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The impact of policy mix on the adoption of energy-efficient lighting

A Qualitative Comparative Analysis study of 28 Indian states

TU Delft

The impact of policy mix on the adoption of energy- efficient lighting- A Qualitative Comparative Analysis study of 28 Indian states

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by

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Preface

Dear reader,

This Master's thesis was performed as a conclusion of the Masters of Science program in Management of Technology at TU Delft. For the past months, I have been working on my thesis project and have developed immense learnings towards the energy-efficiency technology and policy processes followed in India at sub- national levels.

"What an unexpected journey has this been". A lot of surprises on the way but I can confidently say that the people I worked with during my master's degree contributed to this journey in so many ways.

Firstly, I would like to thank Delft University of Technology for accepting me into my dream university and the master's program of my preference. The experience of working with professors and colleagues of such par excellence has been life-changing and I appreciate it.

I would also like to personally thank my chair Dr. Thomas Hoppe, daily supervisor Dr. Nihit Goyal and second supervisor Dr. Jaco Quist for all their guidance and support during my thesis. Despite suffering personal loss due to COVID-19, my supervisors gave me time and support to get back to work mode and complete my thesis work. I am extremely grateful for this support during such trying times and their guidance throughout this thesis.

I would like to thank my committee members for their timely inputs which most definitely helped my thesis work progress in the right direction.

My family and friends means the world to me and this would not have been possible without their unconditional love and support. I would like to take this opportunity to thank them personally for all their contributions during this journey.

With this, I would like to finish by saying that I have learnt a lot both professionally and personally from this experience and I will take all of the learnings with me when I enter the new chapter of my life.

Regards
Nikhil Singh

Executive Summary

Climate change and ever-increasing energy consumption have become a pertinent topic of discussion around the world. There is an urgent need to lower the carbon footprint to meet the requirements of the Paris agreement. Adoption of an adequate number of energy-efficient technologies can help in reducing the CO_2 level in India. In recent times, energy-efficient lighting, especially LED lighting has come to the forefront. In 2015, the government of India launched the UJALA policy scheme to enable mass distribution of energy- efficient LED bulbs. However, despite a nationwide implementation of the scheme, a differentiation in the penetration of this policy at state- level is noticed implying the interplay of other factors that may have led to the facilitation of this scheme. The objective of this research is to determine the combination of conditions in terms of policy mix and exogenous factors for an Indian state that lead to the higher penetration of UJALA policy.

To develop a deeper understanding of the working of the UJALA scheme, exploratory research has been conducted into the energy- efficiency governance of India specific to the governance of UJALA policy and the roles of various actors and stakeholders involved. The energy sector in India being a concurrent sector is governed by both Central and State institutions wherein all institutions hold different roles and responsibilities regarding regulation setting, energy efficiency specific domain and distribution agencies. For the UJALA policy, the major actors are Energy-Efficiency Services Limited (EESL) at the central level and Distribution Companies (DISCOMs) at the state level. UJALA policy is unique in its terms of being a zero-subsidy policy wherein EESL employed the demand aggression price crash model to bring the prices down for the market and aid in market formation. This strategy was designed around bulk procurement of lighting bulbs from the manufacturers and allotting it to the states for local distribution. Overcoming barriers posed by the introduction of new technology was carried out through adoption of local standards and knowledge sharing facilitation by various private and public institutions. The local implementation also involved limited participation from the state agencies that led to easier onboarding of the DISCOMs for the policy. However, the overall state energy-efficiency efforts in terms of RD&D support, monitoring and evaluation and generating consumer awareness contributed to a successful implementation of this policy.

The policy mix refers to the policy elements, policy instruments and policy processes leading to the technology change in a specific geography. Additionally, it also substantiates the importance of characteristics of the policy mix leading to the technology change. These policy mixes are then determined as applicable for UJALA policy implementation. Due to the lack of data availability for the specific schemes, the overall energy- efficiency efforts for the states is taken into account. The policy mix characteristics are considered as causal factors for driving UJALA policy implementation at state-level. These characteristics are consistency of elements, comprehensiveness of elements, coherence of processes and credibility. Consistency is

determined as the consistency of the policy elements with each other that lead to the final outcome. The technology-push instrument; RD&D, demand-pull instruments; power tariff and consumer awareness conduction and systemic process instrument; market maturity are scored in positive or negative towards their impact on the outcome. The comprehensiveness factor scores the similar factors as consistency except for power tariff for their presence or outcome. This characteristic determines the rigor of the policy mix based on its type of constituents. The credibility factor determines the political leadership commitment towards the energy-efficiency efforts. The allotment of resources of the state governments towards energy-efficiency efforts such as finances and human resources are considered as the credibility in this research. The characteristic coherence of processes deals with the process of the policy formulation, inception and revision to be ready for implementation at the local level. Since UJALA is a central policy, this factor is deemed out of scope for this research. In conclusion, the policy causal factors for technology change are consistency of policy mix, comprehensiveness of policy mix and credibility of policy mix. Furthermore, this research takes into account the impact of exogenous factors as well. The exogenous factors are GDP per capita, literacy rate and the percentage of electrified homes in the state.

The dataset for the aforementioned six factors is then calibrated and inputted into the fsQCA 3.0 software with a solution frequency cutoff of 1 and a consistency score of 0.75. The analysis results in five pathways that includes 10 out of the 11 best cases that display the higher penetration of UJALA policy. The results indicate that a higher GDP value, higher percentage of electrified homes and a high comprehensive policy mix could achieve high penetration of LED bulbs among the masses if the: (1) literacy rate is higher, (2) a low credible and consistent mix is adopted by the state, or (3) the policy mix is highly consistent and credible as well. In addition, highly comprehensive and consistent policy mix and an absence of a credible policy mix for an Indian state can lead to a higher penetration of LED lighting in combination of either (1) higher GDP and high literacy rate, or (2) high literacy rate and higher percentage of electrified homes in absence of a high GDP value for the state. The latter configuration presents an emphasis on the policy- mix characteristics and denotes their significance relationship with the outcome of the research.

These pathways represent the combinations that lead to higher penetration of the UJALA policy. The policymakers could take into account the existing exogenous factors and deploy the policy mix based on these pathways. These results are checked further for robustness by varying the frequency, consistency threshold and even the calibration threshold values to understand the internal validity of the results obtained. The verification suggests that the original values considered for the solution are suitable to derive the outcomes for this research.

Finally, a project conclusion is presented through answers to the sub-questions and the main question determined for this research. The main question comprises the resultant solution combinations that are applicable for a policy like UJALA to be successful in local implementation as per the variables present in the state.

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Abbreviations

BEE	Bureau of Energy Efficiency
BYL	Bachat Yojana Lamp
CFL	Compact Fluorescent Lamps
csQCA	crisp set Qualitative Comparative Analysis
DELP	Domestic Efficient Lighting Programme
DISCOM	Distribution Company
DPP	Discounted Payback Period
ECBC	Energy Conservation Building Code
EESL	Energy Efficiency Services Limited
EIA	Energy Information Administration
fsQCA	fuzzy set Qualitative Comparative Analysis
GST	Goods & Services Tax
LED	Light Emitting Diode
MERC	Maharashtra Electricity Regulatory Commission
MSEDCL	Maharashtra State Electricity Distribution Company Limited
mvQCA	multi-value Qualitative Comparative Analysis

NAPCC	National Action Plan on Climate Change
NPV	Net Present Value
PSUs	Public Sector Undertakings
QCA	Qualitative Comparative Analysis
RET	Renewable Energy Technology
SAPCC	State Action Plan on Climate Change
SDAs	State Designated Agency
SIR	Saving to investment ratio
UJALA	Unnat Jyoti by Affordable LEDs for All
UTAUT	United Theory of Acceptance and Use of Technology

Chapter 1: Introduction

This chapter briefly introduces the background and motivation for this master thesis. Along with this, the research gap and objective is clearly stated here. Next, the relevant research questions are also mentioned and finally an outline of the master thesis report, relevance to Management of Technology (MOT) and personal reflection are discussed in this chapter.

1.1 Background and motivation

Climate change and ever-increasing energy consumption has become a pertinent topic of discussion around the world. The US Energy Information Administration (EIA) predicts a global energy consumption rise by 50% in 2018 to 2050, with Asia leading the way (Kahan, 2019). There is an urgent need for the world to change the ways in which energy is generated and consumed, with fossil fuel as the main source accounting for nearly 84% of usage (Ritchie, 2017).

Developing countries such as India, with their sizable population and rapid advancements, require a substantial amount of energy to fulfill its aspirations. It is estimated that India will overtake the EU in terms of energy consumption by the year 2030 and is set to become the third-largest energy consumer following the United States and China (Press Trust of India, 2021). There is a compelling need for the country to find a more sustainable approach to fulfill its energy needs. Adopting Renewable Energy Technology [RET] and energy-efficient technologies are the two solutions that will enable India in meeting its future energy requirements in a sustainable manner (Ramesh et al., 2021).

Energy-efficient technology is one such avenue that can help in reducing energy consumption. Energy-efficient technology is basically defined as technology that reduces the amount of energy required to provide goods and services (Yang & Yu, 2015). These technologies are diversified into various sectors ranging from lighting, construction, transportation, and heat exchangers (Yang & Yu, 2015).

Lighting accounts for nearly 19% of total global energy consumption which makes energy-efficient lighting an attractive subject of study (Mir et al., 2020). India is working towards enabling a widespread usage of energy-efficient lighting by implementing relevant policies. Some of the measures to push energy-efficient lighting into the mainstream are the formulation of the Energy Conservation Act 2001, establishing institutions such as Bureau of Energy Efficiency (BEE) in 2002 and Energy Efficiency Services Limited (EESL) in 2009, and implementation of schemes like Bachat Lamp Yojna (BLY) and Unnat Jyoti by Affordable LEDs for All (UJALA) (Yang 2006, Bhattacharya & Cropper 2010). The learnings from these policies are beneficial for the formulation and implementation of future policies.

In 2015, the Government of India introduced the UJALA scheme. This scheme promotes energy-efficient lighting in both the urban and rural parts of India. The scheme was implemented throughout the country by the autonomous institution Energy Efficient services Limited (EESL). EESL in consultation with different stakeholders from the central and state governments like the electricity distribution company (DISCOM) aimed to implement the UJALA scheme uniformly across all the states. The UJALA scheme has been effective in the adoption of energy-efficient technology with the distribution of 366.4 million LED bulbs and about 10 million street lights (Mir et al., 2020). The scheme was also effective in bringing down the cost of LED bulbs to around 0.8 USD, which is considered the cheapest in the world (Mir et al., 2020).

The implementation of the UJALA scheme could have been more successful across the nation. For instance, despite EESL implementing the UJALA scheme uniformly in all the Indian states, the adoption rate across various states varies. From the research study by Reddy & Painuly (2004), it is apparent that the barriers encountered in the adoption of a new technology are "(1) Lack of awareness and information (2) Economic and financial constraints (3) Technical risks (4) Institutional and regulatory barriers (5) Market barriers and market failures (6) Behavioural constraint" (Reddy & Painuly, 2004). These barriers have to be taken into consideration before a policy is introduced so that the policy could be effective and assist in the successful adoption of energy-efficient lighting. If effective policies are formulated and implemented then some of the barriers, which are common, when a new technology is introduced can be negated.

It is imperative to study how policies in India affect the adoption of energy-efficient lighting and the various stakeholders involved. The study goes into details by analyzing the manufacturing LED sector, procurement process, business strategy and implementation/ distribution of LED bulbs. The research also applies Qualitative Comparative Analysis (QCA) methodology across the Indian states employing the UJALA scheme to understand the various causal pathways for achieving successful outcome i.e. which pathways will lead to higher rate of LED bulb adoption and how policies account for these variations.

In this master thesis, the overall objective is to understand the implementation of UJALA policy across various Indian states and how policies and other exogenous factors interact with each other to influence the rate of adoption of LED bulbs. This exercise was carried out by exploring the relevant policy instruments with respect to the energy- efficiency in India by categorizing them into various policy types such as economic instruments, regulation instruments, information and awareness policies. Once these policies are identified the next step comprises the formulation of policy mixes as per the framework by Rogge & Reichardt (2016) which is explained in chapter three, by investigating how these policies interact with one another and determining the causal complexity to the resulting outcome. It additionally also identifies the various exogenous factors that may impact the final outcome i.e. total number of LED bulbs distributed per capita in our case. Qualitative comparative analysis (QCA) was applied across different states in India to determine the various casualty pathways to study the LED bulb distribution penetration across various states.

1.2 Research gap and objective

The literature review conducted in chapter two implies that the adoption of the energy-efficient technology is studied from the end-user perspective with more emphasis on the behavioral aspects. There is a lack of empirical data on the influence of policies in the adoption and diffusion of energy-efficient technology, specifically lighting in India thus it can state that limited research is conducted on energy-efficient lighting in countries like India in relation to policies. Although theoretical frameworks like Technology Innovation System (TIS) attempt to address the issue with a single instrument (Policy), it fails to fully explain the impact of policies because the combined effect of multiple instruments influences energy-efficiency. It is evident from the literature summary section 2.5, that there is a significant research gap in the impact of policy mixes on energy efficient technology and so there is scope to study the influence of policy mixes on the UJALA scheme in the various Indian states as there is no state-level analysis available of the UJALA scheme even though the policy mix and its outcome vary at the state level.

The objective of the research is to analyze the impact of the UJALA scheme on the adoption of energy-efficient lighting in Indian states. For this purpose the UJALA scheme has been specifically chosen as it is the largest initiative to adopt energy efficient lighting in India. It is evident from the literature summary section 2.5 and research gap that the impact of policy mix on adoption of energy efficient technology has not been fully explored.

1.3 Research question

The adoption of energy-efficient lighting in India is critical as it reduces the carbon footprint of the country and the overall demand for energy consumption will come down. India constitutes one-eighth of the world population and a reduction in energy consumption in India will have a significant reduction in the global energy utilization. The UJALA scheme is critical for the adoption of energy-efficient lighting in India and so it is important to understand the impact of policy mix on the UJALA scheme for answering the research question. In order to approach the main research question in a structured manner, sub-questions have been formulated.

Main question:

How did the characteristics of the policy mix and exogenous factors pertaining to energy-efficiency influence the state-level performance of the UJALA Scheme in Indian States?

Sub questions:

1. *What is the overall governance model and procurement business strategy of energy-efficiency policy with respect to the UJALA scheme in India?*
2. *Which methodology would be suitable to analyze the causal factors pertaining to penetration of UJALA scheme at sub-national level?*
3. *What are the characteristics of the policy mix in terms of UJALA policy implementation in Indian states?*
4. *What are the exogenous factors that may impact the outcome of the UJALA policy implementation?*

5. *What combination of policy mix characteristics and exogenous factors lead to higher penetration of the UJALA scheme at the sub-national level in India?*

The first sub-question will help in understanding the governance model of the power sector in India with emphasis on UJALA scheme by identifying the important stakeholders and the business strategy for the procurement of LED bulbs and the manufacturing setup in India. Desk research will be conducted and will be answered in chapter two and five. The second sub-question argues and describes the methodology utilized in this research, answered in chapter four. The third and fourth sub-question determines the factors that may influence the LED lighting across Indian states, described in chapter three and four. Sub-question five is answered in chapter six by conducting QCA and finding the best causal outcome.

1.4 Outline of thesis

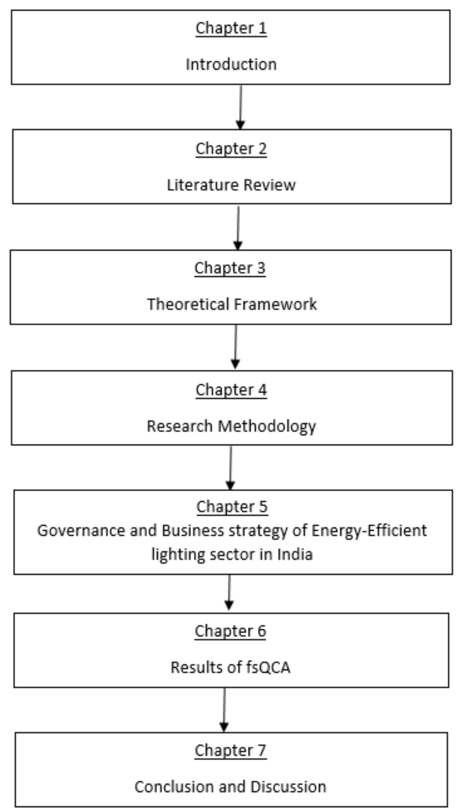

Figure 1. Outline of report

As shown in figure 1, this report is divided into seven chapters. Chapter one introduces the reader to the background and the motivation to select the topic along with the research gap/objective and research questions. Chapter two describes the literature study conducted in the field of energy-efficient technology, energy-efficient lighting and policy mix. Chapter three discusses the theoretical framework of policy mix and identifies various factors within the purview of the framework and also the various exogenous factors that may affect the outcome. Chapter four explains the research methodology adopted such as the Qualitative comparative Analysis (QCA) and operationalization of the factors identified in chapter three. Chapter five discusses the general governance model of India with respect to the power sector and in detail also discusses the various stakeholders involved in the implementation of the UJALA scheme. Exploratory case study is also conducted in this chapter that highlights the procurement process of LED bulbs and the manufacturing of the LED bulb in India and implementation of the UJALA scheme in the state of Maharashtra. Chapter six discusses the results of the fsQCA analysis and the sensitivity analysis conducted to check the robustness and validity of the result. Chapter seven provides the conclusion of the report and discusses the recommendation and limitations of the study. Furthermore, a reflection from the academic perspective highlighting the contribution of the study.

1.5 Personal and societal relevance

The researcher's personal reflection is guided by the immense learnings along the entire process of this masters thesis research. The exploration of the different energy- efficient policies in the Indian context along with their specific details regarding financing methodologies and implementation strategies were quite interesting to compare. Furthermore, given the different policies, the success of the innovative UJALA policy leading to disruption in the lighting industry was commendable even being introduced as a zero subsidy policy. The policy mix concept and the state wise difference was found to be relevant to benchmark the best possible combination leading to the higher penetration levels of this policy. However, the lack of data availability regarding state wise UJALA policy implementation led the researcher to consider an overview of energy-efficiency efforts of the states. Initially, a case study was recommended for the research, however a fit regarding the research objective and number of cases led the researcher to employ fsQCA methodology for this research. The utilization of fsQCA methodology in this research led to learnings of a relatively newer methodology for the concept and its benefits and limitations. Given the limitations of the fsQCA research, a critical approach was required to analyze the results of the study that enabled the researcher to understand the impacts of variation in values set for the research and develop a deeper learning of the methodology itself.

The effect of climate change is becoming more apparent in recent times. There is an urgent requirement to transition to a more sustainable mode of energy production, distribution and usage. Energy-efficiency technology like LED lighting can help India in bringing the carbon footprint down. This study might help in showcasing the causal pathways that may lead to higher penetration of LED bulbs in Indian states. These results can be an assist to the government and institutions like EESL and BEE on implementing the UJALA policy scheme or any planned future schemes more effectively and can bring more societal benefits to the general public on national level and to plant earth on a country level.

1.6 Relevance to MOT

Energy-efficient technology is fast becoming a very important tool that will help in combating climate change by trying to reduce the carbon footprint. Energy-efficient technology is diversified into various sectors ranging from buildings to lighting. Policies play an important role in the adoption of energy-efficient technology and thus it is important to understand how it impacts the technology. From a managerial perspective, it is important to understand these policies and how they may impact the technology before devising a strategy to introduce the technology in a particular geographical area. The insight the research conveys is that managers have to consider not a single but multiple policies effect while taking the decision to adopt new technology. Furthermore, the research addresses the business perspective and impact on the manufacturers of a new technology due to the policy implementation. Even though the UJALA policy allowed a rapid up scaling of the LED technology in the market in a few years, this up scaling might lead to negative impacts in terms of financial troubles in future. The highest selling point of the UJALA policy was the low price of LED bulbs in the market that allowed higher penetration, however, the prices might rise to a higher level when the UJALA policy is discontinued. The analysis of both business perspective and policy causal impact on a sub-national level tries to identify the stakeholders' requirements in this research and viable roadmap for such policies aimed at technology change in a developing country.

Chapter 2: Literature Review

The literature review is divided into five sections. The first section discusses the search criteria utilized for conducting literature review. The second section is a discussion on Energy-efficient technology with highlights towards Energy-efficient lighting. The third section discusses the Energy-efficiency policies in India with an introduction to the UJALA scheme. The fourth section deals with perspective determining the adoption of Energy efficiency. The behavioral, economic and policy perspective is also discussed in this section. The fifth section is an introduction to policy mix and how it governs energy-efficiency. Finally, the sixth provides a literature summary.

2.1 Search criteria

The primary reason for conducting a literature review is to be updated with the current state of research and to discover the knowledge gap which can be explored further. The focus of the research is to investigate the impact of policies on the adoption of energy-efficient lighting in India. Scopus is used to search for the relevant literature. To get relevant articles, the search is conducted in stages, beginning with an initial search for the keyword "energy-efficient technology" and 1447 documents are found. Next, the results are refined using the function 'Limit to' in Scopus to bring down the count of articles. For example, only English is chosen in the language section and subject areas are limited to energy, environmental science, social science and economics. This resulted in reducing the search to 817 articles. A short examination of the articles gave a general idea on the different fields across energy-efficiency technology. One technique used to sort the articles further is to first look for the most cited articles and determine the general theme. The most cited articles on Scopus ranged from topics such as the energy-efficiency gap to residential energy-efficient technology adoption. Articles of relevance are found in the search with articles on the adoption of energy-efficient technology in households and articles on energy-efficient technology itself.

Once the basic idea of the topic is understood the search terms which were closely related to the research topic are narrowed. From desk research, it became apparent that lighting accounts for approximately 19% of the global energy consumption (Mir et al., 2020). Thus, the adoption of energy-efficient technology in the lighting sector was critical and it was interesting to investigate the status of energy-efficient lighting in households. Further research on energy-efficient lighting shows that LED was considered to be the most energy-efficient lighting technology and it was necessary for conventional lighting to be replaced with this more efficient technology. Therefore, a choice was made to focus on LED technology in this research.

India has a population of 1.3 billion people (as of 2019) and so the adoption of energy-efficient technology in India will have an enormous impact on reducing global energy consumption. Thus, the decision to choose India as the geographical location is made. Upon further research on the various LED adoption schemes across India, it became evident that the UJALA scheme is considered to be one of the biggest LED distribution schemes not only in India but the entire world (Mir et al., 2020). This scheme can be considered as the most critical scheme in the energy-efficient lighting sector in India and therefore the ideal candidate for our case study. These were the few rationales that directed both the research direction and search terms.

Further, search applications like Scopus, Google Scholar platforms were used with keywords such as “energy-efficient lighting”, “ Policy”, “adoption”, “ UJALA” and “ India” to get a more targeted outcome. Again Scopus is used with the combination of “energy-efficient lighting” and “Policy” and 54 documents were found. These documents were again scrutinized and a total of 16 articles were found relevant to adoption of energy-efficient lighting in India as well as globally.

Once an overview of energy-efficient technology with emphasis on energy-efficient lighting was done, the focus shifted towards policies and its impact on energy-efficiency. From the literature it is clear that multiple policies are involved and have a combined effect on any technology (Rogge & Reichardt, 2016). Policy mix was one such concept that would aid towards exploring the interaction of policies. Scopus is used with the keyword “Policy mix” AND “energy efficiency” to get more focused information on literature. Articles ranging from policy analysis, innovation studies and environmental economics were found. From the study, it was evident that the policies interact with one another and the boundaries were clouded. Therefore, the interaction of policy mix with the UJALA scheme was selected as the area of research for our case study.

2.2 Energy-efficient technology

Energy-efficient technology is becoming imperative to combat climate change. It is estimated that investment towards energy-efficiency needs to increase up to six times by the year 2050 (Fleming, 2021). In simple terms, it was defined as a technology that helps in reducing the amount of energy consumed while serving the same functionality as originally intended. Generally, the three ways by which energy-efficiency could be improved are adoption of a new technology which is more efficient, advancing the production process or reduction of energy loss in existing technology. The definition of energy-efficient technology varies depending upon the time period, location and the various policies of the government (Yang & Yu, 2015). This is because of the dynamic nature of the energy-efficient technology, for example when time period was considered, in earlier times cost effectiveness was the parameter to measure energy-efficiency but in recent times CO_2 reduction is considered as the most essential parameter (Balachandra et al., 2010).

According to Yang & Yu (2015), energy-efficient technologies could be seen across various sectors ranging from lighting to building. The most significant sectors in which energy-efficient technology are present could be broadly grouped into transport, heat exchange and lighting.

Energy-efficient refrigerators: An attempt to improve energy-efficiency in the refrigeration industry was done in two steps. Firstly, the technology was enhanced by developing an energy-saving compressor and embedding computers to make the refrigerator system smarter and efficient. Secondly, the government of the US introduced programs like the Energy star label, the goal of which was to instill awareness on energy-efficient products and practices (Yang & Yu, 2015).

Energy-efficient Vehicles: It was a highly significant sector for energy-efficiency because of its dependency on fossil fuel. Traditionally, a car utilizes only about 14-26% of energy for motion. Innovation of technologies such as turbo charging and direct fuel injection have significantly reduced the fuel consumption of vehicles (Yang & Yu, 2015).

2.2.1 Energy-efficient Lighting

Lighting has come a long way from the traditional lighting to CFLs to LEDs. As of 2013, lighting accounts for around 19% of the global consumption of electricity (Yang & Yu, 2015). It is estimated that if the adoption of LEDs is widespread then the level of energy consumption in the year 2050 will be almost identical to the year 2005 (Yang & Yu, 2015). Thus, energy-efficient lighting could be considered a crucial tool in decreasing energy consumption as it minimizes CO_2 footprint and reduces the peak demand load. For implementing energy-efficient technology it is essential to have the right policies in place.

One of the key parameters to measure the efficiency of advanced lighting technology was the payback period. Payback period is the time taken to recover the cost of investment. The Payback period for energy-efficient lightings like CFL and LEDs was relatively less compared to the traditional incandescent lighting. According to Reddy (2003), the payback period of CFL was around 1.2 years and can be considered cost-effective because it has a longer life. From this observation, the main question that arises was, why CFLs were not as widely used in comparison to existing lighting systems. A. Kumar, Jain, & Bansal (2003) reported that the awareness of CFLs among the less privileged section of the society was considerably low. It was also observed that LEDs have a far greater advantage compared to conventional bulbs. In table 1, few of the advantages and disadvantages of LED are listed.

