LUT University, School of Engineering Science

Industrial Engineering and Management, Global Management of Innovation and Technology (GMIT)

Author: Shandra Pandey

Master’s Thesis, 2019

Energy Systems Spillovers and Willingness to Change: A Focus on the Oil Sands Region in Alberta

Supervisor(s): Professor Ville Ojanen, Lappeenranta – Lahti University of Technology (LUT)

External Supervisor: Professor P. Devereaux Jennings, University of Alberta, Canada
ABSTRACT

Author: Shandra Pandey

Title: Energy Systems Spillovers and Willingness to Change: A Focus on the Oil Sands Region in Alberta.

Year: 2019 Place: Vantaa

Type: Master’s Thesis. LUT University, School of Engineering Science, Global Management of Innovation and technology

Specification: 127 pages including 1 appendix, list of abbreviations, tables, figures, and images

1st Supervisor/Examiner: Professor Ville Ojanen, 2nd Examiner: Professor Leonid Chechurin

Keywords: Energy Transition, Social Technical Systems, Energy Sustainability, Energy Technology, Spillover Effects, Resistance for Change, Future Energy Systems.

In this thesis, I examine how communities and their members in oil dependent communities perceive energy system spillovers and their willingness to change. Spillovers from energy systems, in the form of GHGs, remediation costs, and local health risks, are considered critical elements to make endogenous to economic decision if the planet is to combat climate change.

The nature of these spillovers in local communities has been partially documented, but less attention has been given to the behavioral components; i.e., to the perception of them and their riskiness and whether such perception is connected to a willingness to change. This is particularly critical for communities in regions dependent on carbon production, because such communities have long been the bulwark against change. In this regard, this study examines communities in Alberta Canada, a province heavily dependent on oil and natural gas.

Through informal interviews, participation in “Future Energy Systems” projects, and survey of three local communities – two without renewable energy and one with substantial renewables, I discovered more willingness and readiness to change than might be apparent from the outside. It would seem that some additional “nudge” incentives might be needed to aid that transition.
ACKNOWLEDGEMENTS

First of all, I would like to thank “University of Alberta” and “Future Energy Systems” faculty and project team members for giving me this excellent opportunity to be a part of this grand project. Especially, I would like to thank Professor Dev. Jennings from University of Alberta for his guidance and sharing knowledge throughout this thesis process. Under Professor Dev, guidance and supervision I have learned and explored new skills which I believe is truly rewarding at the end of this thesis journey. Then, I would like to thank Sarah Wilkinson (Research Program Manager and Co-Coordinator in FES project) and Debbie Giesbrecht (PhD Program Administrator) from University of Alberta for their assistance and support which I sincerely appreciate.

I also would like to thank Prof. Ville Ojanen for his support, guidance, and mentorship during the master’s degree journey and for thesis supervision.

I would like to express my special thanks to Docent (Adjunct Prof. Imran Asghar) from Aalto University for his encouragement and fruitful discussions on the new energy technologies.

Last but not least I would like to thank my colleagues, friends, and my siblings for their constant support and encouragement. I also want to say thank you to my nieces Aashna and Serena and my nephew Abhinav for cheering me up with your innocent and sweet talks.

I would like to dedicate this thesis to my beloved Father and Mother.
TABLE OF CONTENTS

1. INTRODUCTION .................................................................................................................. 8
  1.1 PROBLEM STATEMENT ................................................................................................... 8
  1.2 Goal and Design of the Thesis ....................................................................................... 10
  1.3 Limitation of the Research ........................................................................................... 11
  1.4 Organization of Thesis .................................................................................................. 11

2. LITERATURE REVIEW ......................................................................................................... 15
  2.1 The Transitions to Renewable Energy ........................................................................... 15
  2.2 Climate Change and Planetary Boundaries .................................................................. 17
  2.3 STS and Behavioral Modifications ................................................................................ 18
    2.3.1 A Systems View of Sustainability ......................................................................... 18
    2.3.2 Measuring Sustainability of the Systems ................................................................. 20
    2.3.3 Socio-Tech Systems (STS) ....................................................................................... 23
    2.3.4 Learning and Dynamism ........................................................................................ 24
    2.3.5 Local System Resistance ........................................................................................ 25

3. EXAMINING A LOCAL LEGACY AND LOCAL NEW ENERGY SYSTEM .................. 29
  3.1 Overview on Canada Energy Systems ........................................................................... 29
  3.2 Design and Choice of Local Legacy Vs. New Energy System by Community .......... 32
    3.2.1 Oil and Natural Gas .................................................................................................. 34
    3.2.2 Hydro Energy ......................................................................................................... 41
    3.2.3 Bio-fuel Energy ...................................................................................................... 45
    3.2.4 Wind Energy ......................................................................................................... 48
    3.2.5 Solar Energy ......................................................................................................... 53
    3.2.6 Geothermal Energy ............................................................................................... 57

4. RESEARCH DESIGN ........................................................................................................... 63
  4.1 Research Context and Hypotheses ............................................................................... 63
  4.2 Data Collection .............................................................................................................. 63
  4.3 Methodologies .............................................................................................................. 65

5. RESULTS ANALYSIS AND DEMILITATIONS ............................................................. 67
  5.1 Descriptive Statistics .................................................................................................... 67
  5.2 Association between the Variables .............................................................................. 72
5.3 Model(s), Results and Interpretations .................................................................77
5.4 Future Energy System Preference......................................................................82
6. FINDINGS AND DISCUSSION...............................................................................87
   6.1 Recognizing Spillover Effects ..........................................................................87
   6.2 Environmental Interdependency.......................................................................88
   6.3 Willingness to Change and Satisfaction Level ..................................................88
   6.4 Legacy System VS New Energy System...........................................................90
   6.5 Future Energy System Concerns.......................................................................91
   6.6 Community Based Design Model & Future Recommendations......................93
7. Conclusion .............................................................................................................96
REFERENCES.............................................................................................................97
Appendix 1...............................................................................................................123
LIST OF ABBREVIATIONS

1. Alberta Electric System Operator (AESO)
2. Canada Oil Sand Innovation Alliance (COSIA)
3. Carbon di-oxide (CO2)
4. Chlorofluorocarbon (CFCs)
5. Conferences of the Parties (COPs)
6. Dichlorodiphenyltrichloroethane (DDT)
7. Green House Gases (GHG)
8. Intergovernmental Panel on Climate Change (IPCC)
9. International Energy Association (IEA)
10. Large Technical Systems (LTS’s)
11. Life Cycle Assessment (LCA)
12. Methane (CH4)
13. Nitrogen Oxide (N2o)
14. Not in My Back Yard (NIMBY)
15. Planetary Boundaries (PB’s)
17. Social Development (SD)
18. Social Development Goal (SDG)
19. Social Technical Systems (STSs)
20. Tera Watt Hour (TWh)
21. United States (U.S)
22. World Energy Council (WEC)
23. World Health Organization (WHO)
LIST OF FIGURES

Figure 1: Renewable Energy Technology Growth
Figure 2: The Worldwide Consumption of Energy
Figure 3: Planetary Boundaries
Figure 4: A Simple System
Figure 5: Prevalent Model of Sustainability
Figure 6: An STS View
Figure 7: Canada Energy Generation by Sources
Figure 8: Alberta power mix as of March 2019
Figure 9: Alberta Energy Distribution by Sector
Figure 10: Oil and Gas Spillover effects
Figure 11: Hydropower Spillover and Resistance
Figure 12: Spillover Effects of Bioenergy
Figure 13: Energy Nexus
Figure 14: Wind Energy Spillovers Effects
Figure 15: Solar Energy Spillovers Effects
Figure 16: Geothermal Energy Spillovers
Figure 17: Current Sources of Heating System
Figure 18: Current Satisfaction Level of Participants
Figure 19: Willingness to Change
Figure 20: Key Parameters for Change
Figure 21: Future Energy System Preference
Figure 22: Concern or Positive Impacts on Communities
Figure 23: Factors to Determine Change

**LIST OF IMAGES**

Image 1: Tailing ponds problem covering land area

Image 2: Trans Mountain project

Image 3: Spillover Effects of Hydropower Dam

Image 4: Killing and Migration of birds

Image 5: Wind Turbine on Fire

Image 6: Geothermal Sites

**LIST OF TABLES**

Table 1: Input-Chapter-Output

Table 2: Views of Spillovers

Table 3: Oil Spills Across Alberta from 2011-2019

Table 4: Data Collection

Table 5: Table of Descriptive Variables

Tables 6: Table of Correlations

Table 7: Model 1 Summary

Table 8: Model 2 Summary

Table 9: Model 3 Summary

Table 10: Model 4 Summary

Table 11: Model 5 Summary
1. INTRODUCTION

1.1 PROBLEM STATEMENT

The conventional energy paradigm is losing its legitimacy in many parts of the world due to the increasing number of environmental problems associated with climate change (Joo, et al., 2018). The traditional role held by fossil fuels, which dominated the energy economics of the 19th and 20th century has been challenged. Coal has been dispensed with by most nations of the Europe (Carley, et al., 2018; Rentier, et al., 2019) and is on the retreat in the United States (U.S) and China (Sadamori, 2018). Oil prices have dropped dramatically from 2014 high and oil exploration has slowed. Natural gas, gathered from fracking, has supplanted some of these other sources. But even in countries in the EU with fracking, such as Poland, or in the U.S., natural gas development has been paralleled by the development of non-carbon sources, such as solar, hydro, geothermal and wind. As part of this shift in energy systems, countries are in the process of deregulating and restructuring power industries in order to allow for more innovation and integration. The shift towards the renewable, energy-efficient and low carbon technologies with the least impact on the environment has become the high priority to developing the energy policy strategies on a global scale (Rogelj, et al., 2018) (IEA, 2017). More than a century’s work of science and technology research exists on these varieties of power systems, including research on solar, wind, and geothermal. Indeed, the core technologies themselves are quite old. What is less clear is the behavioral underpinnings of their adoption, and hoped-for usage across societies (Ntanos, et al., 2018; Zografakis, et al., 2010). Socio-technology approaches to systems theory (STS) have been developed to understand the societal and individual factors that might stimulate adoption of new energy technologies (Baxter & Sommerville, 2011; Sovacool & Geels, 2016). A key element of the STS approach is to consider the social actors at different actors in the technical system, isolate leverage points, and then develop policies or economic incentives to induce (incentivize or nudge) change (Davis, et al., 2014). In this thesis I draw on this STS approach to help understand energy transitions.
Spillovers and Transitions: One area that interests me greatly and appears to be an important concern for STS and energy transitions, is spillovers. Spillovers refer to the unintended consequences of action in a system that are not accounted for economically or technologically, by the current system’s operation. Technologically, the spillover is deemed a “knock-on” or “secondary” effect; economically, it is an “externality” to the market. In both cases, the impacts are not directly (or easily dealt) within the system. These externalities are either ignored or not properly taken into account by policymakers, environmentalist or innovator (The Royal Swedish Academy of Sciences, 2018).

Spillovers, however, accumulate (The Royal Swedish Academy of Sciences, 2018), become visible, and cause events - even crises (Hoffman & Jennings, 2018). The cumulative effect of dichlorodiphenyltrichloroethane (DDT) (Maguire & Hardy, 2009) of chemicals plant operations that lead to Bhopal (Broughton, 2005), and of nuclear waste (Ramana, 2018) have stimulated action in the past. One can presume that spillovers will continue to do so in the future; i.e., they will be an important driver for the movement from traditional, carbon energy system to newer, renewable (or at least mixed) ones. However, most climate scientists point out the global warming problem does not fit well within a standard spillover-response framework (Stockholm Institute, 2017). The impact of GHG accumulation is lagged by decades and by the time it leads to a highly noticeable rise in temperature or change in ocean levels, it will be too late to change (IPCC, 2018) Therefore, it becomes critical to identify and amplify spillover effects earlier in energy systems if they are to transition to new ones.

Resistance in Local Energy Systems: A related concern about spillovers from traditional energy systems is not only their lag effect but that the felt impact locally is likely to be dampened – or even resisted. Systems are complex and entwined (Von Bertalanfy, 1968). The economic and technological system of any nation, when looked at in the microcosm of community, is reflected in the routines of its residents, the operation of local industry, and the provision of services by local governments. This day-to-day activity is a source of great resilience in any system, but also a source of inertia.
Any macro attempt in educating a populace to change their habit or regulating them to adopt new practice must be translated into more local and micro action (Lee & Lounsbury, 2015). That micro action has to be generated via awareness of issues and a willingness to change, even before resource and regulatory requirements lead to those changes (Delmas, et al., 2013) Without shifting of the cultural bedrock, it is unlikely the more macro changes will ever be established.

1.2 Goal and Design of the Thesis

The goal of this thesis is to examine how human actors embedded in local communities dependent on GHG producing activities perceive their actions and whether they display much willingness or readiness to change. Without this local recognition and readiness, it would seem very difficult to translate macro policy into micro action, especially if many recommendations are only voluntary, as they currently are under the Paris Accord.

The design of the thesis is to review literature on, energy transition and driver for change, energy systems, and their spillovers effects, along with social - technical behavioral issues on local energy system transitions. I then investigated the degree of local awareness of some of these factors and the willingness to change. I did that by focusing on an energy- producing and energy-dependent locale: Alberta, Canada. Preliminary data was collected on individual’s view of energy system usage in two matched, proximate communities: one group relying on more traditional (fossil fuel) heating systems, and the other on newer (renewable) heating systems. Through my review and examination of the data plus interviews with some of the respondents, I will be able to speak to mechanisms for change and offer a few suggestions about modifying or at least contextualizing them further. The main research questions of this study are presented below.
Research Question(s)

Research question 1: What is the locale awareness of the issue of spillover effects and local energy transition?

Research question 2: How willing community members are to perceive energy system change?

1.3. Limitation of the Research

The thesis has following limitations:

- This study primarily focused on the Alberta oil sand region. The spillover effects were framed to highlight the most prevalent issues in the oil sand region. Desktop studies were carried out to examine the spillover effects of energy system.

- For this study, primary data is collected from three proximate communities in Alberta i.e. Okotoks (OKO), Black Diamond (BD), and High River Valley (HR). The communities were selected based on the source of heating systems (renewable vs non-renewable energy sources).

1.4. Organization of Thesis

This thesis is comprised of the seven chapters including table of content, list of figures, list of tables, list of images, list of abbreviations and an appendix 1. Table 1 presents an input-chapter-output table. The first chapter describes the problem statement, design and scope of the thesis. Besides, it also describes the limitation and the organisation of the thesis. In Chapter 2, Literature Review was carried out to gather information on the key drivers of the energy transition, its limitations and the main challenges for the smooth and sustainable energy transition. The outcome of this chapter is conceptualised energy transition from social- technical and behavioral science perspectives.
Chapter 3 Examining A Local Legacy and Local New Energy System. This chapter describes the energy systems, and their spillover effects, along with issues on legacy and new energy systems transitions. Then after behavioral elements were incorporated to understand the locale awareness on the spillover effects. The energy resources covered in this thesis are fossil fuels (oil and natural gas) energy sources, hydropower, biofuels, wind energy, solar energy and, geothermal energy. The outcome of this chapter was why there is resistance to adopt a new energy system fully? What do individuals say? What does the community say?

Chapter 4 presents the Research Design. This chapter describes the research context, hypotheses, data collection methods, methodological choices to interpret the data in a logical manner.

Chapter 5 Results, Analysis and Delimitation, this chapter presents the results in a detailed and concise form. Both qualitative and quantitative methods have been used in this study. Statistical data is analysed using the descriptive method, table of correlations and binomial logistic regression models. Also, delimitation was set due to the small sample size. The outcome of this chapter presents the main results of this study. The results were broken down into different sections and sub-sections to explain each step in a systematic and holistic manner.

Chapter 6 Findings and Discussion. This chapter presents the main Finding and Discussion on each of the findings in an elaborated manner, and also suggest mechanisms for change and offer suggestions to contextualizing them for the future work in the same domain. Chapter 7 concludes and summarizes the thesis. Table 1 presents systematic presentation of the thesis.
### Table 1: Input-chapter-output

<table>
<thead>
<tr>
<th>Input</th>
<th>Chapter</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem Statement</td>
<td>INTRODUCTION</td>
<td>Goal and Design of the Thesis Including, Scope and Delimitations</td>
</tr>
<tr>
<td>Literature Review on Main Drivers of Energy Transition, Measuring</td>
<td>LITERATURE REVIEW</td>
<td>Social - Technical Theory to Conceptualize Transition</td>
</tr>
<tr>
<td>Sustainability from System Thinking Perspectives</td>
<td></td>
<td>Energy Systems Boundaries</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Causal Relationship</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Behavioral Elements for Endogenous Growth</td>
</tr>
<tr>
<td>on Energy Transition, Spillover Effects of Legacy Systems and New</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Technologies. Incorporating Behavioral Elements to Examine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Locale Awareness on The Spillover Effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Research Context, Methodological Choices, Data Collection Method,</td>
<td>RESEARCH DESIGN</td>
<td>Description of Research Context, Hypotheses, Data Collection and</td>
</tr>
<tr>
<td>Data Analysis and Delimitation</td>
<td></td>
<td>Methodologies Used in the Study</td>
</tr>
<tr>
<td>Collecting Data by Conducting Informal Interviews/Survey from Local</td>
<td>RESULTS ANALYSES AND DELIMITATIONS</td>
<td>Constraint(s) to Adopt a Change</td>
</tr>
<tr>
<td>Populace Delimitation for The Statistical Analysis</td>
<td></td>
<td>Perceived Difference Between the Communities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Future Energy System Preference and Communities Concern</td>
</tr>
<tr>
<td>Locale Awareness of Spillover Effects</td>
<td>FINDING, DISCUSSION AND RECOMMENDATION</td>
<td></td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>----------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Environmental Dependency</td>
<td>The Spillover Effect of New Energy Technologies Are Not Recognized by Local Community Individuals.</td>
<td></td>
</tr>
<tr>
<td>Willingness to Change</td>
<td>Reliability and Efficiency Have A Causal Effect on Environment Degradation</td>
<td></td>
</tr>
<tr>
<td>Future Energy System Concerns</td>
<td>Individuals Current Heating System Satisfaction Level Determines their Future Energy System Preferences</td>
<td></td>
</tr>
<tr>
<td>Community Based Design Model</td>
<td>Mechanism for Change</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Result Assessment</th>
<th>CONCLUSION</th>
<th>Summary of The Results and Concluding Remark</th>
</tr>
</thead>
</table>
2. LITERATURE REVIEW

2.1 The Transitions to Renewable Energy

There is an increasing use of renewable energy transition from the use of carbon to the use of more renewable energy. As can be seen in Figure 1, the uptake of solar power has been particularly remarkable. This increase has been notable in northern Europe, the US, and China; China now leads the world in the month-to-month installation of new solar arrays (IEA, 2017).

