Muskrat Falls Hydroelectric Generating Project

Develop an Integrated Approach to Assess Sustainability

by

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Measurement Units

MW	Megawatts
TWh	Terawatt Hours
Kg	Kilogram
$	Dollar
HVdc	High Voltage Direct Current
kV	Kilovolt
sq mi	Square Mile

List of Abbreviations

AD	Anno Domini
CCEE	Climate Change and Energy Efficiency
DF	Department of Finance
DNR	Department of Natural Resources
DSR	Driver Force-State-Response
EEG	Engendering Economic Governance
EPI	Environmental Performance Index
EU	European Union
GDP	Gross Domestic Product
GovNL	Government of Newfoundland and Labrador
GHG	Greenhouse Gas
HQ	Hydro Quebec
HVdc	High Voltage Direct Current
IRR	Internal Rate of Return
IUCN	International Union for Conservation of Nature
MDGs	Millennium Development Goals
MF	Muskrat Falls
NPV	Net Present Value
NL	Newfoundland and Labrador
NP	Newfoundland Power
NRCan	Natural Resources Canada
OECD	Organization for Economic Co-operation and Development
PESTLE	Political, Economic, Social, Technological, Legal and Environmental
PM	Particulate Matter
R&D	Research and Development
ROE	Return on Equity
SD	Sustainable Development
SDM	Structured Decision Making
SDGs	Sustainable Development Goals
SGIs	Sustainable Governance Indicators
SI	Sustainability Index
SSI	Social Sustainability Index
UNDESA	United Nations Commission on Sustainable Development
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
WCS	World Conservation Strategy
WWF	World Wildlife Fund

Abstract

Hydroelectric energy is the most abundant source of energy for Newfoundland and Labrador. However, the production of this energy has some uncertain and contestable socio-economic and environmental impacts. This research project proposes a new methodology for assessing the sustainability of a hydroelectric project and develops a sustainability index (SI_{HEP}) which can assist policy makers when planning for sustainable development of hydroelectric energy sources. A four pillars concept of sustainability (i.e. social, economic, environmental and governance) is used to construct this SI_{HEP}. The proposed methodology uses the PESTLE framework to identify the relevant parameters. The SI_{HEP} is applied to the Muskrat Falls hydroelectric project in Newfoundland and Labrador. The results show that the project is moderately sustainable, as there are some weak governance issues identified. The research project makes some policy recommendations for the sustainable development of the ongoing Muskrat Falls project which can also be used in other forthcoming hydroelectric energy projects.

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Chapter 1 Introduction

1.1 Background Information

Energy plays a vital role in socio-economic development and in raising standards of living (Oyedepo, 2012). Newfoundland and Labrador (NL) is an eastern province of Canada blessed with different types of energy resources and considered a warehouse of oil, gas, hydro, wind and other energy sources. The province has a total energy potential of 18000 Megawatts (MW) from renewable electricity generation and requires only 2000 MW to meet its own electricity demands (Energy Plan, 2007). Hydroelectric energy is an important energy source for the province because it is renewable, clean, and less impactful on the environment when compared to conventional nonrenewable energies. Moreover, it is a relatively cheap and reliable energy source (Dursun and Gokcol, 2011).

There are two hydroelectric projects planned for development on the Lower Churchill (LC) River in Labrador. Construction of one of them, the Muskrat Falls (MF) project, with the capacity of 824 MW has already started. The second project, the Gull Island (GI) project has an estimated capacity of 2250 MW. Construction of the GI project will start after the completion of the ongoing MF project (though this is unlikely because of uncompetitive energy export price and political issues). Nalcor Energy and Emera Inc., public corporation of NL and Nova Scotia, have signed a contract to develop the phase 1 of the LC project. The construction of MF is already underway, with the construction of main facilities and setup the transmission links ongoing. The produced electricity from the MF project can be used for domestic purposes and for export, thereby accelerating the economic development of the province. The MF project is expected to offer benefits not only by supplying electricity to NL, but also by exporting it to NS, Atlantic Canada and parts of the United States. Moreover, the project is expected to provide electricity to customers with improved reliability and at a reasonable price. This will provide substantial revenue security to the MF project (Weil, 2012). A hydroelectric project like the MF project has the ability to contribute to the sustainable economic development of the province as well as improve the living standard of its people (Dursun and Gokcol, 2011).