Table 1. Advantage and Disadvantage of LED Adapted from (Cowan & Daim, 2013)

Advantages	**Disadvantages**
Efficiency: In terms of theoretical maximum efficiency levels, LEDs deliver more output than any current lighting technologies and remain unaffected by size or shape of the bulb. Also, they seem to radiate little heat as compared to incandescent and fluorescents.	*Efficiency:* Albeit possessing higher theoretical maximum efficiency levels, fluorescent bulbs are more efficient at producing light in desired daylight spectrum ranges, which stands as a drawback of LEDs.
Lifetime: Useful operating lives of LEDs are approximately 400% more than the fluorescent lights. Towards the end of its useful life, the light grows dimmer, rather than abruptly falling, like its competitor technologies.	*High Purchase Price:* Initial purchase price of LEDs is higher than other lighting technologies and are not offset by the higher energy efficiency offered by this technology.
Color: LEDs are able to produce colored light without the use of filters. But since LEDs produce much cooler colors, many people still prefer traditional light sources over LEDs for general illumination.	*Light Quality*: Presently, LEDs produce much cooler and blue light as compared to natural colors produced by its competitor technologies.
Cycling: The cycle response time for LEDs is low and frequent cycle operation does not lead to premature failure as in case of fluorescents.	
Low Toxicity: Recycling of LEDs is easier since no toxic elements such as Mercury embodied in these bulbs.	

2.3 Energy-efficiency Policy in India

The literature on energy-efficient technology and its barriers in India mainly discusses the primary question of how India fair up against other countries in a comparative study and what would be the energy-saving (cost-saving) if a certain technology is applied. However there is a lack of insight on why certain technologies are being adopted over others and the policies related to their adoption and their effectiveness (Bhattacharya & Cropper, 2010).

Yang (2006) reviewed the energy-efficient policies in India from 1986 to 2005 and found six major policies which were enforced, ranging from disclosure of company level energy-efficient information to Passage of policies like the Energy Conservation Act of 2001 followed by the Electricity Act of 2003 (Yang, 2006). These policies were considered important stepping stones to the formation of Institutions like the Bureau of Energy Efficient (BEE) and Energy Efficiency Services Limited (EESL), who are defining the current regulations of energy-efficient technology in India (Bhattacharya & Cropper, 2010).

Balachandra, Ravindranath, & Ravindranath (2010) have divided the evolution of the energy efficiency policy of India into five phases. These phases had different contextual meanings for energy efficiency as the meaning of energy-efficiency has changed over time. Initially, the context was about the scarcity of fossil fuel, then it moved to the target of achieving cost-effectiveness and currently the context of energy-efficiency is towards the mitigation of climate change (Balachandra et al., 2010). The first phase focused on economic growth and poverty alleviation, the second phase targeted economic liberalization and energy conservation, the third phase was about independent initiatives, the fourth phase aimed energy conservation bills that were introduced and this phase marked the advent of mitigation of climate change strategy (Balachandra et al., 2010). Phase five has the same context of climate change mitigation but has a high priority because of the urgency.

Different energy-efficient policies in various sectors are introduced in India. In the building sector Energy Conservation Building Code (ECBC) was introduced. In the lighting sector the two main schemes are Bachat Yojana Lamp (BYL) and UJALA scheme. Considering the magnitude and relevance of the scheme UJALA is considered an important scheme in India. Thus it is very appropriate to further study the UJALA scheme.

2.3.1 UJALA scheme

Unnat Jyoti by Affordable LEDs (UJALA) also known as Domestic Efficient Lighting Programme (DELP) was launched by the government of India in the year 2015 under the energy- efficiency policies (Mir et al., 2020). The main aim of the scheme was to distribute LED bulbs to households in bulk quantities and as per the figures more than 366.4 million LED bulbs have been distributed until August 2020 (Mir et al., 2020). The scheme is introduced by Energy Efficient Services Ltd. (EESL) with two main objectives namely developing a modern LED domestic manufacturing industry and to bring down the electricity demand. The LED bulbs distributed under the scheme are around 0.8 USD, considered as the cheapest retail price anywhere in the world.

Mir et al.(2020) formulated the functions of innovation systems in the Indian LED sector using the UJALA scheme. The framework consists of the main actors, network, institution, and infrastructure and investigates the interaction between various structural elements.

Mir et al.(2020) also found that different policies were simultaneously involved. Several fiscal measures like tax rebate and excise duty exemption were introduced by the government. Thus it is clear that multiple policies are at play. Therefore, the concept of policy mix can be used to study the effectiveness of the UJALA scheme.

2.4 Perspective determining adoption of energy efficiency

In this section the various perspectives that determine adoption of energy-efficiency are discussed. These factors can be subdivided into three headings namely behavioral, economic and policy perspective. The behavior aspect gives more emphasis towards the end-user customer, while cost effectiveness brings the economy into perspective by including parameters such as Net Present

Value (NPV). Policies, the last factor, also determines the adoption of energy-efficiency. The policies factor discusses the type of failures and the various policies that can be used as a deterrent.

2.4.1 Behavioral perspective

The main question discussed in numerous research was, what were the key important factors in the adoption behavior of the end customer with regards to energy-efficient technology. Cowan & Daim (2013) used the United Theory of Acceptance and Use of Technology (UTAUT) to explain the adoption behavior of customers. The four key parameters of UTAUT were performance expectancy, effort expectancy, social influence, and facilitating conditions (Cowan & Daim, 2013). The UTAUT was an evolved theory which was formulated by combining the following eight significant theories namely, Technology adoption life cycle, Base model diffusion, Theory of reasoned action, Motivational model, theory of planned behavior (TBP), Decomposed TPB, Innovation diffusion theory and technology acceptance model (Khorasanizadeh, Honarpour, Park, Parkkinen, & Parthiban, 2016).

Khorasanizadeh et al. (2016) conducted a survey across various cities of Malaysia to investigate the factors that play an important role in the adoption of LEDs in Malaysia. The author used the UTAUT framework and confirmed that all the four factors, performance expectancy, effort expectancy, social influence, and facilitating conditions, played a vital role in the adoption of LEDs. Similarly, Huang (2020) conducted a survey in rural China to study the factors affecting energy-efficient lighting and determined that social support, awareness of the technology, and perception of cost-effectiveness are the major factors (Huang, 2020).

Genus & Jensen (2017) contradicts the assumption of behavior-related purchase decision but argues that social practice which emphasizes routine and ritual of people and the institutionalization of the collective convention is more relevant (Genus & Jensen, 2017). The author concludes that the buying or adoption phenomenon is more a collective habit rather than an individualistic one.

2.4.2 Economic perspective

A Study by Oluseyi et al.(2020) tried to justify the cost-effectiveness from the economic perspective. The author conducted a study on a public building in Nigeria and used three different energy-efficient lighting systems namely, intelligent controlled incandescent lamp (ICIL), compact fluorescent lamp (CFL), and intelligent controlled CFL (ICCFL). The three main economic indices studied were Net present value (NPV), saving to investment ratio (SIR), and discounted payback period (DPP), and the result found that CFL was more effective than conventional incandescent lamps (Oluseyi et al., 2020). In economic perspective the above mentioned indices are used to justify the advantage in terms of financial gains.

2.4.3 Policy Perspective

Few literature studies the issue of energy-efficiency adoption from the prism of policies. The main failures that affect the promotion or adoption of energy efficiency are market failure (including information failure), Behavior failure, and other factors. Market failures are mostly caused due to information failure also known as imperfect or asymmetry information in the market. Behavior failures include decision-making heuristics and inattention (Solà, de Ayala, Galarraga, & Escapa, 2020). These failures are responsible for causing the phenomenon of the 'energy efficiency gap' or 'energy efficiency paradox'. Energy efficiency gap is explained as not embracing the energy-efficient technology by consumers and businesses which are readily available and may be profitable for them. Different types of policies such as information instruments, economic incentives, and energy standards and codes can be used for resolving these failures (Solà, de Ayala, Galarraga, & Escapa, 2020). Markandya et al. (2005) has classified the policies into three groups namely (1) Command and control instruments; (2) Information based instrument and (3) Price instrument. Solà et al. (2020) conducted a literature review to study empirical data of energy-efficient policies and their effectiveness and found that the main three types of policies were not effective in all the cases and had certain limitations like difficulty in implementing the policies.

2.5 Policy Mix and energy-efficiency

The term and concept of 'Policy Mix' was first introduced in the economic policy literature to describe the interaction between the fiscal and monetary policy (Rosenow, Fawcett, Eyre, & Oikonomou, 2016). Currently the interest in policy mix has diversified to various scientific fields ranging from environmental economics, innovation studies and policy analysis. In the field of policy analysis, Kern & Howlett (2009) developed a typology trying to explain the policy regime change process and took up the case of the Netherlands to examine the energy transition management. The policy mixes emerge from basically four methods namely 'drift', 'conversion', 'layering' and 'replacement'. In 'drift' only the goals are changed but the instrument remains the same. In the case of 'conversion' it is just opposite to 'drift' with new instruments added but the goals remain the same. In the process of 'layering' new goals and instruments are simply added to the old goals and instruments. 'Replacement' is the process by which the old goals and instruments are replaced by new goals and instruments (Kern & Howlett, 2009). While in the field of environmental economics, Lehmann (2010) conducted an economic evaluation of the policies and introduced the concept of transaction cost to evaluate the efficiency of climate policy mix.

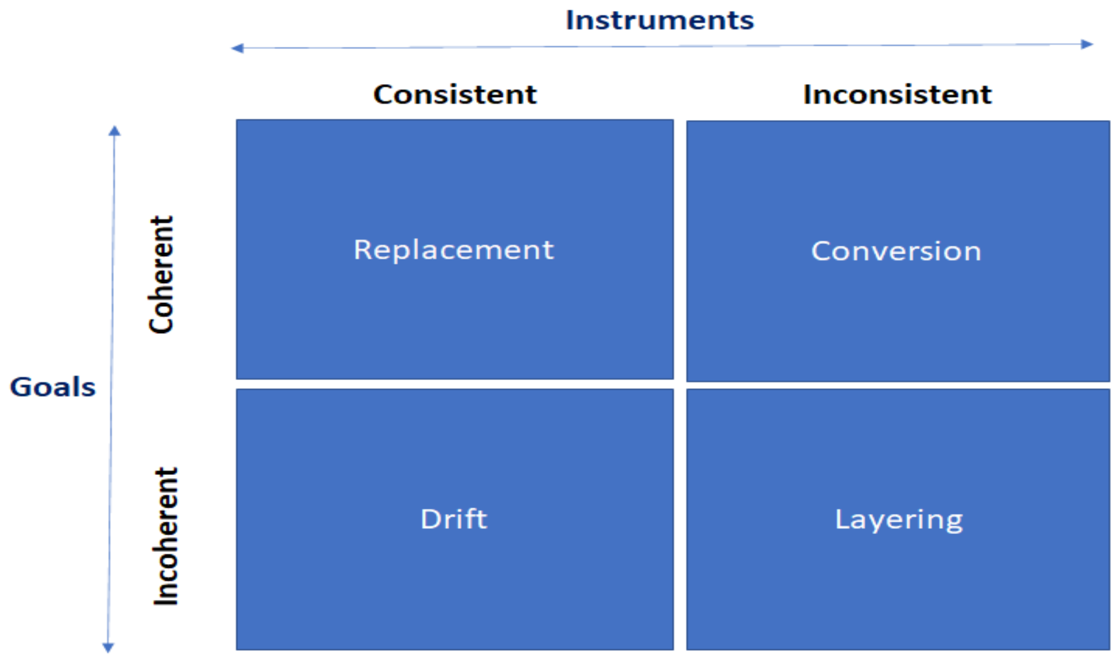

Figure 2. Relationship between Goals and Instruments Adapted from (Kern & Howlett, 2009)

Definition of policy mix has varied across the literature. In its most elementary form policy mix is a combination of various policy instruments. For any technology change, energy-efficient lighting in our case is always subjected to different types of failures like market, instrumental, and system, and a single policy intervention will be not effective in resolving these failures (Rogge & Reichardt, 2016). Studies on Energy policies have dominated the policy mix research with much focus on renewable energy policies and emission trading schemes, and less focus towards energy efficiency (Rosenow, Fawcett, Eyre, & Oikonomou, 2016). In the context of energy-efficiency the most dominating literature found were related to 'policy mix' and energy 'efficiency in buildings' additional literature were found for energy-efficient household appliances, energy-efficiency in general with emphasis on innovation. In case of energy efficient building, Lee and Yik (2004) paid special attention to cost-effectiveness of the instrument but not so much on the interaction between the instrument, while Kern, Kivimaa, & Martiskainen (2017) studied the mix of existing policies in UK and Finland and found that both countries had a complex but very different policy mix despite a shared EU influence. In the field of eco- innovation relating to energy-efficient technology researcher Costantini, Crespi, & Palma (2017) emphasized that a policy mix has a positive effect on eco-innovation if the instruments are more balanced in terms of demand-pull and technology-push instrument. Gana & Hoppe (2017) focused on the energy-efficient appliances for households and used the Governance Assessment tool (GAT) to assess the policy and the related governance system.

Table 2: Policy mix definition reproduced from (Rogge & Reichardt, 2016)

Source	**Definition**
Guy et al. (2009) (p.1)	"An R&D and innovation Policy Mix can be defined as that set of governmental policies which, by design or fortune, has direct or indirect impacts on the development of an R&D and innovation system."
Kern and Howlett (2009) (p.395)	"Policy mixes are complex arrangements of multiple goals and means which, in many cases, have developed incrementally over many years."
Nauwelaers et al. (2009) (p.3)	"A policy mix is defined as: The combination of policy instruments, which interact to influence the quantity and quality of R&D investments in public and private sectors."
Boekholt (2010) (p.353)	"A policy mix can be defined as the combination of policy instruments, which interact to influence the quantity and quality of R&D investments in public and private sectors."
de Heide (2011) (p.2)	"A policy mix is the combined set of interacting policy instruments of a country addressing R&D and innovation."
Ring and Schroter-Schlaack (2011) (p.15)	"A policy mix is a combination of policy instruments which has evolved to influence the quantity and quality of biodiversity conservation and ecosystem service provision in public and private sectors."

2.6 Literature summary

From the literature review it is evident that energy-efficient technology is an immediate concern and energy-efficient lighting technology has a direct impact on our everyday energy consumption. The outlook of the general public on energy-efficient technology is also highly positive as it can be both cost-effective and energy-efficient but there are some questions regarding the awareness of these modern energy-efficient technologies. The first part of the literature review elucidates the perspective governing the adoption of energy-efficient technology in society, firstly, the economic perspective, which uses indices like NPV to prove their point about the efficiency of the technology, secondly, factors such as behavioral perspective and its impact on adoption of new technology. The behavior of the end-user is studied using models like UTAUT. Following this, the progression of energy efficient technology in India and the policies governing it are examined. During the investigation of policies on energy efficient technology it is found that multiple policies are working together and impart a combined effect, the concept of policy mix, a multi-faceted policy intervention to address complex problems, became apparent. However there is inadequate study on the impact of policy mix on energy efficient technology, specifically lighting.

Chapter 3: Theoretical framework

This chapter consists of three main sections. The first section of the chapter discusses the policy mix framework and the building blocks of the extended policy mix concepts such as elements, process and characteristics in detail. The second section gives a brief insight into determination of factors such as policy strategy, policy implementation, instruments, characteristics and exogenous factors. The last section provides a conclusion in terms of the selected causal factors for the research.

3.1 Policy Mix framework

In case of any technological change, energy-efficient lighting in our case (from conventional lighting bulbs to LED bulbs), it is always subjected to different types of failures such as market, instrumental, and system. These failures tend to hinder the new technology transition and a single policy intervention becomes ineffective in resolving these failures (Rogge & Reichardt, 2016). Scholars in the field of innovation and policy analysis are recommending the application of policy mix which is more pragmatic because there are always multiple policies involved and these policies interact with each other and create a combined effect. In the case of energy-efficient lighting in India, many instruments were introduced, like standards & labeling (S&L), the UJALA scheme, and electricity tariffs that interact with each other and result in a combined effect. The "Extended Policy mix for technology change" framework is selected for this research. The framework not only covers the interaction of the various instruments but also emphasizes the overall policy process of how the policy instruments came into effect and interacted. According to Rogge & Reichardt (2016), the three building blocks of the extended policy mix concepts are elements, process, and characteristics.

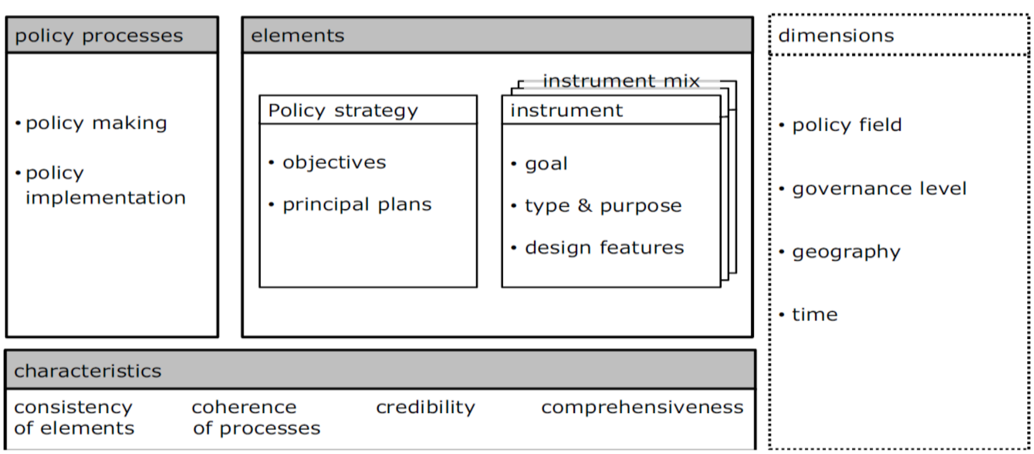

Figure 3: Extended policy mix Reprinted from (Rogge & Reichardt, 2016)

Elements

The elements comprises two important components namely instrument mix and policy strategy. In instrument mix, the interaction of several instruments characterized by their goals, types, purpose, and design features are considered as shown in Figure 3. The instruments are typically classified by the type such as economic, regulation and information as described in Table 4.

Policy strategy deals mainly with objectives which refers to the long-term targets set and principal plan for meeting the end target i.e. the objective. In the case of Energy- efficient lighting, the target may be related to the number of LED bulbs distributed or Paris Agreement targets.

Policy Process

The policy process consists of two components namely policy making and policy implementation as shown in Figure 3. This building block determines how the elements of the policy mix evolve and change over time. The entire policy process covers all the steps of the policy cycle, from problem identification to evaluation. Policy making mainly studies how a solution to the societal problem is derived by the various stakeholders forming advocacy groups using the political problem solving process. The advocacy literature is mostly derived from the work of Sabatier (1988). It is very essential to identify the important stakeholders involved. In the case of energy-efficient lighting, the main stakeholders are the central government, the state government, electricity distribution companies and autonomous government agencies like EESL & BEE.

Policy implementation is defined as the application of the policy into action by the various stakeholders including the government and other actors (Nilsson et al., 2012). For a policy to function in a way it is intended to work it is important that the implementation happens in a correct way.

Characteristics

Characteristics described in the policy mix are consistency, coherence, credibility and comprehensiveness. Consistency describes how well the elements of the policy mix are complementary to one another and aligned collectively to meet the objective. Coherence describes the systematic and synergy of the policy process which includes both the policy making and policy implementation. Credibility is also an important characteristic and is defined as at what level is the policy mix believable and reliable. Comprehensiveness describes the rigorousness of both the elements and process of the policy mix (Rogge and Reichardt, 2016).

Rogge & Reichardt (2016) derived the analytical framework to investigate the impact of policy mix on technological change. The main objective of the framework is to comprehend the complex relation between the policy mix and technology change. The framework can be used to conceptualize the elements and characteristics of the policy mix and its influence on the outcome.

3.2. Determination of Factors

A policy mix in its most simplest form is defined as a combination of relevant policy instruments whereas, Rogge & Reichardt (2016) substantiated that a policy mix framework should comprise of at least the following two components namely, the policy instrument mix and the policy strategy. Moreover, Flanagan et al. (2011) suggests that a policy mix should be more than just a combination of instruments. Taking this into consideration, in this research, a focus on the policy strategy, policy making and policy implementation in addition to the participating instruments is considered vital for "good results".

This section is based upon the determination of factors for the fsQCA Analysis to be considered in this research. The extended policy mix framework considered in Section 3.1 is utilized to determine the relevant factors that drive technological change via UJALA policy implementation at sub-national levels. The consideration of factors is reliant upon the energy-efficiency efforts of the Indian states and are assumed to be drivers for successful energy-efficient policies in India, UJALA. Furthermore, the unavailability of direct contributing factors such as financing for UJALA policy has led to the consideration of overall energy-efficient efforts by states as a relevant factor for this research.

The following Figure 4 indicates all the sub-building blocks and the relevant contributing factors relevant to the energy efficiency. This consideration is based on the framework already explained in Section 3.1. A detailed explanation of each consideration is described as follows.

S.No	Sub-building Blocks	Factors
1	**Policy Strategy**	
	Objective	Setting Quantifiable energy efficiency goals or target
	Principle plans	Policy or legislation aming to improve energy effiency
2	**Instrument mix**	mandates for utilities to invest in energy efficiency
	Economic Instruments	RD&D grants and loans
		Incentives
		State Equity assistance
		Subsidies
		Infrastucture provision
	Regulation	Patent law
		IP rights
		Technology/performance standards
		Probihitions of products or constraints
		market Design/maturity
		maturity
		Monitering and evaluation
	Information and education	Consumer awareness
		Information or tools available to consumenrs on electricity usage
		professional training or qualification
		Education systems
3	**Policy Making**	Policy process
4	**Policy Implementation**	SDAS
		institutional framework and capacity

Figure 4: Sub-building blocks adapted from (Rogge and Reichardt, 2016; World Bank, 2016)

3.2.1 Policy strategy

Policy strategy is defined as a combination of policy objectives and the principal plans for achieving them (Iverson and Andrews, 1987). According to Rogge and Reichardt (2016), policy strategy is classified into objectives and principal plans respectively. The objective here is identified as a sub-building block that defines quantifiable targets based on long-term strategic planning and the visions of the future (Rogge and Reichardt, 2016). The National Action Plan on Climate Change (NAPCC) objective is India's first framework on climate change focusing on a long-term planning to mitigate climate change (MINISTRY OF SCIENCE AND TECHNOLOGY, n.d.). Under the NAPCC, eight missions were defined out of which two missions were relevant to energy-efficiency namely, National Mission on Sustainable Habitat and National mission for enhanced energy efficiency. The National mission on sustainable Habitat aims at promoting energy efficiency in the residential and commercial sector, promoting public urban transport and the national mission for enhanced energy efficiency promotes the labeling of equipment and appliances (MINISTRY OF SCIENCE AND TECHNOLOGY, n.d.). Further, World Bank (2016) reported that fourteen Indian states have adopted the State Action Plan on Climate Change (SAPCC).

The principal plan is identified as a sub-building block to check if the legislation, policy or sector specific plan is undertaken by the individual states aiming to improve energy- efficiency (Rogge and Reichardt, 2016). This constitutes the steps taken towards achieving the set targets of the policy objective, in our case, the SAPCC objectives. In terms of data availability, the status of SAPCC formation in the year 2015 is taken into account. Similarly, the principal plan in terms of regulations or policies directed towards energy- efficiency measures in the state until the year 2015 are considered in this case (World Bank, 2016). The year of 2015 is important due to the conception of UJALA policy in India. However, it is assumed that the states with an established SAPCC tend to lean more towards the policy and drive more efforts towards it since its introduction in the state. Also, the principal plan could involve the UJALA policy as part of the principal plan in achieving their SAPCC targets. The present dataset is part of the report published by World Bank (2016) for Indian states wherein the states that have defined energy-saving targets are awarded 1 whereas those in underdevelopment states are assigned 0.5 and otherwise 0. For principle plan inclusion, a similar process is followed as for objective -setting wherein states with legislation and policy directives for energy efficiency plans are awarded 1, underdevelopment status as 0.5 and otherwise 0 (World Bank, 2016).

In this research, a factor called policy strategy is considered which combines the quantifiable objective set by the individual states to achieve targets or goals and the relevant principle plan of individual states on the implementation of any policies or legislations. Reference to the data used as a cumulative factor "Policy Strategy" is available in the World Bank (2016) and is also used as an input in this research. The following Table 3 indicates the input used.

Table 3. Policy strategy factors determination

Policy Strategy	**Applicable for UJALA policy**	**Data availability**	**Data reference**
Energy efficiency targets and goals	**Yes. Some states have defined objectives for the energy-saving targets.**	**Yes**	State Energy Efficiency Readiness - (World Bank, 2016)
Policies or regulations adopted by states related to energy- efficiency	**Yes. State agencies have undertaken policies for energy savings**	**Yes**	State Energy Efficiency Readiness - (World Bank, 2016)

3.2.2 Instrument

According to Howlett and Rayner (2007) and Salamon and Elliott (2002), a policy instrument is defined as concrete tools or techniques of governance introduced by governing bodies to achieve policy objectives. According to the research framework defined in this thesis and mentioned in section 3.1, technology innovation is attributed to two key features of policy instruments, instrument type utilized by the governing body and the instrument design feature.

Rogge and Reichardt (2016) in their research discussed the various instruments utilized by the governing bodies by characterizing them based on their type and primary purpose and summarized them as shown in Table 4. The primary instrument types are majorly distinguished as economic, regulation and information and the primary purpose are typically classified as technology push, demand pull and systemic.

Table 4: Instrument types and Purpose. Reprinted from Rogge and Reichardt (2016)

Primary type	**Primary purpose**		
	Technology Push	Demand pull	Systematic
Economic instruments	RD & D grants and loans, tax incentives, state equity assistance	Subsidies, feed-in tariffs, trading systems, levies, deposit-refund-systems, public procurement, export credit guarantees.	Tax and subsidy reforms, infrastructure provision, cooperative RD&D grants.

Regulation	Patent law, intellectual property rights	Technology/performance standards, prohibition of products/practices, application constraints.	Market design, grid access, grid access guarantee, priority feed-in.
Information	Professional training and qualification	Training on new technologies, rating and labeling programs, public information campaigns.	Education system, clusters.

Nemet (2009) defines technology-push policies as policies that aim to aid or foster socio-technical change by reducing the cost of research and development or outreach for the programs. Policy inclusions in this type are finance provision for particular R&D development in terms of funds or tax reduction or technical training provision to the concerned employees. This inclusion can be seen as aiding the supply side of technological changes. On the other hand, demand-pull policies are targeted towards market development by supporting the use of these technologies through end-users (Edler and Georghiou, 2007). Examples of such instruments are subsidy provisions and consumer awareness programs. In addition to the above policy-purpose types, Rogge and Reichardt (2016) also include the importance to the instruments functioning at a systemic level that drive the overall change in technology. Such instruments include a greater outreach program such as public debate on policies, infrastructure provision for technological changes and reforms in taxes & educational systems to promote energy-efficient technology usage.

However, these instruments in Rogge and Reichardt (2016) correspond to renewable technological changes, hence, suitable instruments applicable in case of energy-efficient technologies are chosen in terms of UJALA policies implementation at sub-national levels in India for this research.

The first primary type presented in Table 4 are the economic instruments. As defined by IEA (2019), they are “policy instruments that relate to fiscal, financial and other economic incentives and disincentives to deliver energy efficiency improvements across multiple sectors”. Furthermore, the objectivity of these instruments is to create a supply-demand balance of services in the market via modification of prices, taxes or incentives in financial transfer. For this research, the selection of economic instruments factors is based on their relevance to UJALA policy implementation and data availability of state-level energy-efficiency efforts for these instruments. Table 5 summarizes the economic instruments considered for this research.