![Renewable electricity capacity growth by technology](image_url)

*Figure 1: Renewable Energy Technology Growth*  (IEA, 2017)

At the same time, the world as a whole has increased its use of all forms of power. Thus, the relative use of renewable energy is lower than it might appear. Figure 2 displays these figures. We can see that oil and natural gas still account for the bulk of energy, followed by coal and, more distantly, by hydro.
Therefore, at the moment, it appears that the transition to renewable energies is more of a transition to mixed energy use, and a slow abandonment of coal. There are many theoretical studies on energy transition that predicts (B.P p.l.c, 2019; Global Energy Perspective 2019) the share of energy mix will rise in next coming years. “The energy industry is facing decades of transformation” which are complex and perplexed in nature (Gray, 2017).

Replacing the hydrocarbon with zero emission energy sources requires fundamental changes in the efficiency, storage, transmission, distribution and consumption of the system (IRENA, 2019). From the output perspective it has fundamental effect on the energy dynamics. One of the valuable and disruptive effect of renewable based energy system is to meet the end demand (consumers demand) meaning, the electrical energy storage can seamlessly match load, generation, and deliver services to support and stabilize the grid. Although, the renewable energy systems have unlocked the new potential by enabling dispersed energy systems, meaning that one large unit is substituted by many small units (Lopez, et al., 2012) but it has serious implication on infrastructure, and which is a costly and a lengthy process. Rotmans et al.; (2001), states that energy transition is a social, institutional and transformation processes in which
system transforms structurally over an extended period of time (Rotman & Kemp, 2003). As a result, it is probably more accurate to consider this pattern of adoption as slow -much slower, as we shall see than climate change scientists would hope.

2.2. Climate Change and Planetary Boundaries

The changes refer to the consequences of global warming through increased in GHG concentration in particular, increased level of CO2, in the atmosphere (Riebeek & Robert, 2010). Several studies have been conducted to warn the irreversible effects of climate change such as global temperature rise, shrinking ice sheets, warming oceans, sea-level rise, melting snow in northern hemisphere, ocean acidification (Nasa.org). These impacts of climate change are rapid and compelling. Many scientists predict that if fossil fuels consumption continues to grow at the present trend then the earth's temperature may increase between 2°C and 6°C by the end of 21st century (Riebeek & Robert, 2010). In ecosystems terms, because of the entwined nature of planet’s various ecologies, climate change can be conceptualized as one of the planetary boundaries (PBs) that signal’s that overall ecosystem is in trouble (Rockstrom et al, 2009).

When defining the sustainability, the PBs are significantly important. The planetary boundaries pose a significant threat to the nature as well as the economic prosperity and human wellbeing. Each planetary boundary represents a threshold that cannot be safely crossed without consequences of the ecosystem. Figure 3 depicts these PBs (Röckström, et al., 2009).
As can be seen in the figure, the increased use of carbon fuels – through the GHG they create – and pushed our biodiversity into the yellow zone of climate change. Still, as can also been seen, climate change is just one of the several environmental issues facing humanity in the current era – and perhaps less dire at the moment than biochemical degradation and despeciation. These other two dimensions, nevertheless, are known to be affected by climate change. So, addressing GHG production via energy systems would certainly benefit other areas of the planet’s health.

2.3 STS and Behavioral Modifications

2.3.1 A Systems View of Sustainability: Sustainability is a system-based concept which is far more complex to understand. Von Bertalanffy (1968) initially proposed the system theory. The idea behind system theory is that system cannot serve its real purpose by isolating component within a system. This theory suggests investigating every component individually and their interconnection within the system to understand the behaviour of the system as a whole and explore problems and their causes. Systems are comprised of subsystem entities that make up more extensive system (Bertalanffy , 1968).
An example of a simple system is in Figure 4 below. It shows that there are inputs, throughputs, and outputs and a feedback loop. This is a standard “cybernetic” system, with a first-order loop for learning (Reidl- Knez, et al., 2006). More complex systems are built by stacking and interacting these systems, each with its own loops of operation that interact virtuously (or viscously) with other loops (Marshall & Brown, 2003).

Ecosystems are complex forms of systems, ones that have some degree of equilibrium across their cycles and also are characterized by different aggregate entropies (Meadows, 2008). Healthier systems are deemed to have a balance, a possibility of building up more entropy, and also resilience to entropic drops.

This simple system in Figure 4 and the underlying idea about complex systems fits well with the notion of Planetary Boundary (PB) depiction in Figure 3. The PBs reflect aggregate systems health along different dimensions. When entropy is being lost and/or fundamental subsystems are being damaged, then the planetary threshold is crossed (Farley, 2012). The carbon exchange subsystem for the planet, which influences (and is part of) photosynthesis and other critical
processes, is directly affected by the GHG production from carbon-based energy systems (Carnegie Institution, 2010). Therefore, some form of systems thinking is useful for considering these unintended spillover effects. It helps us to isolate subsystems, loops, and critical thresholds. In general, systems are adaptive, complex and unpredictable. The systems have the ability to self-organizing behavior and absorb external pressure (Taysom & Nathan, 2018) (Fiskel, 2003) to survive in an unexpected circumstance. However, a system may become vulnerable to unforeseen situation that can cause disaster (National Academic Press, 2015).

Engineered systems are designed to reliably perform task with a predictable outcome. However, there are several undesirable situations that may occur due to unexpected events that can cause determinantal effects on the large systems. Although some systems have self-healing or self-organizing capabilities that maintains the equilibrium, but ecological systems are not capable to confront any extreme behaviour for a longer period of time (Taysom & Crilly, 2017). Therefore, it is important to illustrate “mental map” model in a behavioral pattern to make more resilient systems. Resilient systems have the ability to prepare to absorb impact, threats and recover and adapt from disruptive events or persistent stress (Marchese, et al., 2018).

2.3.2 Measuring Sustainability of the Systems: The notion of sustainable development has gained attention after the publication of Brundtland report. “our common future”. As per Brutland definition (1987), “sustainability is the integration of economic, social and environmental systems to enhance the quality of life within the earth carrying, regenerating, and assimilating capacity”. Many scholars, and, practitioners are looking better ways to define sustainability (Adetunji, et al., 2003). Sustainability represents three basic pillars i.e. social, economic and environmental. This pillar symbolises “people, planet and prosperity” (Moldan, et al., 2012).
The term sustainability is so widespread that now it is taken as common sense to inevitably practice into different business sectors, in strategic planning and in government policies. Various indicators are developed to measure and monitor the social, environmental and economic sustainability of system. The basic pillars/dimensions of sustainability are basically defined as:

(i). Environmental sustainability is defined as a status quo of parity, resilience, and interdependence that allows mankind to satisfy their needs without transcending the boundaries of its life supporting ecosystems and at the same time persevere to regenerate necessary services to meet needs without diminishing the biological diversity (Morelli, 2011).

(ii). Social Sustainability is generally comprised of processes (formal and informal), systems, its structures, and relationships with the larger system to actively support and create healthy communities. Social sustainability is basically a combination of design of the physical realm with the social world. It provides an infrastructure to support social, cultural and social amenities (ADEC Innovations, 2019).

(iii). Economic sustainability is an integral part of the sustainability which mean that mankind must use, protect, sustain and optimize resources to create long-term sustainable values by recycling and recovering resources. (Löf, 2018).

When measuring the sustainability each pillar/dimension of sustainability is measured independently as well as conjointly in a cross-sectional way because the effect on one dimension will have a repercussion effect on the other dimension. The three dimensions, environmental, social and economic system are interwoven and interconnected to each other. Different indicators, metrics (such as GRI reporting tool, and MSCI KLD index) are set as a benchmarking tools to measure the direct and linear environmental impact on the systems.
The most commonly used tool is the “Life Cycle Assessment” tool (LCA). The LCA tool serves as a guideline and to make a systematic comparison between technologies by assessing their production, recycling, landfilling and incineration of specific waste fractions. Nevertheless, the LCA tools and models hold the capability to predict the linear steady state of physical flows. Thus, the biggest challenge is an urge to measure the “level of sustainability” of a dynamic system in a non-linear way to measure the uncertainties and behavioral pattern. Dynamic system is comprised of several nested hierarchies and subsystem as can be seen in figure 5, the environmental system is at the vertex of the sustainability model. This denotes that, environmental sustainability is the prerequisite to gain social and economic sustainability. In suffice, the social and economic sustainability are dependent on the environmental systems. However, examining each dimension separately cannot be used to measure the sustainability of the whole system. To measure the sustainability of the supersystem all factors needs to be examined to determine how each system behaves when incorporated with the supersystem. (Adetunji, et al., 2019).

![Figure 5: Prevalent model of sustainability (Source: Adetunji, et al., 2003)](image)

With the changing energy scenarios and growing energy demand, it is essential to measure both direct and indirect impact of energy technologies not just from environmental but also from society behavioral standpoint (Ekvall, et al., 2007).
2.3.3. Socio-Tech Systems (STS): The knowledge about the system resilience is vital when the system shift away from the equilibrium state (Fiskel, 2003). By itself, however, a system view – i.e., the planetary boundaries approach to the GHG problem is insufficient. The ecological system interacts with the human system which is the source of the current GHG issue (Hoffman & Jennings, 2018). The social side refers to the different human systems – economic, technological, political, cultural – that interact with the ecosystems of the planet. STS has developed as theoretical area within systems theory (Yurtseven & Buchanan, 2013) (though some argue, standing astride it) for relating the social and the biophysical.

For example, when examining the environmental problems in the global system, different systems dynamics are linked with subsystems such as resource use, pollution, population growth, non-renewable, food production, land fertility, land development and land loss, services output, industrial output and jobs (Meadows, et al., 1992). The widely held view that complexity can be solved from an algorithm or an engineering derived model. However, it is important to note that those algorithm and model could only solve the problem from one dimension and therefore, it is crucial to handle the issues keeping in mind the societal standpoint as well. In today’s “liquid” society, hypothetical and irrational perspective are noticeable in consumer choice and often the emotional symbolic value of good matters the most than the actual cost and benefits from the systems (Steg, et al., 2015).

The problem of climate change and its seen and unseen effects are validated by the material resources emission. In general people have the tendency to think in a correlational way or think under the influence and becomes hyper-insensitive to the feedback (Maani & Maharaj, 2004). However, the nature and consequences reflect the failure on the part of the decision maker and their linkage between the environment and their decision (Stermann, 1989). Richmond (1997) states that the system that are not in the hand of decision makers can be eliminated from the system (Richmond, 1997). However, this perspective might not be feasible when dealing with a complex problem. Instead, external knowledge can be used to produce new goods and new ideas.
2.3.4 *Learning and Dynamism*: The technical system consists of different sets of elements, and in isolation, a complex system gives a false impression of the dynamic behavior which is far from the actual system behavior (Bala, et al., 2017). To study the complex dynamic system bidirectional approach must be adopted to study the cause and effect of the system. Although, a dynamic system does not predict the future rather it gives a valid description of behavior under a given range of condition (Forrestor, 1995).

Dynamic system and its behaviour are often unpredictable especially in the presence of accumulation and delays (Sterman, 2010). To cope up with the unpredictable event or eliminate any possible future threat, dynamic system model uses feedback loop. Feedback loops are extremely useful for prioritizing and handling the system behavior (Senge, 1990).

The system may be sensitive to internal-external fluctuations and disturbance (Scheffer, et al., 2001) which can cause uncertain behavior. “The systems usually have unknown critical thresholds that when pass over yield results that are surprising in their nature and magnitude. The system may evolve or steered into disequilibrium or non-equilibrium states. Then later attempts to restore itself to equilibrium state, that may produce results ranging from wild oscillations to self-organized new structures” (Kenyon, 1993).

“Simplicity is the ultimate sophistication” (Gaddis, 1995); (Granat, 2003). A complex system is often difficult to articulate. Figure 5 below is one way to incorporate the energy systems as a central part of the social system with the ecosystem (ecosystem is comprised of biological community, its physical and chemical environment and dynamic interaction that connects them) (Salomon, 2008). However, the energy system does not hold a central role. It is controlled by a different subsystem.
The important challenge today is that the humanity is already in the unsustainable territory, that have been quantified by the PB’s (Randers, et al., 2018). The endogenous energy feedback dominates the behavior of the critical variables such as - land, water, and air. Given the interconnection between energy systems and variables of SD goals are set as benchmarked. The transition should have no effect on the PBs boundaries and at the same time meet the SD goals. In the path of sustainable future energy systems, it seems challenging to avoid interconnection between land, water and environment. The limits related to PB is raised by human, these limits could increase or decrease with the technology. Transition to sustainable system requires a system change. A change in which each actor of the system has to work with same idea, goal and feedback that motivates the behavior of each actor associated with the system.

Most of the study conducted in the domain of energy sustainability is based on predicting total renewable scenarios to achieve zero emission target. However, the alternative scenarios such as resource reliability and its effects on environment or societal change or adaptation strategies are often underrated. Neglecting these aspects would create unexpected consequences, combined with response delays and lead to overshoot (Meadows, et al., 2006).

2.3.5 Local System Resistance: Energy systems are “Large Technical System” (Geels, et al., 2018). Energy systems travels primarily between two main domains. The first one is a technical domain and the second one is social domain. Technical domain comprised of physical artifacts such as transmission lines, transformers and also organisation such as investment firm, natural
resources, environmental regulations, international compliance and standards. The social domain comprised of users’ behaviour that stimulates and manage energy transformation, accompany shift in energy technologies (Geels, et al., 2018). In order to reach energy equilibrium systems requires a balance between social and technical domain.

In terms of fulfilling energy demand of the society, legacy-based energy systems are stable and reliable. Despite of this, legacy energy system is in flux, primarily due to increasing concerns regarding climate change (World Energy Resources, 2016) depleting energy resources and dwindling prices of fossil fuel resources (Roser & Ritchie, 2019). The environmental impacts are vital to maintain the equilibrium state of the complex issues. Especially the biological and ecological matters are more complex in nature as they are interwoven into different layers.

STSs are often defined by stability and lock-in (Geels, 2006). Stability and lock-ins are manifestation of cultural thinking pattern, and profound of human necessities, strength, weakness and emotions. Changing the behavioral pattern is difficult. Human doesn’t necessarily change after facing first or second comeuppance events. General human behaviour is that they often learn or look for the solutions when they ran into problems. Identifying solution in the time of crisis is called system intervene. Intervening a system may solve the problem for short term but for long sustainable solution it is important to envision/ predict the problem in advance and design or redesign the system structure to avoid any catastrophic event.

Behaviour of the system guide’s us to better shape the system. Individuals often shows deleterious behaviour to adopt the change as they are afraid or have trust issues if the change will have any relative benefits. The radical social changes are usually advocated under anthropocentrism and non-anthropocentrism world views, and ethical issues are considered as main driving force for the protection of nature (Mason 1999).

However, Whitworth (2009) suggests that technical system needed to respect social needs. The failure to incorporate social effects tends to result in unstable requirement and unmatched expectation. It is argued that the human aspect is more expensive and complex which requires greater investment of time and resources in order to develop trust and reliability (Sovacool &
Hess, 2017) and yet they are being ignored in policy making or designing a new system (Geels, 2011). Henceforth, it is essential to study each component separately and understand it behaviour with the other inter-linked components (Richmond, 1997).

The sustainable energy transition requires both technical sustainability and societal acceptance. Without one another the energy transition success rate seems difficult. Social acceptance comprised of attitudes, beliefs and practices. In certain cases, people do not actively criticize RET which doesn’t necessarily represents the willingness of the people to accept the change. Sometimes resistance is uncovered by examining people’s suitableness with the object or cultural norms and societal institutions, guides society or the members of community to identify the event (Hoffman & Jennings, 2010) (Batel & Wright, 2015). Especially when its embodied huge investment and cultural cognition. Individuals cultural beliefs and values intermittently deviate them to adopt system change. The resistance is a challenge to a technological order, and which could cause a substantial conflict, in case the event become the cultural anomaly (Hoffman & Jennings, 2010).

Currently, environmentalism, as a process of social change, is at the grassroot level. Nations around the world are trying to tackle climate change problem by streamline and deploying renewable energy resources in their current energy production mix. However, deployment on large-scale production of RES is not an easy task. Some countries have deployed the technologies successfully as public and innovators, policy makers, polluters understand the importance of RET, whereas, in some countries deployment of RET has faced opposition. The opposition created by public often leads to RET project deployment being delayed or sometime even withdrawn (Batel & Wright, 2015). The resistance to adopt a change is often described as NIMBY concept (Not in My Back Yard).

