Integrative Design Methodology to Produce Multipurpose Energy Systems" (Elango, 2012). As depicted in Figure 9.1.

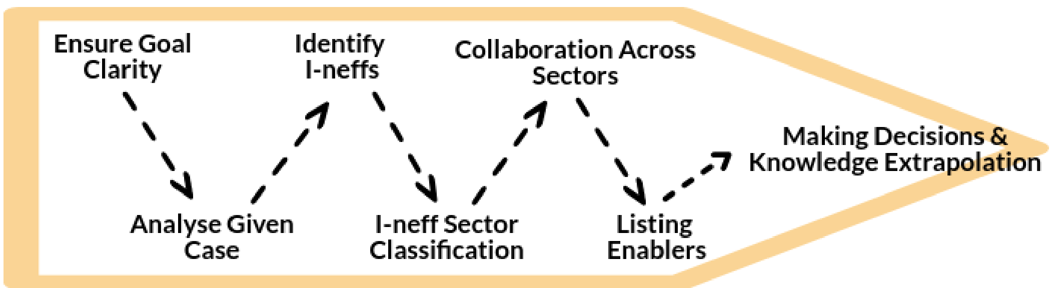

Figure 9.1: Schematic Representation Multi-purpose Energy System Formation Methodology

- **Step 1: Ensure Goal Clarity**
  Since the aim of the project is to lead to integrated multi-purpose energy systems, it is necessary to ensure the clarification of goal first. To clarify goal of the case knowledge of energy systems, I-neffs and enablers is a must which have been discussed in previous chapters. To understand the outcome of the case the concept of integration and its types is important.

- **Step 2: Analyse Given Case**
  The importance of Whole System Thinking has been discussed in the previous chapters. For achieving success in doing so the case needs to be analysed in depth finding interconnections and synergies between technologies and sectors which is the foundation for the whole systems thinking approach. For any case, it is highly significant to asses the case and the scenario first before laying forth any designs. In this step the case is assessed, boundary conditions analysed and system entities and components

observed.

- **Step 3: Identifying I-neffs for Considered Case**
  I-neffs and enablers are the basis of the methodology for forming multi-purpose energy systems. An in depth understanding of the concepts in necessary before diving into an integrated energy system design.

- **Step 4: Classifying I-neffs Under Sector Categorisation**
  Sector categorisation is a broad concept. Integration can be categorised into various types as explained in previous sections. The end solution can be categorised into a broader aspect of 'Sectors'. For example solar hybrid systems (heat, electricity and cooling) fall under multi source multi product energy systems integration type, but categorising under sectors it is a part of the 'Energy Sector'.

  For the purpose of the case study the I-neffs first need to be described associated to system entities then they could be categorised under sectors. After the I-neffs are categorised under different sectors it becomes easier to collaborate across different disciplines.

- **Step 5: Collaboration Across Disciplines**
  By now we have identified I-neffs which have been categorised under sectors, to provide solutions for the identified I-neffs Enablers are required. Collaboration across disciplines does exactly that.

  In Step 4 we described the sector the I-neff can be associated to, in Step 5 we define the collaborating sectors around the categorised sector, enablers come out of these collaborating sectors to target the previously mentioned I-neffs making integration possible. The figure below gives more clarity on this step. The categorised sector with identified I-neffs is in the center and the remaining sectors around can be collaborated to inculcate higher integration levels.

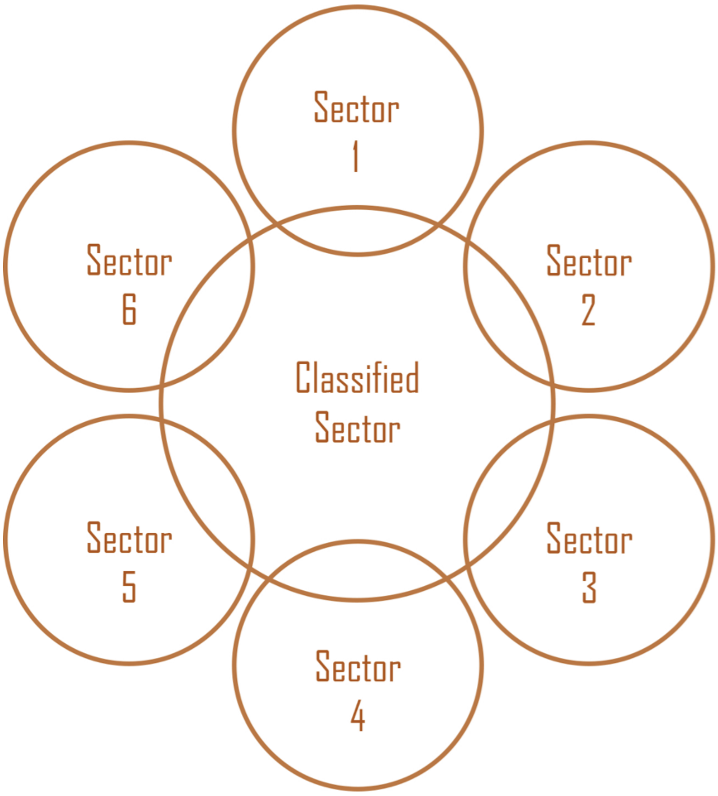

Figure 9.2: Schematic Representation of Step 5 with I-neff Under One Sector

Targeting an I-neff may give rise to another I-neff, in this case the methodology followed is described by the figure below. For example, Photovoltaic panels can be installed on roofs to solve the Unifunctional

I-neff of Rooftops. But the exergy efficiency of PV panels which is less than 100% is a new I-neff which requires another Enabler to solve it. This can again be solved with the same procedure in a repetitive loop until there is no I-neff. The methodology therefore also includes a feedback loop.

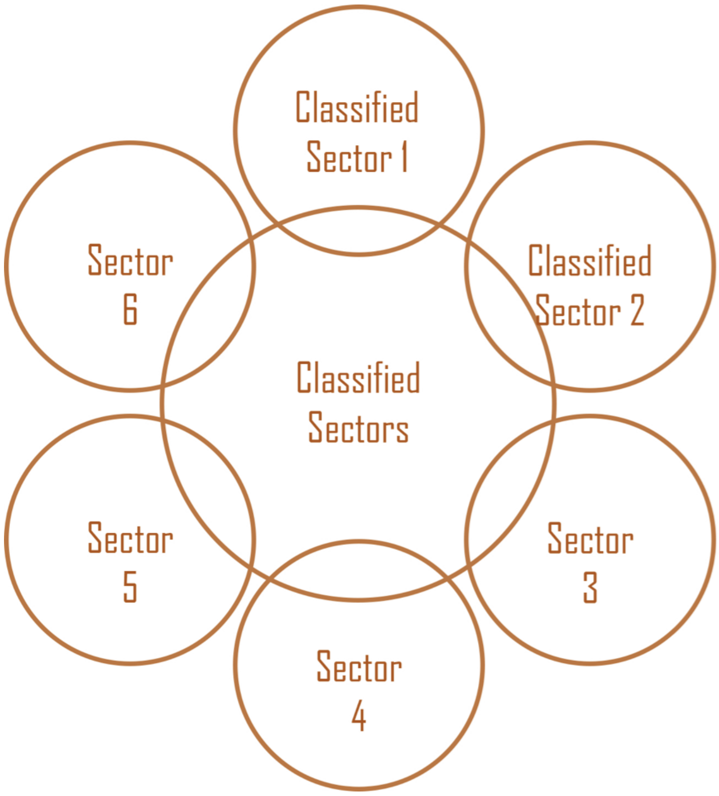

Figure 9.3: Schematic Representation of Step 5 with I-neff Under Multi Sector

- **Step 6: Listing E-nabes**
  Post collaboration definition across different sectors, the enablers needed for I-neffs to make integration possible need to be identified or defined, such is done with a brain storming session with previous knowledge of sectors aimed to be collaborated into multi-purpose energy systems. For the case of this study the enablers with primary benefits to energy and electricity sector are to be considered making energy focused integration possible.

- **Step 7: Making Decisions and Knowledge Extrapolation**
  The final step gives emphasis on choosing the right E-nabes to set in course the integration process while considering inclination of the integration possibility with achievement of Sustainable Development Goals. This can be easily done on the basis of background knowledge of sectors associated to identified integration prospects and local needs and available resources. To attain best outcomes identified integration prospects can be put through multiple iterations till no I-neff exists , thus laying down a foundation for integrated multi-purpose energy systems.

9.2. The Case of Ballia District, Uttar Pradesh, India

9.2.1. Case Introduction

The rural region considered for the purpose of the case study is Ballia in the State of Uttar Pradesh. The data for the research was collected from an existant research by Shweta Singh and Usha Bajpai titled 'Integrated energy planning for sustainable development in rural areas: A case study from Eastern Uttar Pradesh'. The research conducted door to door survey to collect data and from formal institutions such as Revenue and Statistical Office, Ballia, Office of SDM, Rasra Tehsil, Director of Census Operations, Uttar Pradesh, NREDA HQs, Lucknow and Project Officer, Ballia, which has been presented below for the purpose of the case study.

The district consists of three villages Mudera, Beswan and Baijalpur. There are a total of 17 hamlets under these three villages, majority in the Mudera village which consists of 11 hamlets, Beswan and Baijalpur both consist of 3 hamlets each. The District of Ballia is located in the eastern plains of Uttar Pradesh at the junction of two major rivers Ganga and Ghagra at the border between the states of Uttar Pradesh and Bihar. The coordinates of the district are 25.51'N, 83E and 25.85' N, 83.85'E (Singh and Bajpai, 2010).

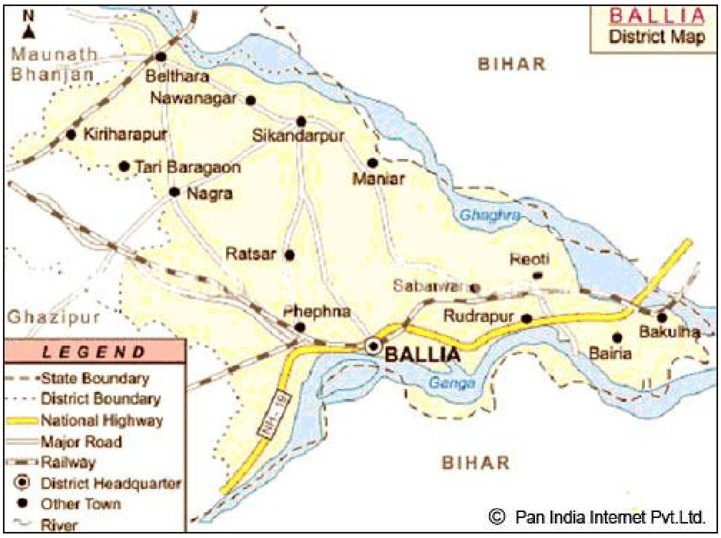

Figure 9.4: District Map of Ballia (Government of Uttarpradesh, 2010)

The district experiences a tropical monsoon type climate with 4 seasonal variations of winter, spring, hot summer and pre-winter transition. The average yearly temperatures range between 5-40 degrees Celsius with an annual rainfall of 1015 mm.

Table 9.1: Demographic Details of Ballia District (Government of Uttarpradesh, 2010)

Village	Total Hamlets	Total Households	Male Population	Female Population	Total Population
Mudera	11	563	1982	1922	3904
Beswan	3	282	986	1029	2015
Baijalpur	3	381	1397	1438	2835
	17	**1266**	**4365**	**4389**	**8754**

Though local problems and conditions of rural regions in India vary with location, Ballia district can be seen as an essence of rural India. Ballia is located in Uttar Pradesh, one of the worst performing states in terms of considered sectors of electricity and water sectors as will be discussed further in this section. In terms of GDP per capita the state ranks 31 out of the 29 states and 7 union territories in India (Central Statistical Organisation, 2017). The argumentation for the consideration of Ballia district as the sample site for the Bottom-Up case study is reiterated through the description of the poor performance of the electricity and water sector for the region below:

Electricity Sector-Ballia

Ballia district falls under the governance of the state of Uttar Pradesh. Uttar Pradesh is considered to be the worst performing Indian state in terms of the electricity sector, 71% of rural households still lack grid connection and access to electricity.Figure 9.5 compares Uttar Pradesh to rest of the states of the country in terms of performance of the electricity sector to lay further stress upon the performance of the electricity sector in the state.

Case of the Underserved

Though majority of the households are connected to the grid not all receive electricity or atleast in ample amounts. Houses in the Ballai district are underserved receiving 4 hours of electricity in a day (Singh and Bajpai, 2010). Poles which supply electricity are damaged during stormy and strong windy days therefore the villages come under darkness for many days and sometimes for many months. With the new government formed in 2017 announcing 18 hours of electricity to all households in Uttar Pradesh a day by 2018 a lot has to be done to achieve reliable, constant electricity access for the locals of the region. The electrification of the region is done through a centralised grid which provides electricity only a few hours in a day (The Indian Express, 2017).

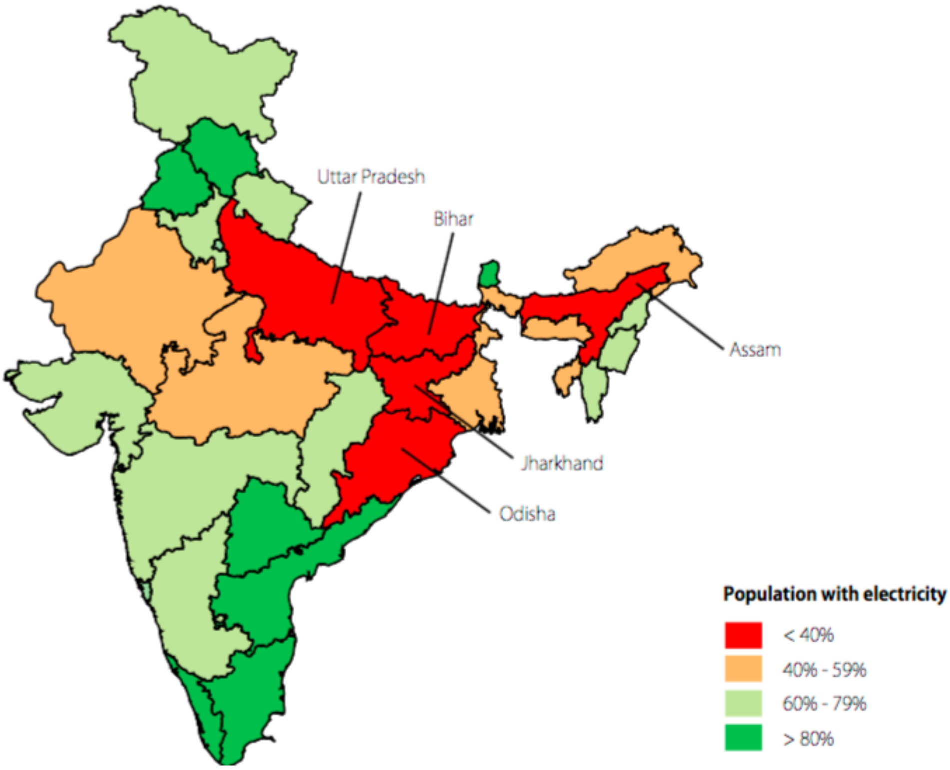

Figure 9.5: State Wise Comparison of Electrified Households (Rockefeller Foundation, 2016)

Water Sector- Ballia

Two major rivers flow near the district namely Ganga and Ghagra, Water availability in the river is almost year round apart from a couple of summer months which where the water is evaporated and low levels not suitable for usage are reached. Even though there is enough availability through the rivers there are no water utility supply pipes or drinking tanks. The district depends on ground water which is pumped by the 250 hand pumps located in the region, there are also 30 open wells which are used for water usage purposes (Singh and Bajpai, 2010).

Even with the major dependence of the local population on ground water for drinking purposes, the major heavy metal contamination of the ground water is overlooked. Ground water is highly poisoned with heavy metals such as lead, flourides, mercury and arsenic. Arsenic contamination being the most worry some in the region. Those living in the district suffer from itchy skin lesions, changes in skin colour, and hardening and thickening of skins into nodules. These afflictions are due to arsenic contamination of their drinking water sources. Arsenic levels permitted in drinking water by WHO is 0.01 mg (10ppb) per litre. Areas in Ballia district have arsenic contamination of 45-130 ppb, that is 13 times the permitted levels safe for human consumption. Even hair samples of residents of the district which were tested showed high levels of arsenic in the range of 2248-6310 ppb (Bose, 2017).

Though the river is not used for water provision, the fact of its existence in the region due to its high levels of pollution anyways make it futile. Ganga now is considered to be the second most polluted river in the world. Bacteria such a coliform in Ganga in the Uttar Pradesh region on average is 100,000,000 MPN per 100 ml where the allowable level for drinking is 50MPN per 100ml and for domestic purposes is 500 MPN per 100 ml, dissolved oxygen over 40 mg/l in the most polluted part of the river which is in Varanasi, a journey of 100

Kms from Ballia District. The reasons that led to such large scale pollution of the river are industrial disposal, sewage disposal and religious practices. (Appendix C)

9.2.2. Implementing Methodology

- **Step 1: Ensuring Goal Clarity for the District of Ballia**
  The goal is development of the rural district of Ballia by creating multi-purpose energy systems that apply to the region. To do so we aim at applying sustainability in a broader sense and integrate the energy,water and waste sectors, mutually benefiting all three sectors with primary benefits for the energy sector.

- **Step 2: Analysis of the Case of Ballia District**
  The rural district of Ballia is located in the Northern State of Uttar Pradesh in India close to the border shared with the state of Bihar. Geographically Ballia falls under eastern plains of Uttar Pradesh. The district is located at the junction of two rivers- namely Ganga and Ghagra and thus hosts highly fertile soil.The district consists of the following types of soils- silti domat, matiyar domat, bhaat domat and balui domat.These various soil types fall under the alluvail soil category and have been formed by the sediments brought and deposited by the two rivers. The major source of income for the region is agriculture, Thus employing the majority of the residents of the region as well as the livestock of the region. 78% of the population of the district is directly or indirectly dependant on the agriculture sector (Singh and Bajpai, 2010).Table 9.2 provides us basic information about the district.

Table 9.2: Sailent Features of the District of Ballia (Singh and Bajpai, 2010)

Particulars	Data & Comments
Total Number of Houses	The house in the cluster are a mix of temporary and permanent constructions. 2915 & 5824 respectively.
Total Human Population & Occupation	8754, 78% of the population relies on agriculture directly or indirectly
Literacy Rate	67.74 %, females- 23.65%, matriculation- 31.5%, graduates- 30%
Total Land Area	890 Hectares
Major Crop Types	Wheat, Paddy, sugarcane, mustard, maize, barley
Animal Population	Total bovine- 1420, others 2561 including chickens
Energy Resources	Agricultural Waste, Oil, Kerosene, LPG, Animal Waste, Electricity, Wood, Coal
Rural Industries	Jaggery, Domestic Goods, bamboo handcrafts, pot making, blacksmiths, general stores, poultry, wood processing
Natural Water Resources	Two Rivers- Ganga & Ghagra, Rivers dry up during summer months (April to July)
Drinking Water Resources	Completely reliant on groundwater, 250 hand pumps, open water wells- 30, ground water heavily contaminated with heavy metals though.

- **Step 3: Identification of I-neffs in Ballia** The District of Ballia comprises of several system entities. I-neffs can be identified for the area. The concept of I-neffs was discussed in previous sections. The I-neffs considered for the case of the study were:

  – Device or component is not operated all the time i.e. operation time is not 100%. In other words the system or component is standing idle (for a significant fraction of the time) (Elango, 2012)

– The system is designed as such for the component or device to have only one function.(Elango, 2012)

– Exergy destruction is said to be occurring (Elango, 2012).

– A potential resource is not utilised or in other terms stands idle.

For ballia region the identified I-neffs have been listen in the tables below.

Identified I-neffs Under Unifunctional Operation

In the following section the I-neffs for Ballia district which fall under uni-functional operation are identified and listed. This is depicted in Table 9.3.

Table 9.3: Identified I-neffs Under Unifunctional Operation for Ballia District

Uni-Functional River Network: The river network of Ghagra and Ganga is uni-functional.
Highway Landscape: Uni-functional highway landscape, for the sole purpose of transport
Uni-Functional Rooftops: Roofs of 8700 homes as well as public buldings are uni-functional, with a sole purpose of providing shelter.

Identified I-neffs Under Idle Performance

In the following section the I-neffs for Ballia district which fall under Idle Performance are identified and listed. This is depicted in Table 9.4.

Table 9.4: Identified I-neffs Under Idle Performance for Ballia District

River Bank Stands Idle: River banks with highly fertile soil stand idle.
Barren Land: The district of Ballia has 100 hectares of barren land.
River Delta Stands Idle: The river delta with highly fertile soil and nutrients stands idle.
Seasonal Agricultural Land Use: Agriculture which is the major occupation of the region is highly seasonal thus leading to seasonal utilisation of agricultural land.

Identified I-neffs Under Exergy Destruction

In the following section the I-neffs for Ballia district which fall under Exergy Destruction losses are identified and listed. This is depicted in Table 9.5.

Table 9.5: Identified I-neffs Under Exergy Destruction Losses for Ballia District

Exergy Destruction Losses on Water Surface: The river water is allowed to evaporate thus leading to exergy losses for the region.
Agricultural Waste Incineration: Agricultural waste is incinerated leading to exergy destruction, incinerating agri waste is less efficient from other potential prospects
Exergy Destruction by PV panels: Utilising PV technology leads to exergy destruction of incident energy due to low efficiency of p

Identified I-neffs Under Un-utilised Potential Resource

In the following section the I-neffs for Ballia district which fall under un-utilised potential resource are identified and listed. This is depicted in Table 9.6.