Table 5. Economic instruments for energy-efficiency policies and their applicability.

Economic Instruments utilized for energy efficiency	**Applicable for UJALA policy**	**Data availability**	**Data reference**
Research, Development and demonstration grants and loans	**Yes.** Eight state governments have signed MOUs and paired with educational institutions providing R&D grants for development and deployment of energy efficient technologies in the state.	**Yes.** A binary data for RD&D efforts made by states is available, however the data regarding the monetary value is missing.	State Energy Efficiency Index 2020 - (AEEE State EE Index, 2021)
Tax incentives	**No.** The light bulbs distributed under the UJALA scheme falls under the category of Goods & Services Tax (GST) that enables uniform prices of bulbs throughout the country under uniform tax slabs and hence does not differ per state that defies its applicability for this instrument (Outlook, 2017).		
Direct investment	**Yes.** States are funded by BEE and EESL to implement energy-efficient policies in the states and their monetary value differs for each state.	**Yes.**	RTI data (2020)
Subsidies	**No.** UJALA is a zero-subsidy scheme aimed to provide low price LED bulbs with no additional subsidies provision by different		

	state or national governments (Mir et al, 2020**).**		
Infrastructure provision	**No.** The switch from CFL to LED technology does not require a different infrastructure to be affixed by the user (Mir et al, 2017)		

In this research, the identified factors from economic instruments are RD&D efforts by states and finances allotted by the BEE (Bureau of Energy Efficiency) to SDAs (State Designated Agency). According to the State Energy Efficiency Index (2020), eight states have provided designated funds towards energy efficiency development and outreach programs via MOUs or partnerships with the help of NGO organizations, universities and other educational institutes (State Energy Efficiency Index, 2020). Based on the available binary data, the states that have made efforts towards promoting RD&D funds at the state-level have been assigned a value "1" and other states are assigned a value "0" against this factor (State Energy Efficiency Index, 2020).

In terms of fund allocation to states by the Bureau of Energy Efficiency (BEE), the monetary value is derived via RTI (Right to Information, 2020) data for different states. It is assumed that this funding would be utilized for strengthening the energy-efficiency efforts in the state and hence would contribute towards effective UJALA policy implementation.

The second type of instruments are regulation policy types. Regulatory instruments are political interventions that are designed to influence social and economic action through binding regulations (Krott, 2005). Similar to economic instruments, the possible regulatory instruments applicable for UJALA policy are summarized in Table 6.

Table 6. Regulatory instruments for energy-efficiency policies and their applicability

Regulatory Instruments utilized for energy efficiency	**Applicable for UJALA policy**	**Data availability**	**Data reference**
Patent Law	**No. The supply side of UJALA policy concerns high volume procurement of existing manufacturers and hence no patent law advantage**		

	is granted in this case.		
Intellectual Property Rights	**No. The supply side of UJALA policy concerns high volume procurement of existing manufacturers and hence no IP rights advantage is granted in this case.**		
Technology/performance standards	**No. The LED bulbs are rated under the standards and labeling scheme implemented uniformly nationwide and hence, no state-level differences would be applicable in this case.**		
Prohibition of products or constraints	**No. The UJALA policy has constrained the provision of government subsidized CFL bulbs, however due to nationwide application of UJALA scheme, all states are now providing LED bulbs under this scheme and hence, no difference is noted in this regard.**		
Market Design/ Maturity	**Yes. Market Design has been enabled via use of experience of implementing previous energy efficiency policies to the end user.**	**Yes. Data measuring the implementation and extent of penetration of energy-efficiency policies in the state would be utilized for this factor.**	State Energy Efficiency Readiness - (World bank, 2016)
Monitoring and Evaluation	**Yes. The states have implemented different monitoring and evaluation techniques to deliver on their energy efficiency objectives that may involve a third-party**	**Yes. The states have been benchmarked for their efforts on monitoring and evaluating**	State Energy Efficiency Readiness - (World bank, 2016)

	or continuous goal tracking.	**their implementation of energy efficiency policies in states**	

The Market Design/ Maturity factor is considered to evaluate the energy-efficiency potential and experience of the state agencies in implementing similar policies that could increase the effectiveness of the UJALA scheme by better outreach. The data from market research available in World Bank (2016) mainly focuses on the demand side management programs that are largely driven by Energy Efficiency Services Limited (EESL) also serving as the driving authority in case of UJALA. The dataset includes program implementation since 2010 and comprises factors that measure states' performances over uptake of the policy and its penetration in the state (World Bank, 2016). The policies included in this analysis are BEE-star rated pump distribution, UJALA bulb distribution in states until December 2015, installing LED street-lighting, domestic energy-efficient fan distribution under Standards and Labelling (S&L) scheme, installing solar irrigation pumps and status of Transmission and Distribution losses in the state (World Bank, 2016). The UJALA scheme penetration has been undertaken in this study to understand the uptake and experience of implementing this policy that might result in better penetration of LED lighting in the states. The other policies could be attributed to domestic reach and hence, this experience can be attributed to result in a positive influence on implementation of UJALA scheme as well. Against each parameter including the uptake of the similar policies, the states are given a value of "0" or "1" and the penetration of these policies are calculated via the distance from frontier approach wherein the states are given points based on their value difference from the best performing states. The summation of these points result in the dataset for energy efficiency potential and experience for the states.

Another factor derived from Market design policy instruments is the level of information provided to the users on their respective electricity bill usage. Majority of Indian states currently provide their consumers with a bill, stating only the electricity usage information and its applicable tariff. However, additional information in the bill such as bill information of the peer group and real time feedback on the bill could lead to better market creation (World Bank, 2016) and aid in diffusion of energy-efficient schemes such as UJALA in the state. This dataset is derived by awarding points to the states based on their adoption of a billing method. Each parameter is given separate points hence, the more information the billing provides the consumers, the more points are garnered by the respective state.

In addition to market design, an effective monitoring and evaluation regulation is a necessary factor to understand the required efforts for a successful policy implementation. Moreover, involvement of independent third-parties and think-tanks on energy efficiency as auditors or panelists in policy implementation efforts and regular tracking of objectives would effectively help in achieving the required energy savings (World Bank, 2016). This factor corresponds to self-regulation practices (OECD, 2005) undertaken by states to achieve their energy saving objectives. The dataset for this factor benchmarks states based on their monitoring and evaluation regulations in the decision-making processes and their tracking. The states are awarded points based on their level of inclusion of independent third-parties in the policy process such as involving them as panelists, KPI tracking for energy-saving and regular audition of these tracking mechanisms by independent parties. The states that involve the most of these mechanisms score higher in this dataset.

The last instrument type is information policy instrument. They are used as an alternative to traditional regulation instruments and are targeted to modify the behavior through the provision of information or distribution of information to different firms or consumers (OECD, 2005). The instrument type undertaken for this research is based upon its applicability to UJALA scheme and the availability of data for the same. Table 7 summarizes the various instrumental policies considered for this research and its applicability.

Table 7. Information instruments for energy-efficiency policies and their applicability

Information Instruments utilized for energy efficiency	**Applicable for UJALA policy**	**Data availability**	**Data reference**
Consumer Awareness	**Yes. Some states have conducted campaigns towards educating the public on energy efficiency practices including on UJALA schemes.**	**Yes. A dataset consisting of a list of states that have conducted consumer campaigns for energy efficiency.**	State Energy Efficiency Index 2020 - (AEEE State EE Index, 2021)
Professional training and qualification	**No. EESL has assigned DISCOMs in states that have undertaken light bulb selling practices, and are equally trained by EESL professionals for the same and hence, no difference is observed among states.**		
Educational systems	**No. BEE conducts energy efficiency**		

	awareness campaigns in schools through drawing competitions, however, the state efforts are not properly notified for this instrument.		

The factor consumer awareness campaigns enables information provision to consumers and increases the policy outreach (State Energy Efficiency Index, 2020) that would lead to increased penetration of UJALA scheme in the states. This determines the importance of this factor for the UJALA policy in states and hence, will be considered in this research. The State Energy Efficiency Index for 2020 lists the states that have conducted energy efficiency campaigns (State Energy Efficiency Index, 2020). This data would be converted into binary data with points for states that have conducted awareness programs as "1" and otherwise "0". This score constitutes the dataset for this factor.

3.2.3 Policy Making

Howlett et al.(2009) and Sabatier (1988) define policy making as a process of identifying the political problem and finding the solution with various parties involved in advocacy. Further, a repeated cycle of problem solving attempts resulting in learning of policies by means of repeated analysis of the experiments and problems with solutions can lead to better policy learning (Rogge and Reichardt, 2016). The Bachat Yojna light (BYL) was a CFL distribution scheme introduced prior to the UJALA scheme and proved to be an ineffective one (Hector & J, 2012). The learnings from the BYL scheme and other relevant schemes gives the policy maker an added advantage for bettering the upcoming policies thus increasing the effectiveness in applying energy efficient solutions.

In terms of UJALA policy, the policy learning and implementation was carried out by EESL and with only distribution duties assigned to states. Therefore, no difference is observed in states from a policy-making perspective that makes this sub-building block inapplicable for our research.

3.2.4 Policy Implementation

Policy implementation is defined as the "arrangements by the authorities and other actors for putting the policy instrument into action" (Nilsson et al., 2012). The efficiency and the effectiveness of the policy instrument can be determined via policy implementation. For implementing any policy in a proper manner it is important to have a defined structure in place and as well as political will. According to May (2003) and Mazmaian and Sabatier (1981), the implementation process will be more effective if it has access to sufficient staff and funding. Table

8 summarizes the indicators for policy implementation process and its applicability for this research.

Table 8. Policy implementation process indicators and its applicability

Policy Implementation	**Applicable for UJALA policy**	**Data availability**	**Data reference**
No. of Staff at State Designated Agency	**Yes. The number of staff assigned for SDAs is different for different states and hence could make a difference in their outreach.**	**Yes. The data of staff assigned by BEE for SDAs for different states is available.**	Right to Information (RTI)
Institutional framework and capacity	**Yes. States have adopted different institutional types and frameworks to drive their energy-efficient policies.**	**Yes.**	State Energy Efficiency Readiness - (World Bank, 2016)

The Bureau of Energy Efficiency (BEE) which oversees the energy efficiency is responsible for assigning the staff to the State designated Agency (SDA). The dataset for this factor consists of the number of SDA staff assigned per state that is assumed to be a determinant of outreach of energy-efficiency policies for these states. The number of dedicated resources could have an indirect but significant impact in coordinating the implementation of policies in the state by training and managing DISCOM resources employed for the awareness creation purposes.

The World Bank (2016) study has identified 5 major functional areas wherein institutional support is required at the state level for energy efficiency implementation readiness. These areas include regulating supply and demand side, setting up a strategy and policy and regulating equipment for energy efficiency standards. Given that SDAs are the dedicated energy efficiency governance system in India, their steps are considered crucial for effective implementation of energy efficient policies in the state (World Bank, 2016). Hence, their setup of a dedicated agency and regulatory bodies for driving energy efficiency programs is considered as a factor for this research. The data for this factor awards points to states per their energy efficiency implementation step undertaken by the state for indicators of setting up a state energy efficiency strategy or policy and regulating demand and supply activities of the state. In regards to UJALA policy, the decision-making process for outreach and implementation of these policies would be a determinant for its successful penetration at state-level.

3.3 Characteristics

The next building block of the framework is the characteristics of the policy mix. These characteristics are listed as follows,

3.3.1 Consistency

Consistency concerns the alignment of elements of the policy mix in order to achieve the policy objectives (Rogge and Reichardt, 2016). This factor examines various policy designs that contribute to an outcome and determines the presence of synergies or contradiction between these policy mixes. The key features of the consistency mix include a temporal analysis of elements and the degree of consistency and its variation across dimensions of time or geography.

In terms of operationalization of this factor, researchers have utilized different methodologies. Rogge and Reichardt (2016b) have conceptualized the consistency factor for adoption and RD&D of offshore wind technology via policy mixes that relate to these factors. A positive or negative influence on these two concepts are determined and labeled as consistent/ inconsistent to the respective concept in conclusion. Furthermore, another research for environmental policy mixes conducted by Lieu et al. (2018) operationalized consistency to stakeholder interactions in the policy mix. The experience of stakeholder's interaction per policy instrument type is taken as a basis for determining the positive or negative interaction for the respective instrument and hence concludes with a consistency score based on these interactions (Lieu et al, 2018). Given these different approaches of determination of consistency, this research will try to employ the consistency of elements in terms of its relevance and data availability for the research policy.

The consistency factor is operationalized for this research as applicable for UJALA policy. In order to drive technological change, its policy instruments need to address two types of primary purposes of the policy: technology push and demand-pull (Sustec, n.d.). The instruments corresponding to these factors have a positive influence on driving technological change if they consist of a high extent of both demand-pull and technology-push policies. This concept could also be visualized in terms of stakeholder interaction of the policy i.e. the suppliers of the technology on the technology-push side and consumers on the demand-push side similar to the operationalization carried out in Lieu et al (2018). The policy framework considered in this research employs an additional dimension to the primary purposes of these instruments which the authors have conceptualized as a "systemic process" that aids in functioning of the other instrument types (Rogge & Reichardt, 2016). The instruments considered in this research are RD&D, Consumer awareness, power tariff and market maturity.

3.3.2 Coherence of Processes

Rogge and Reichardt (2016) define “coherence of processes as referring to synergistic and systematic policy making and implementation processes contributing towards policy objective achievement”. The conceptualization of this characteristic includes comparison on strategic objectives and the ease of communication of corresponding structures or stakeholders involved in the policy processes.

Referring to section 3.2.3 and 3.2.4 that comprise policy making and policy implementation in terms of UJALA policy, the policy implementation only includes three factors namely, number of SDA staff assigned, designated agency and institutional framework and capacity that enhance policy process implementation. However, lack of research in this field makes it difficult to conceptualize these variables in a comparative analysis dataset and understand the synergistic systemic processes and hence, would not be utilized for this research.

3.3.3 Credibility

Credibility is defined in the framework as the alignment of political leadership commitment that enhances the reliability of the policy mix introduced (Rogge and Reichardt, 2016). This could be determined as a mix of factors that range from consistency of policy mix, commitment of political parties or delegation of independent agencies (Rogge and Reichardt, 2016). The lack of research on commitment of political parties makes it difficult to conceptualize this variable. However, it could be assumed that the allotment of resources such as funding and staff dedicated towards energy-efficiency policies by the state institutions display their commitment towards the initiatives. Aligning with the definition of credibility, the SAPCC is regarded as the commitment the political leadership needs to deliver against as applicable for this research. Therefore, the intensity of funding and staff allotted towards achieving this initiative determines their credibility towards the energy-saving commitment in the SAPCC.

3.3.4 Comprehensiveness

Comprehensiveness captures the extensive and exhaustive decision making of the elements involved in the policy mix (Rogge and Reichardt, 2016). Comprehensiveness of policy mix is constituted of policy strategy with both policy objectives and principal plans in place and at least one instrument corresponding to achievement of policy objectives. An increased comprehensiveness comprises all three primary instrument types in the analysis.

Based on the above concept, comprehensiveness is measured in the research as the presence of policy instruments introduced by states. If a state records presence of all policy instrument types, it will be rewarded 3 as a score, if only two types of instrument are present for the state, it will be awarded 2 and only one instrument type is present, it will be awarded 1. A score of ¨0¨ will be assigned to states that have not yet implemented the SAPCC i.e. the policy objective targets for their states.

In terms of factor consideration from the framework employed in this research, the characteristics are considered for fsQCA analysis. The other building blocks such as elements and policy processes are neglected since they are constituents of the characteristics itself and may lead to double-counting. Also, in terms of the differentiation in shortlisted factors considered, although consistency and comprehensiveness are both focused on instrument mix, however, the former considers the extent of each of the instrument type whereas the latter considers the mere presence of the type of instrument.

Furthermore, Fiss (2007) refers to consideration of approximately 5 to 7 factors for fsQCA research. Thus, in addition to the above factors, the behavioural and macroeconomic conditions of states is also considered in this research that lead to increased adoption of energy efficient technologies.

3.4 Exogenous factors

For a "good outcome", dependency on factors outside the scope of factors of the policy mix is possible and these exogenous factors can have a significant impact on the expected outcome. To take this into account, the various exogenous factors are discussed in this section.

According to Wilson et al. (2015), factors that affect the uptake of domestic energy efficiency are a) Personal Factors - (socioeconomic and physiological characteristics); b) Economic factors like power tariff charged by the different Indian states; c) Policy factors and d) Contextual factors like environmental condition and property attributes. The policy factors and economic factors have been considered through the policy mix framework and hence, the other two types, namely personal factors and contextual factors are explored in this section.

Literacy rate can be pointed out as one of the exogenous factors with higher the literacy rate and level of education the more inclined towards accepting the energy-efficient appliance (Morton et al., 2018). This can be traced back to the literature from Mills and Schleich (2012) and Sütterlin et al. (2011) who found that a more educated person has a positive effect on accepting the energy-efficient appliance. Thus in our case study, we have considered literacy rate as one of the exogenous factors. The literacy rate for the different states in India is considered from the census (2011) report.

Age profile can also be considered as an exogenous factor and is classified into personal factors (Morton et al., 2018). According to Wilson et al. (2015), Black et al. (1985) has suggested that age profile has a general implication on the energy and environment and this will shape the behavior and norm setting around the uptake of energy efficient technology.

GDP for the different states can also be considered as another exogenous factor. According to Matisoff (2008) and Chandler (2009), GDP has to be considered in per capita numbers because it will help to differentiate between the large states and small states and the actual affluence of the states can be determined. This factor can be used as an indicator to measure the capacity of the state government. According to Matisoff (2008), more affluent states will have more public funds for investment and are more likely to adopt policies that are more environmentally friendly.

The population growth rate can also be considered as an exogenous factor which may affect the outcome i.e. LED bulbs distributed. According to Carley & Miller (2012), the higher population growth rate will result in higher energy demand and this will force the state authorities to be more open to adopt energy efficient policies in their respective states. However, not all households have access to electricity and the factor population growth might not be a direct indicator to affect the uptake of LED lighting (Singh and Sundria, 2017). Rather than the population growth, the measure of electrified households per state could be a better indicator of increased scale of adoption of energy-efficient measures in the state. Regarding state-wise data availability, the percentage electrification data per state published in the census report of 2011 is utilized in this research. This data is found relevant even though the UJALA scheme was launched in 2015 since the household adoption of appliances increases per time in India specifically related to rural areas (Richmond & Urpelainen, 2019). Given this observation, the electrified households in 2011 would adopt lighting appliances and related infrastructure for bulbs in due time that would enable them to adapt to LED technologies easier. A more recent electrification data might not be very indicative since this time factor will not be included. Furthermore, the census is the most important and extensive source of information collected on the characteristics of a human population (Goswami, 1989). In India, the census is conducted decennially and the latest census count was conducted in 2011 and next counting was due to be held in 2021, however this was postponed due to the COVID -19 pandemic to 2022 (Tripathi, 2021). Hence, this factor and dataset is considered to be of relevance for this research. Being a direct indicator of the outcome (LEDs distributed per capita) considered for our research, it is assumed that the percentage of electrified households in 2011 would indicate an increased number of LED bulbs intake in the states given its consideration of time value of adoption consideration and also, increase in adoption of tech-enabled appliances in the household.

In addition to three types of factors, behavioral factors influencing adoption in middle-income and low-income countries have been explored in literature. The LED lighting adoption in Malaysia and Bangkok has been identified in literature and explored in relation to the UJALA policy and data availability for Indian states.

Leelakulhanit (2014) has identified 13 factors that affect the adoption of LED lamps in households. These factors include:

- Advantages of LED technology usage: Perceived costs of usage of LED lamps, perceived value and benefits of LED lamps over CFL lamps, quality, energy savings, reliability and trustworthiness of LED lamp performance.
- Compatibility of LED lamps with lighting fixtures
- Marketing factors: Brand, product availability and promotion.
- Personal characteristics: environmental consciousness, social well-being and perceived effectiveness of environmental behavior.
- Demographic characteristics: Gender, age, education and household income.

Regarding the first two factor types, advantages of LED technology usage, these factors could be associated with technology use. Given that EESL was responsible for procurement and setting standards for LED bulbs nation-wide, a difference is not observed in state performance of this technology. Also, these bulbs were provided at a constant rate throughout India due to GST roll-out, hence, its upfront costs would not differ among state implementations.

The marketing factors were covered in the policy framework under consumer awareness and to avoid double-counting among factors, this factor is ignored in this section.

According to Leelakulhanit (2014), the personal characteristics of being pro-environmental leads to higher interest in uptake of LED lighting. This factor is explored in the context of India to identify related data sources that could determine the pro-environmental behavior amongst the population of different states. However, the closest data source was the Environmental Sustainability Index for states, but the characteristics included in the reporting consisted of policy initiation rather than the personal preferences of the population. Therefore, due to lack of data availability for this factor type, it is ignored in our research.

The demographic characteristics listed by Leelakulhanit (2014) have been covered mostly in this research previously and hence, it is decided not to be explored further in this research.

For the adoption of LED lighting in households in Malaysia, the technology adoption is hypothesized to be mediated by an attitude of pro-environmentalism (Khorasanizadeh et al., 2016). They have utilized the Unified theory of acceptance and use of technology (UTAUT) to understand the consumer behavior in adoption of new technologies. This factor is similar to the environmental consciousness factor discussed in this research previously and hence is decided to not be explored further.

Table 9. Exogenous factors consideration

Exogenous Factor	Impact on the outcome (Distribution of LED bulbs)	Data availability
Literacy Rate	**Higher literacy rate increases the uptake of energy efficient technology.**	**Yes**
GDP	**Higher the GDP higher the fund available with the state government to spend on environmental friendly policy.**	**Yes**
Population growth rate	**Higher population growth rate increases the energy demand which in turn will force the government to find to bank on more energy efficient technology. But this not be applicable in case of India given many households are still not electrified.**	**Yes**
Percentage of Electrified Homes per state	**State with higher percentage of electrified home would translate into more uptake of LED lighting**	**Yes**
Age profile	**Age profile also affects the uptake of energy efficiency technology.**	**Yes**

3.5 Conclusion

Chapter three is subdivided into two sections. The first section introduces the theoretical framework used in the study and the second section determines the factor based on the sub-building block of the framework. "Extended policy mix" framework of Rogge & Reichardt, (2016) was used in the study. The sub-building block of the framework elements, policy process and characteristics are briefly explained. The second section gives an insight into the various factors and components derived from the sub-building block of the framework. Table 10 provides the details of all the factors that were selected. These factors will be operationalized in Chapter four.

Table 10. Factors and component selected from framework

Factors	Components
Consistency	Technology- push- RD&D initiatives by state governments
	Demand- pull- Consumer awareness campaigns for energy-efficiency policies
	Demand- pull - Power Tariff for domestic consumers
	Systemic Process - Market maturity
Comprehensiveness	Policy Objective
	Principal Plan
	Technology-push (RD&D initiatives by state governments)
	Demand-pull (Consumer awareness campaigns for energy-efficiency policies)
	Systemic Process (Market maturity)
Credibility	Funding allocated to SDA
	Staff allocated to SDA
GDP per capita	
Literacy rate	
Percentage Electrified Homes	

Chapter 4 : Research Methodology

This chapter describes the research methodology followed in this master thesis research. This chapter comprises four major sections. The first section defines the methodologies used to study the governance model and business strategy of the energy efficiency lighting sector. The second section introduces Qualitative Comparative Analysis (QCA) with relevant definition, type, use and limitations. Section three illustrates the operationalization of the factors for fsQCA analysis followed by the validity and reliability of the research based on the methodology utilized in the next chapter. The last section concludes the chapter summarizing the various methodologies utilized in this research for causal factor analysis and their validation.

4.1 Governance model and business strategy of energy efficiency lighting sector

It is essential to study the governance model and business strategy of the energy efficiency lighting sector in order to identify the major stakeholders involved and the procurement process of LED bulbs. Desk research is the primary method used to collect information. The sources majorly are drawn from scientific articles and think-tank reports. The research is substantiated through an expert interview to gather the relevant insights.

4.2 Qualitative Comparative Analysis

According to Ragin (1987, 2014), “Qualitative Comparative Analysis (QCA) is an asymmetric data analysis technique that combines the logic and empirical intensity of qualitative approaches that are rich in contextual information , with quantitative methods that are more generalizable and deal with larger number of cases than case studies.” In order to meet the aforementioned conflicting goals, QCA utilizes the concept of Boolean algebra to configure set memberships that map each case per their causal attributes leading to causal complexity of an outcome (Parente and Fedro, 2019). Parente and Fedro (2019) define causal complexity of an outcome to be based on three main principles; (1) conjunction: interdependence of multiple conditions (Schneider and Wagemann, 2012) (2) equifinality: possibility of multiple pathways leading to same outcome (Gresov and Drazin, 1997), and (3) asymmetry: relation between attributes could be different or even inverse to produce the same outcome (Meyer, Tsui and Hinnings, 1993). These causal complexity principles are not captured by the correlation methodologies and hence, QCA that captures asymmetric theorizing was proposed by Charles Ragin in 1987. Due to the use of Boolean algebra principles, different possibilities of casualties could be tested to determine the decisive configurations suited for the outcome of the research (Ragin, 1987).

Building on the strengths of qualitative and quantitative research, cross-case pattern analysis adapted in QCA combines the diversity of cases based on qualitative analysis and heterogeneity for different causally relevant conditions using configurational analysis (Ragin, 2007).

Furthermore, QCA is recommended for research involving intermediate cases approximately 5-50 cases, since for case studies, this seems to be a higher number due to the substantial knowledge required for this study and too few cases for conventional statistical techniques (Ragin, 2007). However, differentiating between the correlation studies and QCA, QCA results in set relations providing necessary and sufficient conditions for a causal mechanism as opposed to conventional quantitative methods. In addition, it also provides INUS conditions that are "insufficient but necessary parts of causal recipes which are themselves unnecessary but sufficient" (Ragin, 2007). A "necessary condition" is defined as a condition that is present in all causal recipes of an outcome whereas other conditions that may lead to a similar outcome are deemed as "sufficient conditions (Roig-Tierno et al., 2017).

Based on the aforementioned arguments, this research will utilize the QCA methodology to perform a comparative assessment of the penetration of successful energy efficiency policies in India. The causal recipes derived from the analysis would be utilized to determine the causal complexity of policy mixes and exogenous factors indicating the best practices for the success of UJALA policy in the 28 Indian states.

4.2.1 Types of QCA

There are three variants of QCA employed in literature - crisp set QCA (csQCA), multi-value QCA (mvQCA) and fuzzy set QCA(fsQCA). Crisp-set QCA is the first and basic variant of QCA that employs Boolean logic (0,1) to simplify the complex configurations and determine multiple causal configurations for the outcome in consideration (Roig-Tierno et al., 2017). The methodology of csQCA is based on determining the dichotomous conditions such that full membership of a condition corresponds to 1 and full non-membership translates to 0. Thus, each configuration is translated into Boolean values mostly as an indication of presence or absence of the factor or via a more objective analysis of assigning a value of 1 over a certain point. Even though csQCA is widely utilized in various studies, its limitation to apply values to gradual conditions that mostly occur in social reality for instance quality, satisfaction, etc. has led to development of advanced analysis methods such as mvQCA and fsQCA (Rihoux & De Meur 2009; Ragin, 2008).