NIMBY pejoratively classify people who oppose the development of RET technologies. Those who oppose the renewable energy innovation is often based on individual’s selfishness, irrationality or ignorance (Batel & Wright, 2015) and/or individuals are bounded with societal constructed norms and rationality. Norms are normally seen as constraining behaviour. Norms
could thrive, spread and die out especially a well-established pattern of behaviour (Bicchieri, et al., 2018). However, habit can gradually change through education and upon arrival of superior substitutes (Sioshansi, 2011) but also the old systems, artifacts or design holds a deep influence on society even long after it has been gone. For enhancing the existing system Jackson (2005), suggests putting emphasis on “social norms and behavioral drivers” (Jackson, 2005)

The recent development in the renewable energy technology by mainly giving importance to examine the interaction between publics and RET actors, their expectation to support the paradigmatic shift (Batel & Wright, 2015). In this study, I am arguing, to better understand the attitude gap discrepancy. it is vital to identify what situate the acceptance for RET change among the local communities.
3. EXAMINING A LOCAL LEGACY AND LOCAL NEW ENERGY SYSTEM

The energy landscape is changing at different rates in different parts of the world. In some parts of the world, the transition is rapid, whereas in other parts the transition is relatively slower. Especially, in the oil-producing countries and their respective region, the energy transition is happening at a slower pace. The prime challenge with the oil producing countries is to maintain the nation’s economy, but also become a part of the revolutionary change to mitigate the impact on climate. Countries around the world are focusing on reducing carbon emission and the direct environmental impact to mitigate climate change.

Least attention is paid to externalities or the indirect impacts of energy technologies. Nordhaus (2018) stated that for a long-run sustainable energy transition the focus should also be given to the externalities. The externalities are often neglected by policymakers, innovators and polluters. Disregarding externalities could have a negative multiplier effect on the economy. The new energy technologies are added to the system to mitigate the impacts of climate change. However, if introducing a new technology that causes an additional percentage of carbon dioxide (Nobel Prize.Org, 2018) or further contaminates the water systems, and brings changes in the landscapes will deepen the crisis and worsen the circumstances.

In this chapter, firstly I briefly discussed Canada’s energy system. Secondly, I discussed Alberta current and future energy production mix in which I have primarily discussed about the energy technologies and their spillover effects. The spillovers effects are redefined/framed in a way to develop a clear understanding on some of the main issues associated with the legacy and new energy technologies and community resistance towards it.

3.1 Overview on Canada Energy Systems

Canada is the 6th largest energy producers in the world. The Canadian energy industry is characterized by advanced technological artifacts, market structures, regulatory frameworks, user practices, scientific knowledge, and cultural meanings. This unique alignment gives Canada stability and a competitive edge to Canada’s energy industries (NRC, 2019). The legacy energy industry has a wider resource base, which directly employs over 276,000 (National
Energy Board, 2019) and supported about 550,500 jobs across Canada contribute to about 11% to the national gross product development (Natural Resource Canada, 2019). On an average, the nation produces about 3.5mb/d (million barrels per day) of oil and 16.7 Bcf/d (billion cubic feet per day) of natural gas (Natural Resource Canada, 2019). In the years 2017 to 2018, both oil and natural gas activity has increased in Canada. The oil production accounts for about 8.5% rise and similarly 3.9% increase in natural gas (Kalra, 2019).

The latest report published by Bloomberg (2019) indicates that in May 2019 Canadian economy has shown an unexpected growth of 0.2%. The sudden advancement is due to the rebounding oil activities in the oil and gas sector which has also decreased the unemployment rate, since 1976. (Argitis, 2019). Apparently, Canada being one of the biggest energy producers is also one of the biggest GHG emitters in the world. On a global scale, Canada emits 1.7% of the total global GHG emissions and ranked as the 4th largest GHG intensive economies in OECD countries (National Energy Board, 2019).

Nevertheless, the Canada energy sector is changing. Some of the indicators that exhibit the change are; increasing growth of renewable energy sources (Solar, wind, hydro) in total production energy mix, the launch of new programme and policies to mitigate carbon emission, carbon pricing, subsidies and tax rebate on renewable energy technologies especially solar and wind.

It is difficult to comprehend the Canada’s energy strategy fully. As on one hand, government of Canada is presenting itself at the forefront in battling the issues concerning climate change and at the same time building new infrastructure to expand its oil and natural gas both upstream and downstream activities.

In 2016, the government of Canada launched a concrete plan called “Pan Canadian Framework” to reduce the GHG emission level. According to this plan by 2050, the GHG emission level will come down to a total of 80% from the current level. However, revive in oil and natural gas production makes it appear that it could be an aggressive target to achieve by a given timeframe (Energy outlook, 2018). As stated in the report published by “Climate Action
“Network” since the 1990s Canada has been failing each time to meet its GHG emission targets (Climate Action Network, 2019). Increase in oil and gas production activities will certainly bring a positive ripple effect on the economy, but it will cause a detrimental environmental problem that Canada has been neglecting for a long time.

Rhetorically, Canada is not just a leading energy producer but also highest energy consumption rate. On average a Canadian consumes 92.5 gigajoules (GJ) of energy for heating, cooling, lighting, powering their houses and appliances. It is important to note that the emissions per person is highest in Canada than in any other G20 economy (Rabson, 2018). Although, the energy consumption rate has declined by (3.6%) lower than that of 2013 (Statistics Canada, 2015). Canada is a large country with a diverse range of the population; thus, energy production and consumption pattern differ from one coast to another. It is evident that due to the increase in population the energy demand will continue to rise in the near future. However, if emission will continue at the current rate, then it might be difficult to mitigate climate change and its detrimental impacts.

Energy generation by sources is illustrated in Figure 5. As data shows in 2017 country produced 652 TWh of energy for consumption, out of which about 60% comes from hydro, 19% on fossil fuel, 9% on solar, wind and other renewable energy sources and 7% from non-hydro renewable. (Canada Natural Resource, 2019).

![Figure 7: Canada energy generation by sources](Source :Canada Natural Resource,2019)
The Canada energy sector is dominated by carbon energy sources but in coming years the energy production mix will change. Canada is committed to reduce GHG emission level by designing new energy systems to reduce 17% percent of carbon emissions by 2020. The statistics shows that Canada is committed and have shown remarkable progress to reach the carbon emission target set by COP. However, due to the rebounding oil and gas activities Alberta emission level is recorded highest within Canada. Even Ontario a most populated province in Alberta has reduced carbon emission level 45 MtCO2, Alberta has increased the carbon pollution limit by 45 MtCO2. It appears to be that Canada federal government and provisional government do not have unified approach to combat climate change (Saxifrage, 2019) Alberta needs to lower down the carbon emission by 58% to meet the COP target by 2020. The next section will present the Alberta Canada energy structure.

3.2. Design and Choice of Local Legacy Vs. New Energy System by Community

Alberta oil & gas industries are the 4th largest and 5th largest industries in the world, respectively. Alberta’s diverse energy portfolio is comprised of coal, natural gas, conventional oil, minerals, and well-known oil sand (Invest Alberta, 2019). The province energy system is driven by political, institutional and social factors. Alberta government controls the energy resources under the rules of the federal government (Moore, 2015).

Alberta is Canada’s is the bulkiest oil and natural gas producers. Canada produces 170 billion barrels of oil and therein 164 billion barrels of oil are produced in Alberta. Statistics Canada reports that the oil and gas industry accounted for approximately 27.9 % of Alberta’s gross Income. (Alberta Government, 2018).

Over the last ten years, electricity demand in Alberta has grown by approximately 170 MW per year (AMISK, 2015). In 2016, the consumption rate per capita basis was about 3665 petajoules (PJ). As illustrated in Figure 7, the increasing energy demand is fulfilled by coal and cogeneration mix. In the energy production mix, coal is accounted for 35.53 % followed by cogeneration which is 30.65% and the combined cycle which is 10.85%. However, wind,
hydroelectric only accounts for 8.97%, 5.55%, and 2.72%, respectively (Government of Canada, 2019).

**Figure 8: Alberta power mix as of March 2019** (AESO, 2019)

Under the climate leadership plan, the province has taken an initiative to phase out coal production by 2030 (National Energy Board, 2019). This means approximately 40% of Alberta coal installed capacity will be retiring by 2040 (Vrines, Laurens, 2018). The coal will be substituted with natural gas, hydropower, and other renewable energy sources.

The emission level in 2016 was about 262.9 megatons of (CO$_2$e). Alberta uses a single price auction to determine the wholesale price of electricity. To limit the carbon emission the province agreed a capped price of 6.8 cents per kilowatt-hour until the year 2021. The basic idea for putting the capped price is to control the user behavior to mitigate carbon emission. The excess utility bill over the capped price is paid by the federal government from the levy fund which is collected from the taxpayers (consumers) (Alberta Government.ca, 2018). By applying these changes in the current policy, the provisional government hopes that by 2030 more than 30% of electricity consumption in Alberta will come from renewable energy sources (AESO, 2019).

Figure 7 illustrates total energy demand in different sectors. 74% of the energy is consumed by industries, 12% by transportation, 9% by commercial and 5% of energy is consumed by residential sector. In total Alberta has high energy demand (Government of Canada, 2019).
Alberta’s energy production mix is dominated by the fossil fuel energy sources. To mitigate the environmental impact province has made a hefty decision to replace coal plants with natural gas and hydropower energy followed by solar, wind, geothermal energy, and bioenergy. Hence, it is important to examine the externalities associated with future energy. The spillovers effects of Future Energy Systems are framed and discussed below.

3.2.1 Oil and Natural Gas: For the past many centuries, oil and natural gas have been one of the strongest incumbent commodities to powerhouses, businesses, industries, and the transportation sector. So far, the legacy systems have maintained the status of being efficient, reliable and affordable to meet ever-increasing energy demand of Albertans. However, the future of oil and natural gas is coming under scrutiny due to its negative social and environmental impacts.

Both upstream and downstream activities of oil and gas involve lethal lifecycle processes. The exploration and operation process occur mainly near the human population. The detrimental consequences of these activities have been documented in several scientific studies (Johnston, et al., 2019) regardless of that carbon-based fuel operations are constantly on the rise. In the year 2017-2018, Alberta accounted for producing 81.8% of crude oil and 67.7% of natural gas production (Statistics Canada, 2019). Alberta, oil and gas industries come under the scrutiny of
Alberta Energy Regulator (AER). AER is managing, monitoring and safeguarding both upstream and downstream energy activities. The AER is also responsible for the maintenance and transmission of pipelines that are laid across Alberta. Furthermore, AER also ensures that the energy companies operating in the Alberta region follow the compliances and take necessary measures to mitigate environmental and social impacts (Alberta Government, 2016). Some of the spillover effects of oil and gas operations are illustrated in figure 10. Subsequently, these effects are discussed below.

(i). Spillover Effects on Land, Water and Air: The oil and natural gas are retrieved by drilling holes on the earth’s surface or in the sedimentary rocks using explosives or by drilling holes. Explosives are used to identify promising sites for the exploration of hydrocarbon resources. This exploration activity creates noise pollution, dust pollution and creates huge disturbance for
the wildlife habitat and discomfort in the communities living nearby the operation sites (Johnston, et al., 2019). After identifying the suitable site for retrieving oil and gas resources, the next step is to drill a hole in the ground. The drilling is needed to assure the presence of hydrocarbon under the earth surface. In the drilling process, the surface layers of the earth’s get rupture and loosened the topsoil. Sequentially, in the heavy rainfall, the soil and toxic materials or metal enters into the streams and sediments which contaminates the water bodies. In addition, the extraction of oil and gas releases toxic gases and fumes, which mixes with air and water causing water and air pollution which in turns affects human health and marine life.

Hydraulic fracking activities are also picking up in Alberta. Fracking is another way to retrieve the oil and natural gas is through a process called fracking or hydraulic fracking. The fracking process is highly controversial, and it is considered as the most harmful and least sustainable way to produce energy (Cooper, et al., 2019). The fracking practice is banned in many countries, for instance, Bulgaria, France and some parts of the US have banned the fracking operation. But there are no outright fracking bans in Alberta, Canada (Minkow, 2017).

Extracting natural gas using fracking is highly dangerous and sensitive to the environment especially its threat to fresh water because freshwater ecosystem is basic necessity for human survival. In addition, a new study identifies a hydraulic fracking can contribute to major health risks such as depression, anxiety during pregnancy (Science Daily, 2019). Moreover, EPA study shows the leaks and spills of frack liquid have caused long term water concern. In the old fracked wells cement tends to degrade in oil and increases the chances for leakage. Repairing old wells is much more expensive for the companies therefore, they opt for inactive oil well instead of reclaiming the old fracked wells. As a result, the number of unclaimed wells is growing in number. There rising concern that fracking companies might run out of business and taxpayers will end up paying a heavy amount for repairing old wells. (Minkow, 2017). Freshwater threat not only impose threat to human lives but also to the fish species, wetland, river and freshwater habitats. Increase in these unethical practices will damage the freshwater ecosystem faster than the terrestrial ecosystem (National Geographic, 2019).
(ii). Potent and Toxic Gases: Due to the increasing GHG emission problem, the government of Alberta has planned to close down the coal plants. However, fracking releases both methane and carbon gases (Howarth, 2015). This question the legitimacy of methane and carbon reduction target set up by provisional government. As per source the province has already failed to meet provisional carbon and methane target earlier (EDF.org, 2018).

Overall sustainability of fracking is rather ambiguous in nature, much attention has been paid on the environmental issues of fracking, but social impacts are being overlooked. One of the major impediments of fracking is that it can cause mild to medium earthquake. In January 2016, the 4.8 magnitudes of earthquake have been reported in the fox creek area of Alberta (Weber, 2018). Moreover, fracking also requires a huge amount of fresh water which can certainly creates a reduction in the water supply in the near future. The used water must be disposed in tailing pond or injected deep underground that could further contaminate the groundwater and land area.

To recover the land into its original state, AER have established strict regulatory compliance for the energy companies that are involved in the upstream activities. In accordance with rules energy companies must have a reclamation plan land must be returned back to a sustainable landscape. However, study shows that the reclamation rate is relatively low and only small fraction has been recovered. According to the AER, it can take up to 2,800 years to fully reclaim the decommissioned oil and gas well (McIntosh, Emma; Souza, D.M.;, 2018).

(iii). Waste Seepage and Contamination of Water Bodies: The amount of waste produced by the fossil fuels is staggering in amount. Ideally, the liquid waste should be stored in landfills impoundments and, solid waste should be stored in landfills. Unrecovered land disturbs the land surface, vegetation, waterbodies, and biodiversity. According to reports, the collected waste is increasing in amount. The toxic waste from Alberta sand tailing ponds is leaking into the groundwater and nearby Athabasca river (Frank, et al., 2014)
Waste seepage is increasing the risk of groundwater and river water contamination. Furthermore, the waste comprised of several toxic elements that has cancer-causing chemicals (Howarth, 2015) which puts the marine lives and humans lives at major risk. Image 1 depicts the gravity of the situation.

(iv). Hydrocarbon Leakage and Spills: Transporting oil and natural gas by train and pipeline adds another complexity in the oil and gas downstream operation. Generally, the oil and gas are transported by pipeline that are laid across Alberta or by road. The pipeline connects Alberta upstream i.e., production with the downstream sector (Moore, 2015).

The study conducted by EPA, indicates the leakage and spills of disposal waste fluids have affected the water and soil quality in the past (Johnson & Coderre, 2011). Moreover, transporting oil and natural gas using pipeline involves risks of venting and flaring of natural gas. Although, the province has added the safest train cars to transport gas and oil across and outside Canada. However, due to the derailment event in the past, millions of barrels of oil spilled, and gas leakage has caused a lethal impact on vegetation, wildlife habitat, and human lives. The list of oil spill cases in Alberta 2011-2019 are given in the Table 2.

<table>
<thead>
<tr>
<th>Location in Alberta</th>
<th>Quantity / Product type</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Earth Creek</td>
<td>158987.3 litre oil</td>
<td>2012</td>
</tr>
<tr>
<td>Little buffalo</td>
<td>4500000 Crude oil</td>
<td>2011</td>
</tr>
<tr>
<td>Red Deer</td>
<td>461,000 oil litres</td>
<td>2012</td>
</tr>
<tr>
<td>Elk point</td>
<td>230,000 oil litres</td>
<td>2012</td>
</tr>
<tr>
<td>Slave Lake</td>
<td>70,000 oil litres</td>
<td>2014</td>
</tr>
<tr>
<td>Red Earth Creek</td>
<td>60,000 oil litres</td>
<td>2014</td>
</tr>
<tr>
<td>Swan Hills ALTa</td>
<td>320,000 oil litres</td>
<td>2019</td>
</tr>
</tbody>
</table>

In the past few years, the energy companies in Alberta have made heavy investments on research and development activities to develop better tools and technologies to mitigate the spillovers effects on biodiversity, GHG emissions, tailings ponds problem, surface land disturbance, air pollutants, and finding ways to mitigate the usage of freshwater (CCA, 2015).

Land and water hold a special meaning for the aboriginal communities in Canada. The aboriginal people hold a special right which includes responsibilities to protect and use of water (Passelac-Ross & Smith, 2010). For past many years, aboriginal communities in northern Alberta have been raising their concerns regarding magnifying impacts of oil and sand development (Droitsch & Simieritsch, 2010). Now with increasing fracking activities raises significant concern regarding the water resources that has subsequent effects on people’s health (Parlee, 2015). Individuals living in the nearby fracking communities are deeply concerned about the drinking water running low. Community members have shown persistence behavior to intervene to further exploit oil and gas activities (Riley, 2019).
Alberta has maintained its position in the global energy market as an oil producing province. Thus, to compete in the world market, Canada is building an underwater pipeline that would enable to trade oil and gas in the Asian market. The underwater project is one of the biggest pipeline projects in Canada and it’s called “Trans Mountain pipeline project” (Moore, 2015).

The trans mountain pipeline project will have a capacity to carry crude oil from 300,000 barrels up to 890,000 per day. As shown in image 2, the underwaters pipeline will transport oil from Edmonton, Alberta to Burnaby, and British Columbia (BC) to expand the market outside Canada. This project has faced backlash from environmentalist and aboriginal communities across Canada. The pipeline project involves the risk to the coastal water and also endangers sea lives and human lives (BBC NEWS, 2019).