Table 9.6: Identified I-neffs Under Un-utilised Potential Resource for Ballia District

Idle waste: The organic waste (a potential energy resource) from homes, farmlands, poultry and cattle sheds stands idle spreading diseases and pollution.

- **Step 4: Classifying the case of Ballia under a sector type**
In the previous step, the I-neffs for the case of Ballia were identified, these I-neffs after identification can be classified under sector types based on the system entity they are associated to. It is also possible, that a system entity at times is potentially classified under two different sectors. For instance, the water network can be classified under construction as well as the water network. To obtain end results, clarity on sector type is not of paramount importance.Table 9.7 provides the classification of I-neffs in Ballia under sector types.

Table 9.7: I-neffs: Sector Type Distribution

I-neffs	System Entities	Sector Type
Uni-functional River Network	Water Network	Construction & Water
Uni-functional Highway Landscape	Road Network	Transport & Construction
Uni-functional Rooftops	Building/Housing	Construction
Uni-functional Rooftops	Building/Housing	Construction
Barren Land	Urban Planning	Planning, Agriculture & Construction
Seasonal Agricultural Land Use	Farmland	Agriculture
Idle River Delta & Banks	Water Network	Construction & Water
Exergy Loss on Water Surface	Water Network	Construction & Water
Agricultural Waste Incineration: Exergy Destruction	Energy	Agriculture, Waste & Energy Use
Exergy Destruction by PV Panels	Energy	Energy, Construction
Idle organic Waste	Solid Waste	Municipal Waste, Agriculture & Energy

- **Step 5: Collaborating Across Disciplines for the Case of Ballia District**
Unifunctional water network (Rivers) was identified as an I-neff for the Case of the District of Ballia. This was classified under the water and construction sectors. The classified sector here is surrounded by potential collaboration sectors. The figure below provides an example to do so for the considered I-neff.

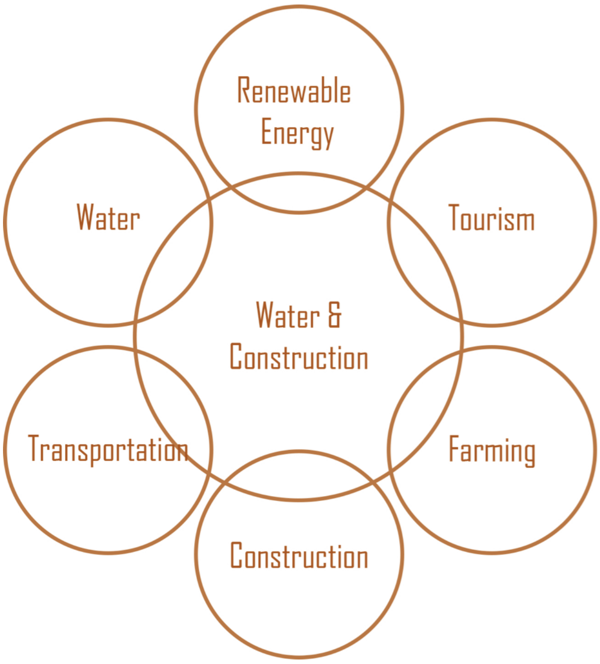

Figure 9.6: Step 5 for the Case of Ballia

- **Step 6: Choosing Enablers for the case of the District of Ballia**
  Distinct I-neffs were identified for the energy, waste and water sectors for the case of the District of Ballia. These I-neffs were then classified under their respective sectors along with identification of collaborative sectors. Progressing, the next step involves identification and thus listing of enablers. Procedure for enabler identification for one of the identified I-neff has been explained elaborately. Further identified I-neffs with their enablers have been listed in the table in the section.

Uni-functional Water Network
The water network is classified under two sectors, namely water and construction. Three different sectors are taken into account for enabler identification for this I-neff, depicted in the figure below.

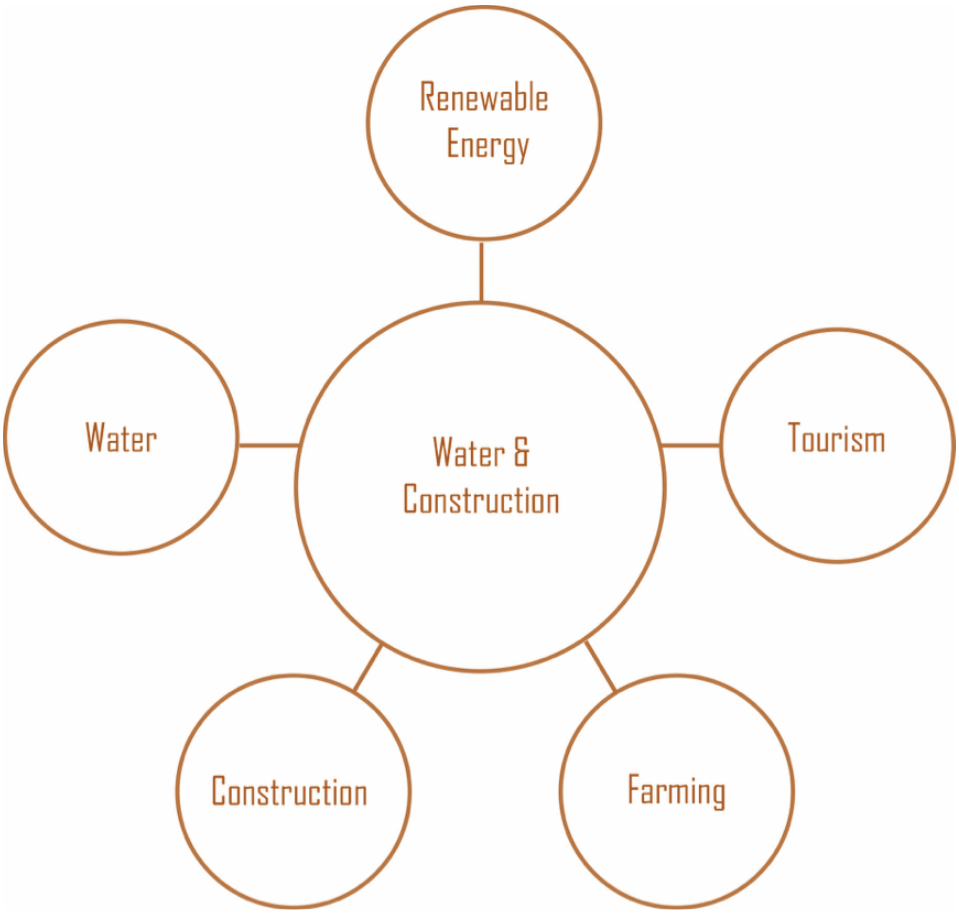

Figure 9.7: Sector Consideration for Uni-functional Water Network

Tourism
Ballia district lies on the banks of the holy rivers Ganga and Ghagra. The rivers are deemed "Boring" and Un-economically inclined. Potential integration possibility is not tapped into from the presence of the water bodies. The river also connects the region to Varanasi, which is a holy city for the followers of Hinduism. The city hosts millions of tourists every year, who visit for both religious as well as recreational purposes.

Enabler 1: Boat connections to Ballia district from Varanasi could be seen a potential for pulling tourists to the region leading to potential integration of water sector with tourism and transport. Recreational activities at the water front could be an additional attraction for those visiting the region.Enablers such as bridges, bank constructions, boats etc for tourism purposes help achieve this idea. The figure below shows a multi-purpose recreational boat service, which are a major attraction across different regions of India.

Figure 9.8: Picture depicting an Enabler Option to Solve Considered I-neff

Renewable Energy
Exergy losses occurring on the surface of river, or water loss due to evaporation in summer months can be avoided by installing PV Panels on water surface. This would reduce the effects of evaporation on water making integration of energy and water sectors possible. Kyocera a large PV Panel manufacturing company, applied this technique to the canal network in the Suburbs of Tokyo, Japan capable to power 5000 households in the region (Chang, 2015).

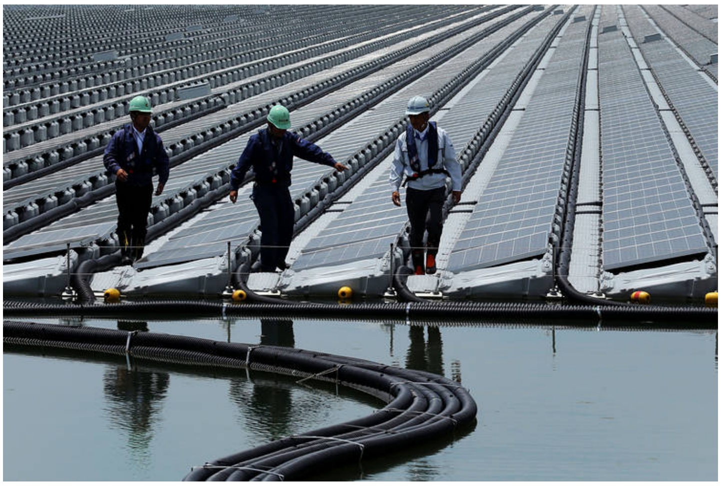

Figure 9.9: Picture depicting an Enabler Option to Solve Considered I-neff Chang (2015)

Enabler 2.1: Existing knowledge of PV technology. Application of Floating PV plants on the river surface. For off-grid locations the PV produced power could also be backed up by bio based power integrating waste sector by targeting the Idle nature of waste, a potential energy resource.

Enabler 2.2: Another possible enabler would be run of the water electricity turbines. These turbines can produce electricity by naturally flowing water again making integration of water and energy sectors possible.

Enabler 2.3: The river network could also be used for transport of heat. Heat pumps could extract heat in colder periods and cooling in hotter period, in combination with underground heat storage which could be made possible easily by the existing ground water wells which at present have a uni-function.

Farming

The region is highly agriculture oriented. As mentioned in this section before, the major occupation of those living in the district is agriculture based, it would be of advantage to use water from river for agricultural purposes and use existing knowledge of farmers in the region to further expand the agricultural base of the region to acquatic farming as well. Acquatic farming has manifold potential benefits for the region. Acqautic plants help prevent evaporation triggered water loss as well as can be economically viable. Water grown lilies in India are a popular favourite, which could be grown and exported for trade purposes. Making integration of the water sector to local economy and agriculture.

Enabler 3: Aqua Farming which is an already existing practice of aquaculture which includes farming of aquatic organisms such as fish, molluscs as well as aquatic plants.

Construction and Water As mentioned before the region lies on the banks of two rivers. The river water in not utilised for domestic purposes. The integration potential of the presence of the rivers are immense, cottage industries with high water requirements could be developed on the banks of the river which are highly water intensive. Also the river water could be used for agricultural purposes since its rich in vital minerals required for crops.

Enabler 4: Reservoir technology and water provision management. Reservoir channels with storage units could be constructed to provide water for cottage industries as well as for agricultural purposes integrating the water sector with various other local sectors.

Enablers for Remaining I-neffs
In this section enablers for the remainder of the I-neffs were chosen using the same procedure as depicted above for the case of I-neff: Uni-functional Water Network. These enabler technologies were chosen on the basis of exiting knowledge of the available technology and I-neff prevalent in the region and are presented in Table 9.8.

Table 9.8: Enablers for Identified I-neffs for Ballia District

I-neffs	E-nabes
Uni-functional River Network	PV Technology, Tourism Constructions, Aquatic Farming, Heat Storage, Reservoir Constructions
Uni-functional Highway Landscape	PV Technology, E Plantation
Uni-functional Rooftops	Rainwater Harvesting, PV Technology, Sustainable Rural Farming
Barren Land	PV Technology, Wind Energy Technology, Energy Plantation for Biomass, Bio gas technology
Seasonal Agricultural Land Use	E Plantation for bio mass production for energy, Biogas technology
Idle River Delta & Banks	E Plantation for bio mass production for energy, Biogas technology, PV Technology, Micro Farming, Sand Dredging
Exergy Destruction Loss on Water Surface	PV Technology, Aquatic Farming
Exergy Destruction by PV Panel	Solar Hybrid System, MSMPs
Exergy loss: Agricultural waste incineration	Biogas technology, Waste for Silica extraction for water sector
Idle organic Waste	Biogas Technology. Silica extraction for water sector, waste recycling

- **Step 7: Making Decisions and Knowledge Extrapolation**
  The rural district of Ballia faces widespread issues impeding rural development. The case study provides a base for integration of sectors, potential multi-purpose energy systems for the region. Stakeholders involved have the decision of choosing the best suited integration prospects and E-nabes. The purpose is to provide integrated multi-purpose energy system options as a platform for stakeholders to make decisions.

The main purpose of carrying out the Bottom-Up case study was to extrapolate gained knowledge for laying out barriers to energy focused integration in rural India and to provide plausible solutions to these barriers, which will be carried out in a further section of this report. These aspects were analysed on the basis of the steps performed in this case study methodology. Where Each of the six steps were looked into with their requirements and outcomes to define these aspects. Knowledge gained from the case study has been stated below:

- Observing from Table 9.7 potential integration of a wide range of sectors is possible for the considered rural setting. For integration of sectors for a rural locality to take place synergetic performance of sectors is required. Questions such as 'How integrated is the performance of the rural sectors?' needs to be answered. Stakeholders from various sectors need to work in synergy to make integration a reality, knowledge sharing and technology transfers being a key aspect of such synergetic performance. It is not only important to identify the synergy existing between the operation of the sectors but also the synergy of policies associated to these sectors, in other terms integration of policy would be a key phenomena to make the integration process possible. ' Are synergies present in the institutional structure, policies and decision making processes for the rural sectors?'
- The integration of such sectors potentially would lead to creation of new jobs, for the local community to really reap the benefits from integration process in economic terms, these jobs need to be filled in by locals of the region, thus raising questions regarding 'whether there would be skilled labour available locally to fill in these jobs to create circularity in the economy?'
- 'How readily available would the technology and knowledge be?'. For integration to be a success, local availability of enabling technology and knowledge can be seen as key driving factors. With technology available locally other relaying factors of O&M (both in technical and economic terms) can be catered to with potential reductions in capital costs.
- Questions pertaining to 'social and professional acceptability of integration' need to be answered, whether it is possible for the stakeholders and sectors to work in synergy and if the locals are accepting change in their usual operation. This aspect could also have a huge impact on knowledge and local workforce availability as well as on costs. 'Risk perception in a technology by stakeholders and investors' leads to higher perceived discount rates thus adding up costs making it more expensive.
- From the case study it can easily be observed that integration heavily depends on the locally available resources and rural sectors. Does the proposed integration fit well with the needs of the locals and the goals set forth by the UN's SDGs.
- Effects of integration are potentially 'non-linear', meaning it would either have exponentially improved benefits or create exponential impedance for rural development. Such aspect considerations are important specially for Chapter-10 while identifying associated aspects to integration also for policy process.
- 'Do the existing policies have the right policy tools to identify externalities for decision making?', considering the example of the I-neff idle river banks, potential E-nabe making the integration of the water sector and energy sector possible is application of PV panels, another E-nabe integrating the water and industrial sectors potentially is industrial development. Though industrial development would lead to higher and more immediate economic benefits, it would create larger damage to environment and life. As for PV panels, they would reap benefits economically in the long run due to their underlying benefits for environment and thus life.

9.3. Conclusions of Bottom-Up Case Study

Integration of sectors of Ballia district was analysed for potential rural development. The goal of the approach followed was to mark out possible integration aspects for tackling the issues of local impeded rural development. The results thus obtained were inclined with the beliefs of such multi-purpose energy systems and systems thinking. For instance for the identified I-neff of uni-functional roof, the uni-functionality of the roof to provide shelter is the highest order factor which needs to be catered to for integration process to be possible, which could be done through the E-nabes of application of PV technology or rainwater harvesting, these technologies make the integration of the sectors of 'building and energy' and 'building and water' possible. Such integration of different sectors would have manifold underlying social benefits inclined with the sustainable development goals. A detailed account of possible integration between the different sectors considered and thus their potential E-nabes making the integration process possible has been described in Appendix-E .

Considering the case of the Bottom-Up case study discussed in the section, the prospects of the 'I-neffs-E-nabes' approach can be observed. The approach or methodology followed as such is highly versatile and can be applied to various cases and locations in India to make integration possible, especially integration of sectors. An inter-sector cooperative study is done leading to directions for integrated multi-purpose energy systems, different from traditional approach where problems are highlighted in the first step. Though the integration outcomes obtained for the District of Ballia cannot be blanketed for the entire nation, as India is a country with distinct variations prevalent in different rural regions. It would not be legitimate to blanket the outcomes as such, but what can be taken away from the case study is the scale of I-neffs existant in rural Indian regions and an idea of the potential of integration possibilities for such rural settings in the nation.

Another key observation made over the course of the Bottom-Up case study was the characterisation of I-neffs under specified categories. The categorisation under the four identified I-neff categories does not hold too much importance as long as the I-neff is identified, once an I-neff is identified plausible E-nabes will be looked into for targeting the I-neff making the integration process possible in one way or the other. For example for the I-neffs of Unifunctional River System and Exergy Destruction on River surface the E-nabe of laying PV panels on the face of the water body was given, in a way taretting the existant I-neffs and making the integration of water and energy sector possible, which is the key aspect and takeaway from the identified E-nabes. The 'I-neff-E-nabe' approach was laid out as a creativity tool for identifying integration possibilities thus leading to multi-purpose energy systems integrated over sectors. Though the categorisation of I-neffs under its types is not seen as of paramount importance, marking out of associated sectors to the sector type the I-neff is associated to is.

10

Top-Down Case Study

This chapter involves a Top-Down case study, which was conducted to analyse the validity of the approach in an Indian Context. A variety of stakeholders from different parts of the institutional structure were interviewed to analyse the potential effectiveness of the approach discussed in previous sections to give solution directions for integrated multi-purpose energy systems in an Indian context. This was done to identify the potential benefits and limitations to such an approach as well as to mark out potential barriers which might turn up during implementation. The section also puts forth some potential solutions to these barriers to help overcome these obstacles.This section of the thesis adds to the scientific contributions made by the thesis as such an analyses for the considered solutions have not been conducted before. The following sections covers all aspects required for policy makers to push through integrative solutions in India, giving them a deep understanding of the benefits, limitations and barriers of such solutions in India. The interviews were conducted in a one to one basis either personally or over video conference in the period of May 2017- June 2017.

10.1. Interview Foundation

For the purpose of analysing the legitimacy of energy focused integration in an Indian Context experts from various fields were interviewed. Experts from the field of policy, technology, research and implementation were interviewed to answers questions pertaining to benefits, limitations, barriers to implementation and plausible solutions to barriers in the context of India.

The core focus of this section is to identify barriers to energy focussed integration for rural development in India and its plausible solutions, hence benefits and limitations identification is not very detailed yet has been put forth to better understand the barriers and their solutions. Since barrier identification has always been at the core of the research, however to establish the feasibility of the same for practical processes, benefits and limitations of integrated approach were looked into. Below is given a detailed account of benefits of interviewing experts from their respective field of expertise:

- **Policy**: The policy makers were interviewed to gather knowledge on the validity of multi-purpose systems from a policy point of view. Apart from the application of the technology itself, policy makers tend to have a broader understanding of the consequences of an application of any new or niche technology or approach. Inputs from experts from such a field would be beneficial to assess the legal, bureaucratic, social and economic aspects of the approach.

- **Implementation:** Experts from institutions responsible for implementation of technologies were interviewed to gather knowledge about the practical aspects related to such an approach. This would help chock out the barriers of such an approach that would be experienced on ground during application and operation.

- **Research:** Experts from the field of research were interviewed to get a theoretical point of view from the world of academia.

10.2. Stakeholders Interviewed

For the purpose of stakeholder analysis, experts from the following institutions were interviewed:

Figure 10.1: Partner Institutions for Stakeholder Analysis

Closely observing the stakeholders, the importance of having interviewees from a mix of departments can be reiterated, the following table provides more depth on this fact:

Table 10.1: List of Partner Institutions and Interviewees

Name of Institution	Institution Type	Name of Interviewee	Designation
Ministry of New and Renewable Energy, Ministry of Power	Policy	Dr. G. Prasad	Director
Ministry of New and Renewable Energy, Ministry of Power	Policy	Mr. T. Kapoor	Ex- Joint Secretary
Rural Electrification Corporation of India	Policy & Implementation	Mr. R.K.Gupta	Associate Manager
TERI	Implementation & Research	Mr. S. S. Garud	Technical Director
Piconergy	Implementation	Mr. B. Trivedi	Partner
University of Delhi	Research	Dr. P. Malhotra	Head of Department-Chemistry
University of Cape Town	Research	Ms.V. Chopra	PHD candidate-

The Interviews are present in **Appendix C**.

10.3. Benefits and Limitation Analysis

10.3.1. Benefits of Integrative Approach

The following subsection analyses the potential benefits associated to integrated multi-purpose energy systems. The analyses was done on the basis of the interviews discussed above. Figure 10.3 depicts these potential benefits. As discussed before benefits will be looked at in brief only to associate to practicality aspect on energy focussed integration as the core of the research aims at identifying barriers and solutions to these barriers.

Figure 10.2: Benefits Corresponding to Sustainable Development Goals

- **Inter-sectoral Benefits**

- **Underlying Benefits:** Serving the greater good, Integrated performance tends not only to serve the needs of considered integrated sectors but tend to have tremendous unseen underlying benefits to other sectors. One big plus is that integration treats a much broader aspect as one, Such can be seen from the introduction chapter, where the energy sector is shown to be able to target all the goals mentioned under the SDGs by the U.N, depicted in Figure 1.3. So much so integration of sectors could potentially lead to attainment of development through targeting all SDGs, as shown in Figure 10.2.
- **Synergistic Performance:** Targeting prevalent synergies between considered sectors with the right policy tools and decision making could potentially lead to hiighly synergystic operation with manifold benefits. Observing from Chapter-5, where the energy dependence of water sectors is discussed, potential synergy of the two sectors can easily be observed. Water supply chains, both purification and distribution of water are highly energy intensive; vice versa energy production is highly water intensive. Tapping synergies existant in these two sectors with their heavy inter dependence with the right policy tools and decision making processes could be a key to major efficiency improvements and thus reduced costs for both sectors.