FsQCA overcomes the limitations of the csQCA method by incorporating set calibration techniques in the process. FsQCA assigns membership values to conditions on a scale of 0.0 (non-membership) to 1.0 (full membership), with 0.5 being the crossover point (Ragin, 2008). In contrast with dichotomous values, the values from 0.0 to 0.5 are treated as "not fully-out" conditions and values from 0.5 to 1.0 are treated as "not fully-in" conditions. Also, the whole value of 0 corresponds to a fully-out condition, 0.5 is the point of maximum ambiguity and 1.0 is treated as a fully-in condition. Hence, fsQCA allows the representation of qualitative values to quantitative values while maintaining original distinctions (Roig-Tierno et al., 2017) and hence, is utilized in researches that require more coverage of values. Furthermore, fsQCA accepts the condition with low levels of membership and includes them in determining the causal configurations as opposed to csQCA that relates it to absence of the condition altogether (Roig-Tierno et al., 2017). This characteristic of fsQCA allows the configurations to be based on irrelevant conditions as well that can result in inclusion of false positives in the solutions. Moreover, another limitation of fsQCA is the non-detection of contradictions that point to the relevance of factors included in the research, and hence indicate towards revision of the model for the researcher.

A few researchers such as Schwellnus (2013) have developed methods such as consistency and coverage to address these limitations of fsQCA. According to Fiss (2011), a value of 0.8 is considered to be a good fit for consistency mark. However, this consistency threshold value is argued by Rubinson (2013) since a condition with 0.75 mark would be neglected in this case even though it could add to the sufficient conditions list. This serves as a limitation for fsQCA technique.

MvQCA tries to overcome the limitations of csQCA by allowing multiple-category conditions, thus forming subtle clusters (Vink and Vliet, 2009). It lies midway between csQCA and fsQCA since it allows different degrees of membership rather than dichotomous as in csQCA but the outcome is always dichotomous as opposed to in fsQCA methodology. MvQCA allows for three or more values in the set such as {0, 1, and 2} and may or may not follow an ordinal sense, wherein 0 means false, 1 means low and 2 means out. These could even be representative of the different categorical values such as race/ethnicity wherein each number is assigned to a different ethnicity type (Vink and Vliet, 2009). Cronquist (2004) argues the usefulness of mvQCA technique with the use of a "dummy condition" that results in lower empty rows as compared to csQCA and hence, better results in terms of configurational analysis which he refers to as "limited diversity" issue of csQCA. However, the limitation of mvQCA is the threshold setting of variables that many researchers deem as inductive and could lead to a certain degree of causal complexity (Vink and Vliet, 2009).

Due to the consideration of factors that involve continuous values, this research will follow the fsQCA technique as each value would be considered for the determination of causal configuration.

4.2.2 QCA use in policy analysis

According to Ragin (2008), QCA's home base is considered to be comparative sociology/comparative politics wherein cross-national or sub-national qualitative case studies are required alongside extensive correlation studies of quantitative nature. Based on this proposition, many policy studies have employed QCA analysis methodology to gather in-depth insight into different cases while attempting to produce a level of generalization (Ragin, 1987; Ragin, 2014).

The use of QCA is argued by De Meur et al.(2004) as a value–addition to policy studies in six ways. Firstly, these studies consist of cases that fit in the small intermediate (N) number and allow for a systematic policy programme comparison in these cases and hence, QCA study is also considered the right approach for them. Secondly, QCA allows for alternative causal models that involve multiple sector-specific features including administrative and cultural that leads to differentiated policy schemes across cases, thus bringing this analysis more close to reality. Thirdly, quasi-experimental design is incorporated as the policy researchers could determine which combination of conditions would affect effectiveness of policy. Fourth, an easy modification of study by incorporating or deleting relevant variables in the research is possible with QCA. Fifth, existing theories of qualitative analysis could be synthesized using relevant quantitative analysis to check their relevance with either research. Lastly, the policy analysis would utilize the combination of conditions in line with the policy instrument mix concept to determine the favorable/ unfavorable causal condition for a particular case.

Furthermore, Rihaux, Rzsohazy and Bol (2011) has performed a systematic review of policy studies that have utilized QCA to conduct a cross-national, cross-states or cross-regional comparison. These studies are classified into four major types based on their purpose for the policy process stage: (1) agenda-setting and policy initiation (2) policy making and policy design (choice of policy instruments) (3) policy implementation and outputs (4) policy evaluation (Rihaux et al., 2011).

Given the objective of this research focused on determination of policy mix employed by different states for UJALA policy implementation, the policy design category is further explored to understand the current research patterns and relevant factors for QCA. At regional and subnational levels, studies such as Hyttinen, Niskanen & Ottitsch (2000) and Ottitsch & Weiss (1998) employ a combination of quantitative studies and a more focused csQCA analysis to test the results of these analysis in field of socioeconomic policies in the EU. More studies focused on USA (Greenberg,Mount & Brandon ,2000; Kitchener, Beynon and Harrington, 2002) and Swiss nations (Christmann, 2010) analyze various policy processes and policy inclusions such as public debates and consumers' representation in the process employ csQCA and fsQCA respectively for the relevant conclusions (Rihaux et al., 2011). These studies are mainly employed for performing checks on relevance of policy frameworks or construction of the framework itself for examining policy design for various sectors. The inclusion of factors in these studies range from policy processes to policy instruments and even presence of exogenous factors in their outcome.

This research would employ factors based on an existing framework as determined in literature study and derive the factors relevant for the policy design that led to better penetration of UJALA policies in Indian states.

4.2.3 Limitations of QCA

The use of QCA methodology in research has substantially increased in the 1990s (Rihaux et al.), however, some researchers have criticized its assumptions and relevance in comparison to conventional quantitative and qualitative research methods. Seawright (2005) has argued the usefulness of QCA research in comparison to quantitative research by pointing to three assumptions that QCA has failed to address: the absence of an established testing tool for non-linear functional form, the treatment of missing variables and the inherent implied causation. Furthermore, in terms of its use in policy research, Tanner (2014) argues that policy research conducted in bounded sets and then aligning these measurements in various membership outcomes is ill-equipped to uncover meaningful variation in outcomes. Moreover, these methods do not seek for marginal changes in human behavior and well-being that policy research analysts seek (Tanner, 2014). A criticism in the QCA conduction has been the data calibration issue in QCA-based studies. The calibration practices employed in several studies have been more towards the mathematical side such as rank orders, percentiles, etc, rather than the theoretical and substantive determination for the data that are listed as best practices by QCA scholars . Also, scholars such as Misangyi,Greckhamer, Furnari, Fiss, Crilly and Aguilera (2017) and Ragin and Rihoux (2004) have strongly argued the use of QCA as a complementary approach to other research methods.

4.3 Steps to conduct fsQCA

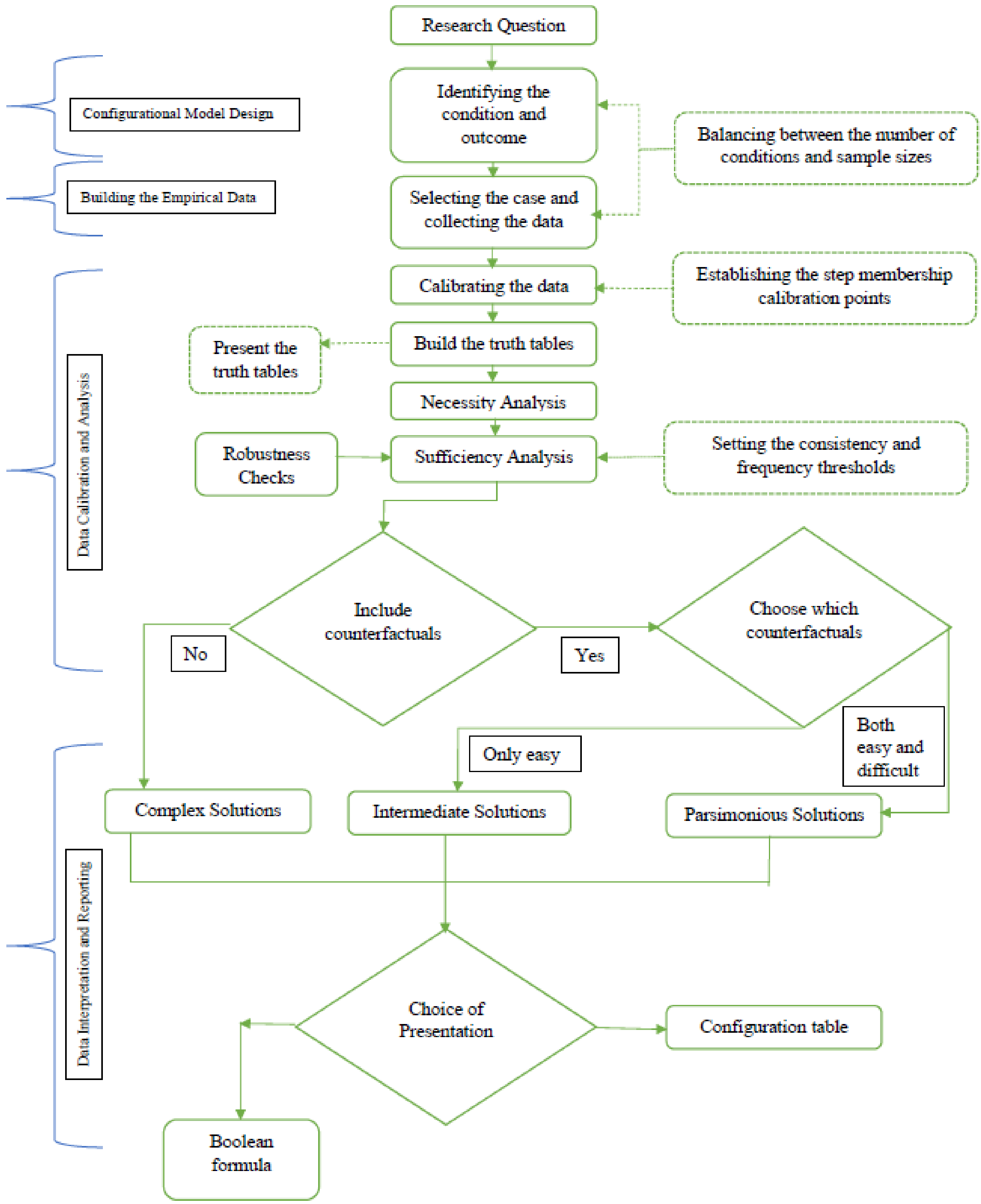

Figure 5: Steps to conduct QCA. Derived from Parente and Federo (2019)

Parente and Federo (2019) classify the process of conducting QCA into 4 steps:

(1) **Configurational model Design**: The first 2 blocks in Figure 5 comprise of designing a configurational model. This involves the identification of conditions that determine the theory of interest. Also, these conditions need to have a balanced number and hence, Ragin (2008) prescribes combinations of conditions whenever possible. The number of logically possible configurations is exponentially related to the number of conditions taken in account by the researcher.

(2) Building the empirical data: This step refers to selecting the cases and the data collection for the determinant factors for the outcome. The goal of this step is to choose the factors that tend to answer the research question. Also, case selection needs to either be representative of the research design or account for the entire population. In this research, given the sample size is small, all the 29 Indian states are considered as cases and the factors are defined from the policy mix framework adopted for this research and exogenous factors that contribute to diffusion of energy efficiency practices in population summarized in previous research.

(3) Data calibration and analysis: The next steps involve calibrating the data into set memberships. For fsQCA, a cross-over point needs to be defined that divides the data into finely-grained degrees of membership. The calibration needs to be identified through theoritially or substantially established thresholds,to ensure validity and replicability of the calibration process (Misangayi et al., 2017). However, in absence of an existing theoretical knowledge, thresholds based on sample properties through its frequency distribution could also be utilized in this case (Greckhamer. 2016).

After calibration, the data needs to be analyzed using the fsQCA software and the truth tables generated need to be analyzed by the researcher. The number of configurations generated would be 2^K where k denotes the number of conditions/factors used in the analysis. The selection of relevant configurations is based on the logic of necessity and sufficiency that rests on consistently producing the outcome. The software also provides consistency and coverage scores per configuration that translates to the consistency of the outcome and the latter refers to the empirical relevance of the configuration (Ragin, 2008). For necessary conditions, a consistency score of at least 0.90 in addition of its presence across all causal configurations is required whereas a consistency score of at least 0.80 and a proportional reduction of inconsistency score of at least 0.65 is recommended for a condition to be considered sufficient (Greckhamer, 2016). A necessity analysis of individual conditions needs to be conducted before the sufficiency analysis. Also, a frequency threshold on the minimum number of cases for a configuration row needs to be set during the analysis. This number is recommended to be 1 as per Roig-Tierno et al.(2017) for N <150.

In order to overcome its limitations on its methodological decisions, a robustness check is recommended to be performed to ensure the validity of the findings. Some recommended ways include the adding, dropping or changing the conditions in the model, modifying the calibration thresholds and exploring multiple consistency thresholds (Fiss, 2011; Ragin and Fiss , 2017). By following the set-theoretic logic, the modifications to the conditions should not lead to substantially different findings.

(4) Data interpretation and reporting: The solution from the truth table is given in three forms: complex, intermediate and parsimonious solutions. The complex solution comprises configurations that at least have a case associated with it. In some instances, some configurations do not correspond to the case outcome and are hence, deemed as logical remainders. These logical remainders are called counterfactuals (Ragin, 2008). The intermediate solution includes the counterfactuals in the solution that seem theoretically and empirically applicable whereas the parsimonious solutions consider solutions that involve only empirically suitable counterfactuals (Ragin, 2008). Researchers recommend use of intermediate solutions as results in this case (Ragin, 2008). Also, an absence of outcome should also be analyzed to ensure that inverse conditions result in absence of outcome.

In terms of reporting of solutions, the researchers have utilized 2 types, namely Boolean formula and Configuration table. The Boolean formula utilizes representation of solutions using Boolean expressions of "NOT", "AND" and "OR" symbols. The configurational table maps the conditions and solutions in a matrix form with denotation of a filled circle as presence of condition, an empty circle as absence and circle with a cross as a don't care condition (Parente and Federo, 2019). In this research, we would employ the configurational table method to report the results in the upcoming chapters.

4.4 Operationalization of factors for fsQCA research

In this section, the outcome and causal factors to be inputted for fsQCA analysis is operationalized in terms of data availability for these factors and their calibration points are addressed further.

4.4.1 Outcome (Dependent variable)

The outcome for the fsQCA analysis is required to indicate the penetration of UJALA policy in the states. The most applicable data for this scheme is depicted as the number of bulbs distributed per state under this scheme. The data source is the official UJALA dashboard that tracks and updates the progress for this scheme (Ministry of Power, 2020). The number of LEDs distributed is converted into LEDs distributed per capita in the state to determine a level-playing field for the smaller and bigger states. The resultant dataset is a continuous one and is calibrated at the mean value of the dataset due to the lack of a theoretical measure in this case. This dataset is plotted and a "Left- skewed" distribution is obtained for its values as depicted in Figure 6. Therefore, as suggested by Pappas & Woodside (2021), the full-membership and no-membership values are set at 80th and 20th percentile respectively. The outcome is referred to as OUT henceforth in this report.

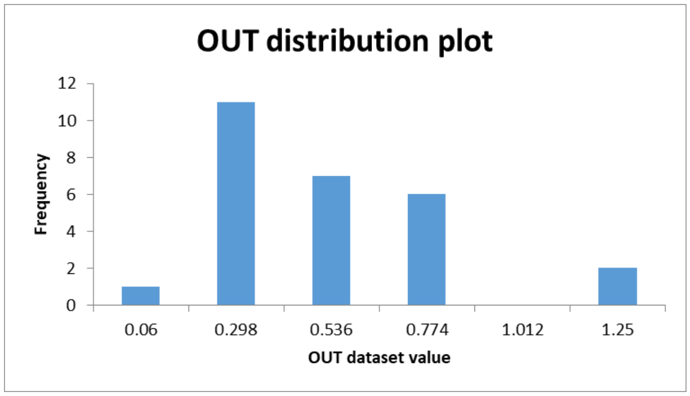

Figure 6: Outcome distribution

4.4.2 Causal factors (Independent Variable) for fsQCA analysis

Consistency

Deriving from the theoretical concepts mentioned in section 3.3.1, consistency for this research is determined as an extent of each primary purpose type instrument for the state that would be assigned strong, neutral and weak interaction based on the strength of their interaction for driving the outcome. These values will then be utilized to derive a consistency data as depicted in table 12 that determines the interaction of policy mixes for the particular state as a combined effect on the outcome.

For each primary purpose type instrument, the values of factors as depicted in section 3.3.1 are considered and are assigned in 2 ways: "HIGH" or "LOW" based on where the value lies with respect to its Indian average value. The Indian average value is the determined average of the factor for all States and Union Territories. Another data type considers the presence and absence of the factor which is translated to a score of "1- YES" and "0 - NO" respectively. The interaction of each factor is determined based on its positive and negative influence on the outcome and accordingly positive or negative weights are assigned wherein the value corresponds to the factor importance. The major primary instrument types, technology-push and demand pull are provided weights of 0.45 each, hence all technology-push instrument types aggregate to the value of 0.45 and similarly for the demand-pull factors as well. The systemic process factor is assigned the score of 0.10 since it helps in driving the change by assessing suppliers and market current maturity, however, may not be as significant as the other instrument types. The consistency score for a state is the aggregation of these weights and this dataset would further be analyzed via fsQCA methodology.

Technology-push primary instrument type

For this instrument type, state governments' efforts towards RD&D are considered. The governments had established ties and signed MoUs with different educational institutes and NGOs to create awareness of the energy efficiency measures. Additionally, the promotion of RD&D research in these institutes would result in advanced energy-efficient technologies in the lighting sector and could enable businesses to offer cheaper rates for the equipment leading to further growth of this scheme. Therefore, RD&D contribution towards energy efficiency is hypothesized to have a positive influence on driving the penetration of LEDs at the state- level.

The dataset of the RD&D factor is obtained in terms of presence and absence of RD&D efforts via states specifically for energy-efficient measures. This dataset is derived from the State Energy Efficiency Index 2020 (AEEE State EE Index, 2021). This is translated into the score of "1- YES" and "0 - NO" for presence and absence of the factor respectively. Given RD&D is the sole factor considered for this instrument type, the weightage assigned for the factor is +0.45 as an increased importance in the whole consistency.

Demand -pull instrument type

The demand-pull instruments are targeted at consumers to increase the demand for the policy initiatives through reduction in prices or increased awareness (Sustec, n.d.). In this regard, the consumer awareness campaigns by the state governments for promoting energy-efficiency policies are considered as a demand-pull instrument. This dataset is derived from the State Energy Efficiency Index 2020 (AEEE State EE Index, 2021) and is presented in the form of "1- YES" and "0 - NO" indicating the organizing and not organizing of energy-efficiency awareness campaigns respectively by the state governments. The consumer awareness campaigns are hypothesized to have a positive influence on the adoption of LED lighting in India. This factor is allotted 0.225 weightage for its contribution to consistency factor.

In addition, power tariff charged for domestic consumers as set by DISCOM is also considered as a demand-pull factor in this research. The power tariff is an economic factor and directly influences the decision of consumers to opt for energy-efficient appliances (Wilson et al., 2015). A high power tariff leads consumers to seek energy- efficient fittings/ appliances for their homes, thus creating awareness leading to better penetration of these appliances amongst the masses (Wilson et al., 2015). The dataset for power tariff factor is a continuous dataset derived from (PHD RESEARCH BUREAU, 2013) and is characterized as "HIGH" or "LOW" as compared to the Indian average value. This factor is considered consistent with the outcome if the value is "HIGH", therefore, the "HIGH" values are allotted a weightage of 0.225 in the consistency factor and "LOW" values are considered at 0.

Systemic process instrument type

The systemic process instrument type aids in establishing market and process requirements that facilitate the technology change (Rogge & Reichardt, 2016). In this research, electricity market maturity is considered one of the systemic process instruments. The market maturity factor dataset in terms of Indian states' data consists of energy efficiency potential of the DISCOMs, the UJALA scheme implementing bodies in the states, and information on tools provided to the consumers and was part of World Bank (2016) data that present a comparison of Indian states' energy efficiency efforts. The data extract in this report takes into account the scenario of Indian states until December 2015 (World Bank, 2016). Given the inception of UJALA policy in the year 2015, a starting point of each states' efforts is considered relevant in this research to map the states regarding their potential and offerings at policy start aiding in market maturity. Regarding the former factor, the penetration of the previous energy efficiency schemes is considered as a dataset and is assumed to enhance the experience of implementation of policy at the local level and market understanding of the state. Given the importance of energy consumption bills for households due to its economic impact, the level of information regarding an ideal level of consumption for the peer group and real-time consumption is considered as a market creation factor in this research. The level of information on the electricity bill would create awareness and motivation to the consumers to reduce their electricity consumption paving easier penetration of energy-efficient lighting, The dataset for this factor is the level of information provided by states on the electricity bills to its domestic consumers allotting ranking from 1 to 4, 4 being the highest. The combination of these factors leads to a continuous dataset for the states which is translated into "HIGH" and "LOW" based on their value as compared to the Indian average value. The market maturity is considered to have a positive influence on the outcome due to the positive effect of its constituents ultimately leading to higher awareness creation and better implementation in terms of the policy implementation. However, since this factor is not directly impacting the scheme implementation but aids in the process, it is allotted a weightage of +0.10 in the entire consistency factor.

Overall consistency calculation

The measure of consistency depends on the alignment of the policies with each other (Rogge and Reichadt, 2016). Reichardt & Rogge (2016) has operationalized this factor with respect to policy effects on adopting the R&D aspect for renewable technologies. Similarly, in this research, the outcome factor is considered as the base factor to which other factors are measured to be consistent. The influence of other factors is allotted a weight based on their relative impact on the outcome which when aggregated results in the consistency measure for the state. The detailed consistency dataset derivation is presented in the appendix E. The resultant dataset is a continuous one and the threshold is set at the average value of the dataset. Table 11 summarizes the consistency score distribution in terms of its influential factors and their respective allotted weights. Henceforth, the consistency factor will be addressed as CON in this report.

Table 11. Consistency score distribution

Factor type	**Factor name**	**Influence on outcome**	**Weightage**
Technology-push	RD&D initiatives by state governments	positive	+0.45
Demand-pull	Consumer awareness campaigns for energy-efficiency policies	positive	+0.225
Demand-pull	Power Tariff for domestic consumers	positive	+0.225
Systemic Process	Market maturity	positive	+0.10
Total			**1**

Total consistency measure for Indian states follows a plotting of a "Normal" curve as depicted in figure 7 and is calibrated at a full membership of 95th percentile, threshold at average value of 0.43 and no membership at 5th percentile of the dataset as suggested in Pappas and Woodside (2021). This factor will then be utilized in the fsQCA analysis to determine the effect of a consistent policy mix in combination of other relevant factors on the outcome.

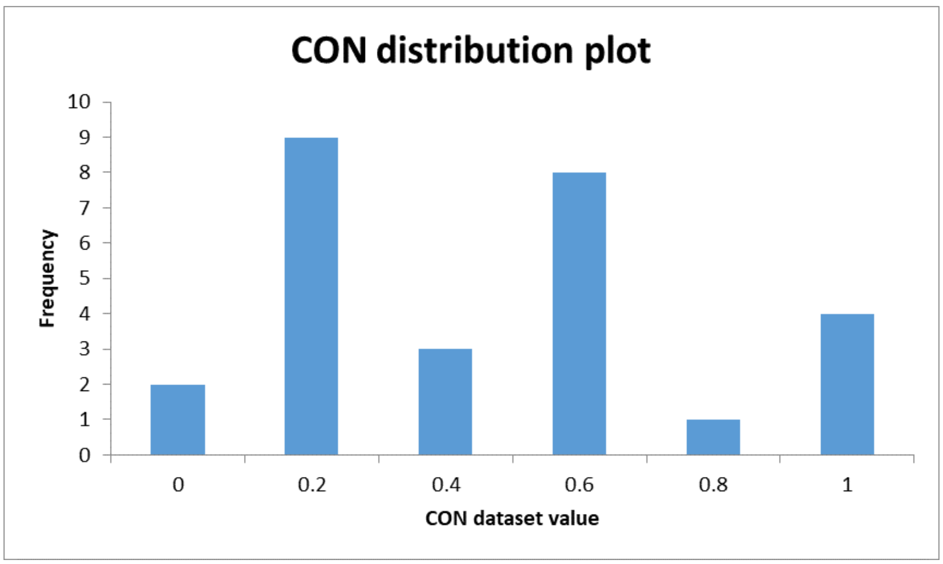

Figure 7: CON distribution

Comprehensiveness

The dataset for comprehensiveness is derived on the basis of presence of constituents of the policy mix that results in a rigorous policy mix. As described by Rogge & Reichardt (2016), the comprehensiveness of elements of a policy mix consists of policy strategy and at least one type of instrument mix operationalizing this strategy. Furthermore, a comprehensive policy instrument mix may address all types of policy instruments. In this research, a utilization of both these policy mix types is addressed and a dataset is derived per state. Building upon these descriptions, the comprehensiveness score for a state is derived as the presence of the policy strategy elements and each instrument type. This dataset was described in the report published by the World Bank (2016). Considerably, this dataset takes into account the state scenarios till December 2015 and is of relevance in this research due to the inception of UJALA scheme in the same year. The setting up of SAPCC and principal plans in this data are derived from the World Bank (2016) dataset and the other factors follow the similar source as mentioned in consistency factor operationalization.

For policy strategy, the policy objective i.e. the setting up of SAPCC is considered in this case and is marked as "PRESENT" or "ABSENT". A similar operation is performed on the principal plan element of the policy strategy as well marking "PRESENT" or "ABSENT" if a regulation or policy is in place for the particular state. In terms of instrument type presence, RD&D efforts are the base for technology-push type, organizing consumer awareness by the state is the basis for presence of a demand-pull instrument and for the energy- efficiency potential and information on tools is the basis of systemic process instrument type. Each of these characteristics is marked as "PRESENT" or "ABSENT" for that particular state. Each "PRESENT" marking is allotted a score of "1" and each "ABSENT" is allotted a score of "0". Therefore, the dataset is a combination of whole numbers ranging from 0 to 5, 5 being the highest wherein all the elements are present for the state and 0 being the lowest if a state lacks any of the policy strategy elements or policy mix instrument type.

The calibration threshold for the dataset is considered the mean value of the dataset which corresponds to the value of "2.66" in this case. The distribution of the comprehensiveness score is plotted and a "NORMAL" distribution is achieved in this case as depicted in Figure 8. Therefore, the full-membership and no-membership values are defined at 95^{th} percentile and 5^{th} percentile of the dataset for fsQCA analysis (Pappas & Woodside, 2021). This factor is referred to as COM henceforth in this report.