Despite escalating environmental threats and wide range of issues such as health problem, impact on water bodies, impacts on wildlife and marine life, vegetation, and air quality, Alberta is still keeping up with the unsustainable practice (Willms, 2019). The oil and gas companies are making heavy investments on (IPCC, 2014) research and development activities in a hope that new innovative and advanced technologies will trade off /eliminate the problem. This is true, to some extent, but if energy companies CSR reports to be believed, the companies have made significant progress in reduction of freshwater usage, reduction in carbon emission, success in reclaiming land area (Suncor Energy Inc, 2019). However, statements published in companies CSR reporting is contradicting with the studies conducted by independent research.
bodies (as discussed above). It appears to be that energy companies are in denial concerning the severity of the unsustainable practice with the oil sand development activities.

3.2.2 Hydro Energy: Hydropower is the most mature technology after fossil fuels. Hydropower is the rate at which hydraulic energy is produced from a specific falling water. Hydropower is a technology that meets the power demand fluctuation much faster than other electricity source (Kaunda, 2012). Alberta has planned to increase it hydropower production to meet the current GHG emissions target and increasing energy demand. AESO has launched a program called Renewable Energy Programme (REP). The long-term outlook renewable energy programme listed additional 350 megawatts of hydro capacity in a replacement of coal by 2032. The additional installed capacity will account for 11% of total generating capacity (AESO, 2018).

According to the Canadian hydro association, Alberta has the remaining potential of more than 11,500 MW. At present, hydro is accountable for producing 5.55% of energy demand in the Alberta region. Now that Alberta has decided to phase out coal production by 2030. The federal government has also imposed a limitation on emissions of gases such as nitrogen oxide (NOx) and Sulphur-oxide (SOx) (Pêloffy, et al., 2019).

Water-based energy source seems to be a great alternative to generate clean dependable electricity. Energy power developers TransAlta, AESO, ATCO have shown interest in the development in the large hydro storage project at its existing Brazeau hydro facility, Amisk and the peace river (Thompson, 2018). The hydro dams will definitely boost the renewables energy capacity in the province. However, the sustainability of the larger hydropower dams includes some subjective judgement. The externalities associated with the hydro dams is presented in figure 11 and discussed below.
(i). Community Relocation and Seismic Activities: Hydropower is a clean energy source. To produce energy using hydropower does not require any drilling or fracking process, unlike fossil fuel energy systems. For power generation hydro energy technology greatly relies on land area, clean water runoffs and rivers. Hydro sites are often located in remote areas (Evans, et al., 2009) which brings investment and creates job opportunities for individuals living in remote or rural areas (Government of Alberta, 2019).

However, as shown in image 3, the downsides of the hydropower plant are that bigger hydro dams require a huge amount of land area with an ample amount of water supply to produce energy. Often setting up large hydro project dams requires community members to relocate which could affect daily livelihood of individuals (International Rivers, 2019).
Hydroelectric dams next to oil and gas extraction projects are highly controversial. Because carrying both hydropower, and oil, and gas operations in the nearby location is prone to earthquakes. An earthquake of 4.3 magnitudes had occurred near the “Brazeau Dam” since then Alberta regulators have restricted fracking activities within 5 km of oil and natural gas operation. In addition, TransAlta has maintained a seismic monitoring program to protect hydro dams and fracking operation. The companies and energy regulators follow the best practices for safe operations; however, industry triggered events are risk prone to human lives and indigenous land resources (Wilt, 2017).

(ii). Threat to Marine Life and Disturbance in the Locale Community: Hydropower requires freshwater as runoffs to produce electricity. Setting up a large hydro project requires to change the hydrology of the water which affects the aquatic lives and its habitat. Changes in the flow of water result in sedimentation and deposits of aquatic weed which makes water odor and discolored. Sedimentation is a threat to the river ecosystem (Tundu, et al., 2018). The odor in the water can cause discomfort for the people living in the nearby communities. In addition, the
discoloration in the river water may become homes for poisonous and venomous insects that can spread illness and cause risk to human lives.

With the increase in the global temperature, will likely to alter river discharge due to the melting of glaciers and snow. This scenario can bring change in the hydropower generation water flow and fluctuation of the hydro project (Berga, 2016). In case of flooding it can bring irreversible destruction for the people living in the nearby communities.

In addition, the construction of hydropower dams can provoke chaos on the economic condition of local farmers and landowners who are primarily relying on fishing and farming activities for their daily livelihood. The large hydro dams’ interference with fish migration, depleting oxygen reservoir and trap sediment and mobilize contaminants (Snyder, 2017). Especially it will affect the “First Nations” archaeological and hunting sites and some of the province’s most productive agricultural land. Due to this environmental activists and aboriginal community of Alberta have constantly opposed building hydropower dams in the province.

(iii). Release of Predominant Gases: Integrating hydropower energy systems into the current energy production mix is to reduce the carbon emissions and mitigate the environmental and social risks. However, a large hydro station with storage facilities are known to emit some greenhouse gases especially methane, and carbon dioxide. Methane is the predominant gas in the GHG that may dissolve in the water and degrades the quality of freshwater. Water is essential for agriculture practices. The release of toxic methylmercury that dissolves into the water can bioaccumulate in the food chain which can risk human lives (Rokosz & Tomaszek, 2015).

Hydropower energy is the oldest and important source of energy for Alberta. However, the overall environmental and social impacts of building large dams instigate to flooding and contaminating rivers. Presumably, hydropower is the cheapest way to produce energy. But given the ecosystem destruction involved in the construction of hydro dams and the disturbance caused to the local communities sparks the debate and begun to question the sustainability of the hydropower system (Yakabuski, 2016).
3.2.3 Bio-fuel Energy: The energy produced by bio crops appears to be one of the viable alternatives to replace legacy systems. Primarily because biofuel crop is a plant-based energy resource that is directly combusted to produce energy. Biofuel energy could be generated from a wide variety of resources such as wood, energy crops (soybeans, palm oil, sugarcane, corn) agricultural residues food waste and industrial waste. The plant-based resources are utilized to further convert biomass energy into biogas or biofuels such as ethanol or biodiesel (EESI, 2019).

![Figure 12: Spillover effects of Bio-fuel energy](image)

In principal the plant-based energy resources do not emit any GHG gas emissions. But it is worth to note that they are “not carbon neutral”. Alberta is at the forefront to produce biofuels due to the changes in the energy security, energy policies driven by investment opportunities (Rulli, et al., 2016). Biogas is referred to as "renewable natural gas" or "green methane, “which
contains approximately 70% methane (Alberta, 2019). The spillover effects of biofuel crops are presented in figure 12.

(i). **Land Change and Land Use:** Food, water and energy are interconnected with each other as shown in figure 13. Agriculturally drawn biofuels have increased deforestation activity and also bring changes in farming practices. The main concern regarding the agriculturally derived biofuels is that it requires a large area of land, and water to cultivate biofuels. This poses a great threat to human food production as well as availability of the water. Water is a vital element for the ecosystem, forest, lakes, and wetlands.

(ii). **Water Scarcity:** Water scarcity is the biggest challenge for the humanity. An agricultural farming account for 70% of world water withdrawals (WEF, 2019). The data suggest that by 2025 nearly two-third of the population will live under water stress (WWF, 2019). The issue of water scarcity is a rising concern and cultivating biofuels production activity will increase the water consumption especially during the low seasonal rainfall, it will put a lot of stress on the local water supply for human consumption. Increased activities in the oil and gas sector have already intensified the problem to a greater degree than it starts to impact on people’s livelihood.
Although, for now, Alberta is a favorable location to cultivate biofuel crops. However, long term availability is unknown due to the depleting water resources.

(iii). Threat to Food Production and Atmosphere: Mankind has already exceeded the limit of nitrogen set by PB. The increasing production of bio crops will certainly exacerbate adverse effects on the environment (Germaine, et al., 2014). Bio-crop requires nitrogen to fertile cropland. The excess of nitrogen flows in the soils can enter waterways and coastal zones or accumulates in the terrestrial biosphere which hampers the soil quality, that will undermine food production.

(iv). Forest Carbon Balance, Soil fertility: Speaking in terms of the circular economy, biofuels are not just energy-efficient but also resource-efficient because plant residue can be further used as a tertiary resource to produce bioenergy. However, there is a constant disagreement that extracting residues, in particular stumps and roots, may alter soil fertility and negatively affect the overall forest carbon balance. Moreover, studies show that residue removal could have implications for long-term carbon storage (Thiffault et al., 2011); (Strömgren, Egnell, and Olsson, 2012). A study conducted by Nave et al. (2010) found that (increased) forest harvesting resulted overall in an average 8 % decrease in total soil carbon in a temperate forest (Nave, et al., 2010). Biomass energy doesn’t have any direct impact on the environment however, processing, transporting and other activities certainly releases the GHG gas emission.

Tackling climate change is a key motivation for using plant-based resources in energy production. Increasing production of biofuels crops is already exacerbating (Germaine, et al., 2014) deforestation activity, changes in land, and water scarcity. Incorporating biofuels into the current energy production mix will further escalate these problems. Human needs land to grow and cultivate food. Biofuels companies promotes biofuels as a clean and sustainable solution. However, increasing land and water usage for biofuels crops will bring mankind to the unsustainable territory. Biofuels as a future of energy systems is a short-sighted way of mitigating carbon impact which in the future can cause great disturbances, societal conflicts, and migration problem.
3.2.4 Wind Energy: The nations around the world are looking for efficient and renewable energy solutions to combat climate change. Wind energy is touted as sustainable ways to produce energy without emitting any pollutants. Studies have shown that wind power has a tremendous potential to meet the current and future energy demand without radically altering the planet (World energy council, 2019).

In Alberta, wind energy contributes about 7% of the electricity in the total energy production mix. At present about 37 active wind projects and a total of 901 wind turbines are installed in the province, which has generation capacity of 1,483MW (Canwea, 2017). Wind energy is steadily reaching its full potential in terms of energy efficiency and dominates Alberta renewable energy production. As per estimation, the total energy produced by provincial windfarm has the potential to power approximately 380,000 average-sized homes (Nia Williams, 2019). The weighted average cost is $37 per MWh.

Furthermore, an increase in the wind energy installation gives a relative advantage to energy consumers. Because wind energy requires a large area of land. The wind farms are often located in remote or rural location to get free flow of wind. As per a study conducted by Alberta Wind Energy Supply Chain (AWESC), annually $13.5 million is given to the landowners for leasing land for the installation of wind turbines. It not only boosts the economic wellbeing of the rural community but leverages their business opportunities (Canwea, 2017). On one hand, it brings economic benefits to landowners, and on the other, it causes huge discomfort and various kind of chronic health issues. From the spectrum of sustainability, it is also critical to understand to what extent wind energy is cleaner and greener. Is it really what it appears to be? Figure 14 highlights the spillover effects of wind energy systems.

Whilst, the wind energy is eco-friendly, and it doesn’t emit GHGs gases during its operation. However, environmental and NIMBY-ism issues have remained consistent over time. The issue of NIMBY-ism (Not in my backyard -ism) the most prevalent issue that has constrained the development of wind projects in many parts of the world due to noise pollution, visual interference with radar and telecommunication facilities, killing of birds and bats (Saidur, et al., 2011). Some of the issues associated with the NIMBYism are presented and discussed below
(i). *Noise Pollution, Visual Interference Effects on Human Health*: There are lots of evidence that supports that individuals exposed to wind turbine harm mental, physical, social wellbeing. The continuous noise produced by moving wind turbine is the prime reason for people showing resistance towards wind energy technology. The level of noise produced by wind turbines is irrefutable. The noise produced by a wind turbine is the second major reason for opposition. The continuous exposure to the sounds has an adverse effect on human health impact especially for individuals suffering from epilepsy. Moreover, constant unpleasant noise can contribute to cardiovascular disease, lack of sleep, hearing loss, an increase in stress level and changes in blood pressure for the individuals living nearby the wind farms. (Botelho, et al., 2017). In
addition, human visual interference and shadow flickering effect causes annoyance, distraction to the people living in nearby the wind sites (Saidur, et al., 2011)

(b). *Interference with Radar and Telecommunication Satellites*: The moving wind turbine produces both electric and magnetic waves which can interference with radar and telecommunication satellites. This can put national and international security into greater risk and affect business operations.

(ii). *Birds Migration*: Bird habitat is a serious problem associated with wind energy which cannot be ruled out. The killing of large birds such as raptors, bats from the wind turbine is widely known and hence when it comes to measuring the sustainability of wind turbines, conservationists often debate on this matter. The wind energy experts have a strong opinion and argument that the number of birds killed each year is substantially lower in comparison to another anthropogenic activities such as vehicles buildings, window, transmission lines, toxic chemicals and, pesticides. However, preserving wildlife is a serious concern, especially for the extinct species. Image 4 clearly illustrates the seriousness of the situation.

![Image 4: Killing and migration of birds (Image source CBC, 2019)](image)

Climate change is already affecting the migratory behavior of the bird (Palacín, et al., 2016). During the early days of wind power development, several cases were reported concerning the fatalities of bird & bats. As per government estimation existing wind turbines killed provincially in total of 1800 to 2700 birds and 2700 to 6,300 bats. The province is taking necessary measure
and precaution to minimize the effects on bird and bat population as it expands the wind power in the near future (Wood & Herald, 2017) (Bellon, et al., 2019). The environmental issues associated with the wind energy are mainly at the production phase are as follows.

(iii). Hazardous Material in Fabrication of Wind Turbine: Material sustainability plays a vital role in combating issues related to climate change and global warming. Wind turbines are made up of various inorganic compounds such as sulphate and nitrates. In disposal phase, these materials are directed to landfills and if left untreated the nitrate and sulphate effluents can penetrate into the land and water bodies that can affect the human health condition.

(iv). Atmospheric Change: Study conducted by Wang & Wang (2015) reports that the observation made with a satellite data shows that the wind turbines causes atmospheric change particularly, at night-time near to the wind farm (Wang & Wang, 2015). Furthermore, Atmospheric change also affects the vegetation growth.

(v) Land Change -Land use: Affordability and reliability are the key to foster future energy system (Harper et al, 2019). Large wind turbine produces electricity at lower cost and with higher efficiency. The wind installation requires large area of land. Most of these sites are situated in the remote areas which mean power generation turbines and power transmission lines supplies energy to the nearby communities. Transmission lines will contribute to land change. One study shows that transmission lines has already contributed to the around 1% of changes in land-use (Wang & Wang, 2015).

(vi). Explosion and fire: Wind turbines are prone to fire. Glimpse of it can be seen in presented in image 5. Every year around 120 wind turbines catches fire. The fire can stimulate other events. According to “website wind-watch” 44 cases were reported between January 2019 to June 2019 (National Wind Watch, 2019).
(vii). Vulnerable Effects of Storage Systems: The wind energy resource is intermittent and requires a storage system such as batteries to store the harnessed energy. For decentralized grid system battery technology comes in handy and very useful to store excess energy. Lithium -ion battery is the most advanced form of battery technology used in the energy storage system.

However, lithium -ion batteries are comprised of several toxic elements and has recycling issues. The battery technology is highly vulnerable and subject to explosion if not handled carefully (Université catholique de Louvain, 2019). Wind energy technology is clean, affordable and reliable. Integrating wind energy technology will certainly diversify Alberta energy generation mix and economy. However, the wind energy is strongly opposed and criticized in another province of Canada.

A recent report published by CBC Canada (2019), the Prince Edward Island started scrapping and dismantling the wind energy (white pines wind project) project started in 2018. The prime reason for discarding the clean energy project is because community resisted to host the project from very initial stage. The Prince Edward county people has opposed the project since it was proposed. The cost associated to discard the 750 contracts (Forbes, 2019) costing ratepayers
approximately $231 million (Crawley, 2019). It is undeniable that wind energy technology needs to be reconciled for future growth and sustainable development but not at the cost of human wellbeing.

3.2.5 Solar Energy: Solar energy technology has emerged as a powerful and most effective ways to mitigate carbon emission. Various studies have proven that solar energy will continue to rise in the near future on a global scale. Solar energy technology has emerged as competitive source of renewable energy due its declining manufacturing cost and highly efficient ways to produce energy with slim to none environmental impact. International Energy Agency (IEA) has reported that price of renewable has declined to $5 c/kwh in 2018. If sources to be believed solar energy is inflecting like coal in the 19th century and oil in 21st century (Fattouh, et al., 2018).

To promote the green growth moment, provisional government has launched a programme called “Energy Efficiency Alberta Residential and Commercial Solar”. Through this programme the provincial government provide rebate to Alberta energy consumers. With the help of this programme the property owner has the possibility to earn cash rebate for solar system installation. Rebate amount depends on the type of utility. The residential and commercial rates are $0.90/watt and $0.75/watt respectively (energyhub.org, 2019). Alberta is speeding up its renewable energy installation capacity to meet the IPCC target by 2030. In August 2019, provisional regulators have approved to build a biggest solar facility in southern Alberta. This facility will have the capacity to generate 400MW which can supply electricity to over 100,000 homes. The complexity of large-scale project is far more complex in comparison to the small-scale residential project. The study published earlier states that solar can expect public opposition if they are to be in vicinity of local residences (Fattouh, et al., 2018).
Like other power sources it too has negative effects such as, reliability, safety, health and environmental (SHE) to the sustainability of the human activities (Aman et al; 2015). List of externalities of solar energy system is presented in figure 15.