• **Aspect Improvement**

- **Efficiency:** Inclined with beliefs of the new dawn of systems thinking, where we aim at achieving higher efficiency , integrative concepts have been repeatedly been brought up, been recognized as a key aspect for efficiency improvements by renowned scientists and research institutions, globally. One of the primary motives of implementing 'Systems Thinking' is to improve efficiency of integrated performance when compared to isolated performance of the sectors.
- **Morality:** On moral grounds integration holds a strong position, many potential aspects associated to integration make it an ethical or moral choice for rural development. To start with, the aspect of non-linearity associated to integration if used in the right way under the right decision makers and policy tools could be used for exponential benefits for the rural community, leading to major efficiency improvements, 'doing more with lesser resources'. In the era of a world where minimalism has become a need rather than a moral consideration, integration can be seen at its core.

• **Social Benefits**

- **Acceptability:** Though social acceptability would definitely viewed under the lens of barriers for India, with the right tools and policies it could be seen as a benefits. A local system solving the most serious prevalent problems of the basic needs (energy,water) could be greeted with high social acceptability with the right awareness created through information sharing with the locals. From the example of the case of Ballia district from Chapter-9, the integration of various sectors if carried out well potentially could lead to manifold benefits for the most serious of the locally prevalent problems, as these problems are highly severe solving them could prove to the locals the worth of integration and thus with the right awareness on top lead to high social acceptability.
- **Local Ownership:** Decentralized systems also tend to create a sense of local ownership, this aspect of local ownership and empowerment can also lead to higher social acceptability of decentralized integration. Such aspects were discussed in Chapter -4 associated to reduced thefts and defaulting when electricity was supplied through decentralized systems in India. Locals perceive decentralized systems as their own and thus bring about a sense of care and responsibility. Such a social perception would also help deal with the large scale urgent problem of vandalism and theft.

• **Waste Reduction**

- **Reduce-Recycle-Reuse:** Consideration of waste sector integration potentially leads to improvements of other sectors through the Reduce-Recycle-Reuse of waste produced, such can be seen from the potential integration of sectors with benefits arising from waste sector integration of Chpater-9. integration potentially highly cuts down wastage of resources, inter sectoral manifold benefits could be extracted from what earlier was believed to be waste.
- **Surplus Utilisation:** Integrated performance under the influence of the right design tools and policies could make optimal use of surpluses between sectors, not only reducing wastes but in return extracting economic benefits from surpluses which cannot be forecasted.

- **Economic Benefits**
  - **Economic Efficiency:** Economic efficiency of systems depend upon layout of integration and the sectors considered, if the resources required for making integration possible are available locally this could lead to improved economics of integration. Also if the right policy tools define the integration considering the non-linearity aspect, then targeting the integration in a way that the non-linearity aspect creates exponential benefits could have tremendous economic benefits.
  - **Social Benefits:** Due to the large number of underlying benefits, energy focussed integration can be viewed as a whole system solving large number of underlying issues with other dependant sectors. For a policy maker's point of view, integration is not only advantageous from a micro economics point of view but also from a macro economics point of view. The increase in incurred costs usually is made up by the increase in the underlying social benefits.
  - **Local Empowerment**: Localised energy focused integration is expected to empower the locals living the region. For such systems to perform, increased involvement of the locals is paramount through local awareness and knowledge development, thus empowering those living in these regions.
  - **Market Disruption:** Integration with all its potential benefits, under the right policy support can be seen as disruptive phenomena to present trends, capable to bring about a change, since we know or at least have a strong intuition about performance improvement and synergies treatable due to integration. Could create a disruptive trend in the market for the better. The approach is new, its a new idea, new way to look at things.
  - **Job Creation**: Potentially integrating performance and operation of sectors with a focus on renewable energy technology enablers leads to a requirement of an increase in personnel (Painuly, 2001). Observed from the Bottom-Up case study of Chapter-9, implementation enablers to target I-neffs and thus enable sector integration for the District of Ballia is expected to create jobs for the local market, also potentially pulling in skilled workforce from outside the district boundaries, adding further value to the region through development prospects.

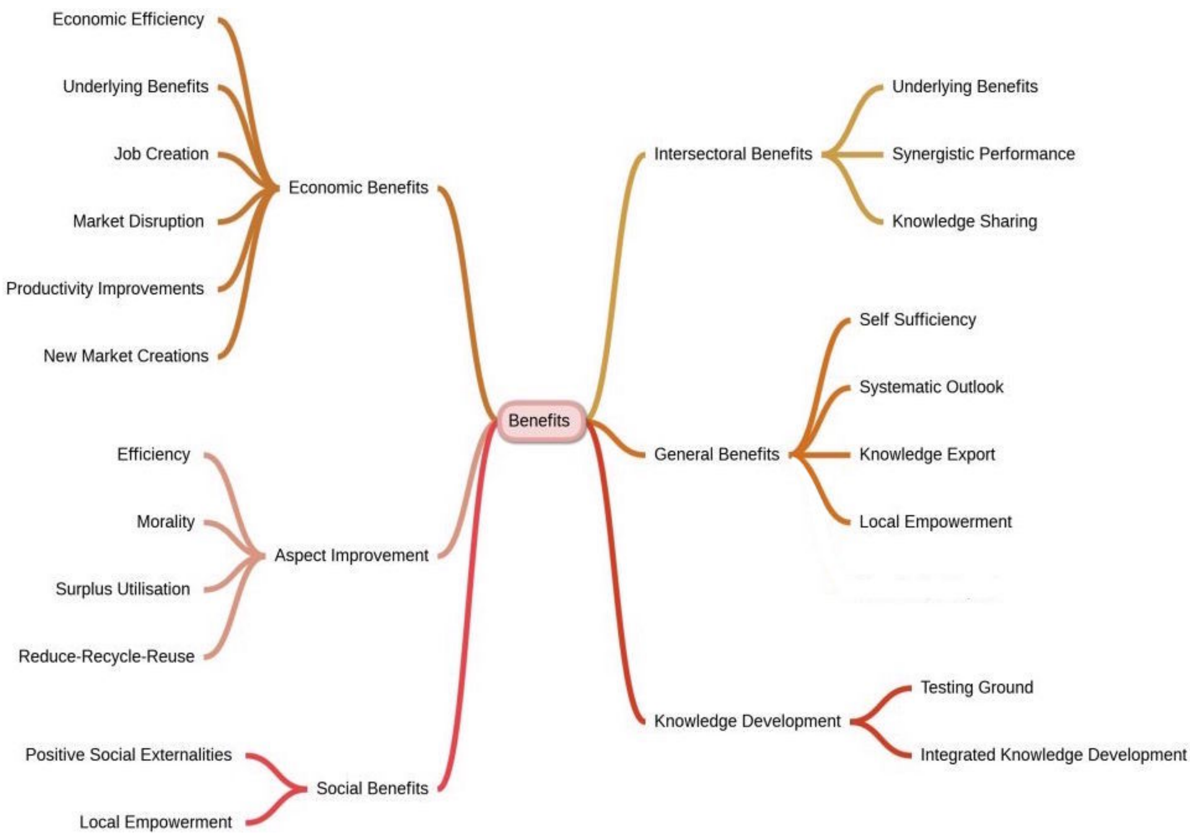

Figure 10.3: Benefits Associated to Integrative Approach

- **General Benefits**
  - **Self Sufficiency:** With global trends moving towards rising decentralisation and grid defection of communities as a whole, self sufficiency of communities becomes an important aspect , potentially energy focused integration could make off the grid living a reality, having tremendous advantages for remote localities, creating self sufficiency and security of supply.
  - **Systematic Outlook:** The positive aspect of an approach that identifies I-neffs and E-nabes is building of a systemic view of the case at hand. In doing so, there is an advantage in moving forward from the current state, through plugging of the things that are not working at the optimum level as well as recognizing opportunities to provide further benefits for the environment, economy and community through integration.
  - **Knowledge Development:** Integrative solutions brings together experts from sectors, working on a common solution with combined goals knowledge and technology transfer between sectors is expected to be achieved. Knowledge growth also occurs over the course of project implementation, as proved by the learning curve in various instances or cases.The solution could serve as innovation and testing ground for services, technology and policies.

10.3.2. Limitations of Integrative Approach

The following subsection analyses the limitations associated to integrated multi-purpose energy systems. The analyses was done on the basis of the interviews discussed above. Figure 10.4 depicts these expected limitations.

- **Interdependency**
  - **Professional Acceptance:** Integrated of sectors tends to involve a variety of stakeholders from various sectors, though they might provide better performing and more efficient inter sectoral operation, lack of acceptability between involved departments is definitely seen as a negative aspect of integrated systems, this aspect will further be discussed in the segmented performance issue identified in the barriers section in detail.
  - **Domino Effect:** Certain integrated systems tend to be highly dependent on one form of energy resource, with future trends if an energy resource becomes unavailable or the policies regarding certain aspect of any of the sectors included changes, this would disrupt the performance in a drastic manner. Another aspects is with sector integrated systems the high level of interconnectivity and dependency between the sectors, disruptions in performance of one sector could bring the entire system to a stand still disrupting the performance of the other sectors as well.
- **Economic Aspects**
  - **Capital Intensity:** Integration of sectors as discussed before shows outcomes displaying characteristics of non-linear natures, if not defined well by implementer, designers under the right policy tools integration could also lead to exponentially negative outcomes which would add up costs by multi-fold factors.
  - **Utility Dilemma:** Till the point the knowledge associated to making energy focused integration a success is questionable, in other terms knowledge gaps are prevalent, costs associated would be expected to be high. The economics of such integration of sectors usually bring about a negative outlook towards them. Knowledge advancements need to be in place to make the utility extractable through integration worth the capital costs required to be incurred.
- **Implementation**
  - **Practicality:** The approach is still an exploratory concept. Needs to be practically viable to be applied on a larger scale. Any solution should be targeting the right market in the right way.
  - **Case Specificity:** The approach is highly case specific and region specific. As observed from the Bottom-Up case study of Chapter-9, integration of local rural sectors depends on the local availability of resources for the enabling technology and operating sectors. Thus such solutions cannot be generalized or be turn key. From a Top-Down perspective for the policists to provide an umbrella policy case specificity can be seen as a limitation.

– **Complex Design:** Systems with energy focused integration of sectors tend to be highly complex and complicated with multi level linkages.

– **Scalability:** Integrated projects are not scalable as the level of inter dependency and inter connectivity is extremely high, a large number of aspects need to be considered when scaling integrated projects.

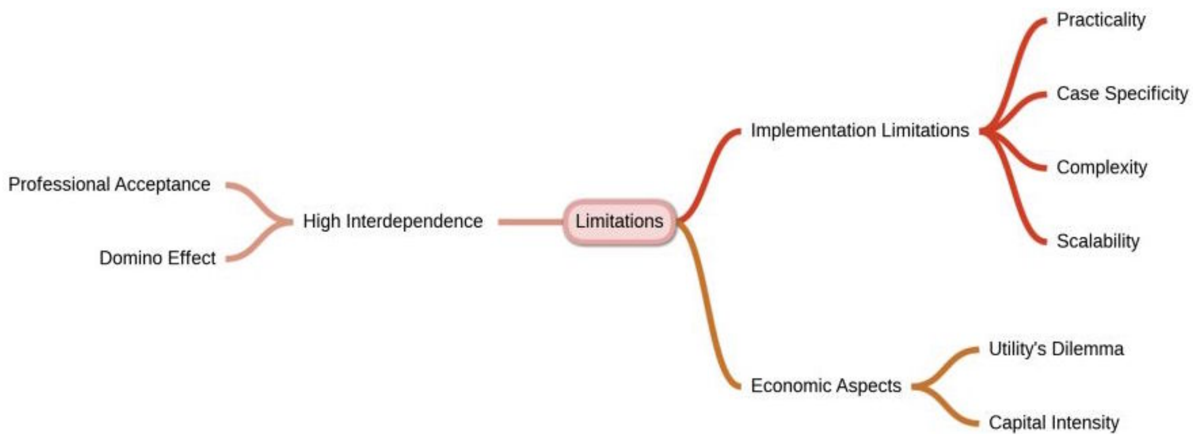

Figure 10.4: Limitations Associated to Integrative Approach

10.4. Barrier Identification

In the following section barriers and other hindrances associated to integrated energy based rural solutions are identified for India. The process of Identification again was through the interviews of stakeholders and literature research. These Measures compliment each other and thus it is recommended to use both while identifying barriers (Painuly, 2001). The interviews are present in **Appendix-C**. These interviews were analysed on the basis of following aspects identified in Chapter-9, these are believed to be prevalent for integration to be a success, thus the barriers and their plausible solutions would be laid out in relation to these aspects:

- Synergistic Performance of rural sectors.
- Synergy in Decision and Policy Making
- Knowledge and Technology Availability
- Social and Professional Acceptance
- Risk perception by Stakeholders
- Local Availability of Skilled Labour
- Non-linear Outcomes
- Externalities Consideration

The methodology to be utilised for barrier identification was provided by Jyoti Painuly, Barriers will be explored in three levels. At first the categoristaion of barriers in a broad aspect is done, getting more narrow and in detail towards the lower level. In the first level, the category of a barrier will be identified, in the second level the barrier itself is identified and the third level the barrier elements are discussed which add up leading to barrier formation (Painuly, 2001). An example of the methodology has been depicted in Figure 10.5

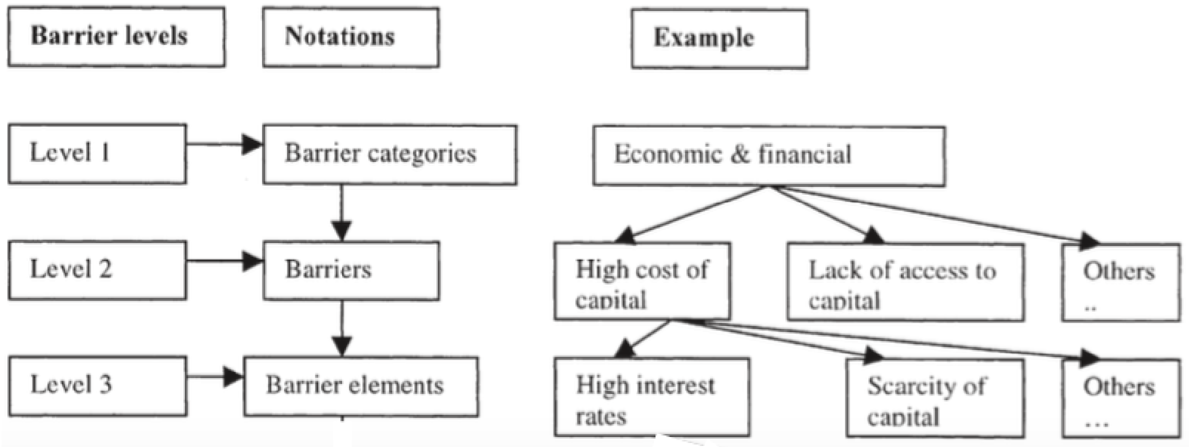

Figure 10.5: Example of Barrier Identification Methodology (Painuly, 2001)

To conclude whether a barrier or barrier category has relevance for Integrated solutions, presence of at least one component in the lower levels is important, that is the barrier should be involving barrier elements.The advantage of breaking barriers up into their elements is in a way a proof of barrier being a real threat and stakeholders involved can be pin pointed towards these existing barriers for which strategies and solutions can be worked out before hand itself (Painuly, 2001).

The following barriers depicted in Table 10.2 were identified using the above mentioned methodology for the purpose of this thesis associated to the aspects layed out in Chapter-9 and discussed above.

Table 10.2: Barrier Category and Identification

Barrier Category	Barrier
Segmented Structure	Hierarchical Bureaucracy Administrative Issues
Economic Barriers	Economic Viability Free Rider Problem High Risk Perception and Discount Rates Funding Problems Market Control
Social Barriers	Social Acceptance Local Perceptions
Policy Barriers	Unstable Existing Policies Policy Formulation Identifying Policy Elements Mismatch in Policy and Agency Goals
Technical Barriers	Local Technology Availability Knowledge Availability Conceptually Inclined Lack of R&D System Complexity External System Constraints

10.4.1. Segmented Structure

As discussed above the barriers category of segmented structure supposedly have two barrier mentioned below, the following sub section discusses the barrier elements of the segmented structure barrier in the context of India:

- Hierarchical Bureaucracy
- Segmented Administration

Professional decision making structure in India is highly segmented. Hierarchical nature prevails in all aspects of different sectors. Such a differentiated bureaucratic professional society would create hindrance in the application of laid out policies. Getting professionals from different sectors to work together on a common goal is hard due to their differentiated views and expertise. The sectors and their policies are highly segmented as well, cooperation between the different sectors is bare minimum, and acceptability between the sectors will definitely be an issue. In a broader sense creating cooperation between experts from different sectors will be one the biggest hurdles of sector integrated energy based rural development.The sectors in India have very few cross-linking, thus funding, operation, policies and management of the three sectors are highly differentiated and distinct, bringing administration as such into question. An a valid example is the execution of the Generation based incentives scheme (GBI) declared for wind energy projects by the MNRE. Indian Renewable Energy Development Agency (IREDA) began accepting applications from players in the wind market under the GBI scheme not long after the declaration of this plan. Notwithstanding, the Government of India,Ministry of Power had rejected applications that were made before the notice of the plan through the gazzete and considered applications were to be made only after such notifications . While this legitimization may hold ground on a basic principle level, practically speaking IREDA ought not have begun acknowledging applications prior to the notifications through gazzete. Such differentiated performance of institutional structures diminish the confidence of investors in projects (Infrastructure Development Finance Corporation, 2010).

The case considered for the Bottom Up case study in Chapter -9 of this thesis report proves to be a good example of this situation. Considering the sectors of rural water and electricity and thus Observing from it can be seen how the sectors have distinct decision makers.It is observable how the two sectors which can be considered as the backbone of rural development according to their potential of achieving SDGs as discussed in the introduction bit of this report lack synergy in decision making. Both sectors observe isolated and differentiated operation and decision making processes. The policies for water sector are laid out in the National Rural Water Mission whereas the policies for rural electrification are laid out under the DDUGJY. Such differentiation in decision making and policy overlooks the potential benefits of integrated operation, acting as an obstacle for integration of rural sectors. The same situation is faced for the remainder of the rural sectors (health,communication,transport,education) as well. Benefits of synergistic performance between sectors with removal of separation boundaries can be seen in earlier sections of this report where synergy between energy and water sectors and synergy between energy and waste sector have been discussed .

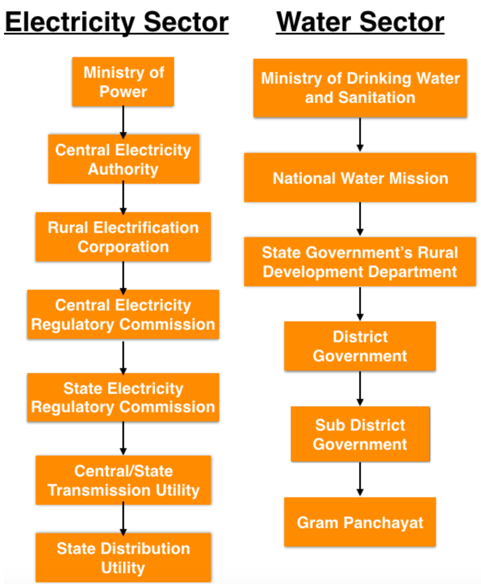

Figure 10.6: Sector Institutional Structure Comparison

The above concept of segmentation and differentiated decision making structures in India can be understood with Figure 10.7, where the Artist Sudhir Das has depicted the same problem with great precision pointing out the realities observed.

Figure 10.7: Sector Segmentation Depiction (Ramachandran, 2012)

10.4.2. Economic Barriers

As discussed above the economic barrier category has five potential barriers mentioned below, the following sub section discusses the elements of these barrier to the context of India and states how these problems are complementary:

- Economic Viability
- Free Rider Problem
- High Risk Perception and Discount Rates
- Funding Problems
- Market Control

With the liberalisation of the power market the country is showing trends of moving towards a capitalistic market. As a result projects are set up based on project costs and forecasted profits ignoring the positive externalities and social benefits (Chatterjee, 2017), since integrated multi-purpose energy systems for rural India would have more of unseen and indirect benefits rather than direct economic benefits, with present trends pushing such indirect benefits under the rug, brings about the concept of free rider problem.

With the social benefits and other positive externalities ignored the perceived costs of integrated solutions to development are expected to be high, making such solutions un-competitive in the market. So was observed while conducting the interviews for this analysis, where some interviewees reacted with criticality towards integration from an economic point of view, a couple of questions put forth by the interviewees on more than one occasion were: "How economical are such multi-purpose integrated solutions?" and "How Cost effective is the implementation and O&M?". Discussions regarding the underlying social benefits or positive externalities were often received with reprehension.