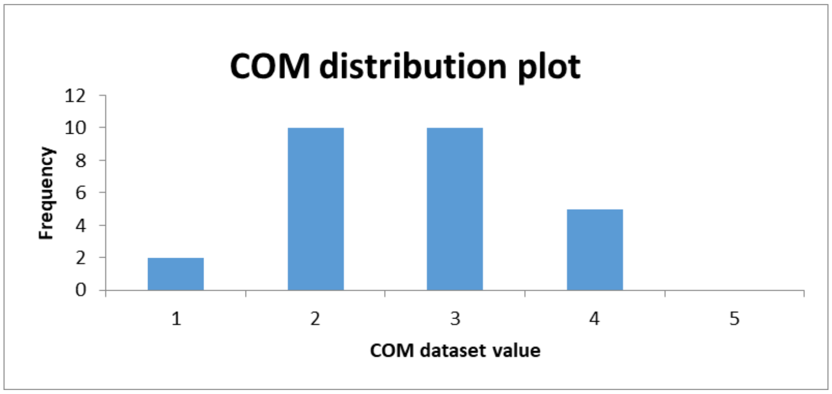

Figure 8: COM distribution

Credibility

The dataset considered for this analysis is the funding and staff allocated to SDA by BEE. The dataset for funding includes the value from six fiscal years ranging from 2012 to 2018. The average of the funding value is derived and the dataset is categorized into "HIGH" and "LOW" based on its position from the average value. A similar operation is performed on the allotted staff by SDA towards energy efficiency as indicated in the year 2018. The source of these datasets is the Right to Information (RTI, 2018) data obtained from official government sources. Each of the values with "HIGH" indication is awarded a score of 0.5 and a "LOW" value is allotted a score of 0. Therefore, the highest point a state could achieve is 1 if both their funding and staff are at higher levels than their respective average value and the lowest score is 0. The detailed credibility dataset derivation is presented in the appendix E. The calibration threshold considered for this dataset is 0.5 based on the theory that the state must qualify for at least one of the credible factors. The final credibility score for states is plotted in a histogram and the resultant is a Normal graph presented in figure 9. Therefore, the calibration points will be (0.95, 0.5, 0.05) as applicable for a normal distribution (Pappas & Woodside, 2021). Credibility is referred to as CRE henceforth in this report.

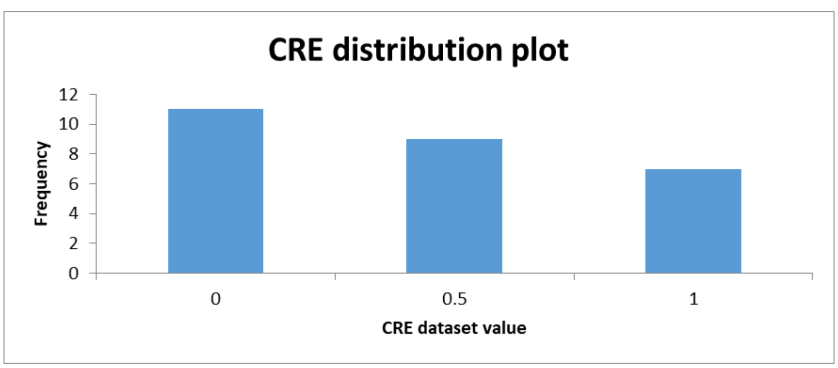

Figure 9: CRE distribution

GDP per capita

As indicated in section 3.4, GDP per capita for the states is considered as one of the exogenous factors impacting the outcome. The GDP in billions USD in 2020 is divided by the population size of the state and the GDP per capita value is determined for states applicable for this research. The source of the GDP values for states is the official Reserve Bank of India data published for Indian states GDP value for the year 2020 (Reserve Bank of India, 2020). However, the population data source is the data published in Census (2011), given this is the official data available for the population. The calibration threshold value is set at 1927.71, which is the GDP per capita for India in 2020 as per the World Bank data (*GDP per Capita (Current US$) - India | Data*, 2020). This value averages out the entire dataset per the population of India and hence the values above this threshold is considered higher for the dataset. The GDP per capita dataset is plotted to determine its calibration extreme data points and the resultant is a "Left- skewed" distribution as depicted in Figure 10. Therefore, this dataset will be calibrated at 80th and 20th percentile extremes regarding full-membership and no-membership values respectively. GDP per capita will be regarded as GDPCC henceforth in this report.

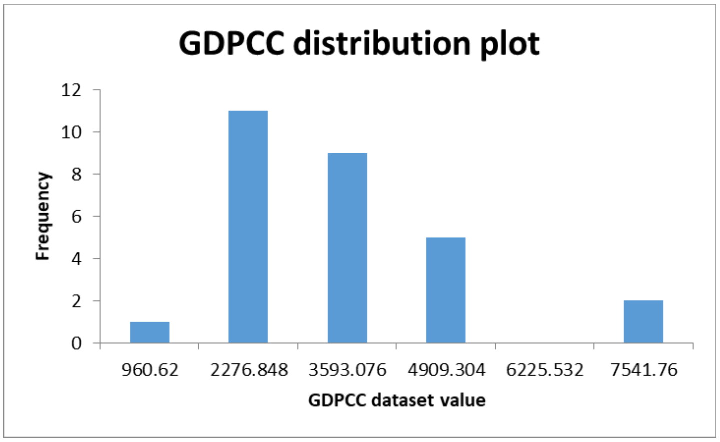

Figure 10: GDP per capita distribution

Literacy rate

The data availability for literacy rate for Indian states is in terms of percentage of the literate population. The source of the dataset is Census (2011) and is assumed to have grown proportionally and hence this dataset is utilized for this research. The plot of the literacy rate distribution is a "Normal" one and is calibrated at 95th percentile and 5th percentile for the full membership and no-membership values as showcased in Figure 11. The calibration threshold is considered at 74.04 which is the literacy rate of the entire Indian population (Census, 2011) as it averages out the entire population and any value above this threshold depicted by a state is considered at a higher level. This factor is addressed as LR in this report henceforth.

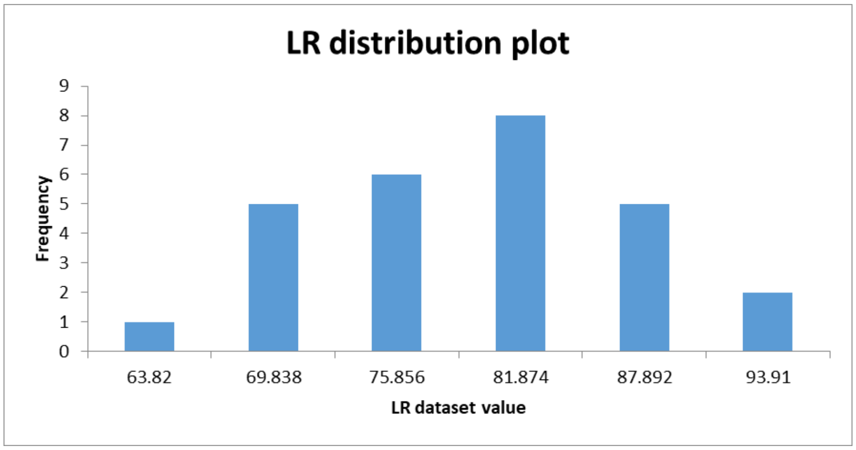

Figure 11: Literacy rate distribution

Percentage of Electrified Homes

Similar to the literacy rate dataset, the data available for electrified homes is in terms of percentage of total homes in the state. This data was published in Census (2011) report and is considered as applicable for this research as depicted in section 3.4. The dataset is plotted for electrified homes percentage per state and a "right- skewed" distribution is obtained as depicted in Figure 12. Therefore, the full-membership and no-membership values are set at 80th and 20th percentile of the dataset respectively as suggested in Pappas & Woodside (2021). The calibration threshold is set as the Indian average value that lies at 67.2 percent in the year 2011 as per Census (2011). This factor is addressed as EH for the upcoming parts of this report.

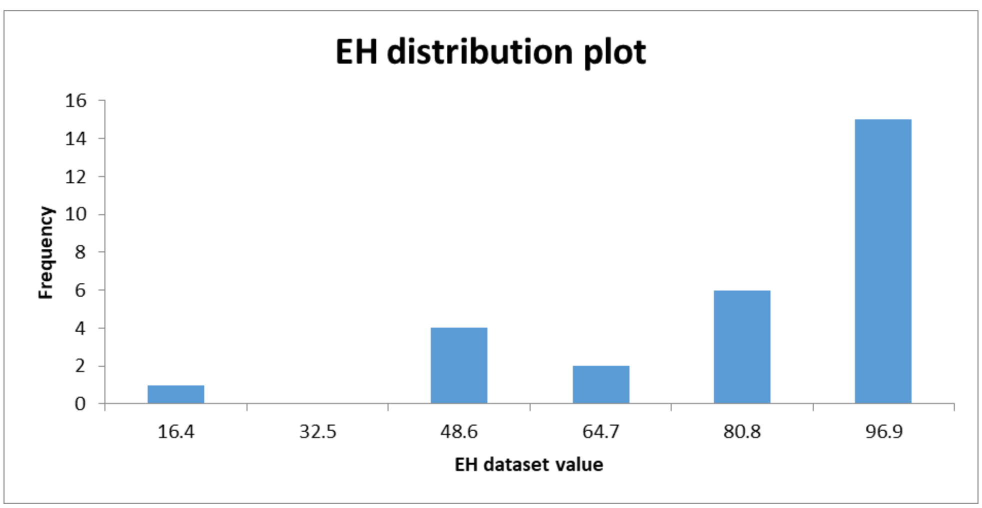

Figure 12: EH distribution

4.5 Validity and Reliability

Validity of a research represents its rigor and quality of the research (Heale & Twycross, 2015). The validity of a research is characterized in two types: external validity and internal validity. The external validity is defined as the extent of the generalization of the research to similar studies (Slack & Draugalis, 2001). The fsQCA research has a relatively higher external validity given the inclusion of all cases for a particular outcome, which is a critique for the case- oriented quantitative studies (Ott, U., Sinkovics, R. R., & Hoque, S. F., 2018). Therefore, this method is preferred over the case studies. The internal validity of a research is measured via its cause and effect relationship representation for the outcome (Slack & Draugalis, 2001). Given that this research does not include the statistical analysis in this area, however the inclusion of most of the cases in the solution generated via fsQCA analysis determines the cause-effect relationship of the combination as a whole. This is also verified through the robustness check performed on the various threshold measures considered in this research to understand the variation and determine suitable values to obtain substantiated results. Additionally, an expert interview is conducted as a part of this research to determine the cause- effect relationship of the causal factors considered in the fsQCA analysis.

4.5.1 Interview

Interviews are the primary source of data collection and are mostly used for qualitative studies (Sekaran & Bougie, 2016). The interviews are broadly classified into three types namely unstructured interview, semi-structured interviews and structured interviews. In the research the method of semi-structured interviews is applied. The semi-structured interviews are defined as a series of questions which are predetermined in nature but are simultaneously open-ended ('Semi-Structured Interview', 2008). In a way making it a combination of unstructured interviews and structured interviews. The selection of the interviewee was based on the criteria of their knowledge in the field of energy efficiency lighting in India with particular emphasis on the UJALA policy scheme. Only one expert interview was conducted in the research to get more insight into the UJALA scheme including the question relating to the manufacturing of the LED bulbs, the exogenous factors considered, characteristics and the pathways that will help states achieve higher penetration of LED bulbs.

4.6 Conclusion

The chapter four presents a description of the research methods and their operationalization utilized in this research. Firstly, the UJALA policy implementation is studied in detail with regards to its stakeholders and their roles in the policy implementation in India. This study is realized through desk research and a validation with an expert in the policy research field based in India. Furthermore, the relative penetration at sub- national levels is studied through fsQCA methodology due to the number of cases involved and the relatively higher external validity posed by this method than case studies. Next, the causal factors utilized for the fsQCA research are operationalized as per UJALA policy based on the policy- mix framework and exogenous factors discussed in chapter three. This is done by realizing each policy- mix framework factor based on the energy- efficiency efforts of the Indian states. The causal factors determined for this research are policy- mix characteristics of consistency, credibility, comprehensiveness and exogenous factors of GDP per capita, literacy rate and percentage of electrified homes in the states. The rest policy mix factors are ignored to avoid their double- counting in the characteristics. Lastly, the validity and reliability of the fsQCA methodology is discussed and in order to provide validation on the causal factor determination and results, an expert interview is conducted as part of this research. The following chapters five and six present the results of this research performed via the methodologies discussed in this chapter.

Chapter 5: Governance and Business strategy of energy-efficiency lighting sector in India

In this chapter, an exploratory case study is presented into UJALA policy implementation at sub-national level. First, section 5.1 presents an overview of the energy-efficiency policy governance in India with regards to the actors involved and their respective roles & responsibilities. The sub-sections 5.1.1 and 5.1.2 provide a detailed analysis into actors involved in the UJALA policy constituting of supply or manufacturing, procurement and demand-side marketing and distribution respectively. Section 5.2 provides the manufacturers' or supply perspective of this policy and the impact on businesses due to the technology change. The next section 5.3 describes the roles and responsibilities of the relevant actors involved in procurement of the LED lighting bulbs and its procedure and impact on businesses and demand side. The next section 5.4 provides a description of policy implementation for the state of Maharashtra detailing the marketing and distribution to consumers and the other actors and factors influencing these activities. The last section summarizes the research and provides a conclusion for this chapter in terms of involvement of stakeholders in UJALA policy.

5.1 Energy-efficiency policy governance in India

Energy-efficiency is considered a critical step towards tackling climate change. According to the International Energy Agency (IEA) (2010), an effective energy-efficiency governance is a combination of technology development, market forces and government policies that promote adoption of energy-efficiency measures in a jurisdiction. The enactment of government policies in this scenario forms a complex yet critical part from legal frameworks to policy implementation. This is handled by establishing an effective energy-efficiency governance.

India hosts a federal system that comprises 29 states and 7 union territories holding legislative and executive powers distributed among the Union and state governments (Sartori and Bianchi, 2018). The power division among the Union and state governments are based on three lists comprising of certain number of sectors with each: (1) Union List, where responsibility exclusively lies with the Central government (2) State List, these sectors are exclusively governed by state governments and (3) Concurrent List, these sectors are managed by both state and Union governments (Sartori and Bianchi, 2018). The Energy sector falls under the "concurrent" category wherein the Union government presides over executive and legislative decisions regarding energy generation and inter-state transmission whereas state governments are responsible for generation, intra-state transmission and distribution (Goyal, 2021). The state governments, hence, play a major role in diffusion of policies while influencing the end-user through policy planning, policy implementation and its monitoring and evaluation (Goyal, 2021). The states utilize this autonomy to define their own mandates, standards and energy subsidy programmes as required per their different resources and respective economic needs (International Energy Agency, 2020). Therefore, in this research, these different policy plans and resource utilization are considered to be causal factors for policy penetration effects observed in various states in india.

5.1.1 Actors involved in Energy-efficiency governance

The concurrent nature of the energy sector results in a multi-tiered governance for this sector presided at federal and state levels. At federal level, the energy policy is governed by five ministries namely, "Ministry of Power (MoP), the Ministry of Petroleum and Natural Gas (MoPNG), the Ministry of New and Renewable Energy (MNRE), the Ministry of Coal (MoC) and the Department of Atomic Energy (DAE)." (International Energy Agency, 2020).

The MoP governs the electricity sector in India and also comprises Bureau of Energy Efficiency (BEE) dedicated towards formulation of energy-efficiency policies in India. Furthermore, technical expertise and supervision is presided over by the Central Energy Agency (CEA) whereas the Central Electricity Regulatory Commission (CERC) formulates regulations regarding pricing, energy security and generation. Other coordinating sectors' ministries utilizing electricity as their power source also contribute to implementation and data collection for these policies. These ministries include "Ministry of Housing and Urban Affairs, Ministry of Heavy Industries and Public Enterprises, Ministry of Micro, Small and Medium-Sized Enterprises, and Ministry of Environment, Forests and Climate Change (MoEFCC)." (International Energy Agency, 2020)

In addition, MoP also comprises Public Sector Undertakings (PSUs) that include the Power Finance Corporation (PFC) and the Rural Electrification Corporation that act as a non-banking funding source for power sector development in the country. For power operations, the PSUs operating under MoP are: the National Thermal Power Corporation (NTPC) that stands as the largest integrated thermal power plant company and serves as the biggest source for electricity generation in India and Power Grid Corporation of India Limited (Powergrid). Powergrid owns and operates the inter-state transmission lines (Sartori and Bianchi, 2018). These four major PSUs came together to form a joint venture called Energy Efficiency Services Limited (EESL) in 2009 which is responsible for implementing market-related policies for energy efficiency missions (International Energy Agency, 2020). Due to its technical expertise and experience in the energy sector, EESL was formulated to assist central and state governments in implementation of the BEE's policies (Prayas, 2017). It is also involved in capacity building of State Dedicated Agencies (SDAs) and therefore influencing the local level implementation (Prayas, 2017). EESL is the main responsible party for implementing the UJALA policy nationwide which is explained in more detail in section 3.1.2.

Similar to the federal model, the state governments also consist of dedicated ministries and departments that work at state-level for implementation of national power regulations while coordinating with the federal government. For energy efficiency policy implementation, states have constituted State Dedicated Agencies (SDAs) acting as counterparts of BEE to enforce these policies at local level and create awareness for these policies (Sartori and Bianchi, 2018). Regarding regulatory measures and tariff-setting per state, the State Energy Regulatory Commission (SERCs) is responsible and power distribution is handled by Distribution company of the states (state-run DISCOMs) (Sartori and Bianchi, 2018). These institutions are also entrusted with the consumer awareness campaigns at the sub-national level (International Energy Agency, 2020).

Figure 13 presents a depiction of the roles and responsibilities of the government actors involved in the energy- efficiency policy governance process.

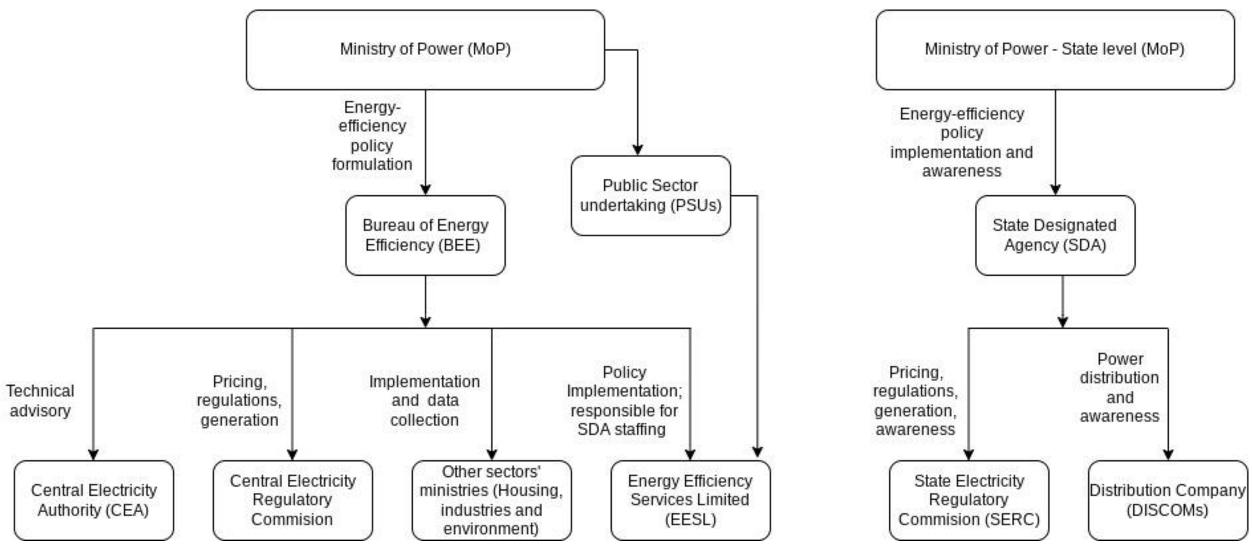

Figure 13. Energy- efficiency policy governance in India. Author's own depiction.

5.1.2 UJALA policy governance

The UJALA program was launched by EESL as a zero-subsidy programme. EESL was established as a group of four main technical companies to address the key barriers to scaling energy-efficiency policies formulated by BEE under MoP (Singh and Bajaj, 2018). UJALA was mainly launched taking in account the economies of scale presented in the Indian market. In order to reduce subsidy burden on government or DISCOMs, EESL targeted bulk procurement of LED bulbs that drives down its manufacturing costs and leads to a reduced upfront price for consumers, driving demand for these bulbs (Prayas, 2017). The technical expertise, obtained from the joint venture, was utilized to formulate technical standards for the bulbs to be submitted to manufacturers (Singh and Bajaj, 2018). Regarding implementation at local level, EESL contracts DISCOMs, local authorities and municipalities to leverage government infrastructure such as post offices for deployment of policy. This agreement also allows EESL to utilize the local-level implementation experience through consultation and coordination with these institutions (Singh and Bajaj, 2018). Engaging local distribution agencies allowed EESL to avoid the mark-up charged by private retailers resulting in increased penetration of the policy due to low market price offering (Prayas, 2017). In order to generate increased demand for the LED lighting, EESL conducted awareness campaigns through social media via government launching events and TV advertisements and even engaging in physical advertisements such as fliers and street-plays. The awareness campaigns were conducted in partnership with the state governments and DISCOMs in the states (Singh and Bajaj, 2018).

5.2 Impact of UJALA policy on the LED lighting sector in India

According to Mir et al (2020), the LED lighting scenario in India in 2006 was limited to a single local LED packaging company with null participation of multinational companies in this segment. However, in 2016, the LED sector was worth a billion dollars annually with 27 large and medium size and 600 small-size manufacturers based in India. The multinational chip producers had also established branch offices in India to cater to this up scaled demand for parts. The major barriers reported for the growth of this industry were lack of local standards, high technology costs, intellectual property rights and the negligible market size for this technology. A lot of this up scaling is accredited to the low-carbon technology requirement due to the Paris Climate Agreement of 2006 that led the government actors to take cognizance of the situation and address the major barriers in this industry (Mir et al, 2020).

The aforementioned barriers for LED industry scaling in India were required to be addressed for the manufacturers to establish a viable business around this technology. The major policy impact came through the establishment of the National Action Plan on climate Change (NAPCC) in 2008 with the mission of focusing on energy- efficiency in demand side energy management (MINISTRY OF SCIENCE AND TECHNOLOGY, n.d.). It was a crucial step in establishing BEE and EESL, the two institutions focused on formulating and implementing energy- efficiency policies. The foremost barrier of establishing local standards was reduced by IEA in collaboration with BEE that adopted the international standards for LED standards localized for Indian use (Mir et al, 2020). This enabled the Indian domestic LED industry to establish domestic manufacturing capacity in India instead of relying on import of final LED products. However, the barrier of high costs of technology establishment were not fully removed due to the lack of domestic R&D advancement and high Intellectual Property Rights (IPR) costs from the competitors of China and Taiwan (Mir et al, 2020). Therefore, the manufacturers are still reliant on the imported chips for manufacturing the LED products. In this purview, the Indian government exempted the special additional duty on the LED chips utilized for manufacturing LED lamps in 2012- 2013 that aided in reduction of price for the LED lamps in market and also to the manufacturer.

Additionally, the fiscal measures also included the introduction of the UJALA policy with the mission of providing LED bulbs for Indian homes at minimal costs. This reduction in cost to market was targeted via bulk procurement of LED lighting products by EESL (Sartori and Bianci, 2018). The increase in LED technology awareness led to market creation of LED products in India. However, an up scaling of manufacturing capacity was posed as a necessary requirement in this case to cater the increased market demand. Knowledge exchange proved to be the key facilitator in reducing this barrier (Mir et al, 2020). Initiated by the private sector association Electric Lamps and Components Manufacturers (ELCOMA), a LED chapter was initiated to enable peer learning among the manufacturers to discuss developments in LED technology via workshops and a dedicated white paper series on the barriers of LED technology and required solutions (Mir et al, 2020). This facilitated knowledge exchange in the industry aided the manufacturers in rapid up scaling of their capacities. Furthermore, the establishment of EESL as a large-scale buyer and distributor paved the path for large-scale manufacturing set-up in India for LED products, relieving it from the previous small and fragmented market- size. On a downside, the bulk procurement tender methodology established by EESL increases the pressure on the manufacturers to reduce the wholesale price of bulbs decreasing their profit margins. This has led to recent dips in the number of participating manufacturers in the bidding process (Prayas, 2017).

Beyond the UJALA policy itself, the manufacturers' saw increased opportunities in other LED products such as LED luminaire designs, retrofitting and customization and other wattage bulbs not offered under the UJALA policy (Mir et al, 2020). Due to the successful market creation from increased awareness in energy-efficient technologies through government policies, the manufacturers were quite confident regarding the potential growth opportunities in the market leading even many international companies to scale their business activities in India. The increased market opportunities enabled the manufacturers to compensate for the imported chips' costs that constitute 15 to 20 percent of the bulb price as they could charge increased prices in the open market for complementary technologies (Mir et al, 2020). This alternative market creation has also been cited as a reason for low manufacturers' participation in the UJALA policy bidding process (Prayas, 2017).

Even though most of the barriers for the up scaling of LED technology were reduced through local standards establishment, knowledge development, fiscal measures and market formation, the imports of chips used in the LED manufacturing is still a barrier for manufacturers due to its high costs. This price has been aggravated due to the ongoing semiconductor chip shortages in the LED sector (Howley, 2021). The LED industry is among the industries affected by this shortage and a viable roadmap is required to tackle this crisis in the long-term and short-term (Howley, 2021). Currently, only one Indian LED manufacturing company called De Core Nano semiconductors Limited hosts in-house production of LED wafer FAB, which is the imported chip component in LED lightings (Sharma, 2016). A short-term plan of increased cooperation among manufacturers may be facilitated through ELCOMA to switch to Indian suppliers and if possible try to establish a shared manufacturing facility for these components through knowledge sharing. Though switching to limited suppliers in the Indian market could lead to increased pressure on these companies and would not resolve the problem for the long-term.

For a long- term plan, India could take advantage of its world-view of an alternative to the Chinese manufacturers to resolve the semiconductor shortage. Furthermore, the Make- in - India campaign can drive these efforts for the domestic manufacturers to produce all concerned electronics parts in India. However, the R&D development in India regarding electronics is still lacking in comparison to its competitors from China and Taiwan (Melissa & Yashoda, 2022). A rapid increase in technology development and knowledge development is required by the manufacturers' industry to reduce its reliance on the imported parts. This could be facilitated via ELCOMA to bridge the knowledge gap among manufacturers to establish the required knowledge for the manufacturing process. Furthermore, the Indian government has initiated a Semicon India scheme to provide incentives to manufacturers willing to establish domestic wafer FAB manufacturing units across countries. The incentives include 50 percent investment support and provision of land, semiconductor grade water and power, logistics and a research ecosystem for the selected companies (Bhardwaj & Cyrill, 2022). The interviewee 1 confirmed this fact and added an insight of many such initiatives promoted by the Indian government under the Production Linked Incentive (PLI) scheme. This fiscal initiative will be helpful in establishing a domestic semiconductor production ecosystem and LED manufacturers could switch to the India-based suppliers based on their needs. This will reduce the reliance on imported parts and may lead to a reduction in price of LED manufacturing in the longer term due to the elimination of import duties benefiting manufacturers and the market as well. However, the interviewee 1 highlighted the concern of the cost of importing these parts being cheaper than manufacturing them domestically that might limit the benefits of these schemes overall. But given the geopolitical situation between India and China, the import costs might be impacted and a switch to domestic manufacturing could be preferred according to the interviewee 1.