(i). Land, Habitat Loss and Biodiversity: To promote green growth, Alberta has integrated solar energy into their current energy mix. The versatile solar panels applications are used for both heating and electrifying houses. In Alberta, about 10% of energy comes from renewables and that includes 0.1% of energy from solar energy (Sharp, Alastair;, 209). Almost 1m2 of land area is required to produce 300 watts of electricity depending on the location, and other environmental conditions. Land area plays a significant role in estimating the price of electricity produced by solar energy (Ong, et al., 2013). Meaning higher the cost of land higher will be the
per unit electricity cost. In the residential project solar panels are mounted on the rooftop of the houses. However, for commercial or industrial scale projects, the solar panels require large hectare of land area. It is worth noting that total area of land depends on the applications of solar panel technologies. The newly announced project in Alberta will comprised of 2.5 million panels. The panels will be mainly installed (erected on) 1600 hectare of cultivated cropland (Global News, 2019).

(ii). *Vegetation and Wildlife*: Installing the solar panels on the cultivated cropland could have the adverse effect on the native vegetation and wildlife habitat. For instance, in case of installation of solar parks in the remote area or in the large open areas, the land is often covered with the natural vegetation that provides food supply for animal gazing. To ensure sunlight directly hitting on to the panel to yield energy efficiently often requires cutting down of trees, bushes or vegetation. It is considered by many scholars the solar cells and wind turbines are considered to be have detrimental impacts to landscapes (Rosen, 2009).

Not only installation of panels could affect the wildlife habitat and vegetation, but it could also affect the production capacity of the solar panels. Animal gazing in the nearby area can create dust which can further obstruct the efficiency of the solar panels to reach its full potential. Moreover, Alberta has an extreme winter conditions, swiping of snow from rooftop or bigger facilities can add another challenge to the system infrastructure.

(iii). *Toxic Material Usage and Recycling*: Solar panel is damaging the environment due to improper waste handling. Considering the fact that fabrication of the solar panels contains some highly restricted toxic material like cadmium, lead and nickel. Use of such compound is highly dangerous for local habitat if the poisonous substances leach out in ground or water bodies. Since the early 2000, solar panel production has grown at unprecedented rates (IRENA, 2016) Looking at the rising trend in coming 5 to 10 years the solar panel waste will increase. In 2016, The International Renewable Energy Agency (IRENA) estimated about 250,000 metric tonnes of solar panel waste and could reach 78 million metric tonnes by 2050 (Shellenberger, 2018).
The natural events such as earthquake or flood can result in the accumulation of e-waste and contamination of land and water resources. Since 2012, waste is now considered potentially dangerous by European Directive WEEE (EU, 2012). This e-waste not only cause environmental damage but also put human health into greater risk (Bakhiyi, et al., 2014). Solar panel performance degrades over the period of time and the current maximum life span of the solar panels is about 25 years (Massachusetts Institute of Technology, 2019). Solar energy technology is relatively new and excess generation of e-waste and landfill problem would have net effect on land and soil properties.

(iv). Rare Metal Ramification and After Effect: The different kind of metals are used in the manufacturing of the solar panels. Among those silver is core element used in solar panels due to its highest electrical and thermal conductivity. Study shows that the increase in the demand of the solar panel will affect worldwide price of the silver. This could lead to manufacturing of far more expensive in the near future (Apergis & Apergis, 2019). The silver is used in many industrial applications, increasing price of silver metal could also bring significant changes in the price of other industrial equipment.

(v). Battery Storage and Vulnerabilities: One of the biggest challenges to the renewable energy system is the intermittency, which is dealt by using battery technology. Battery technology helps to supply energy in cloudy days. Lithium ions is one of the most advanced form of battery technology. The downside of battery technology is that, it is still under the development phase. Besides, there are several environmental and social unprecedented risk involves with existing battery technology such as battery explosion and its recycling.

Earlier it was only the wealthy environmentalist who could afford to install the photovoltaic system on their rooftops but with the increase investment in solar manufacturing industry the cost of solar panel is declining to make it more affordable. With the growing market trend of solar technology, it appears to be the topmost choice among the energy consumers. However, there are certain group of people who have shown resistance towards solar technology.
The solar technologies and its application have sparked protest and resistance from the local communities living in rural areas of U.S. The individuals believes that installation of solar panel would destroy the most scenic areas of their village and they do not see any benefits and massive solar panel plant will ruin their rural way of life (Verdina Natalia, 2018).

In Alberta many households have already adopted the solar energy-based heating system (DLSC, 2018). There are always societal implications to make changes in the society. The implication might lead to unethical practices such as vandalism and theft of the solar panel. Several cases of vandalism and theft of solar panels have been encountered in India and US. Although, no such incidents have been reported in Alberta so far, but these factors are crucial to considered as society is moving towards the new energy paradigm shift.

3.2.6 Geothermal Energy: Geothermal energy is derived from earth’s internal heat which is later converted in the form of energy. The geothermal energy is an effective and reliable source of energy (Bakhiyi, et al., 2014). Traditionally geothermal energy is used in the form of spring water for tourist and recreational activities (Lahsen, et al., 2015). However, now the exploration of ground heat in the form of energy is mainly driven by the need for energy security and to address the issue of climate change.

The geothermal energy is a renewable energy source and the environmental impact is negligible in comparison to the fossil fuel energy systems. One of the greatest advantages of geothermal energy is that it is available constantly and it is relatively inexpensive energy source (Geographic, 2019). In 2017, feasibility studies have been conducted to assess the potential of geothermal energy in Northern Alberta. The study maps out the potential of the geothermal based energy system for small communities in Alberta (Richter, 2019). The main focus of this study was to examine the temperature for power generation, and it has been found out that Alberta has the potential to power houses and businesses using earth internal heat. Both government and public are excited for the upcoming geothermal projects.

The Canadian Geothermal Association has identified massive number of geothermal wells for heat exchange. Alberta is at the early stage to explore the potential of geothermal energy. The
provisional government and companies are determining the potential of geothermal to eliminate expensive risk with its growing unused well. In 2018, the Hinton town of Alberta received federal and provisional funding to explore the potential of geothermal heat and also electricity (Ratjen, 2019) Measuring from the spectrum of sustainability, geothermal energy involves great number of risks such as seismic events, ground water contamination and emission of toxic gases (Shortall, et al., 2015) which are neither good for environment nor for the locale population living nearby operation sites. The spillover’s effects are illustrated in figure 16.

*Figure 16: Geothermal Energy Spillovers*

(i). *Landscape and interruption of scenic quality:* To extract the heat or energy from the earth or rock requires to drill deep holes in the ground which effects the landscape, and surface installation often disturbs or destroys the visuals interruption of great scenic quality as can be seen in the image 6 (Bayer, et al., 2013).
(ii). Water contamination and its usage: The extraction process is similar to the fossil fuel-based energy system. To be noted, the geothermal plant involves large number of variables and often providing the complete disclosure of impact in an operation is not possible. The environmental impact is more significant in direct use application and condensing power plant. Large scale industrial plant geothermal project is different than the small-scale residential use plant. The large-scale plant involves risk to contaminate freshwater aquifers due to the increased level of arsenic, mercury, lithium that occurs in geothermal fluid. Geothermal operation requires freshwater to carry the operation. The water needed to extract the heat from the ground depends on the size of the power plant, geology, technology, number of liners and depth. This means that the amount of water needed to carry out operation in geothermal plant highly fluctuates. The high fluctuation rate could limit the local water consumption supply in case the geothermal power plant exceeds the fresh water supply more than allocated to the particular plant (Berrizbeitia, 2014).

(iii). Gas emission, man-made earthquake and land sink: The drilling of geothermal wells releases GHG including co2, hydrogen sulfide, methane and ammonia (UCSUSA.org, 2013). Although the emissions are much lower than the fossil fuel energy systems, but it is not trivial. The emissions can affect the air quality and cause substantial negative effect on human health
and on the environment. In addition, geothermal power plants require to reinject the hot water that is removed from the ground back into the wells. The study shows that geothermal wastewater could be hazardous for the crops and aquatic invertebrates if the traces of AS, B, and Mo is found. (Berrizbeitia, 2014).

The geothermal on-site construction and operation lead to unpredicted events such as volcanic eruption, earthquake. However, while reinjecting water back to the ground, highly likely some that some amount of water may evaporate which causes ground collapse or sink holes followed by other seismic events. The resulting implication of could trigger events such as landslide and earthquake. These seismic hazards could lead to other multiple events within seconds which cannot be overstated (Esq., et al., 2017)

(iv). Wildlife habitat and human health: Communities living around the geothermal sites can oppose the production of geothermal energy due to noise effects caused during drilling hole into the ground. This can also result into disturbance of the wildlife habitat (Karytsas, et al., 2019; Shortall, et al., 2015) and among the people living by geothermal sites. According to world Health Organization (WHO) guidelines, high amount of h2s (over 15mg/m3 can cause eye irritation). In addition, there is evidence concerning human health issues such as nervous system disease, respiratory and cardiovascular diseases (Hansell, et al., 2006).

Government of Alberta, business groups are highly optimistic about the ongoing geothermal projects development. One of the biggest advantage to expands the geothermal operation is that the oil and gas companies can greatly benefit by utilizing same skilled employees and industrial resources such as reservoir engineer, driller and geologist (Nelson, 2016). However, environmentalist and indigenous community have strongly criticized the geothermal projects due to the development happening in their own land. Nevertheless, the technology also has underlying effects and long-term sustainability issues both in construction and in the operation stage. If they are to be ignored now, the impact could diverge and take a toll on the ecosystem and thereby in human health.
Table 3: Views of Spillovers

<table>
<thead>
<tr>
<th>Renewable and Non-Renewable ENERGY Sources</th>
<th>SPILOVER</th>
<th>RESISTANCE</th>
</tr>
</thead>
</table>
| Fossil Fuel (Oil & Gas)                    | • Spillover effects on land, water and air  
                                           • Potent and toxic gases  
                                           • Waste seepage and contamination of water bodies  
                                           • Hydrocarbon Leakage and Spills | • Slice up the problem  
                                           • Push to tech system |
| Hydro                                      | • Relocation and Seismic activities:  
                                           • Threat to aquatic lives and disturbance in the locale community  
                                           • Release of predominant gases | • Ignore because hydro “is better”  
                                           • Hydro is not costed at market rate |
| Biofuels                                   | • Land-use/Land change (LULC)  
                                           • Water Scarcity  
                                           • Threat to food production and atmosphere  
                                           • Forest carbon balance and soil fertility | • A failure |
| Wind                                       | • Noise pollution, visual interference  
                                           • Birds migration  
                                           • Toxic material uses in fabrication  
                                           • Atmospheric change  
                                           • Land change  
                                           • Explosion and fire  
                                           • Vulnerability effects of battery technology | • NIMBY |
| Solar                                      | • Land, habitat loss and biodiversity | • Solar is for hippies |
Table 3 summarize views on spillover effects of the legacy energy system and new energy systems. Considering the fact that Alberta has plenty of environmental problems such as carbon emission levels, tailing ponds, waste seepage, water contamination, earthquakes, changing landscapes, landslides, and, poor air quality. These issues are widely prevalent and often reported by the media and scientific community. But community members views are seldom documented. Thus, the primary data is collected to examine what could prevent one community to invest in a new system, even when a nearby community has adopted the change – what do individuals say? What does the community say? Based on following questions and literature review data was collected to test the hypothesis.
4. RESEARCH DESIGN

This chapter describes the research design, data collection, and methodologies used in this study. The research design chosen for this study is based on exploratory research model. Exploratory research model is useful for preliminary research study to find current state of problem. This study method is valuable to get new insights (Saundert et al., 2019 p -139) to frame future work in the same domain. The data presented in the thesis does not generalize or represents the entire Alberta’s population group. This study aims to highlight concerns and future energy system preference of the community members that could be further contextualized for future work.

4.1 Research Context and Hypotheses

The primary purpose of this study is to investigate whether or not energy systems spillovers are recognized by the individuals and how willing the individuals are to adopt the RE transition. Three hypotheses were crafted to address the research question.

\( H1: \) Given Alberta has a great deal of energy spillover; individual Albertans will recognize some of those spillovers.

\( H2: \) The more individuals recognize spillovers, the more likely they will switch to Res.

\( H3: \) Less satisfied individuals will be more likely to switch (i.e., satisfaction will at least moderate the likelihood of switching).

\( H4: \) Communities as a whole, not just individuals, are likely to switch to Res.

4.2 Data Collection

Primary data is collected using the survey/informal interviews. The stratified random sample data is collected to examine the perceived difference between three proximate communities of Alberta. Okotoks (OKO), Black Diamond (BD) and High River Valley (HRV).
KO community is relying on a substantial renewable resource, whereas BD and HR are both relying on fossil fuel-based heating system. In total 121 participated in the survey. The response rate of the research survey was approximately 76%.

Primary data was used in this thesis study, the data was collected in 2018. The survey/informal interviews were carried out in three different communities in 2-month time frame. The informal interview survey method was chosen for preliminary study. Proximate communities were targeted for this study.

All three communities were under the distance of less than 50 km (distance between from BD >HRV about 29 km and HRV<OKO about 23 km). At first, the data was collected from OKO community. The OKO community is relying on the substantial renewable heating source and hence, door to door survey was carried out in this community. The reason to carry out door to door survey was because only 55 households were using renewable based heating system. Therefore, in order to get the reasonable responses to statistically analyze the data door to door informal interview were conducted.

Table 4: Data collection method

<table>
<thead>
<tr>
<th>Community</th>
<th>Heating source</th>
<th>Survey/informal interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Okotoks</td>
<td>Substantial Renewable (Geothermal and Solar)</td>
<td>Door to door</td>
</tr>
<tr>
<td>High River Valley</td>
<td>Fossil Fuel</td>
<td>Restaurants, cafes, grocery store.</td>
</tr>
<tr>
<td>Black Diamond</td>
<td>Fossil Fuel</td>
<td>Restaurants, cafes, grocery store.</td>
</tr>
</tbody>
</table>

Then after, informal interviews were carried out in HRV and BD community. In these community, the individuals are relying more on traditional (fossil fuel) heating systems. Since the majority of individuals are using fossil fuel heating systems, informal interview/survey was
carried out in public places (restaurants, cafes, grocery store). In order to collect unbiased responses, each participant got an equal opportunity to take part in the survey.

Altogether 121 responses were collected from three different community. 119 responses were collected in person and 2 respondents replied via email. The participants were randomly selected across communities. Moreover, in order to get the maximum response from the survey questionnaire, the short and concise survey was prepared (see Appendix 1). The closed ended questions were prepared based on ordinal, nominal and Likert scales measurement. Data derived from the stratified random sampling was then investigated statistically. In addition, demographic data was also collected to further investigate the hypotheses to find correlations between the constructed variable and demographic data.

4.3 Methodologies

The gathered data was analyzed using the statistical program called IBM SPSS 2017 version. A quantitative approach was adopted to statistically analyze and quantified the data in a holistic way. Descriptive statistics are used to present the basic feature of the data then after, table of correlation was constructed to investigate the association between the variables. Next, the binomial logistic modeling was carried out separately for both groups (non-renewable and renewable group). Furthermore, the missing data (not recorded by the participant) from the survey questionnaire was filtered out and marked as -9. The parameter chosen for the analysis were coded and recoded three times to construct and analyze variable in a holistic manner. In addition, qualitative analysis is carried out to elaborate the open-ended responses collected in the survey.

For predictability modeling binomial logistic regression methods is used. The “Logistic Regression Model (LRM)” is non-linear transformation of linear regression model (appstate.edu, 2019). LRM analyze the association between a set of independent (explanatory) variables and categorical dependent variable. In the “Logistic Regression”, a set of explanatory
variables is used to predict a logit transformation of the dependent variable. Mathematically, the logit transformation formula is given below (NCSS, 2019)

\[ l = \logit(p) = \ln\left(\frac{p}{1-p}\right) \]

In logistic regression the numerical values of 0 and 1 are assigned to the binary dependent variable (Zellner, 2004).
5. RESULTS ANALYSIS AND DEMILITATIONS

This chapter presents the results of the survey data. At first, the table of descriptive statistics and table of correlations is presented. The table of descriptive statistics includes all variables along with dummy variables. The table of descriptive statistics is formulated to summarize the collected data in a concise form. The table of correlations presents both Spearman and Pearson correlation between the variables. Pearson correlation is used for all bivariate variables and Spearman correlation is used for all categorical variables including bivariate. The table of correlation is carried out to find the pairwise stronger and weaker association between the variables.

Subsequently, the main sample analyses are presented using logistic regression. The binary logistic regression is performed to model the Maximum Likelihood Estimation (MLE) of individuals to adopt the RE systems. The analyses are performed to predict a categorical binary outcome (yes or no). It is to be noted that binomial logistic regression cannot be interpreted as ordinary least square regression (OLS). To interpret the models, the p values (<0.01) and (<=0.05) loglikelihood (LL) values are taken into account. Additionally, to make a comparison between the independent variables with the outcome variable, exp (B) values is taken into account. The main sample analyses represent all cases irrespective of their current source of heating system. However, in subsample analyses only, those cases were selected whose current source of heating system is based on fossil fuels (oil and gas) systems. Afterward, the open-ended questions were quantified.