The concept of sustainability has developed over the last three decades, evolving into three main pillars– social, economic and environmental sustainability (Moldan et al., 2012) and recently the necessity of governance as the fourth pillar has been emphasized by the UN for SD (UN, 2014).

Each of the pillars is so interconnected that the sustainable performance of each of them is essential to ensure the sustainable development (SD) and wellbeing of humanity. Similarly, sustainability of energy is connected with human wellbeing (Jorgenson et al., 2014). According to the International Energy Agency (IEA) definition "renewable energy is derived from natural processes that are replenished constantly" and renewable energy is sustainable because this energy ensures the balance of resource uses with the ecosystem and the wellbeing of humans (S Energy, 2013). Sustainability of energy appeared as great concern in the literature and is considered an essential part of the post-2015 agenda (OECD, 2014). The World's dependence on nonrenewable energy such as fossil fuels is very high (80% of overall primary energy comes from fossil fuels) and this causes many detrimental impacts on both the environment and human life. Stambouli et al. (2012) and Panwar et al. (2011) showed that the quality and safety of both present and future generations strongly depends on the availability and sustainability of energy. On the other hand, improved renewable energy policy and technology contributes to SD and solves many energy related problems (Banos, 2011; Hashim and Ho, 2011; Panwar et al. 2011). The development of renewable energy ensures both a sustainable energy supply and the wellbeing of humans. As such, it is important to establish the level of sustainability a project like MF provides through a holistic, integrated and rigorous assessment process.

1.2 Literature Review

The literature review was conducted with the aim of understanding the impacts of hydroelectric power generation projects on the four sustainability pillars: economic, social, environmental and governance. The findings of the research on hydroelectric projects are mixed (both positive and negative). For example, a survey report on two hydroelectric projects in Uttarakhand, India, shows that the local people and private organizations emphasized that there are adverse social and environmental impacts. The villagers of the affected area think that their way of living and social system is changed significantly. They also think that the future sustainability of the project is uncertain. The industry respondents on the other hand, emphasized the economic benefits (Diduck, et. al., 2013). Sovacool and Bulan (2011) showed that centralized energy megaprojects[1] in Malaysia often fail to address the major development goals like energy poverty reduction, increased living standards within the local community, etc. On the contrary, another research

[1] General the hydroelectric projects are classified in three groups according their scale. Small scale: 1-10 MW, Medium scale: 10-100 MW and Large scale: more than 100 MW. Hydroelectric project with more than 1000 MW

finding on multi-dam (multiple dam on same river) hydroelectric projects in Turkey shows that there are numerous social and economic benefits experienced in the local area, but there are also a multitude of adverse impacts observed on the environment (Berkun, 2010). In the same way, Yuksel (2012) stated that hydroelectric plants often perform better than other power plants from the standpoint of socio-economic and environmental considerations. The environmental impacts of hydroelectric plants are lower than any other alternative sources of energy.

Similar socio-economic and environmental impacts of hydroelectric projects were experienced in Canada. Loney (1995) showed that the social pathology of aboriginal communities in Manitoba has significantly altered with the development of hydroelectric projects. The project created loss in their fishery and that accelerated crime and violence in the locality. According to Helston (2012), Canadian hydroelectric industry stimulates economic growth, creates employment and develops infrastructure. Apart from this, large hydropower projects draw in additional commercial and industrial activities. Helston (2012) also showed that there are both positive and negative environmental impacts of Canadian hydroelectric projects. For example, hydroelectric projects replace energy sources that produce large amounts of emissions and pollutants; however, they hamper water ecosystems, and contribute to plant and animal biodiversity loss.

The variation in socio-economic and environmental impacts of multi-dam or mega hydroelectric projects is apparent from the above literature. The root cause of this variation identified in the literature is governance issues (Grumbine, et. al., 2012; Scanlon, et. al., 2004). Good governance is thus another important and very crucial sustainability pillar that acts as a prerequisite for a successful hydroelectric energy investment; any sustainability assessment of hydroelectric project needs to take this into account. The UN (2014) defines governance as "the process of decision-making and the process by which decisions are implemented (or not implemented)" and good governance prevails when this decision making process covers some major characteristics. The characteristics of good governance include different practices from different groups of people. For example, the rule of law is ensured by law and enforcement agencies; policymakers formulate and implement necessary policies with coordinated efforts; and general citizens raise their voice to help the government to make the right decisions. Many countries find this as a serious constraint; to put the right things together at the right time with the right cost by the right people. Countries like Nepal fail to accomplish their goals because their governance issues are impacting their hydroelectric development (WPDC, 2013). Good governance is very important and essential for the hydroelectric projects that use water resources from trans-boundary water sources. Often, hydroelectric projects lead to international geo-political tensions between two neighboring countries. Good governance helps to formulate proper policy structures and strategic plans to deal with common issues that may arise due to investment in trans-boundary water facilities (Clarke, 2015).