Taking the example of the case study depicted in chapter 9, the benefits of integrated approach are mostly indirect apart from improvements in reliability of electricity and water supply. Social benefits potentially are expected to be experienced in the long run. The benefits are expected to be observed in the long run rather than instantly, this could be an impeding factor for the diffusion of integrated energy solution directions for the nation. Such overlooked social benefits and their potential contribution the the achievement of Sustainable Development Goals are depicted in Figure 10.8

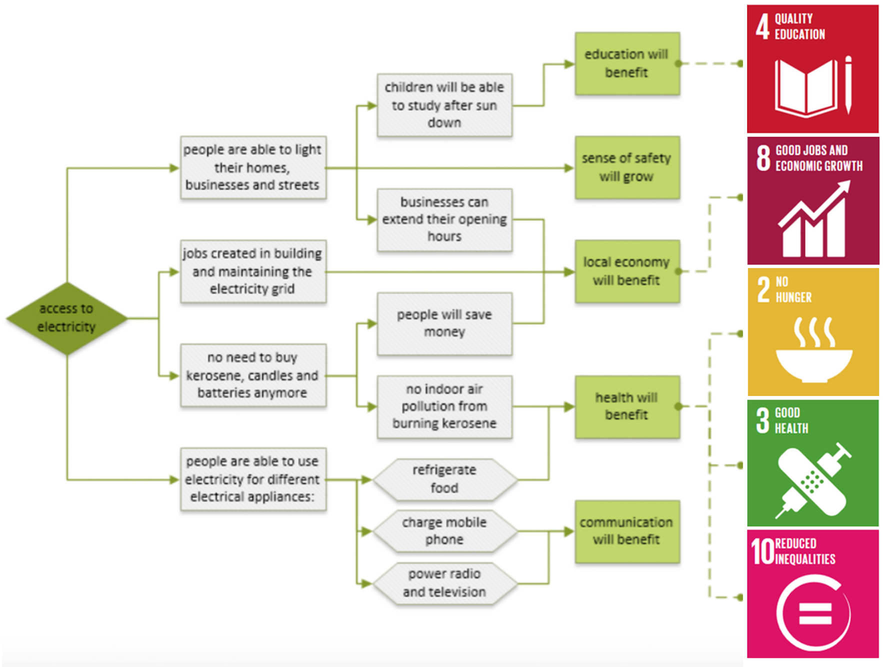

Figure 10.8: Social Benefits Associated to Integrated Rural Development with Electricity at its Core (Elisabeth, 2016)

Since the acceptance of such projects is low and the returns are long term, it brings about a sense of risk association with such systems perceived by the financing bodies. Due to the high risk associated to integrated projects the perceived discount rate is high which in turn leads to higher costs. Utility sectors in India are highly oligopolistic. Incumbents hold immense power and market share. Due to natural and artificially created oligopolistic barriers new techniques, players and solutions find their entry deterred into the market (Economics Online, 2013). The aspects of limit pricing and predatory pricing are also experienced due to collusive nature of the incumbents.

10.4.3. Social Barriers

As discussed above the social barriers category supposedly have two potential barriers mentioned below, the following sub section discusses the elements of these barrier to the context of India:

- Social Acceptance
- Local Perception

Acceptability of new tech and solutions in the local community can be seen as a definite hurdle. Low social acceptability comes from manifold factors which majorly reside on the aspects of legacy and superstitious beliefs. For new integrated systems to survive, economic generation from the project becomes a paramount factor. New solutions entering the rural market in India have faced these repercussions. The factor of 'legacy' associated to low social acceptability can very well be observed from the rural electricity context for India. At present, the rural locals perceive 'Free Electricity' believing free electricity to be their right due to reasons discussed in Chapter-4, electricity theft is a widespread phenomena. India loses 25% (which accounts to $17 billion) of its electricity to losses annually with 80% of this lost through theft (Smith, 2004). Another aspect which has led to defaulters stealing electricity is the unreliability of supply, they do not believe in paying for electricity which is highly unstable, with some localities receiving less than 4 hours a day on average.Acceptance comes with trust. It's a hurdle that can be overcome with the right policy structure and approach with improvements in the reliability of the supply and through awareness.

Another factor leading to lack of acceptance among rural locals is the large belief in superstitions, in many a cases it has been observed that the locals believe change would bring about negative energy leading to environmental disasters. Any calamity post the setting up of new solutions in these localities is blamed on the change brought about by implementation (Joshi, 2016). This can be easily seen from the case of the floods at Kedarnath, Uttrakhand in June 2013, where thousands lost their lives. Just before the floods, construction of 330 MW Alaknanda Hydro dam began on the course of river Mandakini which passes through Kedarnath . Kedarnath is a holy destination for Hindus and thousands of pilgrims visit every day. To make way for the dam the temple of Kedarnath was relocated to another location on higher ground and unfortunately the floods hit the region soon after. The locals believed the floods were Gods Fury for the displacement of the temple. Post the floods construction of 23 out of 24 proposed dams on the course was halted to protests and opposition faced locally (Daily Mail, 2013).

With high level of integration, and inter sectoral dependence- maintaining reliability of supply becomes very important, i.e. O&M of the integrated systems needs to be on point. To do so a large trained workforce should be available locally. Social acceptability and social integration of local workforce is often affected, since they are perceived to help those bringing about disaster by the locals. As a result finding consenting local workforce becomes hard as they worry about theirs and their families social perceptions (Joshi, 2016).

10.4.4. Policy Barriers

As discussed above the policy barriers category supposedly has three potential barriers mentioned below, the following sub section discusses the elements of these barrier to the context of India:

- Instability of Policies
- Policy Formulation
- Identifying Policy Elements
- Mismatch in Policy and Agency Goals

These potential barriers to integrated solutions are multi-dimensional in nature. Directly or in-directly expanding to or depending on social factors, political issues, technical issues, cultural factors, design capabilities, economics etc. The associated factors or effects from decisions made for the discussed sector need not even be in the same sphere of plain, in other terms they could be expanding over national level, state level as well as local level with high interconnectivity between all the elements spread over different spheres of these plains. This aspect is depicted in Figure 10.9.

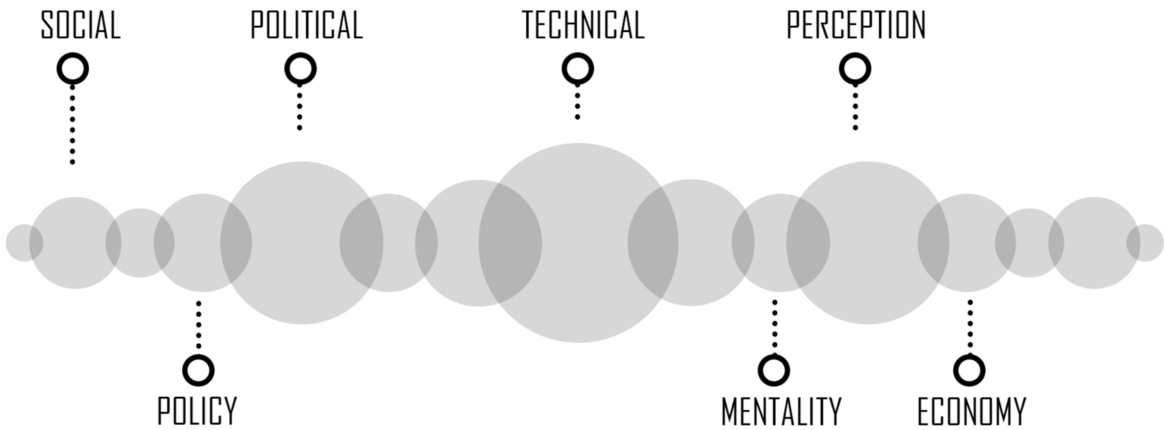

Figure 10.9: Some Multi-dimensional Elements For Consideration For Integrated Policy Design

Aspects associated to integration are a phenomena which cannot be isolated due to their high level of interconnectivity and depth of relations, Depicted in Figure 10.10.

State, local as well as national level aspects are to be considered while designing policies. Identification of elements to be targeted by policy is hard due to the nature of the problem. States in India face different issues, and need policy serving local needs based on available resources and local problems on hand. With such case specification brought into the picture, policy design becomes tideous, cumbersome and complex.

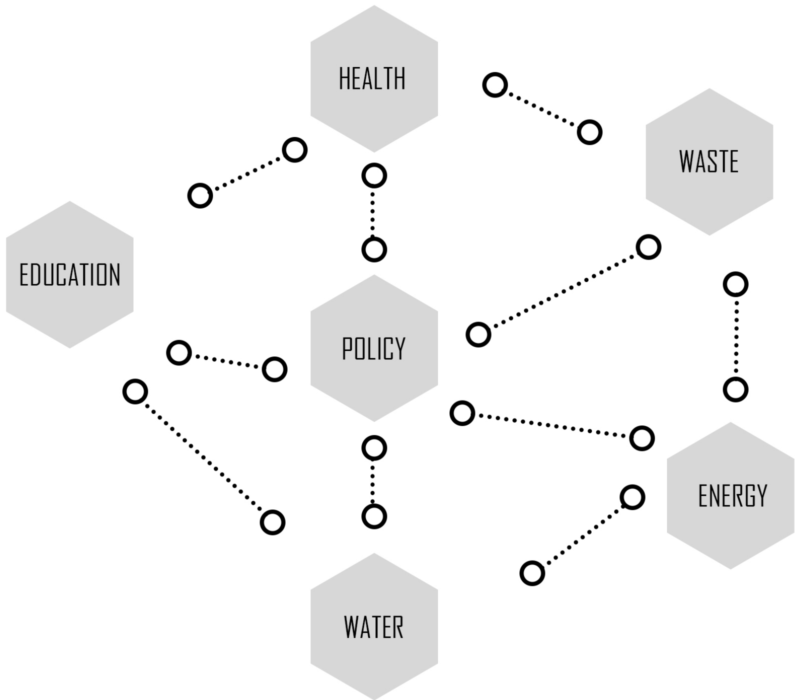

Figure 10.10: Example of Policy Element Interconnections And Dependence

Integrated system policy design is heavily dependant on the available policies of rural sectors. These policies are unstable and continuously change (Infrastructure Development Finance Corporation, 2010), this can be observed by the discussed policies for electricity in Chapter-4 and water in Chapter-5, these policies are created as and when required to facilitate a sector or government motives. This could possibly be blamed on the instability of the central and state government prevalent due to the highly democratic nature of the Indian system. Every 5 years elections are held centrally and in states, which brings about a change in administration, this change in administration is accompanied by change of goals and aims for the governments eventually of policies. New governments create new policies and scrap existing ones dynamically to favour their target audience as a 'Vote Bank'. Political issues additionally assumes a part in enabling state governments to draw more power than they are entitled for. With the formation of coalition government between different political parties, the central authority is frail to discipline those who stray from defined policies—punishing wayward state politicians whose support you depend on is a sure-shot way of losing their support sending them into the arms of your adversaries (Vaishnav, 2012). This concept can be better understood with the help of an analogy: suppose 'party A' is the major party at the central government level, who have been riding on the support of minor 'party B' which has major support locally in major states of the nation, with an eventual goal of remaining in power 'party A' would have its hands tied behind its back and forced to turn a blind eye towards 'party B' if it wishes to stray from goals and policies set by 'party A' to keep 'party B' as an alley in the following election. This concept has been termed as the 'Fragility of the Coalition Government' (Vaishnav, 2012).These conditions create instability in policy design and implementation centrally as well as on the level of state governments creating definite hindrance particularly for the case of integrated solutions.

For integration to be a success, as mentioned before coordination between various decision making bodies can be seen as a supreme requirement. In India, observing from the sector of rural electrification a mismatch in goals of MNRE and the goals and targets set forth by the Jawaharlal Nehru National Solar mission (JNNSM), when compared to the targets of National Action Plan on Climate Change (NAPCC), targets of above mentioned both fall short. Such can be seen from the Table 10.3.

Table 10.3: Mismatch between RE capacity envisaged under policy and capacity addition targeted (Infrastructure Development Finance Corporation, 2010)

Barrier Category	2009-10	2010-11	2011-12	2016-17
Energy Requirement (MU)	820920	891203	968659	1392066
Share of RE as mandated under NAPCC (in %)	5%	6%	7%	12%
Quantum of RE required (in MU)	41046	53472	67806	167048
RE capacity addition targeted by MNRE (in MW)	15542	20376	25211	57000
Solar capacity targeted under JNNSM (in MW)			1000	10000
Quantum of RE available (in MU)	29952	39269	50514	129122
Additional RE required to meet RE share mandated under NAPCC (in MU)	11094	14203	17292	37926

10.4.5. Technical Barriers

As discussed above, the technical barriers category supposedly has six potential barriers mentioned below, the following sub section discusses the elements of these barrier to the context of India:

- Local Technology Availability
- Knowledge Availability
- Conceptually Inclined
- Lack of R&D
- System Complexity
- External System Constraints

The complexity of integrative rural development solutions are not experienced only from policy point of view but also from a perspective of technology, system design, O&M and management. The tedious, complex nature of multi-purpose solutions for rural development require a lot of planning and optimization.

Local availability of technology in rural India is seen as a major barrier to implementation of technology based solutions leading to increased costs due to the need of import, for instance from an energy point of view local energy access and energy security is seen as the major hurdle to implementation since mostly rural regions are remote, grid extensions were not seen as a viable solution in the past and thus interventions now requiring of expensive storage solutions need to be implemented, these decentralized energy technologies are not available locally thus import adds up to the costs frailing the beliefs of investors with increased risk perception (Infrastructure Development Finance Corporation, 2010). Skill shortages are also prevalent in the market which was discussed earlier the thesis, while pointing out the shortfalls of the Rural Electricity, Water and Waste sectors in India. These skill shortages are seen as knowledge shortfalls in design and operation sectors. These skill shortages in their respective sectors can translate to skill shortage and knowledge barriers to integrated systems.

The non-availability of technology for integrated systems can be seen as a direct result of lack of R&D in the sector, with increased investments in R&D and recognition of potential benefits of the solution type technology can be developed over the course of a period (Painuly, 2001). Integrated solutions still remain in conceptual stages as a direct consequence of the above discussed aspects.

External technical parameters play as vital a role as any other, these external technical parameters can be capacity restriction and infrastructure issues. Especially for the electricity sector, where projects are stalled due to local grid's capacity restrictions, the final decisions of capacity additions lie in the hands of the local DSO. Due to the lack of management skills and capacity restrictions , DSOs tend on disallowing the implementation of grid connected projects. (Infrastructure Development Finance Corporation, 2010).

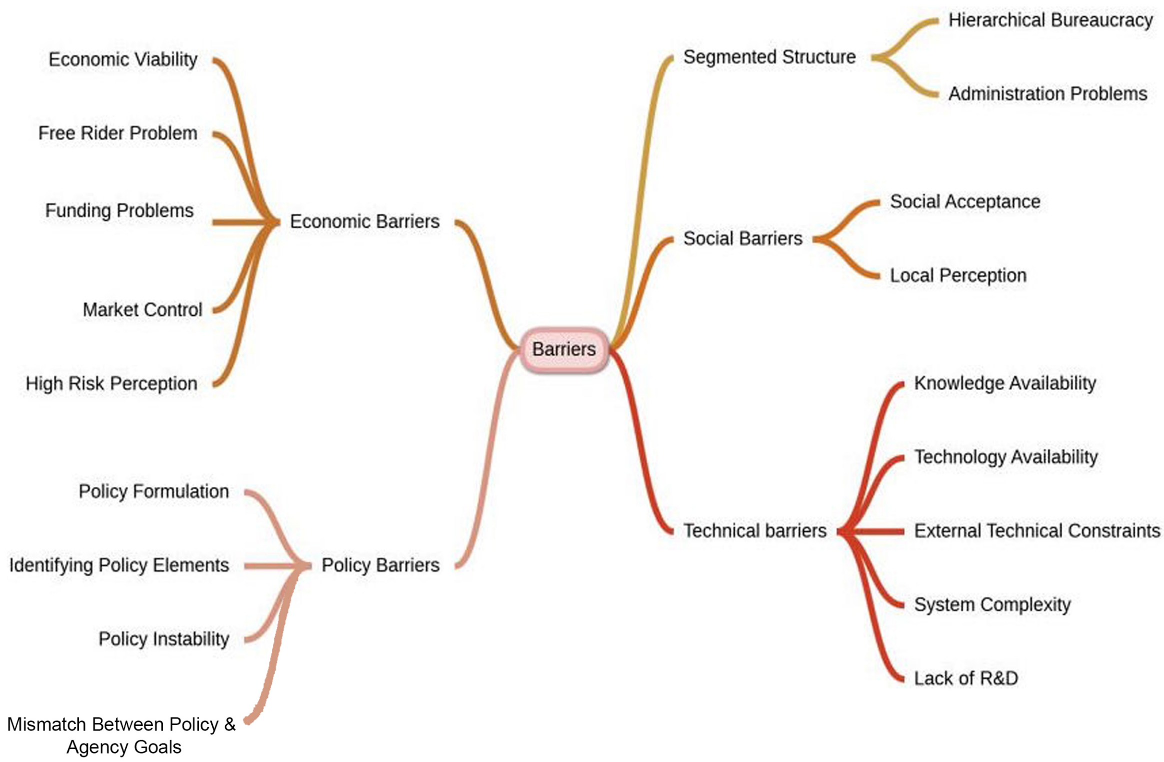

Figure 10.11: Barriers to Implementation of Integrative Approach in India

10.5. Plausible Solutions to Barriers

The following section lays out some plausible solutions to barriers discussed in the previous section. The solutions were put forth on the basis of interviews conducted as well as literature research.

10.5.1. Recommendation for Segmented Structure

- **Authoritative Strategies**
  These give the authority to some institutions, who tackle up the critical problem-solving decision-making process while others consent to abide to these decisions. Identification of this arrangement of authoritative stakeholders or actors may lay on their insight and skill, hierarchical position in the progression or coercive power. In such a scenario a top-down driven decision-making process might work to the advantage of the goal. A basic requirement is that different actors consent to recognizing and submit to the transfer of power to the blessed few and abide by the choices of these few (Government of Australia, 2015). An example of from the present scenario would be the power vested in the Reserve Bank of India for interest rates. Such authoritative power in situations of instability at the center can be advantageous . Authority needs to be vested in more stable decision making stakeholders who would also be responsible for maintaining the direction of existing policies with need be also incorporate requirements of changes in central or state governments.
  Advantages: Efficiency, Timeliness
  Disadvantages: Misuse of power, Blessed few may disregard solutions from other parties and look for solutions within their own narrow thinking capabilities, against the principles of democracy

- **Collaborative Strategy**
  Collaborative strategies are bolstered by the majority critics to be the most effective in tackling multi-

dimensional and structural problems that have numerous stakeholders among whom power and decision making is scattered. It is especially pertinent where part of the issue includes sustained behavioural change by numerous actors or potential subjects. At the center of collaborated effort is a win-win perspective of problem-solving and critical thinking. Associations, partnerships, joint endeavours, government treaties and information campaigns to influence choices in the benefit of this strategy (Government of Australia, 2015).

Advantages: Stakeholder Commitment, Effective and resource efficient solutions, Timeliness
Disadvantages: Collaborations might take a turn for the worst, dialogue could turn to conflict creating a situation of stalemate.

10.5.2. Recommendation for Economic Barriers

- **Moral and Ethical Considerations**
  The moral and ethical considerations of projects can be used as a tool to solve the non-consideration of positive externalities problem. Considering social benefits could be used to prove practicality of approach which at present is overlooked, Figure 10.8 provides a few overlooked social benefits of an improved access to electricity supply. Another good example of moral and ethical considerations comes from the renewable energy sector with measure including green pricing schemes and voluntary action have been implemented. Some countries which are a part of the International Energy Agency have set up green pricing schemes that offer consumers to pay more for renewable electricity, the increment of costs are borne by the users voluntarily for some other benefits (Painuly, 2001), such schemes could be set up to tackle the problems of integrated multi-purpose energy systems in rural India, benefits could be provided for higher prices paid by consumers, helping the solution type diffuse into the market scenario and driving R&D for the sector.

  In case of voluntary action for renewable energy, utilities agree on make a voluntary agreement on increasing the renewable percentage in the mix with targets set through binding agreements (Painuly, 2001). Such can be implemented for integrated multi-purpose energy systems as well with the states having to sign binding agreements to set targets of achieving goals of integrated development.

- **Economic and Financial Incentives**
  Perception of high risks associated to integrated systems is integrally connected to high discount rates and thus high costs. High costs truly are termed as the biggest hurdle for any disruptive solution. To help the solution or technique diffuse in the countries rural development plans the government could set up policies providing capital subsidies for installation of technology.However, with such capital incentives and subsidies the policies need to be slowly phased out in accordance of the growth of the sector (Painuly, 2001). A good example comes from the renewable energy market in Denmark, where capital subsidies for wind were phased out over a period of 10 years. Another example comes from the solar sector in India, where feed in tariffs have been on a constant decline since the application of the policy in accordance to the growth of the sector and implementation of solar PV technology. Provision of such financial incentives brings about the trust factor in investors due to the belief of the government put into the solution type. This helps reduce the high risk perception ultimately leading to lower discount rates and thus costs.

- **Funding Interventions**
  As discussed in policy interventions above, with the government setting up policy structure, incentivising a new solution, a belief is brought about in investors towards the technology or solution type. This would in turn lead to easier access to funds for implementers.

  Another possibility is through government investments. Again we take up the example of the renewable sector, in countries where governments are major players in the energy sector (such as India), they have set up national plans and strategies for promotion of Renewable Energy Technologies. Such can be done for integrated solutions as well, the Government of India can set up development plans with funding opportunities provided to implementers of technology, just as the case of the electricity distribution sector in India, due to the shortfalls of the sector the government of India provides a hefty funding for companies entering the distribution market, after which an optional loan at minimal interest rates are also available.

- **Regulatory Interventions**
  Overcoming the barrier of market control, i.e. major market share in the hands of a few due to the oligopolistic nature of the Indian utility sectors requires government intervention, regulatory bodies need to be set up to put forth pricing mechanisms to avoid limit and predatory pricing techniques of the incumbents. Regulations to guarantee a market for the solution need to be put forth with standard formulation to boost confidence in the solutions (Painuly, 2001).