5.1 Descriptive Statistics

Demographic Data: The data used in this study is collected from three proximate communities in Alberta, Canada. The data represents diversity within communities. Total 121 individuals participated in the survey i.e., OKO (n= 42), HRV (n= 54), BD (n= 25). Table 5 represents the descriptive statistics of the data. The survey participants ranged in the age of 18 to 55 + years (M =3.45 SD = 1.43). Approximately 55% of the survey respondents were male, 41% female and 4% of the participants reported as others (n=3), with the average age being 44.35 years.
The individuals participated in the survey comes from different professional background, 34% of participants reported as professional (M = 0.34 SD =0.475) whereas, 11% of the participants reported as semi-professional (M= 0.11, SD=0.311), 51% of the participants came under unskilled category and remaining 4% of the individuals did not record their occupation. The high number of the participants (M= 1.83, SD = .395) have their own home (82%) and only few participants live in a rental property (18%). Furthermore, 81% of the participants have been living in the same community for more than 5 years (M=1.19, SD=0.397).
Table 5: Descriptive Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (M)</th>
<th>Std. Deviation (SD)</th>
<th>Median</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>#ID No.</td>
<td>61</td>
<td>35.074</td>
<td>61</td>
<td>121</td>
</tr>
<tr>
<td>Community Type</td>
<td>1.86</td>
<td>0.734</td>
<td>2</td>
<td>121</td>
</tr>
<tr>
<td>Gender</td>
<td>1.49</td>
<td>0.581</td>
<td>1</td>
<td>118</td>
</tr>
<tr>
<td>Gender_ 1(Male)</td>
<td>0.6</td>
<td>0.491</td>
<td>1</td>
<td>121</td>
</tr>
<tr>
<td>Age Group</td>
<td>44.3554</td>
<td>18.91686</td>
<td>50</td>
<td>121</td>
</tr>
<tr>
<td>Occupation</td>
<td>2.84</td>
<td>0.791</td>
<td>3</td>
<td>116</td>
</tr>
<tr>
<td>Occupation (Prof)</td>
<td>0.34</td>
<td>0.475</td>
<td>0</td>
<td>121</td>
</tr>
<tr>
<td>Occupation (Semi)</td>
<td>0.11</td>
<td>0.311</td>
<td>0</td>
<td>121</td>
</tr>
<tr>
<td>Occupation (Unskilled)</td>
<td>0.51</td>
<td>0.502</td>
<td>1</td>
<td>121</td>
</tr>
<tr>
<td>Abode type</td>
<td>1.83</td>
<td>0.395</td>
<td>2</td>
<td>121</td>
</tr>
<tr>
<td>Own Home (1)</td>
<td>0.83</td>
<td>0.38</td>
<td>1</td>
<td>121</td>
</tr>
<tr>
<td>Lived in the community for 5+ years</td>
<td>1.19</td>
<td>0.397</td>
<td>1</td>
<td>119</td>
</tr>
<tr>
<td>Lived in community more than five years (1)</td>
<td>0.81</td>
<td>0.394</td>
<td>1</td>
<td>121</td>
</tr>
<tr>
<td>Current heating system</td>
<td>2.61</td>
<td>1.157</td>
<td>2</td>
<td>121</td>
</tr>
<tr>
<td>Renewable and non- renewable system</td>
<td>0.28</td>
<td>0.452</td>
<td>0</td>
<td>117</td>
</tr>
<tr>
<td>Current heating system_ (non-renewables)</td>
<td>0.13</td>
<td>0.335</td>
<td>0</td>
<td>118</td>
</tr>
<tr>
<td>Previous heating System</td>
<td>2.54</td>
<td>1.529</td>
<td>2</td>
<td>117</td>
</tr>
<tr>
<td>Current satisfaction level</td>
<td>3.99</td>
<td>0.742</td>
<td>4</td>
<td>119</td>
</tr>
<tr>
<td>Previous Satisfaction Level</td>
<td>3.746</td>
<td>0.8368</td>
<td>4</td>
<td>114</td>
</tr>
<tr>
<td>Willingness to Change</td>
<td>1.63</td>
<td>0.486</td>
<td>2</td>
<td>118</td>
</tr>
<tr>
<td>Willing to Change (1)</td>
<td>0.39</td>
<td>0.489</td>
<td>0</td>
<td>121</td>
</tr>
<tr>
<td>Expensive</td>
<td>3</td>
<td>1.291</td>
<td>4</td>
<td>31</td>
</tr>
<tr>
<td>Cost as reason_ (Expensive)</td>
<td>-6.6</td>
<td>4.212</td>
<td>-9</td>
<td>0</td>
</tr>
<tr>
<td>Efficiency</td>
<td>2.91</td>
<td>1.264</td>
<td>3.5</td>
<td>34</td>
</tr>
<tr>
<td>Usability</td>
<td>1.95</td>
<td>1.133</td>
<td>1.5</td>
<td>22</td>
</tr>
<tr>
<td>Reliability</td>
<td>2.16</td>
<td>1.281</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>Effect on Environment</td>
<td>3.31</td>
<td>0.867</td>
<td>4</td>
<td>35</td>
</tr>
<tr>
<td>Aesthetic</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Less noise</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>No choice</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>
1. **Current Source of Heating Systems**: The current source of heating system used by all three community individuals is presented in figure 17. From the survey data, it is found out that communities are using wide sources of heating system. The majority number of survey participants are using heating systems based on oil and natural gas (68%) followed by solar energy (18%), geothermal energy (7%), co-generation heating (2%), in-floor (2%), and, hot water (3%).

![Figure 17: Current Source of Heating System](image)

2. **Satisfaction Level**: As can be seen in figure 18, the survey participants are very satisfied with their current heating (M = 3.99 with SD = 0.75). The previous heating system satisfaction level is recorded lower than the current heating system satisfaction level (M = 3.74 with SD = 0.8368). Previous heating system is exclusively based on fossil fuel sources.

![Figure 18: Current Satisfaction Level of Participants](image)
3. **Willingness of the Individuals to Change:** One of the main objectives of this survey is to determine the individual’s willingness to change from conventional based heating system to the new energy systems. As can be seen in figure 19, altogether from three different communities of Alberta only 39% (n=47) of the participants have shown their willingness to adopt the renewable energy-based heating system. HR community shows more willingness to change followed by OKO and BD.

![Figure 19: Willingness to Change](image)

4. **Factors Responsible for Change:** To investigate the perceived difference among the heating sources and community response to it, six variables were pre-mentioned in the survey questionnaire i.e.; expensive, efficiency, usability, system reliability, the effect on the environment. Besides, participants were given an additional open-ended variable to examine awareness level of the participants on spillover effects. The participants were asked to measure the variables in the Likert scale measurement (1 to 4).
Each variable is quantified separately to make a fair comparison between the main drivers for change. The responses of the survey results are presented in figure 20. Interestingly, (22%) of the survey participants have given the highest score value to the variable effect on the environment. Two in ten (21%) individuals are willing to adopt a change to have a more efficient heating system. Also, (20%) of the survey participants are considering adopting a renewable based heating system to reduce electricity bills. In addition, (15%) of the individuals have chosen usability and (16%) reliability as an important determinant to adopt a new energy system. Furthermore, in the open-ended variable, survey participants have reported that the conventional heating system along the wall pulldown the aesthetic (2%) of the room. Additionally, unanticipated noise (4%) in the heating system (4%) cause annoyance during the sleep time.

5.2 Association Between the Variables

Table 6 represents the Pearson and Spearman correlation coefficient between the variables. The first row in the table represents Pearson correlation and the second row represents the Spearman correlation relationship. The relations between the variables are significant at $p <0.05(**)$ and $P <0.01 (*)$. The $P <0.01$ shows the strongest relationship and $p< 0.05$ shows the weaker pairwise correlation coefficient. This applies to all the variables presented in the table.
5.2.1 Association between Variables Satisfaction Level, Heating System and Cost: Both Pearson and Spearman correlation coefficient statistics value shows a weaker negative relationship between the variable satisfaction level (\(r= -394^*, -391^*\)) and expensive. This indicates the variable “current satisfaction level “is inversely proportional to the cost factor. Similarly, the Pearson correlation coefficient between the variables' current satisfaction level and current source of heating system (reference category renewables) shows a strong positive association between the variables (\(r=.296^*\)) which signifies that the usage of renewable energy systems will increase with the increase in the satisfaction level.

5.2.2 Association Between Satisfaction Level and Willingness to Change: The Pearson correlation statistics value indicates that the variable's satisfaction level of the current heating systems and “willingness to change” are inversely proportional to each other (\(r= -.365^*\)). The negative \(r\) value indicates lower the satisfaction less likely individuals would go for renewable energy systems.

5.2.3. Association Between Age Category and/or Expensive, Usability and Reliability: The Pearson and Spearman correlation statistics values between the variable age category and variables expensive (\(r=.632^*, .692^*\)), efficiency(\(r=.432^*,.492^*\)) show a strong relationship. This indicates that higher age group individuals would be more willing to invest in highly efficient renewable based heating systems efficient. Furthermore, variable age and usability (\(r=.493^*, r=.497^*\)) age and reliability (\(r= .427^*,.435^*\)) show positive relationship. This indicates that a higher age group individual is more willing to invest in a heating system with a high degree of reliability.

5.2.4. Association Between Willingness to Change and Renewable Energy Systems: The correlation coefficient between the variable “willingness of individuals to switch to renewable energy system” and” current system satisfaction level” shows negative weak relationship (\(r= -.365^*\)). This reflects that the choice of heating source depends upon satisfaction level of the individuals. This means increase or decrease in the satisfaction level will affect the individual decision to adopt renewable based heating system or vice a versa.
5.2.5. Association Between Willingness To Change, Expensive, Usability, Reliability: Likewise, the variable willingness to change shows the positive strong correlation with the variables expensive ($r= .585^{**}$) efficiency ($r=.465^{**}$), usability ($r=.585^*$) and reliability ($r=.662^*$). This specify, with the increase in efficiency, usability and reliability of the energy of the system will also increase the willingness of individuals to adopt a renewable based energy system will also increase.
Table 6: Pearson And Spearman Correlation Coefficient to Examine the Association Among the Variables.

<table>
<thead>
<tr>
<th>Variables</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current satisfaction level</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expensive</td>
<td>-.394*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-.391*)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Efficiency</td>
<td>0.03</td>
<td>.746**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-0.044)</td>
<td>(.775**)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Usability</td>
<td>-0.19</td>
<td>.557*</td>
<td>.629**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-0.228)</td>
<td>(.532*)</td>
<td>(.627**)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reliability</td>
<td>-0.302</td>
<td>.461*</td>
<td>.673**</td>
<td>.801**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.302)</td>
<td>(.492*)</td>
<td>(.689**)</td>
<td>(.790**)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effect on Environment</td>
<td>-0.176</td>
<td>0.027</td>
<td>0.164</td>
<td>.460*</td>
<td>.426*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.231)</td>
<td>(0.143)</td>
<td>(0.302)</td>
<td>(9.454*)</td>
<td>(.434*)</td>
<td></td>
</tr>
<tr>
<td>Age category</td>
<td>-0.099</td>
<td>.632**</td>
<td>.430*</td>
<td>.493*</td>
<td>.427*</td>
<td>0.248</td>
</tr>
<tr>
<td></td>
<td>(0.125)</td>
<td>(.692**)</td>
<td>(.492**)</td>
<td>(.497*)</td>
<td>(.435*)</td>
<td>(0.202)</td>
</tr>
<tr>
<td>Cost as a reason</td>
<td>0.113</td>
<td>- .465**</td>
<td>-.443**</td>
<td>-.336</td>
<td>-.359</td>
<td>-0.171</td>
</tr>
<tr>
<td></td>
<td>(0.1)</td>
<td>(-0.295)</td>
<td>(-0.313)</td>
<td>(-0.189)</td>
<td>(-0.191)</td>
<td>(-0.119)</td>
</tr>
<tr>
<td>Heating System_ Renewable</td>
<td>.296**</td>
<td>0.203</td>
<td>0.208</td>
<td>0.24</td>
<td>0.276</td>
<td>-0.163</td>
</tr>
<tr>
<td>Gender_Male</td>
<td>-.063</td>
<td>517**</td>
<td>0.23</td>
<td>0.062</td>
<td>0.251</td>
<td>-0.284</td>
</tr>
<tr>
<td>Lived in community more than five yrs_1</td>
<td>-.104</td>
<td>-0.283</td>
<td>-0.288</td>
<td>0.06</td>
<td>0.3</td>
<td>-0.039</td>
</tr>
<tr>
<td>Own Home_1</td>
<td>-0.021</td>
<td>.365*</td>
<td>0.146</td>
<td>0.202</td>
<td>0.162</td>
<td>0.199</td>
</tr>
<tr>
<td>Wiling to Change_1</td>
<td>-.365**</td>
<td>.585**</td>
<td>.465**</td>
<td>.585**</td>
<td>.662**</td>
<td>0.071</td>
</tr>
<tr>
<td>Occupation- Prof</td>
<td>.214*</td>
<td>0.283</td>
<td>0.337</td>
<td>0.306</td>
<td>0.325</td>
<td>0.124</td>
</tr>
<tr>
<td>Occupation - Semi</td>
<td>-.011</td>
<td>0.228</td>
<td>0.021</td>
<td>-</td>
<td>-</td>
<td>0.228</td>
</tr>
<tr>
<td>Occupation - Unskilled</td>
<td>-.17</td>
<td>-.385*</td>
<td>-.332</td>
<td>-.306</td>
<td>-.325</td>
<td>-0.137</td>
</tr>
</tbody>
</table>

(*) significant at least at the .05 level or (**) significant at least at the .01 level.
Table 6 contd. Pearson And Spearman Correlation Table to Examine the Association Among the Variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost as a reason</td>
<td>-0.119</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating system Renewables</td>
<td>-0.069</td>
<td>-0.228*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender Male</td>
<td>0.157</td>
<td>0.01</td>
<td>-0.019</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lived in community more than five years</td>
<td>0.03</td>
<td>0.068</td>
<td>-0.026</td>
<td>-0.048</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Own Home</td>
<td>0.171</td>
<td>-0.12</td>
<td>0.129</td>
<td>.208*</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Wiling to Change_1</td>
<td>0.034</td>
<td>-0.087</td>
<td>-.187*</td>
<td>0.092</td>
<td>0.084</td>
<td>0.052</td>
</tr>
<tr>
<td>Occupation- Prof</td>
<td>.313**</td>
<td>-0.149</td>
<td>.253**</td>
<td>0.117</td>
<td>-0.009</td>
<td>.236**</td>
</tr>
<tr>
<td>Occupation - Semi</td>
<td>0.009</td>
<td>-0.066</td>
<td>0.16</td>
<td>0.009</td>
<td>0.1</td>
<td>0.159</td>
</tr>
<tr>
<td>Occupation - Unskilled</td>
<td>-.272**</td>
<td>.188*</td>
<td>-.318**</td>
<td>-0.115</td>
<td>-0.093</td>
<td>-.272**</td>
</tr>
</tbody>
</table>

(*) significant at least at the .05 level or (**) significant at least at the .01 level.
5.3. Model(s), Results and Interpretations: This section will present logistic regression model to examine the willingness of the individuals to adopt the renewable energy systems. Stepwise variables were added/ removed to get statistically significant model. The dependent variable willingness to change, coded as (yes = 1 and no = 0). The following tables (from 7 to 11) represents the stepwise regression model to test hypotheses.

**Hypothesis 1:** Given Alberta has a great deal of energy spillover; individual Albertans will recognize some of those spillovers.

**TABLE 7: Binomial Logistic Regression Model 1**

<table>
<thead>
<tr>
<th>Step</th>
<th>-2 Log likelihood</th>
<th>Cox &amp; Snell R Square</th>
<th>Nagelkerke R Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>154.538</td>
<td>0.035</td>
<td>0.048</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>S.E.</th>
<th>Wald</th>
<th>df</th>
<th>Sig.</th>
<th>Exp(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender _Male (1)</td>
<td>0.34</td>
<td>0.41</td>
<td>0.69</td>
<td>1</td>
<td>0.406</td>
<td>1.405</td>
</tr>
<tr>
<td>Age Group</td>
<td>0.083</td>
<td>0.144</td>
<td>0.328</td>
<td>1</td>
<td>0.567</td>
<td>1.086</td>
</tr>
<tr>
<td>Lived in community more than five years (1)</td>
<td>-0.521</td>
<td>0.509</td>
<td>1.047</td>
<td>1</td>
<td>0.306</td>
<td>0.594</td>
</tr>
<tr>
<td>Occupation- Prof</td>
<td>-0.469</td>
<td>0.453</td>
<td>1.072</td>
<td>1</td>
<td>0.3</td>
<td>0.626</td>
</tr>
<tr>
<td>Occupation - Semi</td>
<td>-0.744</td>
<td>0.677</td>
<td>1.206</td>
<td>1</td>
<td>0.272</td>
<td>0.475</td>
</tr>
<tr>
<td>Own Home (1)</td>
<td>-0.541</td>
<td>0.57</td>
<td>0.899</td>
<td>1</td>
<td>0.343</td>
<td>0.582</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.533</td>
<td>0.582</td>
<td>0.839</td>
<td>1</td>
<td>0.36</td>
<td>0.587</td>
</tr>
</tbody>
</table>

Table 7 presents the first model. In the first model, out of 121 cases 119 cases were included in model. 2 cases are missing from the model due to the missing value of the cases. The omnibus test of model coefficients shows the model chi-square value is 4.251 and the p-value is less than < 0.05 (significance of .643 and [df= 6]). The Log-Likelihood value is 154. 538 and (R^2) value is 4.8%. The low value of (R^2) indicates that the variables added in the model does not have the prediction capability. Henceforth, this model rejects the first hypothesis.
**Hypothesis 2**: Less satisfied individuals will be more likely to switch (i.e., satisfaction will at least moderate the likelihood of switching.