Another downside of the UJALA policy is the high reliance of the LED manufacturers' on this programme. According to Prayas (2017) , the UJALA policy currently accounts for half of the market demand and a sudden withdrawal of the policy could lead to financial troubles for these manufacturers. EESL has been a priority customer for these suppliers due to the low production and packaging costs for this supplier (Prayas, 2017). But a sudden withdrawal might lead many of these manufacturers to resort back to small batch production strategies and higher supply chain costs due to custom requirements from the different customers and their varied locations and packaging requirements. This could hurt the sudden up scaling of the production facilities undertaken to meet the UJALA policy requirements and therefore a viable and gradual policy withdrawal strategy is recommended by the think-tanks to cause minimal impact to the LED market (Prayas, 2017). According to the interviewee 1, the UJALA policy has helped in establishing the LED market in India that has eventually led to a stabilized demand for LEDs in the open market as well. Also, the UJALA policy has now been focused on catering to the rural market subsidizing the cost of each bulb to INR 10 and the funding source has been changed to Clean Development Mechanism (CDM). The last bulk procurement took place in the year 2020.

5.3 Government institutions coordinating the supply and demand side

The success of the UJALA scheme is accredited mostly to the innovative model adopted by EESL for procurement and distribution of the LED schemes (Mir et al, 2020) . EESL based the UJALA scheme on a “demand aggression- price crash model” that translates into targeting price reduction through economies of scale (Mir et al, 2020). The bulbs in this scheme were procured in bulk from the manufacturers for nationwide distribution and coordinating the distribution with limited support from the state agencies (Prayas, 2017). The existing LED Bureau of Indian Standards (BIS) technical standards were adopted for this programme and the offering was initially limited to one product i.e. a 9W light bulb and was further extended to ceiling fans and tube lights as well (Prayas, 2017). However, in this research the scope is limited to light bulbs distribution since it benchmarks the success of the entire policy due to the product inception from the beginning of the programme itself. The bulb was offered on either upfront costs stated by EESL or via on-bill financing paying the purchase price in monthly installments (Mir et al, 2020; Prayas, 2017).

The main objective of EESL was to promote a market transformation for LED bulbs, keeping the other objectives of promoting domestic production and small- industry upliftment as secondary objectives for the policy (Prayas, 2017). This could be concluded from the change in criteria for manufacturers’ selection wherein the earlier terms favored a domestic LED production but were later liberalized to domestic LED assembly requirement. This was due to the lack of capability of entire LED parts production domestically for many manufacturers participating in the bidding process. Also, the smaller suppliers participated forming a consortium and had a reservation of 20% of the overall requirement. However, many small- scale suppliers did not participate in later bids and no efforts were made from EESL to promote their participation (Prayas, 2017). Furthermore, currently half of the market demand is dependent on the UJALA programme and a systematic withdrawal for the policy is necessary to not leave many manufacturers in financial trouble by the end of the programme. Also, the LED lighting prices could significantly increase leading to their unpopularity and consumers switching to non-energy efficient technologies. Moreover, the researchers suggest a slower market transformation strategy as opposed to a fast transformation followed by EESL for future programmes to provide enough time to accommodate for the build for the supporting technologies (Prayas, 2017).

In order to deliver a successful model, a co- ordinated distribution strategy with clear duties of stakeholders needs to be in place to distinguish the ambiguity in the concurrent energy sector. The involvement of state bodies such as DISCOMs was limited to providing a space for the kiosk, marketing and collecting money in the on-bill financing scheme (Prayas, 2017). This approach of EESL did lead to faster and effective implementation of the policy, however, the researchers suggest that this limited participation has led DISCOMs to not involve an effective evaluation of power savings calculations and reevaluating their power planning due to such programmes. Currently, the savings calculations are carried out by EESL based on the number of bulbs sold until date, however other impacted data that may prove useful for DISCOMs is not under consideration (Prayas, 2017). Therefore, the researchers suggest more involvement of DISCOMs for the future policies' design and EESL and BEE support in building their capacity for effective implementation (Prayas, 2017).

The additional responsibilities of EESL involved monitoring of sales of the LED bulbs through the UJALA policy. A dedicated dashboard was developed and recent sales figures per state are indicated to monitor the policy progress (www.ujala.gov.in). This dashboard was reported in newspapers and government websites for marketing purposes (Prayas, 2017). Furthermore, the marketing efforts were maximized through involvement of public facilities and offices such as post offices and bus- stops to reach out to the larger population. These efforts were carried out in co- operation with DISCOMs.

An important part of this research is to understand the state efforts in implementing the UJALA policy. This indicates the differences in the different penetration values of LED lighting technology in the various states of India. Although the state bodies had limited participation in this policy, their energy- efficiency efforts towards building the capability of the departments and strengthening the marketing efforts through dedicated awareness campaigns is assumed to have impacted the relative success of UJALA policy.

5.4 Local UJALA policy implementation

The local implementation of an energy-efficiency policy is carried out with the direct or indirect help of state designated institutions to reach the masses of the entire population. Similarly in UJALA policy, the state actors have been involved and coordinating in various ways to make the policy a success. DISCOMs are generally considered the major contributors in the UJALA policy from the state side perspective, however the other actors are significantly important given their influence in capacity building and funding to DISCOMs and other significant roles. A detailed case study explanation of the state actors' roles and responsibilities in this policy implementation for Maharashtra State Electricity Distribution Company Limited (MSEDCL), a state- owned DISCOM is presented in this section.

MSEDCL is the DISCOM supplying power to the whole of Maharashtra including a small part of suburban Mumbai alongside other private DISCOMs in the city (Garg & Shah, 2020). The general operations of DISCOMs involve purchasing power from the sources and distributing it among its designated areas depending on the consumer type (World Bank, 2016). The major revenue of the DISCOMs are generated from the tariff charged to the public, however these tariffs are subsidized for agricultural purposes and below poverty line households (World Bank, 2016). This incurs losses for DISCOMs and therefore DISCOMs are not eager to participate in other activities of the state except demand-side management. The additional activities of DISCOMs include managing their kiosks and staff availability to resolve public issues and creating awareness of government schemes in the state. In this respect, the MSEDCL has conducted around four or more energy-efficiency awareness programs in the state in the year 2020 ((AEEE State EE Index, 2021). Given the limited capacity of the state government bodies, an extension of adoption and technological capabilities to other bodies such as education institutions, think- tanks, NGOs, etc. is required to enable successful adoption of energy- efficient measures in the state. The Maharashtra government has introduced several clauses to maximize R&D and innovation activities via legislation to include energy efficiency courses for school curricula and initiating courses at college level at subsidized rates to enable capacity building and generate awareness in the population at early ages itself (State Energy Efficiency Index, 2020).

The partial funding allocation to SDA is undertaken by MSEDCL. An extensive State Energy Conservation Fund (SECF) has been established by the Maharashtra SDA and allocated a part of funding to energy efficiency implementation as well. Therefore, a regular communication between SDA and MSEDCL is required for proper requirement analysis at MSEDCL and which is also documented as a formal report submitted to the Central authorities (AEEE State EE Index, 2021). In terms of financial resources, the interviewee 1 added that SDAs are funded by both BEE and state government and are responsible for energy efficiency policy implementation at the state level. Also, another state body called Maharashtra Electricity Regulatory Commission (MERC) has set energy-efficiency regulations for the DISCOMs to follow in their operations (World Bank, 2016). MERC is also involved in setting tariff regulations for the state, however the tariff collection is the responsibility of MSEDCL in the designated area (Sartori and Bianci, 2018). Therefore, MSEDCL determines the information and means of energy bill payment by the catered population and being of economic influence for households could lead to market creation based on the level of information in the invoice. Only one DISCOM in the country in Delhi provides the real- time consumption for the population that could drive energy- efficiency measures for the household itself. However, MSEDCL provides only the tariff costs and power consumption details in its invoice charged to the customers.

In terms of UJALA policy implementation, MSEDCL signed a standard contract with EESL to provide space in their kiosk to enable distribution of LED bulbs. In some kiosks, the distribution was coordinated via MSEDCL staff and the sales figures had to be reported to the EESL manager of the zone by each day that was then consolidated nationwide and updated in the dashboard (Prayas, 2017). The UJALA scheme posters were required to be displayed at the kiosks as a marketing. Also, UJALA policy awareness was part of the overall energy- efficiency awareness campaigns conducted in the state initiated by MSEDCL. The significance of MSEDCL in implementing the UJALA policy is its agreement with its terms and policies and staff and funding utilization for the scheme which is of utmost importance to the local implementation of the scheme.

Furthermore, the experience of handling similar policy implementation in the past such as the solar irrigation pump distribution in agricultural areas determines the networking and reach of the MSEDCL that is assumed to be impactful for the UJALA implementation as well. The emphasis on monitoring and evaluation of policies are also taken into account with MERC appointing an independent third- party to evaluate their policy implementation and provide guidance and suggestions for the same (AEEE State EE Index, 2021).

According to Prayas (2017), another important point of UJALA implementation was the introduction of on- bill financing mechanism wherein the consumer could opt for a monthly installment payment through their electricity bill towards bulb purchase. This scheme was targeted for low-income households that could not afford the upfront cost of the bulbs. Even though MSEDCL sold significant bulbs through this scheme contributing to the 30% overall sales throughout the state of Maharashtra through this scheme, some other DISCOMs discontinued this scheme due to the added workload for all actors. The DISCOMs had to revise their billing strategy to accommodate this scheme and then EESL had to collect dues from the DISCOMs for this scheme specifically for the enrolled consumers. Therefore, this scheme was eventually discontinued in some states (Prayas, 2017).

Similar to MSEDCL, the other states have a similar setting of DISCOMs that operate for a certain network with defined roles and responsibilities as indicated in Figure 13 of this research. Therefore, the exploratory case study of MSEDCL is considered representative of the state activities and their direct and indirect contribution to the UJALA scheme implementation. This study would be utilized as a basis for upcoming chapters to derive the causal factors for the success of UJALA policy implementation in the states.

In order to understand the factors leading to the success of UJALA policy, the interview conducted with the expert has also emphasized on the bulk procurement and simpler computing models involved in indicating the policy metrics. According to the interviewee1, the government has emphasized more on development of the renewable energy sector than pushing energy- efficiency technologies. The main success of the UJALA program is that it has brought energy efficiency into focus which was not the case earlier. The Unique Selling Point (USP) of ULAJA policy success was that it tried to ease the complex process of calculating the estimated saving potential by building it upon the sales numbers for the LED bulbs rather than complex mathematical models implicated in earlier schemes. This simplified the saving potential calculations for the government institutions resulting in easier tracking of the metrics for the scheme.

For differentiation in state policy implementation, the expert emphasized on the limited role of state agencies and regarded the centrally coordinated role of EESL as one of the primary reasons for the nationwide policy success. According to the interviewee 1, the factors that led to the success of the UJALA scheme implementation include limited roles of DISCOMs, cheap LED bulb prices and strong political backing. These factors pointed out by the expert were mainly concerned regarding the policy design. The simple distribution mechanisms such as setting up of kiosks for the sale of LED bulbs helped in the higher penetration of policy. This move was backed by the facilitation of LED bulbs at much cheaper rates than the open market costs. Other factors such as strong political leadership by the Prime Minister itself and good marketing through public campaigns and advertisements aided in increasing consumer awareness of the policy. In terms of roles of local implementation, the DISCOMs played a major role in distribution of LEDs via on-bill financing mechanism but lesser in outright sales of the bulbs. The bulk procurement of the bulbs brought the procurement costs down for the lighting products and was a simpler funding method unlike the predecessor scheme of Bachat Lamp Yojana that relied on Clean Development Mechanism based on foreign funds which complicated the financing of the scheme overall.

5.5 Conclusion

This chapter presents an overall governance scenario of energy- efficiency policies in India followed by a focus on the UJALA policy governance. The business model followed by the UJALA policy that enabled bulk procurement and brought down the costs of LED bulbs has been accredited for the success of this policy. However, the technological change in the lighting industry could only be enabled through the support of manufacturers and consumers. The section 5.2 describes the barriers for this technological change in the market and the fiscal measures and initiatives undertaken to overcome these barriers by the manufacturers. However, this fast transition could lead to downsides of financial troubles for the manufacturers but the market creation of LEDs led to a stabilized demand even after the phase- out of the policy. Next, the demand-aggression price crash business model followed by EESL in UJALA policy implementation has been described in detail. EESL adopted a nationwide implementation strategy keeping the role of state authorities to the minimum. However, the local implementation was largely carried out from support of the state authorities of DISCOMs that provided space for kiosks and contributed in creating awareness of the UJALA scheme in the states. An important role of DISCOMs was to aid in implementing the on-bill financing mechanism of buying LED bulbs that facilitated the affordability of these bulbs eventually leading to their sales. The section 5.4 describes the local implementation of UJALA policy through a representative exploratory case study of MSEDCL and its role in the UJALA policy.

Chapter 6: Results of fsQCA

This chapter reports the results obtained in the fsQCA analysis for the raw data of factors considered in chapter 3 and 4. The section 6.1 constitutes the raw data sets, calibrated data set for fsQCA analysis followed by the solution types and its plotting. Section 6.2 elaborates on the configurations suitable for high penetration of the UJALA scheme in Indian states. The results obtained are verified via robustness checks by varying certain conditions such as calibration threshold values and consistency thresholds. The robustness checks are reported in section 6.3 followed by validation of results via expert interview analysis presented in section 6.4 of this research.

6.1 Data sets, calibrated data set and solution types

The dataset for the fsQCA analysis was derived for the 28 states of India as mentioned in Chapter 5. The factors include GDP per capita to be referred to as GDPCC, Credibility referred to as CRE, Literacy rate per capita referred to as LR, consistency of elements referred to as CON, comprehensiveness referred to as COM and percentage of electrified homes as EH. According to the Pappas & Woodside (2021), a balance needs to be maintained between the numbers of causal factors to be undertaken for fsQCA analysis. Berg-Schlosser & de Meur, G. (2009) suggests to utilize a causal factor size of 5-7 factors for the fsQCA analysis. The current causal factor size considered for this research stands at six factors that fall within this bracket and also no further combinations are possible for these factors. The dataset reported in table 12 would be utilized for the fsQCA analysis.

Table 12: Raw data set (AEEE State EE Index, 2021; Census, 2011; *GDP per Capita (Current US$) - India | Data*, 2020; World Bank, 2016)

States	**GDPCC**	**CRE**	**LR**	**CON**	**COM**	**EH**	**OUT**
Andhra Pradesh	2787.55	1	67.66	0.9	3	92.2	0.45
Arunachal Pradesh	2601.67	0.5	66.95	0.225	2	65.7	0.36
Assam	1602.28	0.5	73.18	0.325	2	37	0.23
Bihar	960.62	0.5	63.82	0.225	2.5	16.4	0.19

States	GDPCC	CRE	LR	CON	COM	EH	OUT
Chhattisgarh	1800.73	1	71.04	0.225	2	75.3	0.42
Goa	7541.76	0	87.4	0	1	96.9	0.69
Gujarat	3805.45	0.5	79.31	0.225	3	90.4	0.69
Haryana	3944.55	0	76.64	1	4	90.5	0.62
Himachal Pradesh	3059.17	0	83.78	0.1	3	96.8	1.25
Jharkhand	1333.81	0	67.63	0.45	3	85.1	0.41
Karnataka	3731.87	1	75.6	0.55	4	45.8	0.39
Kerala	3292.82	1	93.91	1	4	90.6	0.46
Madhya Pradesh	1789.97	1	70.63	0.55	3	94.4	0.24
Maharashtra	3292.57	1	82.91	1	3	67.1	0.2
Manipur	1470.69	0	79.85	0	2	83.9	0.37
Meghalaya	1550.45	0	75.48	0.45	1	68.3	0.15
Mizoram	3189.92	0	91.58	0.45	3	60.9	0.56
Nagaland	2122.82	0.5	80.11	0.45	3	84.2	0.56
Odisha	1620.04	0	73.45	0.775	4	81.6	1.25
Punjab	2595.22	1	76.68	1	4	43	0.11
Rajasthan	2056.94	0.5	67.06	0.55	2	96.6	0.25

States	GDPCC	CRE	LR	CON	COM	EH	OUT
Sikkim	7042.52	0	82.2	0.225	2	67	0.27
Tamil Nadu	4116.59	0	80.33	0.225	2	92.5	0.06
Telangana	3892.71	0	67.66	0.225	3	93.4	0.45
Tripura	2585.8	0.5	87.75	0.45	2	68.4	0.29
Uttar Pradesh	1351.27	0.5	69.72	0.1	2	36.8	0.13
Uttarakhand	3370.91	1	79.63	0.225	3	87	0.56
West Bengal	1972.04	0.5	77.08	0.225	2	54.5	0.1

The raw dataset needs to go through data treatment methods of determination of a threshold value for each factor and a calibrated dataset with resultant values between 1 to 0 to be inputted for the fsQCA operation (Pappas & Woodside (2021); Ragin (2018b)). The dataset is calibrated to determine the full-membership, intermediate membership and the no membership values interpreted as a data being fully-in, not fully-in not fully-out and fully-out respectively (Pappas & Woodside, 2021). The following Table 13 displays these fuzzy calibration points alongside their membership meanings.

Table 13: Fuzzy-set membership value

Fuzzy-set value	Membership
1	Full membership
1< data < 0.5	Fully -in
0.5	Not fully-in not fully-out
0.5 < data < 0	fully-out
0	No- membership

However, 1 and 0 are not used as calibration points or breakpoints since the calibrated data is the log -odds metric of the actual value and 1 and 0 would lead to the positive and negative infinity of these values (Ragin, 2008a). Therefore, 0.95, 0.50 and 0.05 are utilized as breakpoints in practical cases and to determine these breakpoints for a factor dataset, the relative percentile values are utilized. Moreover, these percentiles need to align with the theoretically selected thresholds and need not be selected mechanically (Pappas & Woodside, 2021). Along these lines, Pappas & Woodside (2021) suggests to utilize 0.80, 0.50 and 0.20 as breakpoints in cases of dataset following a skewed distribution and the 0.95, 0.50 and 0.05 in case of normally distributed dataset.

Incorporating these calibration strategies in this research, the datasets are calibrated as represented in Table 14:

Table 14: Calibration values for data set

Dataset name	**Dataset notation**	**Threshold basis**	**Distribution**	**Calibration rule**	**Full membership value**	**Intermediate membership value**	**No membership value**
GDP per capita	GDPCC	Indian average	Left- skewed	(0.80,0.5, 0.20)	3776.02	1927.71	1609.38
Credibility	CRE	Mean value of dataset	Normal	(0.95,0.5, 0.05)	0.95	0.5	0.05
Literacy rate	LR	Indian average	Normal	(0.95,0.5, 0.05)	90.24	74.04	66.99
Consistency	CON	Mean value of dataset	Normal	(0.95,0.5, 0.05)	0.95	0.43	0.05
Comprehensiveness	COM	Mean value of dataset	Normal	(0.95,0.5, 0.05)	4	2.66	1.35
Percentage of Electrified homes	EH	Indian average	Right- skewed	(0.80,0.5, 0.20)	92.38	67.2	57.06
Outcome	OUT	Mean value of dataset	Left- skewed	(0.80,0.5, 0.20	0.56	0.42	0.19

These calibration values are computed via the fsQCA 3.0 software to derive the calibrated dataset for the fsQCA analysis. Table 15 represents the calibrated dataset derived for this research. The notations for the calibrated datasets are denoted with a "1" behind the raw data notations.

Table 15: Calibrated data set

States	**GDPCC1**	**CRE1**	**LR1**	**CON1**	**COM1**	**EH1**	**OUT1**
Andhra Pradesh	0.8	0.97	0.06	0.94	0.68	0.95	0.66
Arunachal Pradesh	0.75	0.5	0.05	0.17	0.18	0.39	0.31
Assam	0.04	0.5	0.41	0.3	0.18	0	0.08
Bihar	0	0.5	0.01	0.17	0.41	0	0.05
Chhattisgarh	0.23	0.97	0.22	0.17	0.18	0.72	0.5
Goa	1	0.03	0.92	0.03	0.02	0.97	1
Gujarat	0.95	0.5	0.73	0.17	0.68	0.94	1
Haryana	0.96	0.03	0.62	0.96	0.95	0.94	0.99
Himachal Pradesh	0.86	0.03	0.86	0.07	0.68	0.97	1
Jharkhand	0	0.03	0.06	0.53	0.68	0.89	0.47
Karnataka	0.95	0.97	0.57	0.67	0.95	0	0.4
Kerala	0.9	0.97	0.98	0.96	0.95	0.94	0.7
Madhya Pradesh	0.21	0.97	0.19	0.67	0.68	0.96	0.09

States	GDPCC1	CRE1	LR1	CON1	COM1	EH1	OUT1
Maharashtra	0.9	0.97	0.84	0.96	0.68	0.49	0.05
Manipur	0.01	0.03	0.75	0.03	0.18	0.88	0.34
Meghalaya	0.03	0.03	0.57	0.53	0.02	0.53	0.03
Mizoram	0.89	0.03	0.96	0.53	0.68	0.13	0.95
Nagaland	0.58	0.5	0.75	0.53	0.68	0.88	0.95
Odisha	0.05	0.03	0.44	0.88	0.95	0.85	1
Punjab	0.75	0.97	0.62	0.96	0.95	0	0.02
Rajasthan	0.55	0.5	0.05	0.67	0.18	0.97	0.1
Sikkim	1	0.03	0.82	0.17	0.18	0.49	0.12
Tamil Nadu	0.97	0.03	0.76	0.17	0.18	0.95	0.01
Telangana	0.96	0.03	0.06	0.17	0.68	0.96	0.66
Tripura	0.74	0.5	0.93	0.53	0.18	0.54	0.16
Uttar Pradesh	0	0.5	0.14	0.07	0.18	0	0.02
Uttarakhand	0.91	0.97	0.74	0.17	0.68	0.91	0.95
West Bengal	0.52	0.5	0.64	0.17	0.18	0.02	0.02

The fsQCA analysis is performed on the calibrated dataset and the truth table is obtained with 64 rows. Each of these causal recipes have a certain number of cases and consistency measure corresponding to it. Corresponding to the methodology described in section 3.2, the number of cases (N) considered in this research are 28 that falls in the criterion of N < 150 and hence, the frequency is set as 1 for this research. Furthermore, the consistency threshold is set at 0.75 for the solutions to account for most consistent causal recipes represented in the truth table. Additionally, a necessary analysis is performed to identify the necessary factors that are required to be present for the outcome to occur. This is represented by the consistency score of an individual factor and the qualifying score is 0.90 (Parente, 2019). In this research, none of the factors obtained an individual consistency score of 0.90, however, the factors Percentage of electrified homes, GDP per capita and policy comprehensiveness obtained the scores of 0.85, 0.75 and 0.77 respectively that could be deemed closer to the score of 0.90. The sufficiency analysis is executed through the three types of solutions obtained via the truth table analysis. The Complex solution includes the causal configurations for the cases that display the selected frequency and consistency. However, these solutions would rather be deemed very large and impractical due to the multitude of factors that make this solution quite complex to analyze (Pappas & Woodside, 2021). A simplified version of the complex solution is the parsimonious solution that only includes the important conditions also known as "core conditions" through simplifying assumptions and combining similar solutions (Pappas & Woodside, 2021). The last type of solution is called Intermediate solution that further simplifies the complex solution by including only theoretical plausible counterfactuals into the complex and parsimonious solution (Pappas & Woodside, 2021). The counterfactuals are conditions that are logical remainders and are similar to the solution configuration extracted in the analysis. This leads to the inclusion of "core conditions" in both intermediate and parsimonious solutions while the factors included only in the intermediate solutions are called "peripheral conditions" (Parente, 2019). Fiss (2011) suggests the inclusion of both parsimonious and intermediate solutions in the results to present a more detailed and aggregated solution. These solutions are discussed in detail in section 6.2.

The next step is the plotting of the solutions. Ragin and Fiss (2008) have utilized the notation of " ●" to denote the presence of a condition and the symbol "⊗" to represent the absence of the condition. However, most of the researchers have utilized these symbols consistently since only the intermediate solution is plotted. In this research, following the suggestion of Fiss (2011), both parsimonious and intermediate solutions are plotted with notation of core conditions being a bigger symbol and peripheral conditions as the smaller notation in the plotting. The section 6.2 represents the solution plotting along with the interpretation of the results to derive the causal configurations for the outcome.

6.2 Configuration with presence of outcome

The intermediate and parsimonious solution for the fsQCA analysis is plotted and represented in the Figure 14.

Solutions @ 0.75 consistency and theoretical thresholds					
	Solution 1	Solution 2	Solution 3	Solution 4	Solution 5
GDPCC	⬤	⬤	●	⬤	⊗
CRE		⨂	⨂	●	⨂
LR	●		●		⊗
CON		⊗	●	●	●
COM	⬤	⬤	⬤	⬤	⬤
EH	⬤	⬤		⬤	●
Raw Coverage	0.397466	0.265241	0.216152	0.253365	0.167063
Unique coverage	0.0617577	0.0482977	0.0387965	0.047506	0.0791766
Consistency	0.835275	0.905405	0.875	0.780488	0.929515
Overall solution consistency	0.853				
Overall solution coverage	0.62				

Figure 14: Intermediate and parsimonious solution for the fsQCA analysis

The fsQCA analysis accounts for a total of five causal combinations that indicate a higher penetration of UJALA policy in the Indian states. The configurations are accompanied by three major characteristics: raw coverage, unique coverage and consistency score for each solution. In regards to the significance of each term, the raw coverage signifies the extent of the result explained by each configuration whereas the unique coverage shows the extent of the result explained by each solution term individually (Florea et al., 2019). The raw coverage for these solutions lies between 0.16 to 0.39 along with a high consistency score of almost 0.80 for each solution. The unique coverage score also lies between 0.03 and 0.08 for the solution pathways. The overall consistency of solutions lies at 0.85 with a coverage score of 0.62. The consistency score indicates the extent of the causal configuration leading to the outcome whereas the coverage score provides the number of cases leading to the outcome for the particular analysis (Elliot, 2013). Therefore, a higher consistency score leads to a low coverage value (Elliot, 2013) as represented in this research as well wherein a consistency of 0.85 corresponds to an average score of 0.62 coverage.

Furthermore, the causal configurations represented in figure 14 are interpreted to understand the factors combination that result in a higher UJALA policy penetration in the Indian states. The solution 1, 2 and 4 represent that an Indian state that possesses higher GDP value, higher percentage of electrified homes and a high comprehensive policy mix could achieve high penetration of LED bulbs among the masses if either the: (1) literacy rate is higher, (2) credibility and consistency of policy mix are at lower values, or (3) the policy mix is highly consistent and credible as well. The core conditions in these solutions are GDPCC, COM and EH that represent a strong causal relationship with the outcome whereas the factors LR+ (~CRE* ~CON) + (CRE* CON) are peripheral conditions and display a weaker relationship with the outcome. The + symbol donates the "OR" condition whereas the * symbol denotes the "AND" condition in this case. A closer analysis of the solutions reveal the contradiction in the solutions 2 and 4 with regard to the peripheral conditions of CRE and CON wherein one of the solution conditions denotes the presence of both these conditions and one denotes the absence of combination of these solutions. These findings are reflected upon further in this chapter with analysis of the inclusion of states.