10.5.3. Recommendation for Social Barriers

- **Awareness Campaigns**
  Organisation of awareness, information and education campaigns in rural regions could help overturn the social acceptability and mentality problem faced in India. The locals need to be informed about the benefits held in new technological solution and this can be done through these awareness campaigns (Jones, 2010). Information regarding the moral, social, environmental and economical benefits should be provided to the locals.

- **Local Empowerment and Engagement**
  "Initiatives to foster adaptation will ultimately fail if they do not empower and inform individuals who remain confined in their adaptive behaviour and have limited access to key resources" (Jones, 2010). In the past local decentralised solutions with a proven track record and reliability when applied locally have been able to overcome the social barriers, by creating a sense of local ownership and thus empowerment amongst the rural locals. Such has been experienced with the application of Localised Micro-Grids in villages of India, which was discussed earlier in chapter-4, which lead to lessening the number of defaulters. Invovling locals and local governing bodies is very important when dealing with areas of such fragile social acceptance.Local belief in the solution is empowerment for local engagement which in turn would lead to locally operated O&M of the project leading to lower costs.

10.5.4. Recommendation for Policy Barriers

- **Adaptive Policy**
  Policy makers need to anticipate the evolving problem set while designing polices for integrated solutions. Since the problems associated to all rural sectors show evolution properties, right policy tools with adaptive, incremental and conditional characteristics need to be in place capable of adapting to the dynamic nature of the problem set. In other terms "the policy design should not be optimal for a best estimate future but robust across a range of optimal futures" (Walker et al., 2001). With the case specificity of integrated solutions and varying problem sets, local resources and aims of different rural regions, the policy structure should be capable of encapsulating changes in all elemental policy structures.

  To do so the policy makers need to need to take into consideration the problems of social mess and fragmentation, which ride on the level of interdependence of rural development elements and how each element in the system is highly linked to every other element, effects on any one element creates an effect on all the others as well. Defining policy elements and policy making boundaries is important, such fragmented policy design require integration among the ministries and policy makers which can be achieved either through authoritative strategies or collaborative strategies discussed above.

- **Policy Monitoring**
  As mentioned before due to the evolving nature of problem sets , policy designers cannot take into consideration all future aspects even when policies require no adaption the laid out policies require updating to encapsulate environmental factors and organisational goals, here the organisational goals refer to the goals of implementing states and government bodies (Bakshi et al., 2013). Figure 10.12 depicts a possible methodology for policy monitoring by involved organisations.
  To do so a policy monitoring process can be set into play with a feed back looping in a two fold manner. First, between the central government,(laying out the policy outlines) and the state governments and

second between the state governments (who are responsible for adapting the policies to local conditions) and the implementers and other local stakeholders thus encapsulating all associated aspects to continuous policy adoption. Such strategies could trigger the aspects of learning by doing constantly showing drastic improvements on the learning curve.

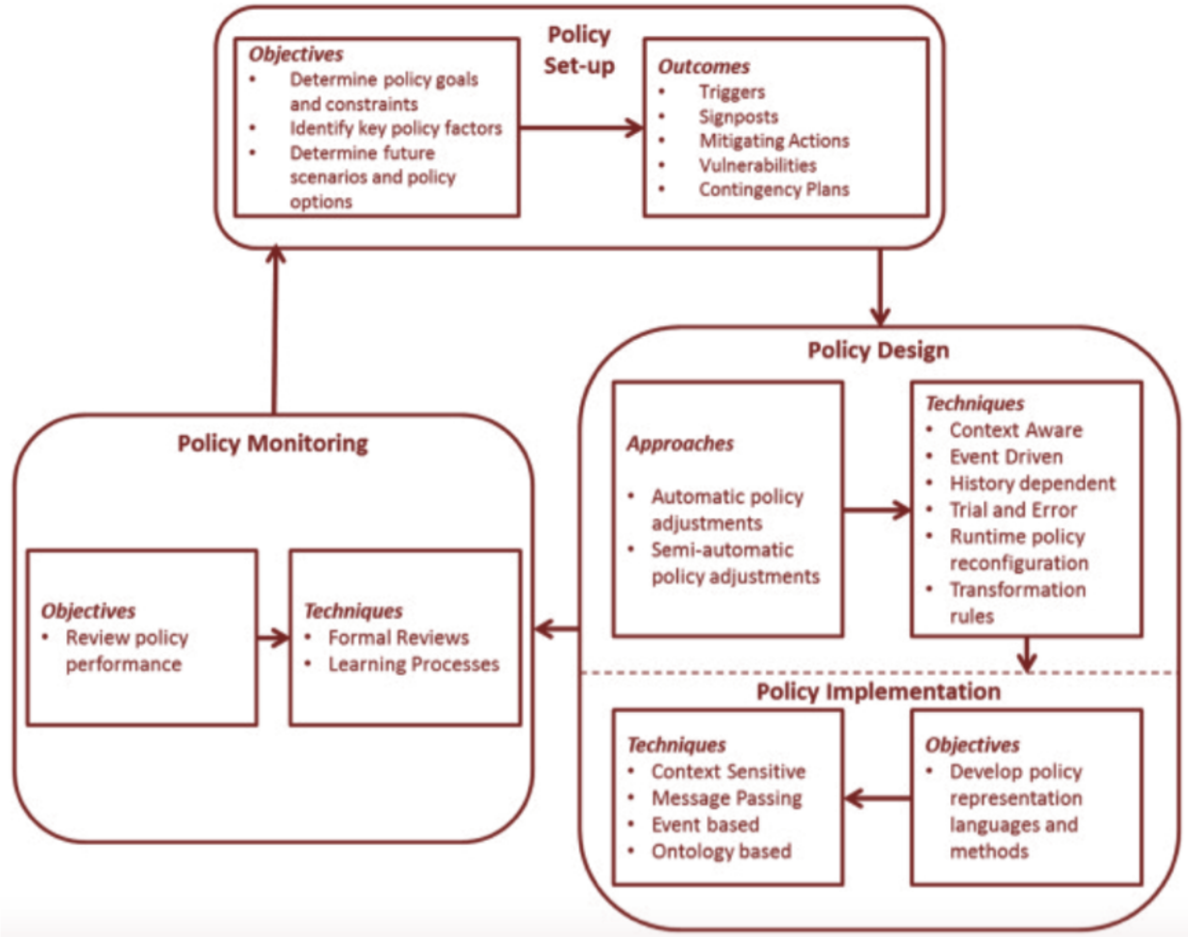

Figure 10.12: Proposed Integrated Development Policy Design Process (Bakshi et al., 2013)

10.5.5. Recommendation for Technical Barriers

- **Research and Development**
  The problems of system complexity and solution conceptuality can be resolved through research and development. R&D facilities should be set up leading to advancements in technology eventually also contributing to reduction in high perceived costs(Painuly, 2001). For example R&D in the field of solar biomass integrated solutions have led to large reductions in costs of the system due to optimal design strategies eventually lead to lowering the battery storage requirements. This was achieved by operating biomass energy in times of solar shortfalls.

- **Facilitating Measures**
  Examples from various sectors show how governments can take several facilitating measure to ensure technological development in the country. This could be done by financing R&D, feasibility studies and laying out standards for technology to be achieved by institutions (Painuly, 2001). Subsequently, the facilitating measures could also be extended to solve the external technical aspects such as external grid management barriers by extending facilitating measure to train professionals to add to the skill set of these bodies to be able to incorporate integrated decentralised systems.

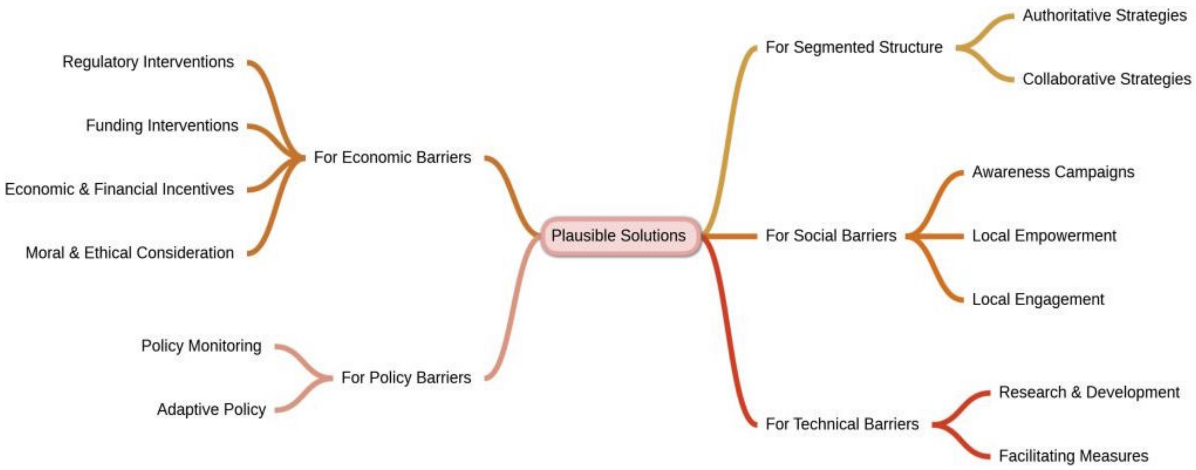

Figure 10.13: Plausible Solutions to Barriers to Implementation of Integrative Approach in India

Observing from the plausible solutions discussed with the influencing stakeholders in India it can be reflected over in the following manner. Seeing the bigger picture and integrating the many different perspectives and various domains to the problem. I.e. Systems thinking to identify the nexus which defines the whole domain at the core or heart of the problem. Boundaries of Systems thinking needs to be expanded from a macro point of view. The systems performance of all the involved actors needs to be viewed from a collaborative systems thinking point of view as well. Need to gain a fundamental perspective to encapsulate the many diametrically opposed views and thus, work backwards to be able to conceptualise the perspectives of the problem. Creating a paradigm for stakeholders to integrate their own context and meaning in policy formulation. Tackling problems requires a structure of trust and collaboration to overcome the need of a long term investment whether even if it lacks short term incentives. The stakeholder and power dynamics around these systems are critical to designing stakeholder collaboration. Platform for co-creation of solutions and an iterative experimentation ad implementation to develop project due to the co-evolutionary nature of problems and solutions.

10.6. Conclusions of Top-Down Case Study

In this section a Top-Down case study was performed to mark out certain aspects of the Integrative Approach in an Indian context. This was done by interviewing various stakeholders in the Indian sector. Stakeholders from the aspects of policy, implementation and research were interviewed to analyse the validity of the approach for the Indian market on the basis of the potential benefits, limitations and barriers of the approach in an Indian context. Some plausible solutions to these barriers were also discussed.

The Top-Down approach, intended on analysing interviews conducted with the fore mentioned stakeholders in India on the basis, of certain aspects identified by the Bottom-Up case study in Chapter-9. These so to say aspects were seen a base of identification of barriers and thus provision of plausible solutions to the barriers in this section.

11
Conclusion

In this section, the thesis is concluded. The aim of the project was to provide solution directions to problems of impeded rural development in India, with a focus on energy, the thesis also aimed at marking out the barriers such an integrative approach would face in an Indian context. The following section answers the sub research questions, altogether these sub questions provide an answer to the main research question.
Main research question was:

'Having recognized the importance of systems thinking, how can energy focussed integration of sectors provide directions to overcome the problem of impeded rural development in India?'

How is rural electrification related to rural development?
Energy supply and GDP of a nation go hand in hand thus electrification of rural regions has manifold benefits for those living in such under developed regions. A stable power supply provides increased revenues for the locals, automation can be achieved which would increase productivity and hence local GDP. It helps create jobs and provides new business opportunities. Lifestyle improvements are potential benefits with large scale underlying social benefits branching to other sectors such as education, health-care and communication. These above mentioned benefits are inclined with the values of the Sustainable Development Goals set out by the United Nations in 2000 for improved global rural development and directly or indireclty improved electrification targets achievement of all the goals set under SDGs..

How is the application of integrative approach inclined with the objectives of Sustainable Development Goals for rural development?
For the purpose of this thesis an energy focused integration of sectors was looked at to augment impeded rural development in India. For the purpose of broader rural development the sectors of water and waste were inculcated in the integrative approach, as rural development was deemed as a wicked problem. Solving wicked problems requires broader boundaries of system considerations. The thesis try lay forth integration as a method to augment issues of rural development by creating multi-purpose energy systems. Inter connected performance of sectors potentially could target all the goals set under the Sustainable Development goals on a deep level.

What are the concepts associated to integration?
The belief behind integration is based on the concept of systems thinking, where we tend to treat systems as a whole catering to the performance of the entire system and not trying to improve the performance of each element of the system. Characterisation of integration can be done on the basis of:

- Integration of components into a system
- Integration of energy sources into multi-source multi-product systems
- Integration of industries into Eco-parks
- Integration of sectors

- Integration of new technology into existing
- Integration of Functions
- Integration of sustainability into energy systems
- Integration of Sites
- Integration of Goals and Multiple Objectives

For the purpose of this thesis, integration of sectors is of prime importance, since we try to augment rural development through energy focused integration of sectors.

What is the present state of art of the rural electricity sector in India?
At present problems of high levels of energy poverty were observed to be prevalent in the rural regions of India. These rural localities observe no self sufficiency in terms of supply and are highly dependant on a centralised grid supply for electricity. The centralised grid further faces problems associated to reliability of supply thus leading to issues of availability for the rural regions. Such issues of impeded supply have led to large scale social drawbacks branching to other sectors leading to impeded rural development.

What are the shortfalls being faced by the electricity sector in rural India?
Problems of reliability of supply and thus local availability of electricity are prevalent in rural India. The problems with the rural electricity sector in India does not lie with generation capabilities but with the supply. In terms of generation, India is an energy surplus country with enough generation capacity to see the country through to 2027, the problem thus arises with inefficient supply. These problems add up leading to the 'Issue of the Underserved', where centralised electricity grids stand idle for majority of time due to lack of centralised supply. These issues are an outcome of a variety of problems associated to the technology, economics of the sector, social aspects and related political aspects.

What efforts have been made by the Government of India to improve the shortfalls associated with the rural electricity sector?
The Government of India has been tackling problems of rural electrification since India's Independence in 1947. New policies are laid out every few years aiming at higher levels of electrification. The present policies aim at electrifying villages through the extension of a centralised national grid.

What are the potential benefits for consideration of water and waste sectors?
Inclusion of water and waste in the above mentioned energy focused integration of sectors for augmented rural development have manifold benefits to target a broader prospect of the Sustainable Development Goals. Presently the two considered sectors have faced large scale issues in rural regions which have lead to impedance in development and have large potential synergies prevalent with the energy sector which could be targeted for integration of these sectors.

What are the present alternatives to solve problems associated with rural electrification shortfalls in India?
The Government of India, laid down policies to provide solutions to problems of rural electrification shortfalls by implementation of decentralised renewable energy. This is done through application of either solar home systems, local grid connected or grid defected renewable energy micro-grids. Policies for decentralised energy are laid under the Remote Village Electrification Program of the Ministry of New and Renewable Energy.

What methodology will be followed for energy focused integration of sectors for augmented rural development in India?
The approach to be followed has been given a terminology of an Bottom-Up-Top-Down approach. A Bottom-Up case study was performed to provide sector integrated solution directions for the selected rural region. The approach followed for the Bottom-Up case was based on I-neffs and E-nabes, the Bottom-Up case study was performed on a sample site, knowledge gained from performing the case study was extrapolated to provide certain aspects which would be required for integration process to be a success and thus the barriers and

their identified solutions were defined on the basis of these identified aspects in the Top-Down case study.

The Top-Down case study was performed as well, where stakeholders and experts from various sectors of the institutional structure were interviewed to get a better overview of the aspects associated to the Integrative Approach defined in the Bottom-Up case study ,for creating multi purpose energy systems for rural development in an Indian context. it is this aspect if the thesis which provides detailed information regarding the barriers and obstacles expected to be faced while implementing such high integration of sectors while laying out certain possible solutions to those barriers, also laying down the benefits and limitations associated in brief.

How can gained knowledge of the Bottom-Up case study be extrapoltaed for India?
While performing the Bottom-Up case study it was observed that certain aspects need to be catered to, for making the energy focused integration of sectors a success, these are:

- Synergistic Performance of rural sectors.
- Synergy in Decision and Policy Making
- Knowledge and Technology Availability
- Social and Professional Acceptance
- Risk perception by Stakeholders
- Local Availability of Skilled Labour
- Non-linear Outcomes
- Externalities Consideration

What are the potential benefits and limitations associated with energy focused integration of sectors ?
The overview of the positive and negative aspects are given below:

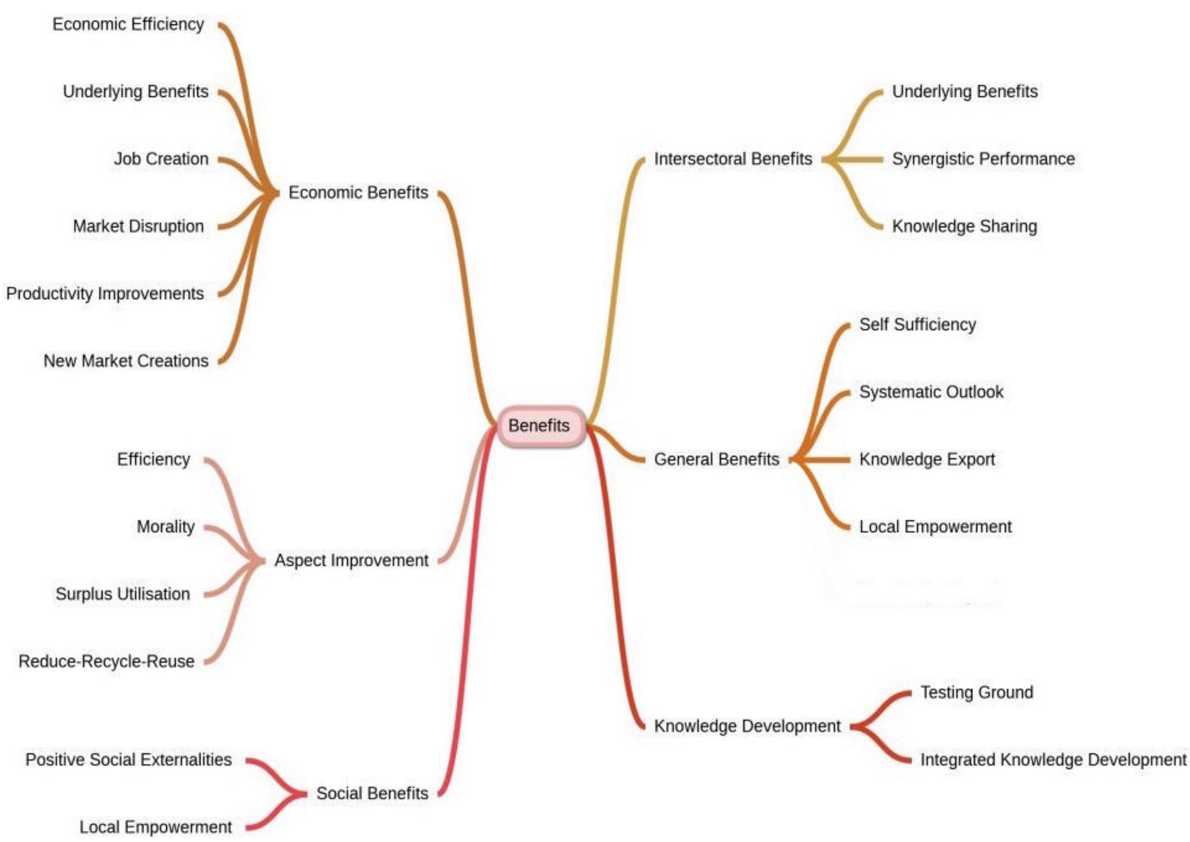

Figure 11.1: Positive Aspects Associated to Integrative Approach

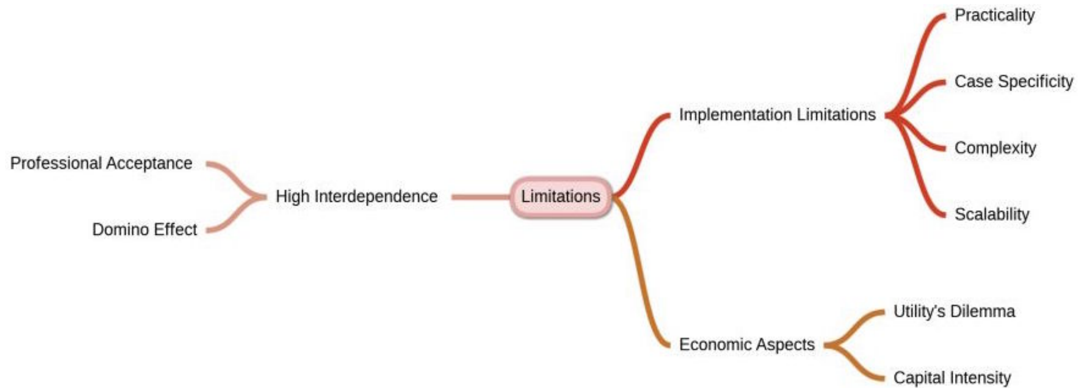

Figure 11.2: Negative Aspects Associated to Integrative Approach

What are the potential barriers to implementation of such energy focused integration of sectors in an Indian context?
The figure below provides an overview of the potential barriers expected to be faced to implement an integrative approach in an Indian context:

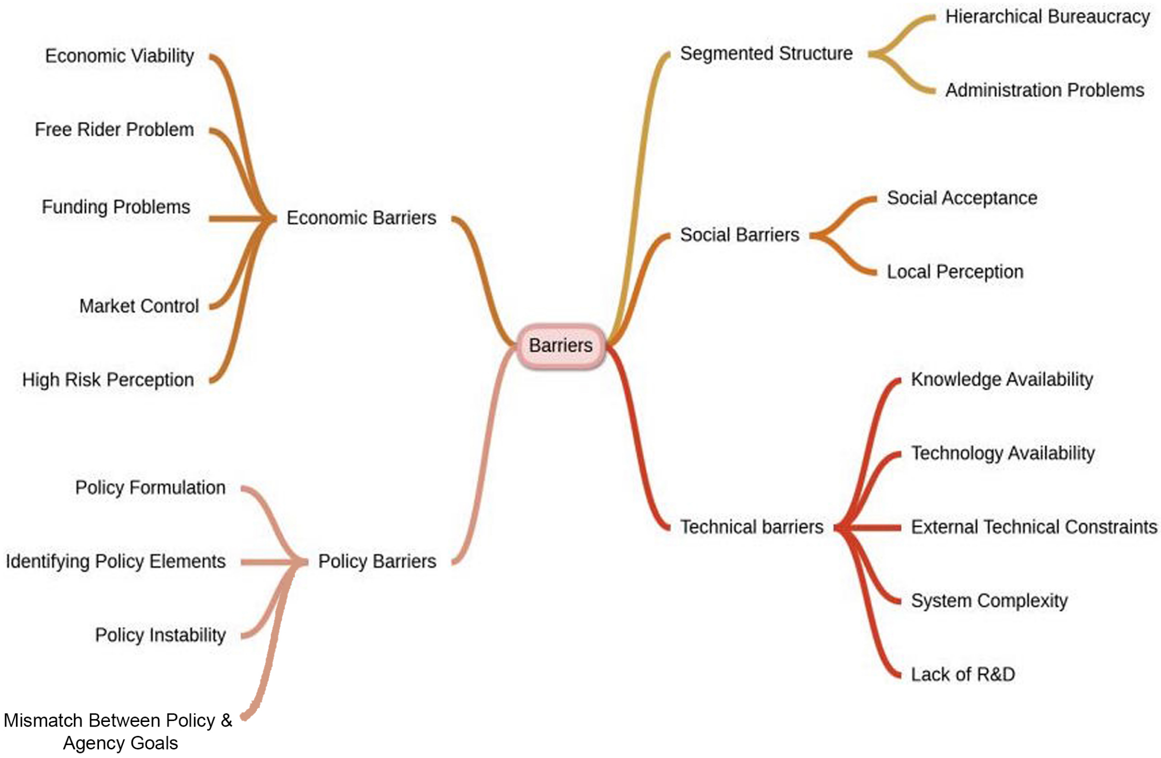

Figure 11.3: Barriers to Implementation of Integrative Approach in India

What are plausible solutions to overcome these barriers in an Indian context?
The figure below provides an overview of plausible solutions to overcome barriers of an integrative approach in an Indian context:

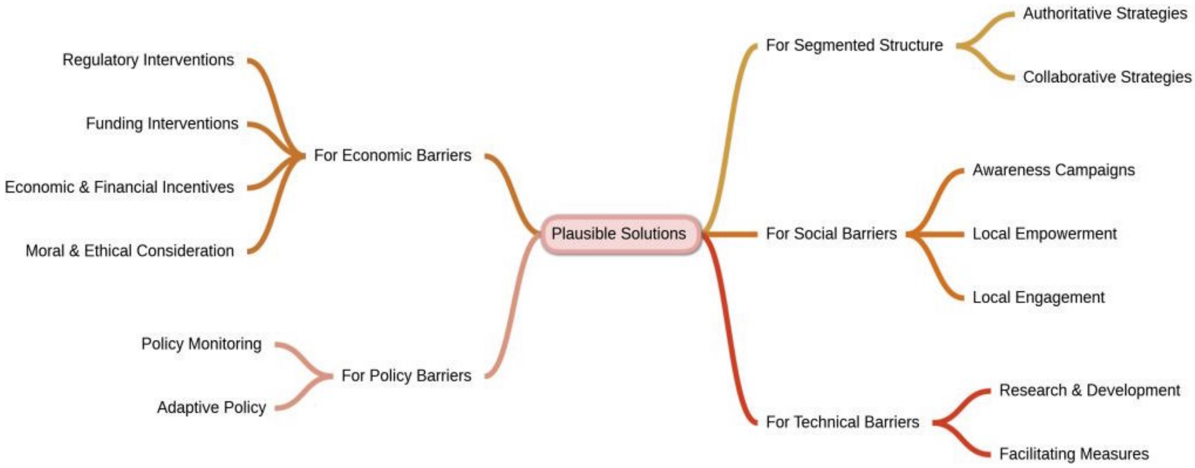

Figure 11.4: Plausible Solutions to Barriers to Implementation of Integrative Approach in India

12 Reflections

12.1. Research Limitation

The methodology applied in this thesis aimed at performing Bottom-Up case study and thus extrapolation of knowledge gained for energy focused integration of rural sectors for augmented rural development in India was based on a sample site. The limitation of doing a sample site study in India comes with the prevalence of geographical, economical and social diversity in India. Rural regions in different parts of the nation face distinctly different barriers to development and thus outcomes of a local case study might not hold true for the purpose of the entire nation. Though argumentation was provided for considered site to be the essence of rural India, more case studies in different regions would be required for more legitimate results.

The thesis takes an energy centric approach. Rural development is looked at through sector integration with a core focus on energy. Barriers and plausible solutions for overcoming those barriers were put forth for multi-purpose energy systems were put forth, energy focus was due to external constraints. The thesis thus ignored the possibility of integration of sectors with the possibility of other rural sectors at its core. A deeper analysis of stakeholders could also not be conducted due to time and resource limitations, a stakeholder analysis would have strengthened the foundation of this thesis.

12.2. Relevance

Energy focused integration of rural sectors is believed to be key to achieving fast paced rural development in a sustainable world in this thesis. Through this research potential of contribution to lower Top-Down knowledge gaps in India to augment integration were identified and thus plausible solutions were laid forth. Following are the relevant contributions made over the course of the thesis.

12.2.1. Scientific Contribution

Existing work in the field of integration was discussed in Chapter-3. The discussion concluded the existence of integrative design principles, techniques and related concepts. In particular concepts of I-neff and Enablers were discussed. Provision of highly integrated performance of rural sectors for augmenting development in the under served regions of the nation was the main contribution of the research. A methodology consisting of a Bottom-Up - Top-Down approach was devised for the same. The main scientific contributions of the research are documented below:

- Identification of aspects absolutely essential to make integration a success were identified through the application of I-neff and E-nabes methodology which potentiates and enables integration of sectors.

- Identification of potential barriers to energy focused integration of rural sectors from an India centric view. These barriers were identified through a set of interviews conducted with the policy makers and experts from other institutions and were analysed on the basis of aspects absolutely essential to make integration a success . The validity of these barriers was then put forth through a literature research backing.

- Plausible solutions for barriers to energy focused integration of rural sectors from an India centric view, again identified through a set of interviews and backed by literature survey.
- Identification of on ground dynamic problems associated to the Indian rural electricity sector, through a string of interviews and literature survey.

12.2.2. Societal Contribution

Sustainability in a broader sense is aimed at in the thesis, including social, economical and environmental sustainability. The thesis aims at achieving a broader aspect of Sustainable Development Goals set by the United Nations. Integration leads to underlying social benefits which are highly socially inclined in the case for rural India.

12.3. Future Recommendation

This section deals with providing recommendation for future related research.

Barrier Dimensions Identification
For the Top-Down case study, in the part of the barrier identification we identified 3 levels of barriers, barrier category, the barrier itself and the elements of the barrier. With each step the barrier further decomposing. Another aspect which could be identified would be the fourth step of the research ti.e. identifying the dimensions of a barrier element. For example, if economics is the barrier category, which further decomposes into high capital costs, the barrier element considered for high capital cost is high interest rate, so the barrier dimension for this barrier element would be the deviation of the present scenario from the idle sceanrio, for instance, % by which interest rates are higher are say 20%.

Practicality Analysis
The thesis analyses energy focused integration of sectors from a theoritical perspective, further research can be conducted to analyse the practicality of such integration for rural India. As mentioned over the course of the thesis ,the market in India is capitalistic driven , thus questions pertaining to practicality need to be answered, both technical and economical practicality needs to be taken into consideration. Answering questions pertaining to economics of the approach thus become important for a country like India.

Alternate Prime Sector Consideration
The integrative approach in this thesis had a prime focus on the energy sector. Future research directions could use a different approach to perform the study with prime focus on other rural sectors. Doing so would provide a more wholesome answer regarding integration of sectors being a key to rural development in India.

Stakeholder Analysis
A deeper analysis of stakeholders could also not be conducted due to time and resource limitations, a stakeholder analysis would have strengthened the foundation and findings of this thesis.

A
Appendix

Energy System
An energy system is defined as a system where the constituting components have their functions integrated to supply energy in one or multiple useful and appropriate forms. While analyzing energy systems apart from studying and analyzing the components of the system, the history should be looked into in detail as well to asses the future developments of the system. Energy system analysis also include the impacts of external drivers on the considered system such as economic progression on the nation, environmental impact and policies of the government which are in place to to further develop these systems Hemmes et al. (2007). The

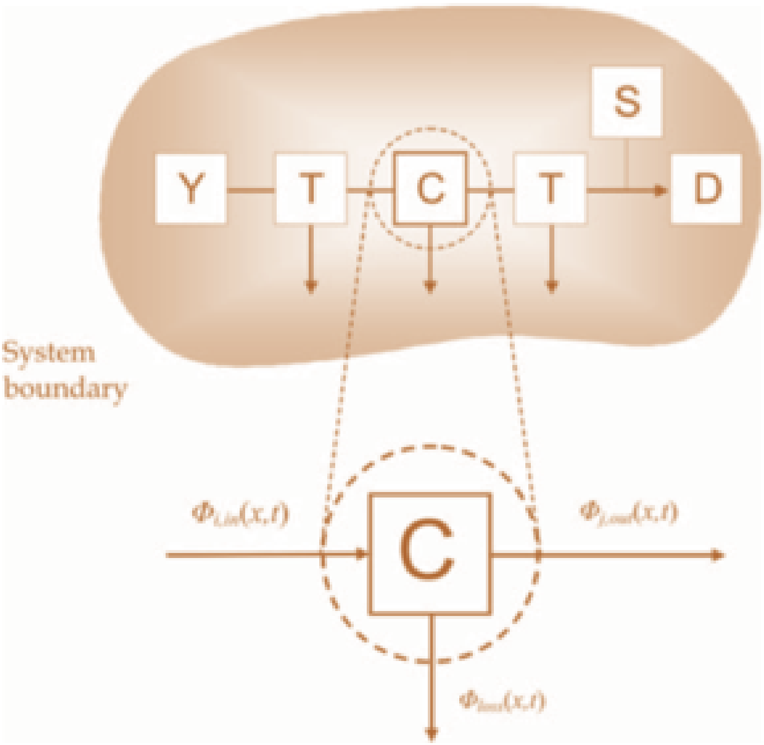

Figure A.1: System Boundaries of a generalised energy system Hemmes et al. (2007)

figure above depicts a simplified and very general context of any energy system. Where “Y” depicts the source of energy, “T” depicts transportation, “C” is the conversion process, “S” is the energy storage unit and “D” depicts the demand for energy.

Shortfalls in an energy system occur due to mismatches between supply and demand, There are three types of mismatches occurring between supply and demand: Hemmes et al. (2012):

- **Mismatch in Time:** A mismatch of energy between demand and supply on the basis of time occurs if the demand load is not available at the time of demand, this usually is experienced with renewable energy systems such as wind and solar due to the fluctuating energy produced by these systems, as a result of their intermittent nature. A mismatch in time has conventionally been solved with storage solutions. Since storage solutions and highly expensive and inefficient the mismatch in time need not be solved by storage solutions in the future. As in the time to come untill the renewables are highly developed to a point where they need not be applied with storage other integrative methods are to be considered to cater to the problem of mismatch in time. Flexible coproduction and demand side management are such techniques which are to be considered to solve these issues.

- **Mismatch in Space:** A mismatch in space occurs when the source of energy is not present locaaly and thus has to be imported. A mismatch in space is usually catered to by transportation solutions and is majorly a part of energy systems based on fossil fuel energy. Since fossil fuels are not readily available everywhere they have to be transported and thus compromise the energy security of the system. The transported energy need not be in the original form, for eg since concersion of coal to LNG is more economical for tranportation purposes, this is a viable solution to solving the transport problems associated to coal.

- **Mismatch in Form of Energy:** A mismatch in the energy form occurs when the energy is not available in the form it could be deemed useful for the consumers. A mismatch in the form of the energy can be solved with the application of certain conversion devices. The most logical solution to these issues is a multi source multi product system, capable of providing electricity, heat, cooling and based on the system-chemicals. Provision of multiple forms of energy imroves the operational efficiency while providing flexibilty to the whole system.

B

Appendix

Issues associated to Central Grid Electrification- Generalised View

Presently we are majorly dependant on a centralised systems running on conventional sources of energy such as oil, gas, coal etc. to satisfy our needs. These conventional energy sources have a huge negative impact on the environment and health. Lately, scholars, scientists, world leaders, governmental and non-governmental organisations have repeatedly stressed on reducing humanity's global carbon footprint which originates from burning these fossils and thus turning to renewables to generate electricity. The following issues related to centralised systems have been brought to the forefront lately (Bouffard and Kirschen, 2008):

- **Terrorist Threats:** Lately terrorists have aimed at targeting the energy and transport infrastructure. With the current level of integration and scale of these systems, Unfolding of such unfortunate events potentially brings vulnerability to the lives of large number of citizens as well as the economy. Such an event would affect the end user prices and supply security substantially.
- **Natural Disasters:** Fragility of energy supply chain can potentially be affected by natural disasters as well causing large scale disruptions in energy supply. Increase in the number of blackouts or impedances in the energy supply chain observed due to natural disasters have caused a loss in entice of these centralised systems. The nuclear disaster of Fukushima and shortage in oil production in USA after the Katrina hurricane are possibly the best examples.
- **Geopolitical Decisions:** Geopolitical relations and policies make the energy scenario of importing nations highly volatile. The decisions related to energy exports by the energy exporting and transit countries can have dire implications. Due to any circumstances or developments if the fuel exporting or transit nation cut off supplies to importing nations it would lead to a large scale energy shortage for the victim nation in turn leading to un affordably expensive energy costs. Cutting off natural gas to Ukraine by Russia over a row on prices throws some light on the implications of geopolitics on the energy scenario of the importing nation.
- **Out-dated Complex Infrastructure:** A large segment of the electricity infrastructure is nearing the end of its lifecycle. These systems are highly integrated and connected in complex ways between nations over which international trading takes place. A high rate of intrusions in power supply is a direct result of the maturing gear utilized by the present network. A large number of segments of the power framework need repair and rebuilding. This compromises reliability, as well as it ups the operation and maintenance expenses (Meyer, 2016). The blackouts in North America in 2003 and in Europe in 2006 caused widespread disruption of daily life and business.
- **Efficiency:** With climate change being given importance in the recent years, centralised systems, which usually run on fossil fuels, have been becoming a matter of concern. These plants have extremely low operational efficiencies; waste heat along with transmission and distribution losses make matters worse.

C

Appendix

This section of the appendix holds summarised versions of interviews conducted with stakeholders to define prevalent electricity issues in rural India.

C.1. Interview 1: R.K. Gupta, Associate Manager, Rural Electrification Corporation of India, Ministry of Power, Government of India

The interview was conducted at the participants office in New Delhi, India on the 8th of May 2017. The duration of the interview was limited to one and a half hours due to the interviewee's schedule. The interview proceeded on a very structured path defined by the preliminary question set used by the interviewer to assure coverage of the topics of importance to the research. Interviewee gave very tight concise answers to the questions and kept the discussion on track to an on time conclusion.

Q. What circumstances or reason have lead to power shortage in the rural regions?
Two reasons for non-availability of electricity -
Facilities not provided
Customer's bad economic condition, thus not wanting facilities

Q. Where in the electricity supply chain do the discrepancies arise?
India is a energy surplus country, the generation capacity is ample to take the country through to 2027. The problem of shortage arises due to lack of efficient power supply by the discos.

Q. Why do these discrepancies arise?
Technical issues:The main reason why discos face heavy losses is power theft or illegal connections. This is the reason why the viability of the government' grid extension policy is also being questioned. If we look at the electricity supply chain 'Generation' of electricity happens in a protected, highly monitored and closed environment and thus power discrepancies are rarely observed, similarly the high voltages of electricity during the 'Transmission' part of the supply chain protects the sector from thefts, but when we look at the 'Distribution' sector the voltages are low also there is no protective environment making the sector highly vulnerable to theft and other discrepancies. With lower legal connection density the price of utility provision also increases .
Social Issues: (mindset of the locals) Households not willing to take connections They feel free electricity is their birth right. Secondly they are scared of high utility bills and the initial fixed costs.
DSO intervention to prevent electricity theft does not go down well with the locals and thus they tend to get violent and threaten the on ground officials due to their strong belief.
Political Issues: The political party in power wants to keep the villagers happy to extract votes, thus the villagers on ground even get political protection, further creating problems for the discos.

Q. What is the state of the illegal connections in India ?
Averaging out in rural India just about 35-40% of connections are legal.

Q. What are your takes on application of DG's to solve this problem? Microgrids! Microgrids do not face the problem of electricity theft.
Micro-grids involve local participation, create a sense of ownership among the villagers as the villagers feel its their own.
The microgrid is locally installed, the concept of feel and touch further enhances the feeling of involvement amongst the villagers.
The micro-grids have constrained load catering capabilities and the villagers are aware of this phenomena. After a point of excess load provision the micro-grid fails an in situation of failing because of illegal connection the blame is on the person with the illegal connection.
The micro-grid operator is usually local and thus theft is prevented as the flow of information about illegal connections is easily available locally. The DGs have also experienced more legal connections and laser payment delays compared to the grid scenario. Q. What other solutions can be considered in your opinion?
Changing the mindset of the villagers: awareness campaigns and education facilities to help them understand the electricity scenario better. Making them understand if every house would have a legal connection the discos would not face the need to cut power to cut losses and thus availability of power will be improved significantly.
Government support to the discom: policies for government compensation of DSO losses. Illegal connection to be dealt with severity.

C.2. Interview 2: Dr. G. Prasad, Director, Ministry of New and Renwable Energy, Government of India

The interview was conducted at the participants office in New Delhi, India on the 13th of May 2017. The duration of the interview was limited to one and a half hours due to the interviewee's schedule. The interview proceeded on a very structured path defined by the preliminary question set used by the interviewer to assure coverage of the topics of importance to the research. Interviewee gave very tight concise answers to the questions and kept the discussion on track to an on time conclusion.

Q. What circumstances or reason have lead to power shortage in the rural regions?
Generation capacity is sufficient, problem arises with distribution and social issues.
Technical Issues: The distribution system operator try to cut losses by providing lesser energy. Supply of electricity is highly un profitable for the DSO. The scenario is not appealing for DSOs to enter the market. Another aspect observed due to which the problem is said to arise is the absence of infrastructure.
Social Issues: The free electricity perception of the locals and electricity theft. Free electricity perception has been prevalent due to the fact of having a long multi generation wide history of stealing electricity. The situation now is such that the rural households tend to believe that free electricity from the grid is their birth right. Those born in such families experience theft since a young age and grow up while doing the same does the concept of normalcy gets attached to electricity theft for such individuals. which leads them to believe that free electricity is their birth right.
Agricultural misuse: agricultural electricity is highly subsidised ad in most states absolutely free of cost. Agriculture load accounts for 20% of total energy consumed but the revenue generated in just 5% of total revenue generated from by the electricity sector.
Political issues: The problem also arises with policy irregularities. The policies in every state are vastly different thus further creating issues for DSOs wanting to expand business to underserved states making the market entry process more tedious and cumbersome as the discos first need to fill in the knowledge gap and then apply for government tenders after a proper economic analysis of new business opportunity with the new state's policies as constraints.
Policy irregularities and blame game between the central and state government is leading causes of political instability of the electricity sector, truth is both are equally responsible.
Q. According to you what solutions can be applied ?
Solution to the unreliability of power in the rural regions is the application of DG. DG's may not be able to solve all of rural energy problems but they can serve majority of the issues- lighting, hand-pumps, entertainment, educational equipment and facilities, health facilities.

Q. What are some barriers with implementation of DGs?

Heavy one shot investment.
DSOs are hesitant in integrating DGs in the electricity system due to limitations of transformers and capacity, also the DSO doesn't want to lose out on a registered customer.

Q. What are some solutions to overcome these barriers ?
The DG system should be designed for self consumption and not for export to the grid. In this scenario the losses of the DG are cut and the problem of need of high communication with DSO to sell power is reduced.

C.3. Interview 3:Aklavya Sharan, Energy Manager, Desi Power, India

The interview was conducted over video conference on the 20th of April 2017. The duration of the interview was limited to one hour due to the interviewee's schedule. The interview proceeded on a very structured path defined by the preliminary question set used by the interviewer to assure coverage of the topics of importance to the research. Interviewee gave very tight concise answers to the questions and kept the discussion on track to an on time conclusion.

Q. What circumstances or reason have lead to power shortage in the rural regions?
There are two main reasons leading to shortfall of power in the rural regions:
Unavailability of Infrastructure
Energy availability issues of grid

Q. Where in the electricity supply chain do the discrepancies arise?
The problem of energy shortfall in existent grid is real. The main issue arises with the losses faced by the distribution companies. These losses arise due to the bad economic performance of the grid due to either electricity theft or old outdated infrastructure or both. Even with the government's policy stated in the DDUY to connect every existent village to the grid this problem will still be prevalent and thus needs to be catered to with utmost importance and urgency.