**TABLE 8: Binomial Logistic Regression Model 2**

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>S.E.</th>
<th>Wald</th>
<th>df</th>
<th>Sig.</th>
<th>Exp(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender_Male (1)</td>
<td>0.221</td>
<td>0.431</td>
<td>0.262</td>
<td>1</td>
<td>0.609</td>
<td>1.247</td>
</tr>
<tr>
<td>Age Group</td>
<td>-0.004</td>
<td>0.158</td>
<td>0.001</td>
<td>1</td>
<td>0.979</td>
<td>0.996</td>
</tr>
<tr>
<td>Lived in community more than five years (1)</td>
<td>-0.34</td>
<td>0.545</td>
<td>0.389</td>
<td>1</td>
<td>0.533</td>
<td>0.712</td>
</tr>
<tr>
<td>Occupation- Prof</td>
<td>0.137</td>
<td>0.494</td>
<td>0.077</td>
<td>1</td>
<td>0.781</td>
<td>1.147</td>
</tr>
<tr>
<td>Occupation - Semi</td>
<td>-0.372</td>
<td>0.691</td>
<td>0.29</td>
<td>1</td>
<td>0.59</td>
<td>0.689</td>
</tr>
<tr>
<td>Current satisfaction level</td>
<td>-1.117</td>
<td>0.324</td>
<td>11.891</td>
<td>1</td>
<td>0.001</td>
<td>0.327</td>
</tr>
<tr>
<td>Constant</td>
<td>3.864</td>
<td>1.448</td>
<td>7.122</td>
<td>1</td>
<td>0.008</td>
<td>47.678</td>
</tr>
</tbody>
</table>

To test hypothesis 2, stepwise variables are added to develop 2 model. Model 2 is presented in table 8. In model 2 variables from the 1st model is transferred to the second model. However, additional variable “current satisfaction level” is added into model 2. In model 2, 117 cases were included, and 7 cases were excluded from the analysis. The omnibus test of model 2 shows that the model is significant ($p<.009$ chi - square of 17.179 and $df = 6$). The log likelihood value of the second model ($-2LL = 138.74$) is lower than the log likelihood value of the first model (154.538). Using (0.01) level of significance, confirms our hypothesis 2 because the “current satisfaction level” coefficient is significant ($p<0.01$). The current satisfaction level Exp (B) is 0.327, which means decrease in the current renewable energy satisfaction level would likely to affect the willingness of the individuals to accept the renewable energy change.

In addition, model 2 also shows the coefficient of the variable “gender” reference category male is not significant. However, interpreting the Exp(B) relative odd ratios of variables gender (reference category male is 1.25 times more likely to adopt a change in comparison to females. Similarly, the Exp(B) of the variable “lived in a community for more than five years” means if individuals have lived in a community for less than 5 years then they are 0.712 less likely to
perceive a change. However, Exp(B) value indicates that semiskilled individuals will 0.689 less likely to accept the change.

**Hypothesis 3:** The more individuals recognize spillovers, the more likely they will switch to Res.

**TABLE 9: Binomial Logistic Regression Model 3**

<table>
<thead>
<tr>
<th>Step</th>
<th>-2 Log likelihood</th>
<th>Cox &amp; Snell R Square</th>
<th>Nagelkerke R Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>136.759</td>
<td>0.151</td>
<td>0.205</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variables</th>
<th>B</th>
<th>S.E.</th>
<th>Wald</th>
<th>df</th>
<th>Sig.</th>
<th>Exp(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male as 1, female as 0</td>
<td>0.22</td>
<td>0.432</td>
<td>0.259</td>
<td>1</td>
<td>0.611</td>
<td>1.246</td>
</tr>
<tr>
<td>Age Group</td>
<td>-0.035</td>
<td>0.161</td>
<td>0.048</td>
<td>1</td>
<td>0.827</td>
<td>0.965</td>
</tr>
<tr>
<td>Lived in community more than five years (1)</td>
<td>-0.324</td>
<td>0.548</td>
<td>0.35</td>
<td>1</td>
<td>0.554</td>
<td>0.723</td>
</tr>
<tr>
<td>Occupation- Prof</td>
<td>0.347</td>
<td>0.517</td>
<td>0.451</td>
<td>1</td>
<td>0.502</td>
<td>1.415</td>
</tr>
<tr>
<td>Occupation - Semi</td>
<td>-0.156</td>
<td>0.723</td>
<td>0.046</td>
<td>1</td>
<td>0.829</td>
<td>0.856</td>
</tr>
<tr>
<td>Current satisfaction level</td>
<td>-1.047</td>
<td>0.325</td>
<td>10.373</td>
<td>1</td>
<td>0.001</td>
<td>0.351</td>
</tr>
<tr>
<td>Solar or geothermal</td>
<td>-0.7</td>
<td>0.506</td>
<td>1.916</td>
<td>1</td>
<td>0.166</td>
<td>0.497</td>
</tr>
<tr>
<td>Constant</td>
<td>3.797</td>
<td>1.436</td>
<td>6.987</td>
<td>1</td>
<td>0.008</td>
<td>44.553</td>
</tr>
</tbody>
</table>

Model 3 is constructed to test hypothesis 3 and for this purpose model 2 is further expanded by adding binary variable “current source of heating system” reference category “solar or geothermal”. In the 3rd model 117 cases were considered for the analysis. The table 9 presents model 3. The model summary shows -2LL (Log Likelihood) value is (136.759) is lower than the model 1. In addition, R² value is 0.205 (20.5%). The omnibus test of model coefficient explains the model is significant (p< .008, chi square of 19.150 and df = 8).

The coefficient value of “current source of heating system” reference category “solar or geo” is insignificant (P values is 0.166 >0.05). However, the Exp(B) of “solar or geo” is (.497) which means that if renewable energy users are not satisfied with the heating system then they are 0.497 times more likely to switch back to the fossil fuel systems. Similarly, the Exp(B) variable
occupation reference category indicates that “professional” are 1.41 times more likely to switch to renewable energy systems despite of their satisfaction level. The Exp(B) value of individuals living in the community for less than 0.71 times less willing to adopt the change.

Models Summaries: Model 1, model 2 and model 3 forecasts the willingness of community members to adopt a renewable energy change. Model 1 does not have capability to anticipate the willingness of the individuals because R square value of the first model is lower than 20. By adding variable “current satisfaction level” in model 2 and “current heating system” (reference category renewable i.e; “solar or geo”) in model 3, increases the overall fit of the model by that it proves our H2 and H3 and reject H1.

The model 2 and 3 predicts that an increase or decrease in the satisfaction level would affect the willingness of the community members to adopt the new energy systems. Particularly, gender male and professional members of the community are more willing to adopt a change in comparison to the female and the semi-skilled group of individuals. Furthermore, from survey data, it’s also found out that individuals living in the same communities for less than 5 years would less likely to adopt new energy systems change.
To determine the willingness of oil and gas users/community members sub-sample analysis is performed. The primary data was divided into two groups. The “oil & gas” users and “renewable energy” user. 82 cases were taken into account to test Hypothesis 4.

**Hypothesis 4**: Communities as a whole, not just individuals, are likely to switch to REs.

**Table 10: Binomial Logistic Regression Model 4**

<table>
<thead>
<tr>
<th>Step</th>
<th>-2 Log likelihood</th>
<th>Cox &amp; Snell R Square</th>
<th>Nagelkerke R Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>110.613</td>
<td>0.027</td>
<td>0.037</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variables</th>
<th>B</th>
<th>S.E.</th>
<th>Wald</th>
<th>df</th>
<th>Sig.</th>
<th>Exp(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male as 1, female as 0</td>
<td>0.131</td>
<td>0.479</td>
<td>0.075</td>
<td>1</td>
<td>0.784</td>
<td>1.14</td>
</tr>
<tr>
<td>Occupation - Semi</td>
<td>0.041</td>
<td>0.883</td>
<td>0.002</td>
<td>1</td>
<td>0.963</td>
<td>1.042</td>
</tr>
<tr>
<td>Occupation- Prof</td>
<td>0.017</td>
<td>0.529</td>
<td>0.001</td>
<td>1</td>
<td>0.975</td>
<td>1.017</td>
</tr>
<tr>
<td>Lived in community more than five yrs</td>
<td>-0.002</td>
<td>0.588</td>
<td>0</td>
<td>1</td>
<td>0.998</td>
<td>0.998</td>
</tr>
<tr>
<td>Own Home</td>
<td>0.796</td>
<td>0.622</td>
<td>1.636</td>
<td>1</td>
<td>0.201</td>
<td>2.217</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.923</td>
<td>0.771</td>
<td>1.432</td>
<td>1</td>
<td>0.231</td>
<td>0.397</td>
</tr>
</tbody>
</table>

Model 4 was constructed to test hypotheses 4. In model 4 is presented in table 10. The variables such as gender, occupation, living in the community for more than 5 years, and abode type does not have capacity to the predict weather individuals would be willing to change their heating system. As shown in the model summary the value of $R^2$ is 0.037 and lower than the 20%. Thus, model 4 rejects the assumption and fail to prove hypothesis 4.

Thereafter, model 5 is constructed to test hypothesis 4. The variables “gender” and “lived in the community” are eliminated from previous model instead, variables “current satisfaction level” “cost as a reason” and “efficiency” is added into the model 5 as presented in table 11. This model includes only 27 cases and 55 cases were excluded from the analysis because of missing value in the dataset. The omnibus test shows the model is highly significant ($p<.009$ chi – square
$-2LL = 15.619a$ and $R^2$ value is $0.471$. The log likelihood value of the second model is $-2LL = 0.670$ and $R^2$ value is $0.6704$.

**TABLE 11: Binomial Logistic Regression Model 5**

<table>
<thead>
<tr>
<th>Step</th>
<th>-2 Log likelihood</th>
<th>Cox &amp; Snell R Square</th>
<th>Nagelkerke R Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15.619a</td>
<td>0.471</td>
<td>0.670</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variables</th>
<th>B</th>
<th>S.E.</th>
<th>Wald</th>
<th>df</th>
<th>Sig.</th>
<th>Exp(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own Home</td>
<td>1.287</td>
<td>2.284</td>
<td>0.317</td>
<td>1</td>
<td>0.573</td>
<td>3.62</td>
</tr>
<tr>
<td>Occupation- Prof</td>
<td>19.989</td>
<td>14637.812</td>
<td>0</td>
<td>1</td>
<td>0.999</td>
<td>4799500</td>
</tr>
<tr>
<td>Age category</td>
<td>-0.005</td>
<td>0.042</td>
<td>0.015</td>
<td>1</td>
<td>0.902</td>
<td>0.995</td>
</tr>
<tr>
<td>Cost as a reason</td>
<td>-0.311</td>
<td>0.159</td>
<td>3.829</td>
<td>1</td>
<td>0.05</td>
<td>0.732</td>
</tr>
<tr>
<td>Current satisfaction level</td>
<td>0.206</td>
<td>0.917</td>
<td>0.05</td>
<td>1</td>
<td>0.822</td>
<td>1.229</td>
</tr>
<tr>
<td>Efficiency</td>
<td>0.587</td>
<td>0.607</td>
<td>0.936</td>
<td>1</td>
<td>0.333</td>
<td>1.799</td>
</tr>
<tr>
<td>Constant</td>
<td>-3.918</td>
<td>4.713</td>
<td>0.691</td>
<td>1</td>
<td>0.406</td>
<td>0.02</td>
</tr>
</tbody>
</table>

The coefficient value of variable “cost as a reason” is statistically significant ($p= 0.05$). The Exp(B) indicates if the cost is higher than the individuals are $0.732$ times less likely to adopt an energy system change. Similarly, the variable “age group “is statically insignificant. However, the Exp(B) value of variable age group indicates that lower age group individuals would less willing to change. This implies that cost plays a significant role in changing individual’s perception to adopt the renewable based energy systems. Moreover, the age factor is inversely proportional to the willingness to change. For the “oil and natural gas community” individuals with the lower age group and cost factor can become barrier for the change. Thus, model 5 identify the cost being the prime reason for the community members to show reluctance to adopt the new energy systems.

**5.4. Future Energy System Preference:** In the open-ended questions, individuals were asked to choose their future energy system. The high number of participants have responded to this question.
As shown in figure 21, the majority of the participants have shown their willingness to adopt renewable based heating systems. However, some participants are still in dilemma to adopt the renewable based heating systems or muddle along the legacy energy systems.

Nonetheless, solar powered heating system is exceptionally popular among the community member as 30% of participants prefer to adopt solar based heating system whereas, 12% of participants prefers geothermal based heating system in the future. 8% of participants have chosen to adopt the hot water-based heating system and 4% of individuals would continue to use natural gas. Moreover, remaining 2% of individuals prefer co-generation systems in the future.

Additionally, about 1% of individuals have chosen hydro and wind as their main source of heating systems in the future. Interestingly, about 12% of participants have shown their interest in adopting a new renewable based heating system however, participants are indecisive to choose solar or wind or geothermal based energy source. Furthermore, 30% of individuals are have shown no interest in changing the system. But surprisingly none of the participants have chosen biofuels energy source for future energy preference.

5.5 Concerns or Positive Benefits/Impact on Community: In total only 29% of the participants have responded to this question as depicted in figure 22. 27% of the participants
have given no response for it. Whereas, 44% of the participants are not familiar and have shown no concerns by simply writing “none”, “no concern” or “N/A” (Not applicable).

![Figure 22: Concerns or positive impact on communities](image)

5.5.1. Renewable Energy Community: Overall response of the renewable heating system user group is positive. The participants have rated their “current satisfaction level” as 4 (very good). The participants responses are mainly positive. The responses are presented below.

(I) Lower GHG Emission, Economic, and Ecological Gain: The survey participants identify renewable energy system has a positive impact on the environment such as offsetting carbon emission, ecological sustainability and highly economical for usage. The renewable group have the higher level of satisfaction presumably due to lower electricity bill. As participants mentioned that using renewable based heating system have significantly recued the electric bill.

(ii). Equal distribution: Renewable based group have shown pleased with their heating systems however, 1 participant concern concerning grid parity. Although only one participant is worried about the fair usage of energy. However, this issue could lead to other behavior issues across community such as anger, annoyance, chaos and may provoke bigger events. To maintain peace and harmony in the community grid parity must be maintained at all costs.
(iii). *Degradation, learning about the systems and pro-environmental behaviour*: In addition, survey participants showed concern regarding degradation of the solar panel components is a matter of concern. The community members have expressed their desire to learn more about the solar based heating system. Interestingly, one participant acknowledged “the prime reason to move to the OKO community is to reduce the carbon footprint. It is noteworthy, participant working in the “oil and gas sector” are also interested to adopt the renewable heating system. Individuals shows the pro environmental behaviour to protect nature and the environment.

(iv). *Inclusivity and togetherness*: Survey participants expressed that living in the community where everyone is using renewable based heating system promotes inclusivity and togetherness in the community.

It appears that substantial renewable group individuals have adopted the renewable based heating system as they may have understood the environmental consequences and ill effects of traditional heating system. The informal interviews further describe participants willing to lower down their carbon footprints by continue using the renewable based heating system. However, the renewable energy group did not consider externalities associated with the renewable based heating system such as landfiling, landscape change, recycling, and battery fire and safety issues are not anticipated by the users.

**5.5.2 Oil and natural gas-based community**: The responses recorded from communities based on fossil fuel energy systems show heterogeneity on opinions.

(i). *Environmental impact of the legacy system*: Survey respondents identify that legacy energy systems are non-eco-friendly, antiquated, and noisy. The participants have expressed their willingness to abandon the traditional systems and adopt the renewable-based heating system based on the price factor.
(ii). Reliability and Cost: The fossil fuel group have two greatest concerns, firstly, participants are worried about the reliability of the renewable-based heating systems and secondly, due to the high initial cost individuals are less willing to adopt system change. This is further proven by logistic model 5. Due to the higher cost factor individuals are reluctant to adopt the future energy system change.

(iii). Monetary gain: Fossil fuel group is more inclined towards adopting a solar-based heating in comparison to the renewable energy source. The choice is mainly driven by monetary advantages such as rebate, lower tax rates, and energy trading.

(iv). Job insecurity and resource usage: The fossil fuel community individuals are excited about the ongoing energy change. However, the job insecurity, declining employment rate is one of the concerns for the individuals living in oil and gas community. Additionally, individuals are not in favour to abandon fossil fuel resources completely. It is mainly because province and country economic growth is dependent on oil and gas sector.
6. FINDINGS AND DISCUSSION

This exploratory study aims to investigate the individual willingness to adopt renewable energy systems. To investigate this question, I started my research by examining the spillover effects of legacy energy systems and renewable energy technologies such as hydro energy, biofuels, wind energy, solar energy, geothermal energy. Although, renewable energy technologies are relatively new, and their effects have not been fully understood by individuals. Some believes that society is lurching towards second disaster first was coal, oil and natural gas. Studies (Nazir, et al., 2019); (Abbasi & Abbasi, 2000) have proven that new energy technologies have some serious challenges which must be resolved and prioritize when designing a new system. Timely transition to renewable energy sources is essential. Undoubtedly, renewable energy technologies are the ultimate solution to mitigate climate change. However, the energy shift from legacy energy systems to new energy technologies entails energy actors (prosumers), different user practice, market change, and policy change. Therefore, to stimulate energy transition endogenously it is crucial how locale population perceive the energy transition. Identifying underlying perception will help in building more resilience, and adaptation strategies for the community members.

6.1 Recognizing Spillover Effects: Survey data underpins both renewable and non-renewable group identifies the negative effects of the legacy energy systems on environment as well as on community at large. The renewable energy users are optimistic about the ongoing energy transition. It might be because renewable energy technologies are relatively new and still under the expansion phase. The long-term impacts are unforeseen.

The willingness to adopt a new energy system is driven by environmental factor. The effect on environment received the highest mean value ('μ' = 3.31) among the other parameters. This indicates that individuals from both groups recognizes the spillover effect of the legacy energy systems. However, the logistic model 1 failed to predict the hypothesis 1 based on demographic information of the individuals.
6.2 Environmental Interdependency: The table of correlation presents that the variable “effect on the environment” has a positive interdependence with the variable’s “usability” and “reliability”. This stipulates that as the usability and reliability increase, the variable “effect on environment” also increases. However, if the individuals are not satisfied with the reliability and usability of the renewable energy systems, then they are less likely to perceive renewable energy change. Particularly, the higher age group individuals. Because the variables – “age group”, “efficiency” and “reliability” have strong positive association with each other.

Furthermore, the data also suggests that older age group individuals are more willing to invest in an efficient and reliable system. The general conception is that older generation tend to opt for things that are frugal, in comparison to younger generation however, right attitude, income level, and increased awareness about the environmental issues are important determinants to adopt a change (Shioshansi, 2011, p -25).