The solutions 3 and 5 indicate that highly comprehensive and consistent policy mix and an absence of a credible policy mix for an Indian state can lead to a higher penetration of LED lighting in combination of either (1) higher GDP and high literacy rate, or (2) high literacy rate and higher percentage of electrified homes in absence of a high GDP value for the state. The core conditions in these solutions are presence of COM and absence of CRE that represent a stronger relationship with the outcome. The absence of the CRE condition determines that the human and financial resources allotted by the states for the energy efficiency efforts are not important in leading to the outcome itself. However, the presence of components of the policy mix in terms of policy strategy and instrument types is a major causal factor noticed in case of state-level implementation of policies. The peripheral factors CON along with GDPCC* LR + (~ GDPCC * ~ LR* EH) present a weaker relationship with the outcome. The presence of CON factor in both solutions signifies the relative importance of this factor along with the core conditions, the rest factors are understood to hold a lower significance in the outcome.

All the causal configurations possess the presence of COM as a core condition that determines the higher importance of this factor in propagating the uptake of LED lighting in India. In terms of policy mix, at least three components of the COM out of five considered in this research i.e. policy objective, principal plan and three types of instruments are present in these states. The presence of at least three policy mix components of COM in combination with other policy mix characteristics and exogenous factors plays a significant part in driving the outcome. However, COM is not considered a necessary condition since it displays a lower consistency score in the necessary analysis. Upon closer analysis of the dataset, all the states except Goa that stand at an outcome score of 0.69 LED bulbs per capita display this characteristic.

The case of Goa is not represented in the five solution pathways and is considered an exception in terms of its composition. All the policy mix characteristics are at lower values than the threshold for this state; however, the exogenous factors uphold significant higher values than the threshold values set for this research. It is assumed for this research that the exogenous factor values such as higher GDP per capita have propagated higher energy-efficiency efforts in terms of setting up large numbers of distribution centers. Also, the consumer led factors of higher electrification rate and literacy rate have driven the consumers to uptake a higher number of LED bulbs than other Indian states. Another possibility would be an extra causal factor that is not considered in this research which could have played a significant role in propagation of the UJALA policy in this state.

Solution 1: **GDPCC** * LR* **COM* EH**

The states corresponding to solution 1 are Kerala, Gujarat, Himachal Pradesh, Uttarakhand, Haryana and Nagaland. This solution corresponds to the highest frequency of states represented by the pathways derived in this research. The combination of causal factors in this solution depicts the importance of exogenous factors along with a high comprehensive policy mix. In the perspective of government institutions, the states that have higher GDP per capita could invest more in the energy- efficiency efforts. This is even visible in the introduction of a policy mix that is highly comprehensive in terms of its components. These states have also driven the domestic electrification that led to higher uptake of LED lighting once the policy efforts are in a positive direction. Moreover, the literacy rate in these states have led to higher propagation of awareness towards the new technology hence resulting in a larger penetration of LED lighting.

Solution 2: **GDPCC*** **~CRE*** ~CON* **COM*** **EH**

The states corresponding to the solution 2 pathway are Himachal Pradesh and Telangana. Himachal Pradesh has the highest outcome value of 1.25 whereas the outcome of Telangana is near the average value at 0.45 but both these states qualify above the threshold value considered for this research. Additionally, this solution pathway comprises of both the parsimonious solutions: ~CRE* COM and GDPCC* COM* EH leading to four conditions i.e. higher GDP per capita, high comprehensive policy mix, higher rate of electrified homes and low credibility of policy mix significantly impacting the outcome. This solution signifies the importance of both exogenous and policy mix characteristics for the states with inclusion of five out of six conditions that lead to the outcome. This pathway depicts that the states with high GDP per capita with higher percentage of electrified houses would require a comprehensive policy mix necessarily to obtain a higher penetration of UJALA policy in absence of other characteristics of the policy mix. The higher GDP of these states has driven the governments to increase their energy-efficiency efforts through other means captured in the policy mix characteristics considered for this research. However, their policy mix components at least comprise three of the major components required to qualify for high comprehensiveness characteristic for this research but their extent does not have an impact on the outcome. Also, the resource allocation to DISCOMs that constitute the credibility factor does not impact the outcome which may lead to the conclusion of the limited role of DISCOMs in this policy in presence of high extent of exogenous factors and a comprehensive policy mix.

Solution 3: GDPCC* **~CRE*** LR* CON* **COM**

The states corresponding to the solution 3 pathway are Haryana and Mizoram. The outcome for these states are in mid-range from the threshold and the highest point of the outcome value. The combination of factors in this solution point towards the importance of the policy mix characteristics of consistency and comprehensiveness where the extent and the presence of the components play an important role in achieving the outcome. But these conditions are supported by the higher GDP per capita and literacy rate of the states. In the perspective of actors, the government has a higher role to play in terms of policy push and ability of investing in energy-efficiency efforts of the states. An aid from the higher literacy rate in the states led to a higher adoption of energy-efficiency technology in these states. The absence of credibility factor is highlighted in this pathway and this displays the lack of impact of indirect resources dedicated for this policy.

Solution 4: **GDPCC*** CRE* CON* **COM*** **EH**
The states exhibiting these conditions to achieve the outcome are Kerala and Andhra Pradesh. The combination in this solution is unique in terms of inclusion of high credibility in the states even though it displays a weaker relationship with the outcome. Similar to solution 3 pathway, this solution also depicts the importance of policy mix characteristics in achieving the outcome. However, the difference in this solution pathway is the inclusion of percentage of electrified homes instead of literacy rate in case of solution 3. This determines that the high resource allocation is required in the absence of literacy rate.

Solution 5: ~GDPCC* **~CRE*** ~LR* CON* **COM*** EH
The states corresponding to this solution pathway are Odisha and Jharkhand. Jharkhand follows an exceptional case in depicting a comparatively lower value than the threshold value set for this analysis. Interestingly, Odisha displays the highest value of outcome that stands at 1.25 LED bulbs per capita distributed by any state. Also, this result displays the importance of all conditions considered for this research. The presence of consistency and comprehensive policy mix accompanied by a higher percentage of electrified homes besides the absence of other conditions is considered sufficient to drive the outcome. Furthermore, the core conditions of high comprehensive policy- mix and low credible policy mix represent their stronger relationship in achieving the outcome. Nevertheless, the high value difference between the states following this pathway could point towards an inclusion of another factor that might not have been considered in this research.

6.2.1 fsQCA for policy mix characteristics

In addition to the above analysis, a fsQCA analysis was also conducted for the policy mix characteristics alone to determine the most contributing policy factors responsible for achieving a higher penetration of UJALA policy in Indian states. The solution indicates only one pathway depicting the combination of COM and absence of CRE. In this case, the parsimonious solutions and the intermediate solutions are identical that make COM and ~CRE the core conditions playing a significant role in achieving the outcome. The states corresponding to this outcome are Haryana, Odisha, Himachal Pradesh, Jharkhand, Mizoram and Telangana that constitute more than half of the states above the threshold value set for the outcome. Furthermore, this pathway is also represented as a parsimonious solution in the fsQCA analysis taking in account the exogenous factors as well.

Causal factors	Solution 1
GDPCC	
CRE	⊗
LR	
CON	
COM	●
EH	
Overall coverage	0.52
Overall consistency	0.83

Figure 15: Policy mix characteristics fsQCA analysis

The indication of presence of a comprehensive policy mix of at least three of the policy components is regarded as an important factor leading to a high outcome applicable for this research. The credibility factor comprising of resources allocated to the state agencies does not hold significance in this case due to the nature of the policy limiting the role of state agencies, however the constituents of a consistent policy mix in other pathways indicate a significance of extent of the policy mix constituents as well though at lower levels.

6.3 Robustness Check and validation

According to Parente (2019), the methodological decisions related to threshold selection for consistency and dataset membership are experimental and need to be verified for their robustness. The suggestion is to verify the solutions against modified datasets with slight variation in consistency thresholds, factors and calibration thresholds. The resultant solution cases should follow the set-theoretic logical variations that do not differ much from the original necessity and sufficiency analysis solution (Schneider & Wagemann, 2012). The dataset applicable for this research has been tested for robustness with a few variations as follows:

(1) **Variation in Consistency threshold**

Consistency cut-off is set according to the solutions covered in the truth table. A different consistency measure leads to inclusion or deletion of other cases considered in the analysis and hence the result could be different combinations as well due to the counterfactual inclusion. In this research, the consistency threshold is varied by +0.05 and -0.05 to check for robustness of solutions at the 0.75 score,

The consistency score of 0.80 corresponds to 5 solutions quite similar to the 0.75 consistency score. A few variations are noticed in 3 solutions and could be explained via theoretical observations due to inclusion of a lesser number of truth table columns in the solution. The Figure 16 represents the solution obtained for 0.80 consistency threshold value:

Solutions @ 0.80 consistency and theoritical thresholds					
	Solution 1	**Solution 2**	**Solution 3**	**Solution 4**	**Solution 5**
GDPCC	●	●	●	⊗	⬤
CRE	⊗			⊗	●
LR		●	●	⊗	⊗
CON	⊗	●	⊗	●	●
COM	⬤	⬤	⬤	⬤	●
EH	●		●	●	●
Similarity	sol 2	sol 3	sol 1	sol 5	sol 4
Difference	same	CRE not indicated	CON involved	same	LR not involved

Figure 16: Solution plotting for 0.80 consistency threshold and theoretical calibration thresholds

The solution 1 and solution 4 in Figure 16 are the same as solution 2 and solution 5 respectively as indicated in Figure 14 for consistency threshold of 0.75. However, the differences of a factor property is found in solution 2, solution 3 and solution 5 in this analysis. The "Difference" row in the figure 16 indicates the difference from the original solution to this analysis. The solution 3 possesses an indication of Consistency factor but since 0.75 had more logical remainders in its truth table comparison, these terms could get nullified with a row that contains these missing terms and hence could result in a "Do Not Care" condition for a lower consistency value leading to its absence in Figure 14. The other differences noted are in the solutions 2 and solution 5 wherein one term is missing, however, an inclusion of more truth table algorithms could lead to an importance of a certain factor that might lead to its occurrence in lower consistency values.

Additionally, the consistency threshold at 0.70 score has also been analyzed and plotted in Figure 17.

Solutions @ 0.70 consistency and theoritical thresholds						
	Solution 1	**Solution 2**	**Solution 3**	**Solution 4**	**Solution 5**	**Solution 6**
GDPCC	⬤	⬤	●	⬤	⊗	⊗
CRE		⊗	⊗	●	⬤	⊗
LR	●		●		⊗	⊗
CON		⊗	●	●	⊗	●
COM	⬤	⬤	⬤	⬤	⊗	⬤
EH	⬤	⬤		⬤	●	●
Similarity	soll	Sol 2	Sol 3	sol 4	new sol	sol 5
Difference	same	same	same	same	Addition al sol	same

Figure 17: Solutions @ 0.70 consistency and theoretical calibration thresholds

The solution count obtained is six, however, five solutions are exactly the same to the solutions obtained for 0.75 consistency. An additional solution is obtained in this analysis and is found to be similar to solutions obtained in absence of outcome. On further analysis, the corresponding solution points to only state i.e. Chhattisgarh and its outcome is below the average value of 0.42. Hence, this combination is correctly part of the combinations that lead to absence of outcome rather than its presence. Therefore, 0.70 is considered a low consistency score for this fsQCA analysis.

In this research, the consistency threshold value of 0.75 is considered to be suitable due to the aforementioned reasoning. In addition, the cases covered by the solution combinations for this score includes the highest number of states that display the presence of outcome i.e. 10 out of 11 states. This can also be verified via the coverage score for the variations wherein the coverage score of 0.56 is indicated for 0.80 consistency threshold. However, the consistency threshold of 0.70 has a higher coverage value but the inclusion of solution combinations coincide with the absence of outcome and hence is not considered the correct consistency threshold for this research.

(2) **Variation in Frequency threshold**

The second variation suggested by Parente & Federo (2019) is variation in the frequency threshold set by the researcher. The frequency is varied by 1 point and is set at "2" for this analysis. The solution obtained is plotted and represented in Figure 18.

Solutions for frequency threshold 2	
	Solution 1
GDPCC	⊗
CRE	⊗
LR	⊗
CON	●
COM	●
EH	●
Overall coverage	0.17
Overall consistency	0.95

Figure 18: Solution for frequency 2

The solution represented for this variation has a low coverage score at 0.17, however the consistency is improved by 0.10 points in this analysis. Elliot (2013) indicates that though it is not possible to set a lower limit for the coverage score, it is suggested to have a balanced coverage and consistency scores for the overall solution. Therefore, the frequency threshold value of 2 is not considered suitable for this research and "1" is deemed suitable for this measure.

(3) **Variation in Calibration threshold**

The calibration threshold is performed in two ways to check the robustness of the theoretical thresholds utilized in this research. Firstly, for policy characteristics factors are calibrated at their median values instead of mean for fsQCA analysis. Secondly, for all the causal factors determined for this research, the calibration threshold is varied by slight points and an analysis is performed to verify the robustness of the utilized threshold measure.

The corresponding median values for the factors measuring policy characteristics, CRE, CON and COM are 0.5, 0.38 and 3 respectively. Table 16 represents the calibration threshold variation considered for this robustness check.

Table 16: Calibration threshold variation

Factor	**Mean value (old calibration threshold)**	**Median value (new calibration threshold)**
CRE	0.5	0.5
CON	0.43	0.38
COM	2.66	3

The solution obtained in this analysis is represented in Figure 19.

Solutions for median instead of mean		
	Solution 1	**Solution 2**
GDPCC	●	⊗
CRE		⊗
LR	●	⊗
CON	●	●
COM	⬤	⬤
EH	⬤	⬤
Overall coverage	0.35	
Overall consistency	0.82	
Similarity	sol 1	sol 5
Differences	CON included	same

Figure 19: Solution for median instead of mean

The solution table obtained for this variation consists of two causal combinations. One of the combinations is similar to solution 5 in Figure 14 whereas the other combination has a variation with inclusion of one factor in solution 1 of Figure 14. The overall coverage score for this solution stands at 0.35 which is a low score and only covers 3 states for its analysis as opposed to 10 obtained at mean calibration threshold values. The extra factor in solution 1 of Figure 19 could be explained via the lower value of the threshold, however, the low coverage score points towards the low effectiveness of this solution table.

The second variation has been considered for all the factors included in this research. The new calibration threshold values are represented in Figure 20.

Solutions for cal threhold variation						
	Solution 1	Solution 2	Solution 3	Solution 4	Solution 5	Solution 6
GDPCC	●	•	⊗	•	●	⊗
CRE		⨂	⨂	⨂	•	●
LR	•			•		•
CON		⊗	•	•	•	⨂
COM	●	●	●	●	●	⊗
EH	●	•	•		●	⨂
Similarity	sol 1	sol 2	new sol	sol 3	sol 4	new sol

Figure 20: Solution for calibration threshold variation

As indicated in the row "Similarity" of Figure 20, four out of six solutions obtained in this analysis match the solutions in Figure 15. The solution 3 and solution 6 are the different solutions obtained in this analysis. Upon further analysis of the solutions, the states corresponding to these solutions lie very close to the calibration threshold but are at lower than the calibration threshold of the outcome dataset. Corresponding to the states lying on the lower side of the outcome dataset, these solutions could be ignored in this analysis. Therefore, it could be concluded that the original threshold values are deemed suitable for this research since it included only the correct level of outcome data in the solutions.

(4) **Factor Variation:** The last robustness check is performed upon the factors determined for the research. This test is benchmarked on the basis of importance of a causal factor considered for this analysis. The factor CRE is tested for this robustness and variation in solutions is recorded. If the corresponding solution does not display much variation, the solution might hold no to minimal impact on the outcome.

Solutions for CRE delete		
	Solution 1	Solution 2
GDPCC	●	
LR		⊗
CON		●
COM	⬤	⬤
EH	⬤	⬤

Figure 21: Solution for CRE deletion

The two solutions represented in Figure 21 do not match the solutions in Figure 14. Hence, it could be concluded that the factor CRE holds immense importance in this analysis and could conclude that the factor selection for this data set is robust for this research.

In regards to the internal validity of this research, the inclusion of most of the cases in the solution generated via fsQCA analysis determines the cause-effect relationship of the combination as a whole. This is also verified through the robustness check performed above since on variation of particular threshold measures, no significant unexplained change is noticed in the original solution generated for this research.

Additionally, the expert interview conducted regarding the impact of causal factors considered in this research provided a validation for these factors and also their relative impact. In terms of policy mix factors, the expert could not comment on this field due to their lack of expertise in the policy mix. Furthermore, for the exogenous factors, the interviewee 1 emphasized on the EH factor and agreed to its significant contribution for the relative policy outcome in the Indian states. But the GDP per capita and Literacy rate factor were pointed out to be of less importance for the uptake of the LED bulbs. The cheaper price of LED bulbs and marketing outreach programs were identified as major contributors for the success of this policy but their state wise differentiation is irrelevant due to its nationwide implementation.

Chapter 7: Conclusion and discussion

This chapter provides the conclusion and further recommendations for this research. The section 7.1 summarizes the solutions to the sub-questions and the main research question discussed in section 1.3 of this report followed by an overall project conclusion. The following section summarizes the findings and discusses the findings from the solution pathways obtained in this research as well as the causal factors considered for fsQCA analysis. The next section determines the limitations of the research study which will be addressed as recommendations in section 7.4. This section would include additional recommendations to increase the validity of the research as well. The section 7.4 provides the researchers' academic contribution through this research.

7.1 Conclusion

The adoption of energy efficient technology is becoming an important factor that will not only help in saving energy but also enable smooth energy transition to become more sustainable. The objective of the research was to study the adoption of energy-efficient lighting (LED) in 28 Indian states and to find out different causal pathways that lead to higher penetration of LED lights. This will give insights for other non-performing states to improve their penetration rate of LED adoption if they try to replicate the causal pathways and the overall adoption of LED bulbs will increase on the national level. Subsequently, all the sub questions and main questions will be answered in this section.

Sub questions:

What is the overall governance model and procurement business strategy of energy-efficiency policy with respect to the UJALA scheme in India?

It is very important to understand the governance model of the UJALA scheme and how it is implemented in all the Indian states. This is done by conducting an overall exploratory case study analyzing the identification of the stakeholders and the corresponding responsibilities associated with these shareholders. From the discussions in chapter five of the report, it can be concluded that the most important stakeholder in the case of the UJALA scheme is Energy Efficiency Services Limited (EESL). Learning from the previous experience of implementation of energy efficient schemes, EESL has held on to more responsibilities than the previous schemes. This is evident from the fact that it has itself taken the responsibility of activities like bulk procurement of LED bulbs, monitoring and evaluation activities for all sale points. Although EESL has taken greater responsibility, it cannot perform all the activities and has to involve the concerned state's stakeholders like DISCOMs in the local implementation of the scheme.

The bulk procurement strategy undertaken by EESL led to market creation for LED products, meanwhile allowing manufacturers' in the lighting business to upscale their production capacity to meet this demand growth. The major barriers to the growth of this technology regarding local standards creation, IPR costs and high investment costs were subsided through government initiation and the manufacturers' bodies itself by conducting expert workshops and seminars. A large single buyer and higher quantities of batch production brought the production costs further down. However, a few LED components are still imported and are hit by the ongoing semiconductor crisis. A viable roadmap based on increasing domestic capacity as initiated by the government of India through fiscal incentives is presented in chapter five. Furthermore, the downside of this sudden up scaling could leave many manufacturers in financial troubles at the end phases of the UJALA policy. However, the alternate market creation and technology awareness among the Indian population could sustain the market for a longer term but still a gradual phasing out of the policy is recommended by the think-tanks in the energy-efficiency field.

Which methodology would be suitable to analyze the causal factors pertaining to penetration of UJALA scheme at sub-national level?

In this research, all the 28 Indian states were selected for analyzing the penetration of ULALA scheme at sub-national level. Among these selected states, multiple states have above average LED per capita bulb distribution but, may have different policy mix characteristics and exogenous factors and can be classified as equifinality in nature. Therefore, Qualitative Comparative Analysis is recommended for this research which can involve intermediate cases approximately 5-50 cases, since for case studies, this seems to be a higher number due to the substantial knowledge required for this study and too few cases for conventional statistical techniques (Ragin, 2007). Parente and Fedro (2019) define causal complexity of an outcome to be based on three main principles ; (1) conjunction: interdependence of multiple conditions (Schneider and Wagemann, 2012) (2) equifinality: possibility of multiple pathways leading to same outcome (Gresov and Drazin, 1997), and (3) asymmetry: relation between attributes could be different or even inverse to produce the same outcome (Meyer, Tsui and Hinnings, 1993).These causal complexity principles are not captured by the correlation methodologies and hence, QCA that captures asymmetric theorizing was proposed by Charles Ragin in 1987.

What are the characteristics of the policy mix in terms of UJALA policy implementation in Indian states?

The policy mix framework proposed by Rogge & Reichardt (2016) was utilized in the research to derive the relevant causal factors that impact the penetration of UJALA policy in Indian states. Three out of the four characteristics like consistency, credibility and comprehensiveness are operationalized in the study. These factors are a combination of identified policy elements and policy strategy from the same framework itself that are also considered as causal factors for policy-inspired technology change. However, other factors are scoped out of the research to avoid the double counting in the factors' relevance.

Consistency of elements identifies the impact of policy instruments on each other. Considering UJALA policy penetration as a base, the instruments are weighted on their relative impact as positive or negative. The comprehensiveness of a policy mix is operationalized by understanding the extent of the constituent- mix of the policy mix deployed by states. The consistency measures the extent of the instruments of the policy mix whereas the comprehensiveness determines the presence of the type of instruments in the policy mix. The last characteristic is credibility that determines the dedication of the political leadership towards the policy mix. The extent of policy processes such as funding allocation and dedicated resources for energy- efficiency is considered as a credibility factor for this research. These characteristics are considered as causal factors for the LED penetration at sub-national level in India.

What are the exogenous factors that may impact the outcome of the UJALA policy implementation?

There may be factors outside the framework that may also impact the outcome of LED bulbs distribution. The three exogenous factors utilized in this research are: GDP of the states, literacy rate and percentage of electrified homes in the state. The GDP of the state determines the states' contribution in making the policy a success and might require lesser help from other funding sources. The literacy rate of the states could translate into higher uptake of newer and energy-efficient technologies by the masses. The percentage of electrified homes is considered as a quantitative measure and the relative scaling for the state playing a direct role in the UJALA bulb uptake by an Indian household. These factors are utilized as an input in the fsQCA analysis alongside the policy mix factors to understand their combined impact on the outcome of the policy.

What combination of policy mix characteristics and exogenous factors lead to higher penetration of the UJALA scheme at the sub-national level in India?

The results discussed in section 6.2 benchmark the high-performing states for their causal factor combinations to generalize the factor combination for energy-efficiency technology penetration in a developing country like India. A total of five solution pathways have been derived that result in a higher penetration of UJALA policy at sub-national levels. A higher GDP value, higher percentage of electrified homes and a high comprehensive policy mix could achieve high penetration of LED bulbs among the masses if the: (1) literacy rate is higher, (2) credibility and consistency of policy mix are low, or (3) the policy mix is highly consistent and credible as well. In addition, highly comprehensive and consistent policy mix and an absence of a credible policy mix for an Indian state can lead to a higher penetration of LED lighting in combination of either (1) higher GDP and high literacy rate, or (2) high literacy rate and higher percentage of electrified homes in absence of a high GDP value for the state. The latter configuration presents an emphasis on the policy mix characteristics and denotes their significant relationship with the outcome of the research.

The solution pathways indicate the presence of a high comprehensive policy mix to be of high significance contributing to the UJALA policy penetration in the Indian states. Furthermore, the 10 out of 11 cases displaying higher outcome values are represented by the five solution pathways. All these pathways are a combination of both policy mix characteristics and exogenous factors. The only unexplained case of Goa is not covered by these solution pathways. This state exhibits higher values of exogenous factors and very low values of policy mix characteristics. It is concluded that these higher values of exogenous conditions were sufficient to drive the higher outcome in Goa or a possibility of an additional factor not considered in this research that could have led to the favourable result in this case.

These results were further checked for robustness by varying the input factors calibration threshold points, frequency score threshold and consistency score for the solution. The variations did produce some different solution combinations in a few cases, however, they could be explained via observation and hence it could be concluded that the threshold values considered for fsQCA analysis was suitable for this research.

Main question:

How did the characteristics of the policy mix and exogenous factors pertaining to energy-efficiency influence the state-level performance of the UJALA Scheme in Indian States?

The pathways obtained as the result of the fsQCA analysis conducted as part of this research determines the combined influence of the policy mix characteristics and exogenous factors on the UJALA penetration in the Indian states. These combinations include the energy-efficiency efforts of the states as well that determine an indirect influence on the UJALA policy implementation. The solution pathways are discussed in the last sub question of this research. The combination determines the balance of each causal factor to lead to the outcome. The policymakers could utilize these combinations in future studies to examine the policy implementation in purview of an energy-efficiency policy. Given a region's exogenous conditions, the policy mix could be adjusted to the suggested pathways to achieve a better policy penetration.

7.2 Discussion

The research conducted in UJALA policy implementation and its relative penetration at state- level has resulted in solution pathways that facilitate higher penetration of UJALA policy in these areas. The pathways are analyzed in this section to understand the combination of causal conditions and their significance in driving the outcome.

The solution pathways are characterized into two ways based on the core conditions displayed by these pathways. Solutions 1, 2 and 4 represent the strong relationship between higher GDP per capita, higher percentage of electrified homes and a highly comprehensive policy mix with the outcome. These solution pathways represent eight cases out of eleven cases and could be considered the most important factors in terms of leading the penetration of an energy- efficiency policy at state-levels. Furthermore, the case of solution 1 with higher values of all exogenous factors along with a high comprehensive mix is deemed quite a significant pathway in terms of its highest frequency representation and importance of exogenous factors. Hence, the exogenous factors are considered of significant importance in this analysis alongside the policy mix characteristics in terms of penetration of energy-efficient policies. Moreover, the contradictory representation of other policy mix characteristics while combining solutions 2 and 4 could lead to their lower significance in the outcome. Also, deemed as peripheral conditions in these solutions, the combination of credible and a consistent policy mix could be deemed of less importance in this case as they exhibit weaker relationship with the outcome.