Q. Why do these discrepancies arise?
Technical issues: Absence of infrastructure or outdating of existent infrastructure is one main reason due to which large discrepancies are faced in the electricity distribution scenario. The infrastructure when designed did not take into consideration the large increase in demand which is observed today and thus failure due to overloading are experienced on a large scale in the rural grid.
Social issues: Large-scale theft of electricity due to the "Free Electricity Perception" of the locals, households thus tend to restrict application of legal connections. Free electricity perception has been prevalent due to the fact of having a long multi generation wide history of stealing electricity. The situation now is such that the rural households tend to believe that free electricity from the grid is their birth right.
Economic Issues: Large scale theft leads to economically non efficient performance of the distribution sector and thus they tend to cut losses by cutting power. Say there are 'X' houses in a village with 'Y' paying customers, DSO tends to provide electricity only when the cost price of electricity for he DSO is so low that the paying 'Y' customers can make up for the remaining non-paying 'X' customers as well.

Q. What are your takes on application of DG's to solve this problem?
For the case of villages with no existing grid connection DG's make a lot of sense, as the villagers have no access to electricity and thus do not mind paying for electricity as long as the government provides subsidy on power. As observed in many cases the application of DG's in remote regions with no grid connection has shown extremely low number of defaulters and thus payments are received on time and in full amount, in a way solving two-fold problem of lack of electricity and changing the "Free Electricity Perception" of the locals. The case of application of DG's to villages with pre existent grid, large scale social set backs could be experienced, as the villagers are used to not paying for electricity, application of expensive micro-grids could put them in an uncomfortable spot, Secondly micro-grids cannot compete with highly subsidised grid electricity.
Q. What other solutions can be considered in your opinion?
Government policy intervention and stricter punishment of defaulters.
Awareness campaigns to try changing the mindset of the locals

C.4. Interview 4: Amit Kumar, Senior Director-Social Transformations, The Energy and Resources Institute, India

The interview was conducted at the participants office in New Delhi, India on the 14th of May 2017. The duration of the interview was limited to one and a half hours due to the interviewee's schedule. The interview proceeded on a very structured path defined by the preliminary question set used by the interviewer to assure coverage of the topics of importance to the research. Interviewee gave very tight concise answers to the questions and kept the discussion on track to an on time conclusion.

Q. What circumstances or reason have lead to power shortage in the rural regions?
India is considered to be an electricity surplus country. There are two reason why power issues arise- lack of infrastructure or lack of management skill. With the new government policy of grid extension the problem of lack of infrastructure gets catered to. The problem causing shortfalls in the rural sector is not lack of production capacity whereas it is the distribution of electricity.

Q. What reasons create these shortfalls?
large economical and technical losses of the discoms. Discos tend to neglect rural electricity supply due to the lack of profits. These losses arise due to two main reasons:
Outdated infrastructure: Old infrastructure, substations, transformers , wires etc. Theft of electricity: Illegal connections The rural electricity scenario is not expected to improve even 5 years down the line, reliability of power will still be an issue. One of the main reasons face Discom propositions of losses is because of not receiving the full charge
. Subsidies on agriculture loads do not make it any easier as villages tend to connect as much load as possible terming it as agricultural load to attain subsidy.

Q. What is your take on the application of DGs to cater to this issue?
It is a known fact that DGs can solve problems of electricity reliability and availability with ease and in an economical manner, as a result the government and utilities have laid stress on the application of DGS ,microgrids in particular to improve the reliability of the local energy system.

Q. Any Other solutions ?
Agricultural misuse: A solution to this problem is using the Gujarat model where two feeders are used, one for agricultural loads operating at subsidized rates and the other for domestic usage. The feeders for agricultural loads is highly subsidized and operates only during the day for a set period of time.
Stricter policies
Government aid to DSOs

C.5. Interview 5: Bhushan Trivedi, Partner, Piconergy, India

The interview was conducted over video conference on the 14th of May 2017. The duration of the interview was limited to one and a half hours due to the interviewee's schedule. The interview proceeded on a very structured path defined by the preliminary question set used by the interviewer to assure coverage of the topics of importance to the research. Interviewee gave very tight concise answers to the questions and kept the discussion on track to an on time conclusion.

Q. What is the reality of electricity availability in the rural regions?
Facts and the reality are very different what is shown on paper is not what the true reality is.Reality a lot more houses are connected to the grid but illegally.

Q. What is the cause of shortfalls in power supply?
Electricity theft is the most major reason for the failures in the rural Central grid.
Company has experienced economic growth as well as educational growth in regions where the products have been installed.

Q. What is your take on DGs for improvement of the scenario?
Though the potential is very high the government policy to extend the central electricity grid impedes the

integration of renewables into the rural electricity scenario, but application of DGs could be used for backing up the grid and provide un interrupted power. Company has experienced economic growth as well as educational growth in regions where the products have been installed. The other aspect of DG which is of substantial significance is the higher number of paying customers, 96% of customers are paying customers.

Q. What is the local perception?
Villages do not tend to focus much of the attention on the education aspect of development as they would rather have their kids work in the fields. Village or rural perception is more important to the provision of water than electricity.

Q. Your take on the water scenario?
Water shortage is a highly prevalent phenomena in all indian villages even in the ones receiving high amounts of rainfall annually.
The reasons for water shortage are:
1. The rivers are dry.
2. Groundwater ran out.
3. Mismanagement of resources.

C.6. Interview 6: Tarun Kapoor, Ex- Joint Secratary, Ministry of Power, Ministry of Renewable Energy, Government of India

The interview was conducted at the participant's residence in New Delhi, India on the 16th of May 2017. The duration of the interview was limited to one and a half hours due to the interviewee's schedule. The interview proceeded on a very structured path defined by the preliminary question set used by the interviewer to assure coverage of the topics of importance to the research. Interviewee gave very tight concise answers to the questions and kept the discussion on track to an on time conclusion.

Q. What circumstances or reason have lead to power shortage in the rural regions?
The rural power issues arise with discrepancies in power supply.

Q. Why do these discrepancies arise?
Stratergy: Discos face heavy losses, this creates a situation where supply of electricity becomes unfavourable for the DSOs. Discos tend to buy less power and thus sell less to cut losses.
Mentality:The mindset of the discos is such that they don't feel its their duty to provide reliable power. (Mentality)
Technical: The discrepancies in power supply are due to heavy losses in transmission, which occur de to large scale theft of electricity, outdated infrastructure, substation losses (overloading, low capacity, voltage issues)
Economic:The power regulator disallows power cuts beyond a point thus continues operation in losses becomes a negative entry for discos.
The rural demand is not very appealing for the disco's to cater to, low number of users and low load demand do not make up high profits.
Agricultural Subsidy: Another issue the rural electricity sector of India faces is the highly subsidised agricultural electricity supply, the misuse of this subsidised power leads to heavy losses.

Q. What is your take on the application of DG's to cater to this prevalent issue?
DG's surely will help improve reliability if applied locally in the grid connected scenario.
DG's also create local participation which has shown positive results in terms of reducing the number of illegal connections.
Q. What in your opinion are the drawbacks of the application of DGs?
Economic: High capital costs
Lack of awareness and knowledge of the technology amongst the consumers. Villagers tend to not understand the concept of load serving capabilities specially in the case of SHS. They tend to connect excess load to the system leading to failure. Lack of skilled workforce capable of operating and maintaining the system in the remote rural locations. The government policy of extending the grid to villages.

Q. What are some other possible solutions?

Inculcating smart grids for electricity distribution in rural regions.
Government protection and backing for DGs. Creating awareness towards the use, application and technicalities of DGs.

C.7. Interview 7: Anupam Mishra,Gandhi Peace Foundation, India

The interview was conducted over video conference on the 17th of May 2017. The duration of the interview was limited to one hour due to the interviewee's schedule. The interview proceeded on a very structured path defined by the preliminary question set used by the interviewer to assure coverage of the topics of importance to the research. Interviewee gave very tight concise answers to the questions and kept the discussion on track to an on time conclusion.

Q. What is the state of water availability in rural India?
India is considered to be a water adequate country, we have ample water resources to serve the water needs of our population. The problem arises with the management of water resources.

Q. Why does the water shortage issue arise?
Technique and skills: In villages the resources have run out be it ground water or other over ground resources due to mismanagement. We have not applied proper storage solutions and techniques.
Social Issues(mindset):The problem also lies with the perception and mindset of the people and policymakers, we have given land more importance over water , we have built buildings, roads highways etc over water resources.
Geopolitical Issues:Water disputes between various states have been observed creating further shortage due to lack of supply from water rich states.
Technical Advancement: Electrification of rural regions also lead to depletion of ground water due to the ease of ground water extraction that came with the application of electrical pumps when compared to hand pumps.
Infrastructure: In cases where local water resources are prevalent the infrastructure is missing. The government hasn't invested in water provisional infrastructure for the rural sector. the lack of storage problem also leads to floods due the the ample amount of rainfall received in india annually.

Q. What have been the consequences of the shortfalls?
Rural ground water is in what is called the dark zone, it needs to be catered to with supreme urgency. Water provision is either done by tankers or by local resources.
For the case of tankers women usually spend 3-5 hours filling water daily, and for the case of river water availability women in India walk on average 1400 Kms a year to attain water.

Q. Any examples?
The water scenario in Cheerapunji, Cheerapunji receives the highest rainfall in the world yet suffers from water shortage, this is due to the fact that firstly cheerapunji is present on higher ground all the rai water drains away and secondly the resources are not managed well.

Q. In your opinion what are the solutions to cater to these water shortage problems?
Devicing a better management strategy. Government investment for continuos water supply for the cases where water resources are locally available For the cases where water resource is not locally available : Rainwater harvesting and creating water self sufficiency.

C.8. Interview 8: Manoj Mishra, Yamuna Jiye Abhiyaan, Delhi

The interview was conducted over video conference on the 18th of May 2017. The duration of the interview was limited to one and a half hours due to the interviewee's schedule. The interview proceeded on a very structured path defined by the preliminary question set used by the interviewer to assure coverage of the topics of importance to the research. Interviewee gave very tight concise answers to the questions and kept the discussion on track to an on time conclusion.

Q. What is the state of water availability in rural India?

Water presence is ample to meet demand. Problem arises with water management.

Q. Why does the water shortage issue arise?
The present resources have been exploited to extreme levels, not just on the basis of usage but for waste disposal as well. The rivers have become a dump yard for industrial and sewage waste, thus the available water also becomes unusable.

Q. What are the major reasons leading to these shortfalls?
Heavy metals such a lead, cadmium, mercury, chromium, manganese and arsenic are highly prevalent in the freshwater in India. These heavy metals aren't processed or removed even with the present cleaning technologies applied. In the rural(specifically) and urban regions water contaminated with heavy metals is used for domestic as well as consumption purposes.

Q. What consequences have been observed or can be expected?
The consequences of consuming heavy metal contaminated water are severe, lead is known to cause reduced IQ whereas mercury majorly affects the nervous system, specially those women breast feeding their young pass on mercury to the next generation.

Q. Any examples?
Large scale consequence observed is the condition of the river Yamuna, Yamuna a river considered to be holy by a major chunk of the population is in a deplorable state, out of 1400 kms stretch of the river, 600 kms is deemed completely unusable due to extreme levels of pollution and the remaining 800 kms has reached red alert pollution levels.

Q. What in your opinion would be the solution to solving this crisis in rural India?
The solutions for the rural sector involves decentralisation of water supply-
Rainwater Harvesting
Lake replenishment
Domestic water re-use
Management solutions such as growing crops according to water availability, i.e growing water intensive crops only in the year of heavy rainfall.
Government intervention, making policy changes and deeming disposal of industrial waste in rivers and deep injections illegal and punishable by law.

D

Appendix

This section of the appendix holds summarised versions of the interviews conducted with stakeholders to analyse the validity of solutions considered for section 9 of the thesis report.

D.1. Interview 9: Shirish Garud, Technical Director, The Energy and Resources Institute, India

The interview was conducted at the participants office in New Delhi, India on the 10th of May 2017. The duration of the interview was limited to one and a half hours due to the interviewee's schedule. The interview proceeded on a very structured path defined by the preliminary question set used by the interviewer to assure coverage of the topics of importance to the research. Interviewee gave very tight concise answers to the questions and kept the discussion on track to an on time conclusion.

Q. What according to you are the positive aspects associated to such an approach?
The approach seems to optimise resource utilisation. In a world grappling with resources scarcity and security, optimum or efficient resource utilisation is a massive plus point to have in any energy system. The overall performance of the system becomes more efficient. Systems thinking is known to be highly advantageous for system efficiency.
The approach in a way aims at achieving one the modern goals of system sustainability i.e. Recycle- Reuse-Reduce. Wastage of resources is highly cut down, economic benefits are extracted from what earlier was believed to be waste.

Q. What according to you are the negative aspects associated to such an approach?
The capital costs of such a project are definitely expected to be higher.
Designing and sizing of such systems to meet requirements is complex, the systems are tedious and complicated. Scaling up of system with increase in demand would be an issue.
The approach is still an exploratory concept. Needs to be practically viable to be applied on a larger scale. One major aspect which needs clarification is how connected and thus how dependant are the three sectors on each other, if tech for one fails it would lead to failure of the other dependant sectors.

Q. What could be the potential barriers faced with respect to the Indian Market?
Inter sector systems are always a challenge due to the bureaucracy prevalent in India's professional structure. The departments are highly segmented. Getting professionals from different sectors with different ideologies and goals to work together on a project can be seen as definite barrier.
The sectors in India have very few cross linking, funding , operation, policies and management of the three sectors are highly differentiated and distinct. Data collection is another definite barrier, for a multi-purpose system to run reliably accurate data is required. Collecting data of three sectors with old infrastructure and were transparency is not prevalent could hinder the whole process of operation of such a system.

Q. What could be some possible solutions to these barriers?

Answering questions pertaining to economics of the systems.
The system though highly interconnected, in a freak circumstance of a failure , sectors should be capable of isolated isolation to maintain the reliability of supply.
Education and training will solve operational challenges by providing inter sectoral expertise.

D.2. Interview 10: Dr.G.Prasad, Director, Ministry of New and Renewable Energy, Government of India

The interview was conducted at the participants office in New Delhi, India on the 17th of May 2017. The duration of the interview was limited to one and a half hours due to the interviewee's schedule. The interview proceeded on a very structured path defined by the preliminary question set used by the interviewer to assure coverage of the topics of importance to the research. Interviewee gave very tight concise answers to the questions and kept the discussion on track to an on time conclusion.

Q Given the possible conceptual solution integrating the three sectors what according to you are the positives of the approach?
The project serves the greater good leads to large scale indirect benefits for various sectors. Improvements in electricity and water are expected to lead to improvements in health leading to improved education and economic development in the region. The system will definitely lead to improved technical efficiencies, performance of the integrated system should be better than the performance when the three sectors are catered to separately.

Q. What are the negative aspects associated to this approach in your opinion?// Economic inefficiency of implementation,the project in expected to be highly capital intensive and thus economic affordability of the project becomes an issue.The locals at present demand catering to just the provision and availability of basic survival needs and not the quality due to constrained expenditure capabilities.
Scalability of the project, usually integrated projects are not scalable as the level of inter dependency and inter connectivity is extremely high very large number of aspects need to be considered when scaling integrated projects.

Q What barriers are expected to be faced?
High initial capital costs.
Acceptability in the community.
Purchasing power of rural local consumers. Funding and economic feasibility of the project, the government structure is designed as such that government funding of such projects is near to impossible.
Changing the perception of existent non-paying customers or defaulters will be on the greatest barriers.

Q What could be the possible solutions to overcome the barriers?
Though government funding and involvement will not possible, nevertheless the project might get funded by NGO's.
To tackle the problem of economic feasibility hybrid energy solutions could be looked into designed optimally based on the availability of energy source locally, hybrid generation has lower costs of electricity generation, for example, biomass solar hybrid has shown to lower investment and operations costs, leads to reduction in battery sizing by operation biomass in times of solar shortfalls.

D.3. Interview 11: Tarun Kapoor, Ex-Joint Sectratary, Ministry of Power (Ministry of Renewable Energy), Government of India

The interview was conducted at the participant's residence in New Delhi, India on the 22nd of May 2017. The duration of the interview was limited to one and a half hours due to the interviewee's schedule. The interview proceeded on a very structured path defined by the preliminary question set used by the interviewer to assure coverage of the topics of importance to the research. Interviewee gave very tight concise answers to the questions and kept the discussion on track to an on time conclusion.

Q. What according to you are the positive aspects associated to such an approach?

Integration as a concept is highly underrated and thus not applied on a large scale. We are heading into times where minimalism will highly be valued, thus playing a major role to help minimise wastage and thus maximise efficiency.
Present trends of integration, i.e. within the energy sector and not cross sector have shown trends where the costs of operation and in some cases even capital costs have reduced whereas the performance of the system has improved.
Integration tends to make optimum use of surpluses or in other terms utilise what is termed as a waste for a certain technology or sector to the advantage of the other.
For the solution considered in the project integration of water with energy is highly synergetic. Water supply chain both purification and distribution of water are highly energy intensive. An integrated approach to meet that demand would be highly beneficial in improving the performance of both sectors.
For a policy makers point of view, integration is not only advantageous from a micro economics point of view but also from a macro economics point of view. The increase in incurred costs usually are made up by the increase in the underlying social benefits.
With trends moving towards rising decentralisation and grid defection self sufficiency comes into question, integrated systems make it possible to be completely self sufficient making off the grid living a reality.

Q. What according to you are the negative aspects associated to such an approach?
Integration creates tedious systems. The systems are highly complex both to design and operate. This is one of the major drawbacks of the approach, as your approach tends to create highly integrated multi purpose systems, system operation, maintenance would be a definite issue which would crop up.
Usually with such an approach, the resulting system is beneficial for the present scenario. It is hard to inculcate scaling up into integrated systems, dealing with an increase in demand over the years becomes an issue.
Certain integrated systems tend to be highly dependant on one form of energy resource, with future trends if an energy resource becomes unavailable or the policies regarding certain aspect of any of the sectors included changes, this would disrupt the performance in a drastic manner.

Q. What could be seen as the barriers which might be faced in the Indian Scenario?
As mentioned above the tedious, complex nature on multi-purpose energy systems require a lot of planning and optimisation. As the approach itself is based on integration, not only technology but the landing process and thus the professionals need to apply solutions in a highly integrated manner. Professionals tend to give priority to areas of their expertise and thus would lead to difference of opinions, that is how the human or professional psychology works.
The whole institutional structure is highly divided in every sector, getting all the players from all sectors to agree on a common solution even if case specific would be hard. The hierarchal structure of the supply chain in India can be seen as a definite barrier which would be have to overcome. The policies are highly divided as well.
Coming up with policies for a technology which is so highly case dependant.

Q. What are some plausible solutions to these barriers in your opinion?
One of the main solution which can be seen for such systems depends on the market or the trends of the technology. The approach could lead to solutions which improve overtime, as proved by the learning curve for all cases. The second aspect which cannot be influenced by one organisation or policy maker is the mass application of the technology, overtime with more applied cases of multi purpose energy systems the costs are brought down, and the acceptability and skill set improve.
Provision of technology and expertise, making both the tech and the knowledge and expertise available to all. Awareness about the benefits, social, economical, moral and as well technological should be created.

D.4. Interview 12: Bhushan Trivedi, Partner, Piconergy, India

The interview was conducted at the participant's office in Mumbai, India on the 26th of May 2017. The duration of the interview was limited to one hour due to the interviewee's schedule. The interview proceeded on a very structured path defined by the preliminary question set used by the interviewer to assure coverage of the topics of importance to the research. Interviewee gave very tight concise answers to the questions and kept the discussion on track to an on time conclusion.

Q. What according to you are the positive aspects of such an integrative approach?
The approach is new, its a new idea, new way to look at things. Integration is not inculcated in the present solution set in a broad sense, like the two sides to a coin, such an approach can be seen as either too good to be true or too idealistic.
Capability to bring about a change, since we know or at least have a strong intuition about performance improvement due to integration. Could create a disruptive trend in the market for the better.
Inclined with beliefs of the new dawn of energy systems, where we aim at achieving higher efficiencies for systems using existing technologies, such an approach has been repeatedly brought to the notice of the scientific community globally by renowned scientists and research institutions. Expected to improve performance efficiencies.
Morally the approach makes sense, and can definitely be viewed in a positive sense, as it would definitely be improving efficiencies. The approach aims at doing more with lesser resources.
A local system solving the most serious prevalent problems will be greeted with high local acceptability. The system in consideration aims at solving problems and issues that have been prevalent since ages and it solves issues that hurt the most, not just for the local community but for the government as well. Decentralised systems also tend to create a sense of local ownership, which prevents or reduces the theft problem.

Q. What according to you are the negative aspects of such an integrative approach?
By what it sounds like, till the point the technology is not mature the costs are expected to rise. The economics of such integrated projects usually bring about a negative outlook towards them. Is the expected increase in utility or efficiency worth the expected increase in costs.
Practicality of such an approach would be under question for the case of India, maybe not for more developed western countries. Any solution should be targeting the right market in the right way. The skill shortage in India, might hinder the application or operation of multi purpose energy systems. Maintenance staff would require training adding up costs.
The approach is highly case specific and region specific and solutions cannot be generalised or be turn key. The market is looking for turnkey solutions thus some research might be needed to help make turn key multi purpose energy systems

Q. What could be the potential barriers faced in the Indian scenario?
As mentioned before, the market is the biggest test for any so to say disruptive approach or technology. Something that might seem brilliant on he drawing board or the or in the lab just might not be too acceptable in the market.
Oligopolistic sector, incumbents have a lot of power and market share. Could make life difficult for a new player coming into the market with a disruptive technology.
The structure in India is highly segmented, hierarchical nature prevents organisations or professionals for taking up responsibility of new techniques. Bureaucracy would play a major role to hinder the application of such systems.
Indian market tends to ignore underlying indirect social benefits.
Q. What could be some possible solutions to overcomes these barriers?
Using the democratic nature of the Indian government to your advantage! Overlook the central government and getting in contact with the local authorities or panchayats. Having a very dynamic plan for implementations and overcoming barriers on the go. Policy improvements, having benefits for efficiency improvements. Integrative policies considering various sectors.