The reliability of renewable based heating system is the main challenge for energy operators in Alberta (Shaffer, 2019). As reported by Statistics Canada, in 2015, Alberta has one of the highest energy consumption rates among the G20 economy (Canada Statistics, 2018). The high energy consumption pattern is driven by need of the individuals. However, needs are dynamic in nature. Rogers (2005) stated, one aspect of the social structure is norms, the established pattern behavior for the social systems (Rogers, 2005). Individuals are reluctant to make any adjustment particularly, at the cost of their “needs”. Therefore, it is a prime challenge of the contemporary society to deal with the management of energy demand (Shioshansi;2011, p-83). The energy demand challenge could be avoided by changing behaviour pattern. Shifting from one system and adopting new system is not an easy process. System change also requires behavioral change. In general, people tend to go for system change if it is attractive or beneficial to them. Most often change is also driven by cost factor or by the influence of the peer group.

6.3. Willingness to Change and Satisfaction Level: Out of 121 cases 47 cases are willing to power their homes with the renewable-based heating systems. Whereas, 75 cases have shown resistance for change. Interestingly, the individuals who are fully or partially using the
renewable-based heating system, do not wish to change their systems in the future and are willing to adopt renewable-based heating systems. Among 75 cases, 30 cases have already adopted the fully renewable-based heating systems or are currently using co-generation heating systems.

![Figure 23: Factors to determine change](image)

From tables of correlations, and, models 2 and 3, it appears that willingness to change is highly significant with the current level of satisfaction. The increase or decrease in satisfaction level will have a repercussion on the willingness of the individuals to adopt the energy change. Meaning with the increase in the satisfaction level community members would be able to make better decision to pursue renewable energy systems. Which also verifies our hypotheses 2 and 3, that less satisfied individuals will be more likely to switch (i.e., satisfaction will at least moderate the likelihood of switching).

Furthermore, the negative association between the variable “expensive” and “current level of satisfaction” signifies that an increase or decrease in the cost of the renewable energy system will affect the decision-making ability of the individuals. This can further affect their willingness to change. Especially to the lower age group individuals and individuals who are engaged in the semi-skilled job profession.
According to SDG 7, the key to the future energy system is to have an affordable, reliable and sustainable supply of energy (SDG, 2018). Apparently, besides the reliability, the price is a major barrier for the people to adopt a new energy system. However, Bakers (2000), structural model shows that perceived performance quality has a stronger influence than satisfaction. It is logical to conceptualise, reliability, cost and efficiency as an important determinant to measure the level of satisfaction.

6.4 Legacy System VS New Energy System: Both groups were examined distinctly to understand the variation between the proximate communities. To examine the discrepancy and underlying perception between the two groups. Binomial logistic regression analysis is carried out. Model 2 and 3 represents the finding of renewable energy community and model 5 represents the legacy energy group.

(i). Attitude of substantial renewable group: Model 2 and model 3 explains, the renewable energy system user group overall satisfaction level effect the decision-making ability individuals. But as discussed earlier, satisfaction has a causal relationship between the variable’s efficiency, reliability and cost factor. Supposedly, environmental factor is the key driver for the substantial renewable energy group to adopt a change but as soon as the reliability, efficiency and overall cost will increase the willingness to adopt a system will likely to decline. In that case the community members will switch back to the traditional heating systems based on fossil fuel. Nudge “incentives” is needed to motivate individuals to avoid any heuristic decision that could have an unseen impact on the community (IRF, 2017). In general individuals act in a rational manner or in their best interest.

(ii). Attitude and perceived differences of traditional system users: Model 5 represents the oil and gas community individuals are willing to adopt the renewable based heating system but due to the high initial cost needed to install renewable based heating community members have shown reluctance to adopt the change. In the model 5 the variable “cost as a reason” shows the statistical significance of (p =0.05). This indicates for the oil and gas community; the cost is
pre-requisite factor in making a decision more than efficiency, reliability and effect on environment. especially, for lower age group individuals.

The Alberta government has introduced tax rebate for adopting renewable based system, the cost still seems to be less affordable for the lower age group and lower-income individuals. In the past decade, renewable energy technologies (solar, wind) prices have reduced dramatically. However, these renewable systems are still expensive mainly because of high maintenance, installation and overall operational cost. Shioshansi (2011) suggested there are two choices either to wait until fossil prices are multiplied or the authority should internalize the external cost or instead gain little advantage of renewable energy through subsides. The earlier option entails significant threat to the environment. Thus, sustainable paradigm shift requires extensive strategy and measure to diverge community members towards more sustainable and carbon free society (Shioshansi, 2011, p 140 -141).

In addition, renewable energy systems are associated with externalities. The externalities are interlinked with different environmental problems such as, land filling, landscape change, lethal lifecycle process equipment’s, fire and safety issues. These issues have been overlooked and renewable energy consumers, policy makers and innovator are not taking this into account how these problems will impact the society. Technology single handedly solve or overcome the energy transition. As new technologies have certain limitations and these limits must not be surpassed.

As discussed in section 3. Alberta is commissioning a solar project. In this project 2.5 million panels will be erected on 1600 hectare of cultivated cropland. The spillover effects of this project could be detrimental for nearby communities. Therefore, it is important for the energy industry and the provisional government to educate communities, build resilience and develop adaptation strategies to make energy transition smooth and sustainable.

6.5. Future Energy System Concerns: Solar energy technology particularly standout when it comes to public perception and acceptance (Heras-Saizarbitoria, et al., 2011). The survey results
have further proven it. The survey results indicate that the future energy system will be
dominated by solar based heating system followed by geothermal and natural gas. Both legacy
and non-renewable community concerns vary broadly.

The oil and gas community respondents’ concerns were job insecurity and Albertan energy
resource. Additionally, the Albertans greatest concerns beside the cost of the renewable energy
is the efficiency of heating systems. Whereas, renewable energy group is more concern with the
gird parity and degradation of the solar panel. Individuals showed interest in adopting
geothermal and natural gas-based heating system. but no survey respondent directly mentioned
their concern on geothermal energy source. Although, it is the second popular preference for the
future energy system. However, biofuels, hydro power, wind energy seems infamous energy
source among Albertans. The high number of individuals are going to adopt the solar energy
system. Especially the current installation of solar panel in Alberta region where industry has a
plan to install million panels to meet the energy demand. Some of the major concerns are
discussed below.

(i). Techno-Environmental Concerns: When comparing the usability and reliability of the new
energy system vs legacy systems, the reliability of the solar energy is often questionable due to
the swing in the intermittent demand. Failure to meet the demand can cause an interruption of
supply to the end-users. Nevertheless, on-grid solution operators have a possibility to meet the
fluctuating demand with non-renewable resources. However, the off-grid users, excess energy
produced is stored in the battery for later use. Battery technology act as a lifeline for solar and
wind energy technologies. Homeowners and utilities are relying on battery technologies to
strengthen the intermittent energy supplies for renewables. The battery storage system conflicts
with the idea of sustainability due to different technical reasons such as recycling, land fill,
batteries fire hazard and other toxic products used in the manufacturing of the technology.
Similarly, geothermal and natural gas energy source requires drilling. During the drilling
process both geothermal and natural gas releases gases, cause seismic activities, contaminates
water bodies. Constant exploration of these resources will affect the human health and could
lead to several other unpredictable environmental problems.
The current state of the art is that lithium is the mainstream technology that has proven to be capable of bringing energy storage. However, lithium-ion batteries are prone to explosion and fire hazards. A recent report published in Bloomberg states that battery explosion has occurred in a complex in the U.S. This is the first case recorded in U.S. However, there are 21 other cases of fire and explosion reported in Korea (Eckhouse, Brian; Chediak, Mark, 2019). Lithium-ion batteries are made up of various lethal elements and compounds. Although they are not inherently dangerous, if handled inappropriately, they are prone to explosion and fire. Small events could bring a massive loss to human lives. Therefore, these issues must be taken into account while designing new policies or formulating the new adaptation strategy in order to build resilience for the community members. The solar panel is an unscrupulous commodity especially when it comes to its usage. Similarly, solar panel components or panel degradation, wearing out or inefficient solar panels will bring the changes in the landscape, particularly with the astonishing amount of material waste.

(ii). Behavioral Concerns: The techno – enviro issues discussed above will have direct and indirect impact on the community members which springs behavioral and other unpredictable events. Social acceptance is essential for the successful adoption of Res (Heras-Saizarbitoria, et al., 2011). With the ongoing energy transition, there might emerge unprecedented events such as people’s values, beliefs, and culture. These eccentric issues are often driven by injustice in the energy distribution or changes in landscapes. In the future, the solar panel theft and vandalism issue could become an entropy. Earlier theft cases have been reported in Australia, the U.S, and India (Simon, 2009). Assuring long term durability and adequate energy supply to all also requires considering behavioral elements.

6.6 Community Based Design Model & Future Recommendations: Public acceptance and perception of renewable energy sources are key factors for accomplishing the transition (Heras-Saizarbitoria, et al., 2011). The government of Alberta seems to focus more on the energy sources inflows by integrating more renewable-based energy sources to mitigate the GHG emission level rate. The province has reduced the overall coal production rate whilst increasing the oil and gas activities such as fracking to retrieve the remaining oil and gas from the used
wells. Undoubtedly, increasing oil and gas activities will enable more employment opportunities and improve provisional economic conditions. Similarly, for the renewable. However, environmental impact cannot be overstated, when the boundaries will be crossed, these problems will overshoot and will have a detrimental impact on both the community and the environment. The Canadian energy companies have built an alliance called Canada’s Oil Sands Innovation Alliance and in shorthand, it’s called COSIA. The alliance is formed in 2012 to co-create and share knowledge to improve environmental performance, measurability and accountability in environmental priority areas such as - GHG gases, land, tailing and water (COSIA, 2019).

Besides, the province is focusing on increasing its renewable energy production capacity to build a more sustainable energy production mix. According to Meadow (2004), the only way to fix the system is by rebuilding the system. The paradigm shift in the energy systems requires an endogenous perspective to welcome the resurgence of interest to identify the determinants (Pack, 1994) for long - term sustainable growth. Thus, here are some mechanisms for change and to offer suggestions about modifying or at least contextualizing them further

(i). To accelerate the adoption of renewable energy technology in Alberta the government should focus on formulating energy policies that could provide monetary support to initiate endogenous change among individuals. The main focus should also be given to the lower age group and lower-income households. The monetary incentives will steer people’s behavior to adopt the change. Giving nudge incentives will influence people’s judgment and behavior to make a decision (Hansen, 2016). These nudges could be combined with the traditional regulatory approach or independent policy to aid the energy transition.

(ii) Survey data points out that males are more willing to adopt the ongoing future energy transition in comparison to females. Therefore, females must be encouraged to actively participate in a new energy paradigm shift. The world economic forum acknowledged that more woman participation is needed to build resilience towards the ongoing environmental
circumstances to navigate the practical solutions that are needed to fight for the ongoing change (Sinha, 2019). Thus, it could also be implemented in the Albertans energy transition process.

(iii). Alberta has the highest energy consumption rate among G20 countries. To foster effective ongoing transition requires changes in individual lifestyles which might affect the decision-making ability or willingness to adopt ongoing change. Thus, the government should host educational events concerning future energy transition. The ideal would be to bring both renewable and non-renewable communities together for an open-ended discussion on adopting the ongoing energy transition in the province. In general, people tend to accept change under the influence of others. The ideas and concerns should be shared through a common platform where businesses, innovators, government representatives would also participate and address some of the community concerns and also get a new perspective to design the future energy policies.
7. Conclusion

The findings of the thesis show that Albertans are willing to adopt the ongoing energy transition. The data collected from two proximate oil and gas communities and one substantial renewable community revealed the likelihood of the individuals to adopt a renewable based heating system primarily depends on the cost factor and current satisfaction level respectively. Moreover, satisfaction level shows a causal link with reliability, efficiency and cost parameter. Both groups show heterogeneity of opinions for adopting renewable energy systems in the future.

The results show that substantial renewable energy systems users are pleased with current heating system usage and would prefer to continue with a renewable-based system in the future as well. Furthermore, community members are determined to use other forms of renewable-based heating systems to compare the performance of different renewable energy systems. The data also unveiled that community members recognize some of the spillover effects of the legacy system and their readiness to adopt the change is driven by the environmental factor.

Whereas, the communities relying on fossil fuel energy sources showed unwillingness to adopt a renewable-based heating system due to the high initial cost but, likely to adopt a 100% renewable-based heating system only if there are monetary incentives.

Albertans are more inclined to solar, geothermal systems. To accelerate the transition and to bring endogenous change incentives should be offered to diverge community members towards more sustainable and carbon free society. The incentives combined with the traditional regulatory policy or independent policy will aid the energy transition. Renewable energy technologies are also subject to externalities. The long-term effects associated with new energy technologies are still understudies and not yet fully understood. Thus, for smooth energy transition, externalities should also be taken into account for long - run sustainable growth.
REFERENCES


Barclays, 2015. Environmental and Social Risk Briefing Oil & Gas, Barclays Bank PLC.


K.Benjamin, S., n.d.


M.M.Aman, K., n.d.


Randers, J. et al., 2018. Transformation is feasible Report, s.l.: Stockholm Resilience Centre.


SDG, 2018. HLPF Review of SDG implementation: SDG 7- Ensure access to affordable, reliable, sustainable and modern energy for all, s.l.: United Nation.


Sharp, Alastair;, 209. Canada's National Observer. [Online]. Available at: 

development: A review of sustainability impacts and assessment frameworks. Renewable and
Sustainable Energy Reviews, Volume 44, pp. 391-406.

Simmie, J., 2012. Path Dependence and New Technological Path Creation in the Danish Wind

[Accessed 19 10 2019].

Sioshansi, F. P., 2011. Why Do We Use So Much Energy , and What For ?. In: F. P.
Sioshansi, ed. Energy Sustainability and Environment , Technology , incentives and Behaviour.

Snyder, J., 2017. Financial Post , Two thirds of Canada's electricity now comes from
renewable energy. [Online] .Available at: https://business.financialpost.com/news/two-thirds-

Solangi, K. et al., 2011. A review on global solar energy policy. Renewable and Sustainable

Sovacool, B. K., & Hess, D. J. 2017. Ordering theories: Typologies and conceptual
frameworks for sociotechnical change. Social studies of science, 47(5), 703–750.


Suncor Energy Inc, 2019. REPORT ON SUSTAINABILITY , Suncor Energy Inc..


Whitworth, B., 2009. A Brief Introduction of Socialtechnical Systems,


Willms, I., 2019. This is the world's most destructive oil operation—and it's growing Can Canada develop its climate leadership and its lucrative oil sands too?. [Online]. Available at: https://www.nationalgeographic.com/environment/2019/04/alberta-canadas-tar-sands-is-growing-but-indigenous-people-fight-back/. [Accessed 06 10 2019].


Appendix 1 - Survey Questionnaire on Perceived Differences among Heating Sources

Dear Potential Participant,

I am a master’s Degree Student at Lappeenranta University of Technology (LUT), Lappeenranta, Finland. Currently, I am a visiting University of Alberta to work on my master’s degree (M.Sc.) thesis. The research focuses on differences among types of energy systems used in communities and community response to them. This survey focuses on the second portion – community response (e.g., acceptance, satisfaction, and suggested changes). Your involvement by filling out the survey will be invaluable for examining the pros and cons of different systems. I greatly appreciate your candid responses.

Please note the participation in this survey is voluntary, and your will be anonymous. I have found that the survey takes 10 minutes or less to complete.

Thank you in advance for your time and effort.

Sincerely,

Shandra Pandey
Lappeenranta University of Technology (LUT) School of Engineering and Science

1. Please indicate your apartment or home type: *
   - Rental
   - Owned
2. Please indicate what kind of heating system you have in your house? *
   - Primarily oil
   - Primarily natural gas
   - Primarily solar
   - Primarily geothermal
   - Other please specify ……………………….

3. Please rate your overall satisfaction level with your current heating system: *

   1…………………….2…………………….3…………………….4…………………….5
   Strongly Dissatisfied   Strongly Satisfied
   Dissatisfied          Dissatisfied Neutral Satisfied
   Satisfied             Satisfied

4. Please indicate what type of heating system you have used before?
   - Primarily oil
   - Primarily natural gas
   - Primarily solar
   - Primarily geothermal
   - Other please specify

5. Please rate your overall satisfaction level with that your prior system:*

   1…………………….2…………………….3…………………….4…………………….5
   Strongly Dissatisfied   Strongly Satisfied
   Dissatisfied          Dissatisfied Neutral Satisfied
   Satisfied             Satisfied

6. Would you like to change the way you heat up your housing? *
   - Yes
   - No
7. If “Yes”, why do you want to change? (Please choose one of the following and rate it from 1 to 4, with 1 as unimportant, 2 as somewhat important, 3 as important, and 4 as very important.)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Too Expensive</td>
<td></td>
</tr>
<tr>
<td>Efficiency</td>
<td></td>
</tr>
<tr>
<td>Usability</td>
<td></td>
</tr>
<tr>
<td>Reliability</td>
<td></td>
</tr>
<tr>
<td>Effect on environment</td>
<td></td>
</tr>
<tr>
<td>Other please specify:</td>
<td></td>
</tr>
</tbody>
</table>

8. Are there any concerns with or positive benefit from your current energy system’s impact on your community?
____________________________________________________________________________
____________________________________________________________________________

9. Presuming it was not too costly or unreliable, what type of system would you prefer?
__________________________

Demographic Information
10. Gender: __________
11. Approximate Age:

☐ Under 25
☐ 25 - 34
☐ 35 - 44
☐ 45 - 55
☐ Over 55

12. Your current (or most recent) occupation? ______________________
13. Have you lived in the community for more than five years? Yes__ No __

Thank you!

Internal Codes:
Respondent #: _____
Date, Time: ____________________________