The next solution pathways 3 and 5 represent the strong relationship of a consistent policy mix and a low credible policy mix leading to the higher penetration of UJALA policy at state-level. The lower credibility displayed by the solutions could be the result of the lower participation of state institutions in the UJALA policy. The credibility factor comprises the state resources in terms of finances and human capital dedicated for energy-efficiency efforts, however the business model of the UJALA policy itself required less participation from these sources. These core conditions are aided by the peripheral conditions of exogenous factors along with the consistent policy mix that exhibit a weaker relationship with the outcome in this case. In solution 3, higher GDP per capita and higher literacy rate aid the policy mix characteristics in driving the outcome for the states. However, in solution 5, the percentage of electrified homes aid the high consistent and comprehensive policy mix towards a favourable outcome. It can be concluded that the GDP per capita and literacy rate work together and are enough to drive the outcome in this case whereas in the case of high presence of electrified homes, the high percentage of consumers eligible for the scheme are influenced by the policy mix introduced in the state and tend to buy more LED bulbs through the scheme.

7.3 Limitations

The limitations for this research are identified as following:

1. *Entire policy mix framework could not be utilized:* The entire policy mix framework of Rogge & Reichardt (2016) was not used in the study. Main emphasis was given to the policy implementation and not to the policy making process. Policy design, policy making process and advocacy may also have an impact on the final result which is not studied in the research.
2. *Limitations related to causal factors identification*: The fsQCA study typically employs five to seven factors. In our study we have applied six factors. The number of configurations generated would be 2^{K} where k denotes the number of conditions/ factors used in the analysis. Thus greater the number of factors greater the number of configurations. Thus large numbers of factors cannot be included in this study because there will be exponential increase in the number of configurations and it will be difficult to interpret the result. This signifies that there can always be factors that may be important to the study but are not included in the study.
3. *Limitations of data availability:* Some of the data available to the study were present in the binary form just stating the presence and absence condition but not the magnitude. The funding to SDAs that manage the DISCOMs and consumer awareness conduction for the energy- efficiency policies are such factors. Thus giving us the sense of the direction of

the result but not the extent of it. Availability of the data was also limited and not all the desired data was readily available.

7.4 Recommendation

The further recommendations are as follows:

The fsQCA could be verified with other complementary analysis such as case studies via interviews or quantitative analysis. The UJALA policy is believed to be the least impacted via state bodies, however, the differences in the performance in the states for the policy penetration could be attributed to their overall energy- efficiency efforts. Therefore, it is recommended that research into state capabilities for UJALA policy could be extended further with a closer look and interactions with the practitioners. This might even provide a better availability of data such as into finances utilized by the high- performing DISCOMs and low-performing state bodies.

The criticism of policy research is the lack of human factors considered into the fsQCA research. This critique holds true with the perspective of UJALA policy, given the low costs of bulbs that stimulated the market to buy them at cheaper prices, however, a state wise difference could not be observed since the prices were similar nationwide. Therefore, if the research is extended to other energy- efficiency policies following different implementation models, the low cost offering under UJALA policy should be considered to be a success factor.

A quantitative analysis is recommended as a complementary analysis to understand the relative importance of factors considered in this research. Also, the data availability has been an influential factor for the consideration of factors included in this research. Given there are different means available to extract government information such as via Right to Information (RTI) Act, however due to the time limitation, this exercise could not be carried out for this research. Therefore, for further research, the operationalization of factors could be based literally on the higher extent of data availability, thus reducing the last limitation of the type of data available for research.

7.5 Academic Contribution

This research commenced with exploration of the current available research studies in the perspectives of benchmarking UJALA policy studies. The current research available for analyzing UJALA policy is in terms of Technology Innovation Systems (TIS) framework wherein the actors, institutions and processes behind the diffusion of LED lighting in India are explored (Mir et al, 2020). However, a lack of research is noticed in terms of emphasis of the policy mix that accompanied the UJALA policy in the state-wise rollout that could be attributed for the relative difference in the penetration levels. Moreover, given the concurrent nature of the energy sector, this research objective was chosen to be significant and relevant to be explored to benchmark state impacts for successful energy- efficiency policy rollout. Alternatively, a more inclusive study of technology and policy factors could be conducted in future terms to compare and understand the relative importance of both factors and its validity for other technologies as well that might require different complementary conditions such as different light holders, etc. The study operationalizes three characteristics namely consistency, credibility and comprehensiveness of the policy mix framework adding to scientific knowledge of (Kern & Howlett, 2009; Rogge & Reichardt, 2016; Lieu et al., 2018).

The fsQCA methodology was chosen in this research to derive the combinations that lead to successful penetration of this policy as an advice for policymakers to understand the policy mix impact for a statewide policy rollout. The policy outcome could be impacted by different factors beyond the policy mix itself, hence, the inclusion of exogenous factors was considered in this research identified through literature studies. The resultant combinations did signify the impact of exogenous factors alongside the policy mix factors verifying their suitability for this research. The study of combined impact of policy mix characteristics and exogenous factors in energy efficiency lighting is considered a contribution to the existing literature of policy mix and energy efficiency.

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Appendix

Appendix A: Configurations for absence of outcome

Figure 22 presents the combinations derived in the absence of outcome i.e. cases with lower levels of UJALA policy penetration. As summarized in the "Similarity" row, none of the solutions match to the solutions present in figure 14 and hence, could be concluded that the values considered for the fsQCA analysis were suitable in the scope of this research.

Solutions for negated outcome				
	Solution 1	**Solution 2**	**Solution 3**	**Solution 4**
GDPCC	●	⨂	⨂	●
CRE	⊗	⬤	⬤	⬤
LR	●	⊗	⊗	●
CON	⨂	⊗	●	●
COM	⨂	⊗	●	●
EH	⨂	●	●	⨂
Similarity	NONE	NONE	NONE	NONE

Figure 22: Configurations for absence of outcome

Appendix B: Selection of framework

Policy Mix feedback framework

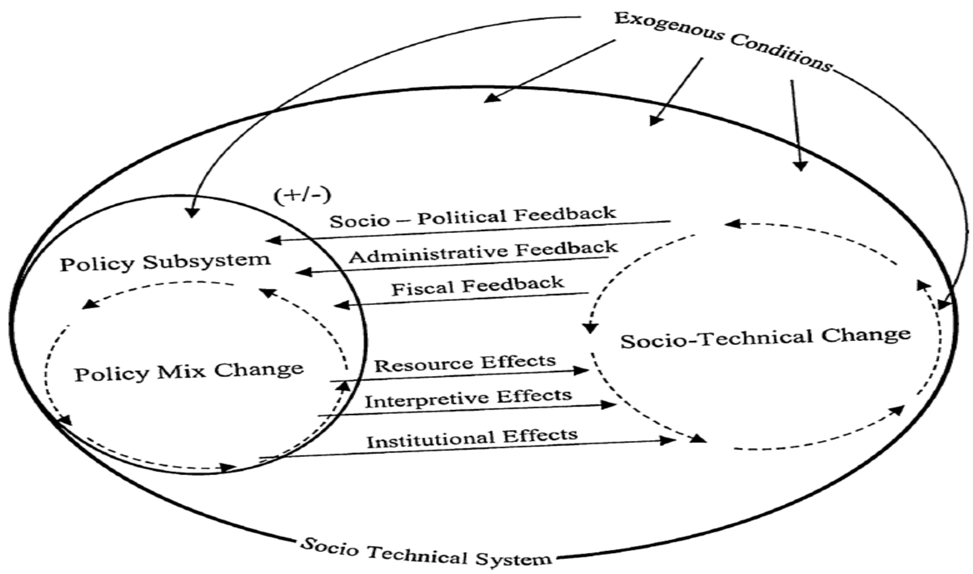

Figure 25.

Figure 6: Interaction of policy mix and socio- technical system (Edmondson, Kern, & Rogge, 2019)

This framework analyzes the co-evolution of policy mix and socio technical system. As per framework policy mix has resource, interpretive and institutional effects on the socio-technical system while socio-technical system has an indirect effect on the policy mix via policy subsystem using feedback mechanism which includes socio-political feedback, administrative feedback and fiscal feedback (Edmondson, Kern, & Rogge, 2019).

Effects of Policy mix on socio technical change : Resource effect is due to the resource the policy mix gives to the actor to carry out socio technical changes. Resources can be in the form of R&D, creating favorable market conditions (Edmondson, Kern, & Rogge, 2019). In the case of energy efficient lighting this can be related to the incentives the government is giving to the local manufacturer to set up LED bulbs production locally. In Interpretive effect the policy mix provides the actor with insight on information, changing patterns of cognition, understanding and meaning. These effects can not only influence the actors but also in turn the stakeholders. In Institutional effect the policy mix has an effect on the institutional structure like law, rule and regulation. This can have an effect on socio-technical changes.

Feedback Mechanism : Using mechanisms such as socio-political, administrative and fiscal feedback, the framework aims to recalibrate the policy mix. The feedback can be both positive and negative. Socio-political feedback concerned with whether the support for the policy mix is reinforced or undermined over time. Fiscal feedback captures the fiscal implication of the policy mix and its effects on budgets (Edmondson, Kern, & Rogge, 2019).

Selected framework

Two frameworks on policy mix considered were the policy mix for technology change and policy mix feedback for sustainable transition.

The first framework on Policy mix can be used to investigate the impact of policies on technology changes and it is very close to our research interest. The primary objective of the research is to investigate the impact of policy mix on adoption of energy efficient lighting in India and compare it at the state level. The various aspects of energy-efficient lighting in India such as policy strategy formulated by the government, long-term targets and strategies to achieve these targets can be analyzed and applied in the framework. The UJALA scheme being the central instrument, and various other supporting instruments like the electricity tariffs, fiscal measures which may be supporting or contradicting the central policy will be studied and their joint impact can be investigated. Thus the first framework helps us in answering the sub question on policy mix thereby enabling us to answer the main question.

The second framework gives more emphasis on how the policy making process can influence socio-technical change. This framework may not fully fit into our research because the research question wants to investigate the impact of the policy itself rather than the policy making process, which does not match the research objective. Thus this framework will not be considered.

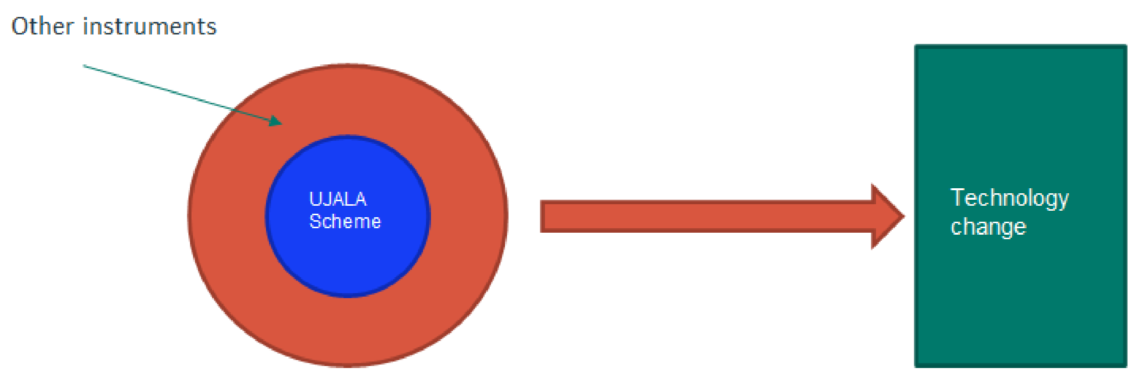

Figure 26. Policy- Mix framework adopted from first framework

Appendix C : Interview guide

Interview Guide

Research Title: Impact of policy mix on the adoption of energy-efficient lighting in India - A case study of UJALA Scheme
Researcher: Nikhil Singh
University: Delft University of Technology
Email: n.singh-4@student.tudelft.nl

Purpose of Research

In this study, the overall objective is to understand the adoption of energy-efficient lighting (LED bulbs) in different Indian states and how the policies and other exogenous factors interact with each other to influence. This exercise was carried out by exploring the relevant policy instruments with respect to the energy efficiency in India by categorizing them into various policy types such as economic instruments, regulation instruments, information and awareness policies. Once these policies are identified the next step comprises the formulation of Policy mixes as per the framework of Rogge and Reichardt (2016) by investigating how these policies interact with one another and determining the causal complexity to the resulting outcome. It additionally also identifies the various exogenous factors that may impact the final outcome i.e. total number of LED bulbs distributed per capita. Qualitative comparative analysis (QCA) will be applied across different states in India to determine the various casualty pathways to study the LED bulb distribution penetration across various states.

Policy Mix

The term and concept of 'Policy Mix' were first introduced in the economic policy literature to describe the interaction between fiscal and monetary policy (Rosenow, Fawcett, Eyre, & Oikonomou, 2016). In case of any technology change, energy-efficient lighting in our case is always subjected to different types of failures like market, instrumental, and system. These failures will hinder the new technology transition and a single policy intervention will be not effective in resolving these failures (Rogge & Reichardt, 2016). Scholars in the field of innovation and policy analysis are recommending the application of policy mix which is more pragmatic because there are always multiple policies involved and these policies interact with each other and create a combined effect. In the case of energy-efficient lighting in India, many policies were introduced, like funding, R&D, the UJALA scheme, and electricity tariffs.

The characteristic of the policy mix is consistency, coherence, credibility, and comprehensiveness. Consistency describes how well the elements of the policy mix are complementary to each other and aligned collectively to meet the objective. The extent of technology-push, demand-pull and systemic process instrument types are determined to understand their combined influence on the state's energy efficiency policy consistency. Coherence describes the systematic and synergy of the policy process which includes both policymaking and policy implementation. Credibility is also an important characteristic it is defined as at what level the policy mix is believable and reliable. The extent of State Designated Agency (SDA) funding allocation by Bureau of Energy Efficiency (BEE) and SDA staff allocation is taken as a measure of credibility for the states. Comprehensiveness describes the rigorousness of both the elements and process of the policy mix. The presence of types of policy instruments in states' energy efficiency policies is considered as a rigorous measure for comprehensiveness for that state.

In this research, the factors considered to have an impact in the context of energy-efficiency in India are

Table 17: Policy factors and its constituents

Policy Factors	**Constituents**	**Definition**
Consistency	RD&D	Initiatives of state governments to sign MOUs or provide grants to research institutes and colleges for promoting research in areas of energy efficiency technology and distribution.
	Consumer Awareness	Consumer Awareness is conducted by states for promoting energy efficiency.
	Power Tariff	Average consumer power tariff set by states.
	Energy Efficiency Potential	Energy efficiency potential and experience of DISCOMs in handling similar policies and their related influence.
	Information on tools	Extent of information provided to consumers on the electricity bill usage; comparison with peer groups, real-time monitoring.
Comprehensi-veness	Policy objective	Setting up of the State Action Plan on Climate Change (SAPCC).
	Principal plan	Legislation or policies in place to achieve targets set in SAPCC

	Technology-push instrument (RD&D)	Presence of RD&D initiatives by states.
	Demand-pull instrument (Consumer awareness conduction)	Have the states conducted consumer awareness campaigns?
	Systemic process instrument (EEP +IT)	
Credibility	SDA funding	Funding provided to SDAs by BEE for energy efficiency measures in states.
	SDA staff	Staff dedicated to energy efficiency measures by SDA.
Exogenous factors		
GDP per capita		
Literacy Rate		
Percentage of electrified households		

Appendix D: Search criteria

The primary reason for conducting a literature review is to be updated with the current state of research and to discover the knowledge gap which can be explored further. The focus of the research is to investigate the impact of policies on the adoption of energy-efficient lighting in India. Scopus is used to search for the relevant literature. To get relevant articles, the search is conducted in stages, beginning with an initial search for the keyword “energy-efficient technology” and 1447 documents are found. Next, the results are refined using the function ‘Limit to’ in scopus to bring down the count of articles. For example, only English is chosen in the language section and subject areas are limited to energy, environmental science, social science and economics. This resulted in reducing the search to 817 articles. A short examination of the articles gave a general idea on the different fields across energy-efficiency technology. One technique used to sort the articles further is to first look for the most cited articles and determine the general theme. The most cited articles on Scopus ranged from topics such as the energy-efficiency gap to residential energy-efficient technology adoption. Articles of relevance are found in the search with articles on the adoption of energy-efficient technology in households and articles on energy-efficient technology itself.

Once the basic idea of the topic is understood the search terms which were closely related to the research topic are narrowed. From desk research, it became apparent that lighting accounts for approximately 19% of the global energy consumption (Mir et al., 2020). Thus, the adoption of energy-efficient technology in the lighting sector was critical and it was interesting to investigate the status of energy-efficient lighting in households. Further research on energy-efficient lighting shows that LED was considered to be the most energy-efficient lighting technology and it was necessary for conventional lighting to be replaced with this more efficient technology. Therefore, a choice was made to focus on LED technology in this research.

India has a population of 1.3 billion people (as of 2019) and so the adoption of energy-efficient technology in India will have an enormous impact on reducing global energy consumption. Thus, the decision to choose India as the geographical location is made. Upon further research on the various LED adoption schemes across India, it became evident that the UJALA scheme is considered to be one of the biggest LED distribution schemes not only in India but the entire world (Mir et al., 2020). This scheme can be considered as the most critical scheme in the energy-efficient lighting sector in India and therefore the ideal candidate for our case study. These were the few rationales that directed both the research direction and search terms.

Further, search applications like Scopus, Google Scholar platforms were used with keywords such as“energy-efficient lighting”, “ Policy”, “adoption”, “ UJALA” and “ India” to get a more targeted outcome. Again scopus is used with the combination of “energy-efficient lighting” and “ Policy” and 54 documents were found. These documents were again scrutinized and a total of 16 articles were found relevant to adoption of energy-efficient lighting in India as well as globally.

Once an overview of energy-efficient technology with emphasis on energy-efficient lighting was done, the focus shifted towards policies and its impact on energy-efficiency. From the literature it is clear that multiple policies are involved and have a combined effect on any technology (Rogge & Reichardt, 2016). Policy mix was one such concept that would aid towards exploring the interaction of policies . Scopus is used with the keyword "Policy mix" AND " energy efficiency" to get more focused information on literature. Articles ranging from policy analysis, innovation studies and environmentals economics were found. From the study, it was evident that the policies interact with one another and the boundaries were clouded. Therefore, the interaction of policy mix with the UJALA scheme was selected as the area of research for our case study.

Appendix E: Dataset derivation for policy characteristics

Consistency

Table 18: Constituents of Consistency score

States	RD&D	CA conducted	EEP+IT	PT
AndhraPradesh	YES	YES	LOW	HIGH
ArunachalPradesh	NO	YES	LOW	LOW
Assam	NO	NO	HIGH	HIGH
Bihar	NO	YES	LOW	LOW
Chhattisgarh	NO	YES	LOW	LOW
Goa	NO	NO	LOW	LOW
Gujarat	NO	YES	LOW	LOW
Haryana	YES	YES	HIGH	HIGH
HimachalPradesh	NO	NO	HIGH	LOW
Jharkhand	NO	YES	LOW	HIGH
Karnataka	NO	YES	HIGH	HIGH
Kerala	YES	YES	HIGH	HIGH
MadhyaPradesh	NO	YES	HIGH	HIGH
Maharashtra	YES	YES	HIGH	HIGH

States	RD&D	CA conducted	EEP+IT	PT
Manipur	NO	NO	LOW	LOW
Meghalaya	YES	NO	LOW	LOW
Mizoram	NO	YES	LOW	HIGH
Nagaland	NO	YES	LOW	HIGH
Odisha	YES	YES	HIGH	LOW
Punjab	YES	YES	HIGH	HIGH
Rajasthan	YES	NO	HIGH	LOW
Sikkim	NO	YES	LOW	LOW
TamilNadu	NO	NO	LOW	HIGH
Telangana	NO	YES	LOW	LOW
Tripura	NO	YES	LOW	HIGH
UttarPradesh	NO	NO	HIGH	LOW
Uttarakhand	NO	YES	LOW	LOW
WestBengal	NO	NO	LOW	HIGH

Table 19. Consistency score calculation

States	RD&D	CA conducted	EEP+IT	PT	Consistency score
Andhra Pradesh	0.45	0.225	0	0.22	0.9

States	RD&D	CA conducted	EEP+IT	PT	Consistency score
				5	
Arunachal Pradesh	0	0.225	0	0	0.2
Assam	0	0	0.1	0.225	0.325
Bihar	0	0.225	0	0	0.225
Chhattisgarh	0	0.225	0	0	0.225
Goa	0	0	0	0	0
Gujarat	0	0.225	0	0	0.225
Haryana	0.45	0.225	0.1	0.225	1
Himachal Pradesh	0	0	0.1	0	0.1
Jharkhand	0	0.225	0	0.225	0.45
Karnataka	0	0.225	0.1	0.225	0.55
Kerala	0.45	0.225	0.1	0.225	1
Madhya Pradesh	0	0.225	0.1	0.225	0.55
Maharashtra	0.45	0.225	0.1	0.225	1
Manipur	0	0	0	0	0
Meghalaya	0.45	0	0	0	0.45

States	RD&D	CA conducted	EEP+IT	PT	Consistency score
Mizoram	0	0.225	0	0.225	0.45
Nagaland	0	0.225	0	0.225	0.45
Odisha	0.45	0.225	0.1	0	0.725
Punjab	0.45	0.225	0.1	0.225	1
Rajasthan	0.45	0	0.1	0	0.55
Sikkim	0	0.225	0	0	0.225
Tamil Nadu	0	0	0	0.225	0.225
Telangana	0	0.225	0	0	0.225
Tripura	0	0.225	0	0.225	0.45
Uttar Pradesh	0	0	0.1	0	0.1
Uttarakhand	0	0.225	0	0	0.225
West Bengal	0	0	0	0.225	0.225

Table 20. Weights allotted to factors considered in consistency score

Points Legend:	
RD&D	0.45
CA	0.225

PT	0.225
EEP+IT	0.1

Credibility

Table 21. Credibility score calculation

States	**SDA funding (2012-2016)**	**SDA funding (2017-2018)**	**SDA fund total**	**SDA Staffing**	**Fund**	**Staff**	**Credibility score**
Andhra Pradesh	350.33	50	400.33	8	HIGH	HIGH	1
Arunachal Pradesh	248.31	192	440.31	6	HIGH	LOW	0.5
Assam	315.5	0	315.5	7	LOW	HIGH	0.5
Bihar	308.53	50	358.53	4	HIGH	LOW	0.5
Chhattisgarh	330.29	111.9	442.19	8	HIGH	HIGH	1
Goa	178.59	0	178.59	2	LOW	LOW	0
Gujarat	309.79	25	334.79	8	LOW	HIGH	0.5
Haryana	268.5	24.34	292.84	5	LOW	LOW	0
Himachal Pradesh	220.79	0	220.79	3	LOW	LOW	0
Jharkhand	216	55.6	271.6	6	LOW	LOW	0
Karnataka	371.5	195	566.5	7	HIGH	HIGH	1

States	SDA funding (2012-2016)	SDA funding (2017-2018)	SDA fund total	SDA Staffing	Fund	Staff	Credibility score
Kerala	360.41	184.1	544.51	13	HIGH	HIGH	1
Madhya Pradesh	430.16	15	445.16	8	HIGH	HIGH	1
Maharashtra	494.16	190	684.16	16	HIGH	HIGH	1
Manipur	89.29	0	89.29	3	LOW	LOW	0
Meghalaya	249.1	0	249.1	4	LOW	LOW	0
Mizoram	246.16	89.5	335.66	4	LOW	LOW	0
Nagaland	272.86	96	368.86	6	HIGH	LOW	0.5
Odisha	296.16	38.4	334.56	6	LOW	LOW	0
Punjab	340.41	145	485.41	8	HIGH	HIGH	1
Rajasthan	353.41	0	353.41	8	LOW	HIGH	0.5
Sikkim	182.5	73	255.5	5	LOW	LOW	0
Tamil Nadu	339.41	0	339.41	4	LOW	LOW	0
Telangana	47	159	206	6	LOW	LOW	0
Tripura	262.5	25	287.5	8	LOW	HIGH	0.5
Uttar Pradesh	428.79	0	428.79	4	HIGH	LOW	0.5
Uttarakhand	259.91	137	396.91	7	HIGH	HIGH	1

States	SDA funding (2012-2016)	SDA funding (2017-2018)	SDA fund total	SDA Staffing	Fund	Staff	Credibility score
West Bengal	360.16	0	360.16	5	HIGH	LOW	0.5

Each factor is provided equal weightage here and the point score corresponds to “0.5” for each HIGH and “0” for each “LOW” value.

Comprehensiveness

Table 22. Comprehensiveness score calculation

States	Policy Objective defined	Principal Plan	Technology-push	Demand-pull	Systemic Process	Comprehensiveness
Andhra Pradesh	ABSENT	PRESENT	PRESENT	ABSENT	PRESENT	3
Arunachal Pradesh	ABSENT	ABSENT	PRESENT	ABSENT	PRESENT	2
Assam	ABSENT	ABSENT	ABSENT	PRESENT	PRESENT	2
Bihar	ABSENT	Under-development	PRESENT	ABSENT	PRESENT	2.5
Chhattisgarh	ABSENT	ABSENT	PRESENT	ABSENT	PRESENT	2
Goa	ABSENT	ABSENT	ABSENT	ABSENT	PRESENT	1
Gujarat	ABSENT	PRESENT	PRESENT	ABSENT	PRESENT	3
Haryana	ABSENT	PRESENT	PRESENT	PRESENT	PRESENT	4
Himachal Pradesh	ABSENT	PRESENT	ABSENT	PRESENT	PRESENT	3

States	Policy Objective defined	Principal Plan	Technology-push	Demand-pull	Systemic Process	Comprehensiveness
Jharkhand	ABSENT	PRESENT	PRESENT	ABSENT	PRESENT	3
Karnataka	Under-development	Under-development	PRESENT	PRESENT	PRESENT	4
Kerala	Under-development	Under-development	PRESENT	PRESENT	PRESENT	4
Madhya Pradesh	ABSENT	ABSENT	PRESENT	PRESENT	PRESENT	3
Maharashtra	ABSENT	PRESENT	PRESENT	PRESENT	PRESENT	3
Manipur	ABSENT	PRESENT	ABSENT	ABSENT	PRESENT	2
Meghalaya	ABSENT	ABSENT	ABSENT	ABSENT	PRESENT	1
Mizoram	ABSENT	PRESENT	PRESENT	ABSENT	PRESENT	3
Nagaland	ABSENT	PRESENT	PRESENT	ABSENT	PRESENT	3
Odisha	ABSENT	PRESENT	PRESENT	PRESENT	PRESENT	4
Punjab	ABSENT	PRESENT	PRESENT	PRESENT	PRESENT	4
Rajasthan	ABSENT	ABSENT	ABSENT	PRESENT	PRESENT	2
Sikkim	ABSENT	ABSENT	PRESENT	ABSENT	PRESENT	2
Tamil Nadu	ABSENT	PRESENT	ABSENT	ABSENT	PRESENT	2
Tripura	ABSENT	ABSENT	PRESENT	ABSENT	PRESENT	2

States	Policy Objective defined	Principal Plan	Technolog y-push	Demand-pull	Systemic Process	Comprehe nsiveness
Uttar Pradesh	ABSENT	ABSENT	ABSENT	PRESENT	PRESENT	2
Uttarakhand	ABSENT	PRESENT	PRESENT	ABSENT	PRESENT	3
West Bengal	ABSENT	PRESENT	ABSENT	ABSENT	PRESENT	2

Table 23. Points basis for comprehensiveness score

Points Legend:	
5	All Present
4	4 factors present
3	3 factors present
2	2 factors present
1	1 factor present
0.5	Under- development
0	All Absent