D.5. Interview 13: R.K. Gupta, Associate Manager, Rural Electrification Corporation of India, Ministry of Power, Government of India

The interview was conducted at the participant's office in New Delhi, India on the 29th of May 2017. The duration of the interview was limited to two hours due to the interviewee's schedule. The interview proceeded on a very structured path defined by the preliminary question set used by the interviewer to assure coverage of the topics of importance to the research. Interviewee gave very tight concise answers to the questions and kept the discussion on track to an on time conclusion.

Q. Given the possible conceptual solution integrating the three sectors what according to you are the pos-

itives of the approach?
One big plus point which could also be seen as a weak point is that the solution treats a much broader aspect as one, the integration of sectors do will not solve the problem of just the three chosen sectors but a lot of other underlying problems of other sectors in directly linked to these three sectors, for example an improved water availability and purity scenario will lead to improvements in rural health one of the major issues faced by he government of India, other examples include improved education facilities due to energy availability.

Q. What are the negative aspects associated with the approach?
As mentioned above the solution treating a much broader problem as one can be seen as a shortfall as well. Since the professional structure of the three chosen structures is designed as such that the cooperation between the different sectors is bare minimum, acceptability between the sectors will definitely be an issue. In a broader sense creating cooperation between experts from different sectors will be one the biggest hurdles of the project.

Q. What barriers are expected to be faced?
Implementation and operation of the project will definitely be a barrier. Question of who is to implement it and who is to operate will pop up.
Skill shortages in the industry.
Economic feasibility of the project.
Funding of the project(is the project bankable and economically efficient?)
Mentality of locals, changing the perception of free electricity will pop in this scenario as well. Local availability of technology

Q. What could be the possible solutions to overcome the barriers?
Local cooperatives to take on project.
Vender implementation of project, after recovering capex by vendor a government take over to operate project.
Government could be involved and fund as project leads to large scale savings to government through indirect benefits (health improvement, solving purpose of Swach Bharat Abhiyaan, Generating power capacity improvement)

D.6. Interview 14: Vrinda Chopra, Phd Candidate, University of Cape Town

The interview was conducted over video conference on the 15th of August 2017. The duration of the interview was limited to one hour due to the interviewee's schedule. The interview proceeded on a very structured path defined by the preliminary question set used by the interviewer to assure coverage of the topics of importance to the researcher. Interviewee gave very tight concise answers to the questions and kept the discussion on track to an on time conclusion.

Q. What according to you are the positive aspects associated to this approach?
The positive aspects of an approach that identifies inefficiencies and enablers is building of a systemic view of the case at hand. In doing so, there is an advantage in moving forward from the current state, through plugging of the things that are not working at the optimum level as well as recognising opportunities to provide further benefits for the environment, economy and community.

Q.What according to you are the negative aspects associated to this approach?
Sometimes when we try to break down a system to understand its components, in this case to identify the inefficiencies and enablers, we tend to lose sight of the whole. As one of the principles of systems thinking says – the sum of the parts is greater than the whole.

Q. What barriers are expected to be faced while implementing such an integrated approach?
Implementation: The people concerned with running the system may not be ready to accept the inefficiencies that exist. Moreover, in trying to introduce them to enablers or opportunities, they may be resistant to change – that is they may not want to change business as usual (and this could be for a number of different reasons).

Funding: There may be problems in acquiring funds for the said project unless you find a champion (that is a funder) who believes in the model and is willing to take some risks.
Community Integration: It might take a long time to get the community to accept some of the changes as well (if community is a part of the solution – that is if they are going to benefit from it)
Technology: It might take a long time to train local managers to run any new technological components

Q.What could be the possible solutions to overcome these barriers?
Solutions to the barriers will have to be as multifaceted as the barriers:
To overcome some of the implementation barriers, you would possibly have to work on engagement with the local teams, community, government officials etc. Find one person within the system, usually someone with authority to encourage their colleagues to accept the changes. Even then it will be a slow process, but that is one way to get the ball rolling.
Tapping into energy policies of donor agencies, multilateral and bilateral agencies, the state etc are other ways in which to attempt at getting financial and policy support – through showcasing the benefits of the work to the environment, economy and the community.
Another possible route is to work with local civil society organisations (CSOs), those that have the trust of the project as well as the community to understand and help in implementation. In that way you are also up-skilling more local people to manage the project better.

D.7. Interview 15: Dr. Priti Malhotra, Head of Department, Daulat Ram College, University of Delhi

The interview was conducted at the residence of the interviewee on the 27th of May 2017. The duration of the interview was limited to one hour due to the interviewee's schedule. The interview proceeded on a very structured path defined by the preliminary question set used by the interviewer to assure coverage of the topics of importance to the researcher. Interviewee gave very tight concise answers to the questions and kept the discussion on track to an on time conclusion.

Q. What according to you are the positive aspects associated to this approach?
Integration tends to have a lot of social benefits potentially targeting social aspects. These are indirect benefits. This aspect could be seen as advantageous. If policy tools are in place, potentially lead to synergy in performance of all sectors. In terms of moral aspects integration will definitely lead to large scale acceptance on moral grounds.

Q. What are the negative aspects associated with the approach?
Designing systems with considerations of integration is highly complex and tedious. Aspects of high interdependence of sectors could lead to entire system failure if one sector fails to perform. Exponential outcomes if not catered to can turn to exponential negative outcomes.

Q. What barriers are expected to be faced while implementing such an integrated approach?
Major hurdle as observed through experience would be creating and targeting synergy prevalent. Indian professional structure is highly segmented and differentiated. Getting these stakeholders together and make them agree to work on common goals is not an easy task. Policy structure and available policies is also seen as a barrier. Policies at present are highly sector specific and not integrated. Level of democracy of India makes it harder, because policies are changed with governments. Economic viability needs to be answered and looked into. Policy and goals are usually not met. Also social acceptability would play a pivotal role.

Q.What could be the possible solutions to overcome these barriers?
Solutions to the barriers will have to be as multifaceted as the barriers:
Incentives taken up by government, changes in policy to better incorporate integration through social considerations. Feedback looping of policy and policy design. Impementation should be supported by an authoritative body. Economic aspects could be better improved with R&D in the field and through financial incentives provided by the government.

E

Appendix

The following section of the appendix depicts the possible sector collaborations for all identifed I-neffs for Chapter-9. Thus implementing Step-5 for all of the I-neffs. As discussed in Chapter-9 this is important to show the scale of energy sector focused integratibility of rural sectors, the sector in the middle signifies the sector the identified I-neff can be associated to whereas the sectors around signify the potential collaborative sectors for integration.

Possible Collaborations for I-neff 'Uni-functional Highway Landscape'
The following are the potential integrative sector identifications of the I-neff 'Uni-functional Highway Landscape':

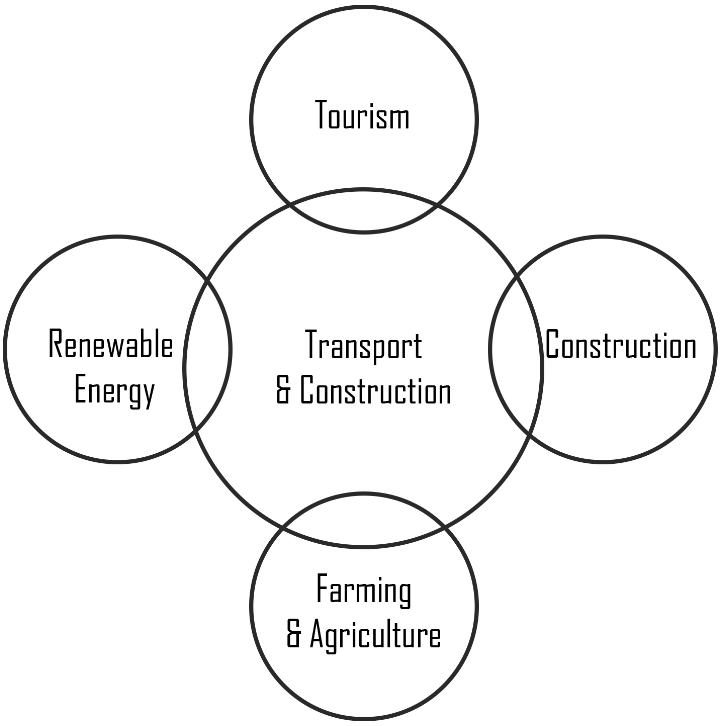

Figure E.1: Sector Collaboration For Uni-Functional Highway Landscape

Enabler 1: Application of PV panels, the highway landscape is uni-functional and thus can be seen as an I-neff. Application of PV panels to the side of the highways as noise barriers as well to the landscape could reap benefits to the electricity sector while enabling the integration of the transport and energy sectors.

Enabler 2: E- plantation could be carried out on the uni-functional highway landscape, reaping benefits for the energy sector while integrating agriculture sector, energy and transport sectors.

Enabler 3: Tourism constructions can be seen as a an enabler of integrating Tourism sector to Transport. Constructions such as utility parks and picnic destinations are highly popular across India and can be seen as a key enabler

Possible Collaborations for I-neff 'Uni-functional Rooftops'
The following are the potential integrative sector identifications of the I-neff 'Uni-functional Rooftops':

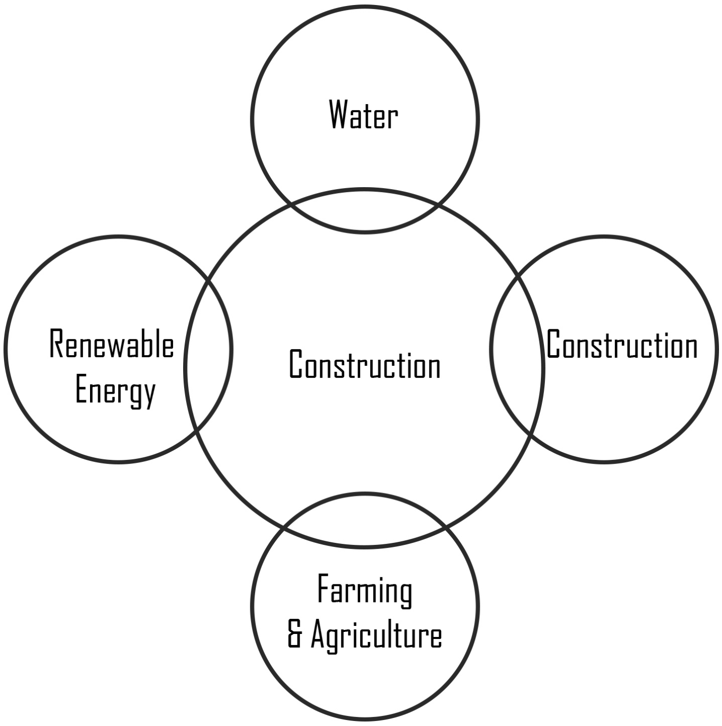

Figure E.2: Sector Collaboration for Uni-Functional Rooftops

Enabler 1: Application of PV panels, the rooftops are uni-functional only perform the sole function of providing shelter, thus can be seen as an I-neff. Application of PV panels to these rooftops can reap benefits to the electricity sector while enabling the integration of the housing, construction and energy sectors.

Enabler 2: Rain water harvesting can be deployed on the rooftops pf domestic buildings as well as public utility buildings. This application would enable the integration of the building sector to construction and water.

Enabler 3: Sustainable rural farming activities could carried out on these rooftops, thus potentially integrating the housing sector with agriculture and farming.

Possible Collaborations for I-neff 'Barren Land'
The following are the potential integrative sector identifications of the I-neff 'Barren Land':

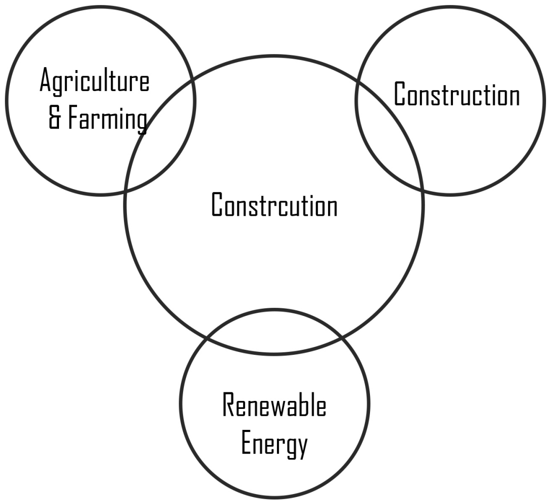

Figure E.3: Sector Collaborations for Barren Land

Enabler 1: Application of PV panels, these lands lie barren potentially ignoring multiple potential benefits, thus can be seen as an I-neff. Application of PV panels to these barren lands can reap benefits to the electricity sector while enabling the integration of the construction and energy sectors.

Enabler 2: E- plantation could be carried out on these unused barren lands, reaping benefits for the energy sector while integrating construction sector and energy sector.

Possible Collaborations for I-neff 'Seasonal Agricultural Land Use'
The following are the potential integrative sector identifications of the I-neff 'Seasonal Agricultural Land Use':

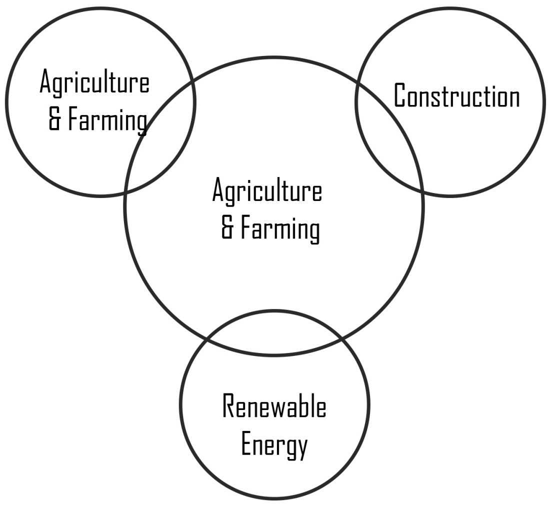

Figure E.4: Sector Collaborations for Seasonal Agricultural Land Use

Enabler 1: The agricultural land is used seasonally during summer months up till the harvesting season, thus lying idle for the remainder of the season E- plantation could be carried out on these seasonal lands, reaping benefits for the energy sector while integrating construction sector, agriculture sector and energy sector.

Possible Collaborations for I-neff 'Idle River Delta & Banks'
The following are the potential integrative sector identifications of the I-neff 'Idle River Delta & Banks':

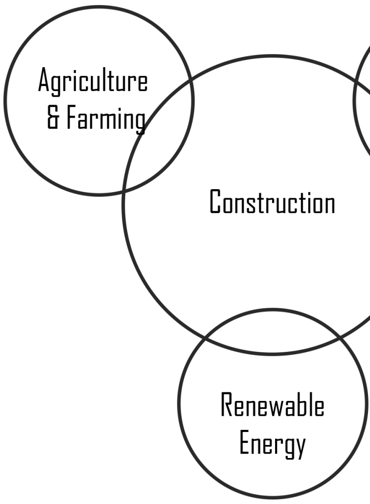

Figure E.5: Sector Collaborations for Idle River Delta & Banks

Enabler 1: Application of PV panels, these river banks and the river delta lie idle potentially ignoring multiple potential benefits, thus can be seen as an I-neff. Application of PV panels to these banks and delta can reap benefits to the electricity sector while enabling the integration of the water, construction and energy sectors.

Enabler 2: The barren river banks and the river delta lie idle, these lands potentially hold large benefits due to the highly fertile soil of these regions brought to the banks of the river and the delta by the river Ganga. E-plantation could be carried out on these idle lands, reaping benefits for the energy sector while integrating Water, construction sector, agriculture sector and energy sector.

Enabler 3: Construction of water reservoirs for water storage to benefit the agricultural sector can be seen as another integration prospect integrating the construction, water and agriculture and farming sectors. This potential integration is enabled by the water reservoir technology.

Possible Collaborations for I-neff 'Exergy Loss on Water Surface'
The following are the potential integrative sector identifications of the I-neff 'Exergy Loss on Water Surface':

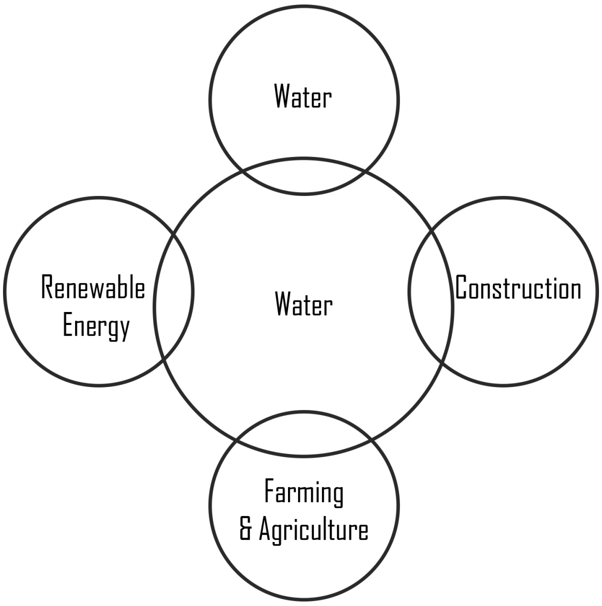

Figure E.6: Sector Collaborations for Exergy Loss on Water Surface

Enabler 1: Application of PV panels on face of the water body, . Application of PV panels to the river face can reap benefits to the electricity sector while enabling the integration of the water, construction and energy sectors. Also catering to the problem of exergy destruction on water surface.

Enabler 2: Aqua Farming which is an already existing practice of aquaculture which includes farming of aquatic organisms such as fish, molluscs as well as aquatic plants. It enables the integration of water and agriculture and farming sectors

Possible Collaborations for I-neff 'Agricultural Waste Incineration: Exergy Destruction'
The following are the potential integrative sector identifications of the I-neff 'Agricultural Waste Incineration: Exergy Destruction':

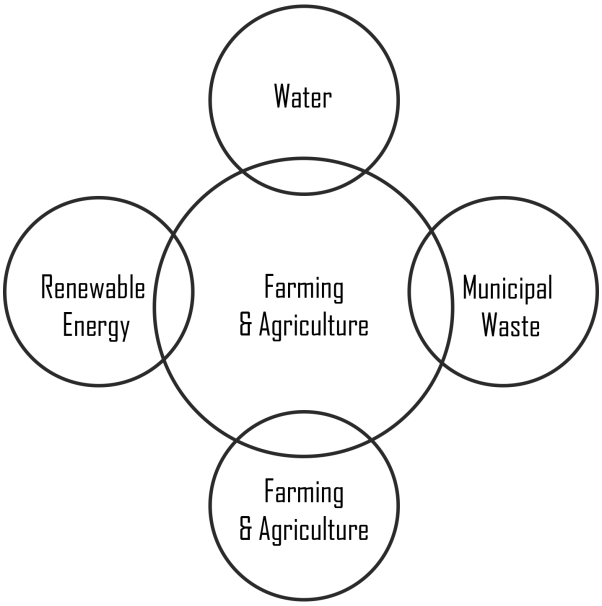

Figure E.7: Sector Collaborations for Agricultural Waste Incineration: Exergy Destruction

Enabler 1: Instead of burning agricultural waste directly which leads to loss of exergy, the waste could first be converted to biogas through existing technology and thus further be used for domestic purposes. Biogas technology is more efficient than waste incineration. This enables the integration of Agriculture, waste and energy sectors.

Enabler 2: Agriculture waste of wheat, which is a heavily grown crop in the region of ballia is high in silica content, this characteristic of the waste could be used for silica extraction using existing technology which is used as a adsorbant for water purification to remove heavy metals from water, thus enabling the integration of water, waste and agricultural sectors.

Possible Collaborations for I-neff 'Idle organic Waste'
The following are the potential integrative sector identifications of the I-neff 'Idle organic Waste':

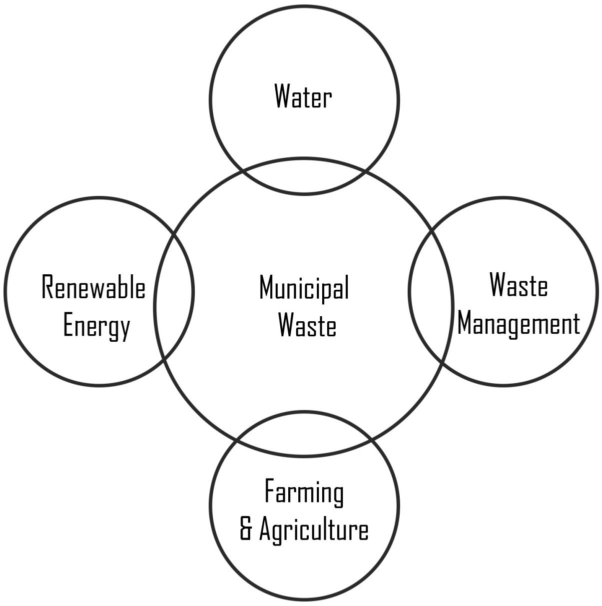

Figure E.8: Sector Collaborations for Idle organic Waste

Enabler 1: The organic waste accumulated from domestic uses as well as farms, poultries and market places could be used to produce biogas for energy use. Existing biogas technology acts as the enabler here enabling waste and energy sectors.

Enabler 2: Oganic waste of wheat, which is a heavily consumed entity in the region of ballia is high in silica content, this characteristic of the waste could be used for silica extraction using existing technology, silica is used as an adsorbant for water purification to remove heavy metals from water, thus enabling the integration of water, waste and agricultural sectors.

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