Generally, research on the subject concludes that hydroelectric power generation projects are socio-economically sustainable; however, they are also linked to adverse environmental impacts and governance issues that may hold back their development. Thus, the balance of beneficial and adverse effects is uncertain and context specific, suggesting the importance of measuring overall project sustainability where such energy developments take place. There are a number of studies on hydroelectric energy generation worldwide that investigate their social, economic and environmental impacts (Akyurek 2005, Emiroglu 2009, Frey and Linke 2002, Choy and Yee 2005). However, there is no study to measure inclusive sustainability of a hydroelectric project. Further, no research has been done on the MF project at LC specifically to measure its sustainability. The provincial government has completed two assessments of the MF project: Environmental Impact Statement and the Economic Feasibility Report. Neither of them offers a structured way of measuring sustainability and on top of this, Public Utilities Report (PUB, 2012) stated that there is not enough information to determine whether MF is the best long-term power option for NL. More importantly, there are no standard composite metrics to evaluate the sustainability of a hydroelectric energy project that take all four pillars into accounts.

1.3 Research Objectives

This research offers a methodological framework and sustainability index for a hydroelectric energy project (SI_{HEP}) (focusing on four pillars) that can be applicable to any hydroelectric energy project to measure its sustainability. This tool is then used to evaluate the sustainability of the new renewable energy project in the province- the MF project at the LC River. The methodology applied the Structured Decision Making (SDM)[2] approach (Wilson and Arvai, 2011) and logically designed it into a series of steps, which were: define the problem related to the hydroelectric project; set objectives; link to performance measures or criteria; account for uncertainty; demonstrate the utility of the index to create alternatives; show utility of the index to

[2] Structured Decision Making (SDM) is an organized approach used when identifying and evaluating creative options and making multifaceted decision in complex situations.

characterize consequences; use of the index in case studies for monitoring and adaptive learning; identification of policy gaps and proposing prescriptions. This logical structure is focused mainly on answering the following questions:

- What are the criteria for measuring sustainability of a hydroelectric energy project?
- What are the potential social, economic and environmental impacts of this project at the local, provincial and federal levels?
- What is the state of governance for developing this project?
- What is the level of sustainability to invest in such hydroelectric generation project?
- What are the policy essentials to ensure the sustainability of this project?

Assessing the sustainability of the MF hydroelectric project by using an integrated four pronged sustainability index (social, economic, environmental and governance), this thesis identifies some weak sustainability aspects of the project and recommends several sustainability-oriented policies for improvement. This thesis is divided into several chapters. The first chapter defined the research problem and objective of the study. Chapter 2 provides a brief outline of the methodology that is used for the research. Chapter 3 presents a description of the study area that includes the energy status of the province along with its socio-economic and environmental attributes. Chapter 4 presents the application of PESTLE analysis to identify the key issues (parameters) related to a hydroelectric project and a detailed discussion of the design, construction, and operation of the sustainability index. Chapter 5 presents the practical application of the developed framework on the MF hydroelectric project. Chapter 6 presents the analysis on existing energy policies, identifies the policy gaps and recommends necessary policies. Overall, the research work presented in the following chapters will measure the sustainability of the mega hydroelectric project in MF and will also provide a holistic tool to measure the sustainability of hydroelectric projects anywhere in the world.

Chapter 2 Research Methodology

This research proposes a new methodology for estimating the sustainability of a hydroelectric energy project. This framework will use a Structured Decision Making (SDM) approach (as shown in Appendix B) for the creation of the SI_{HEP}. A set of specific criteria has been developed by the researcher to measure and categorize the sustainability of a hydroelectric energy project. The framework sets four fundamental objectives for measuring sustainability:

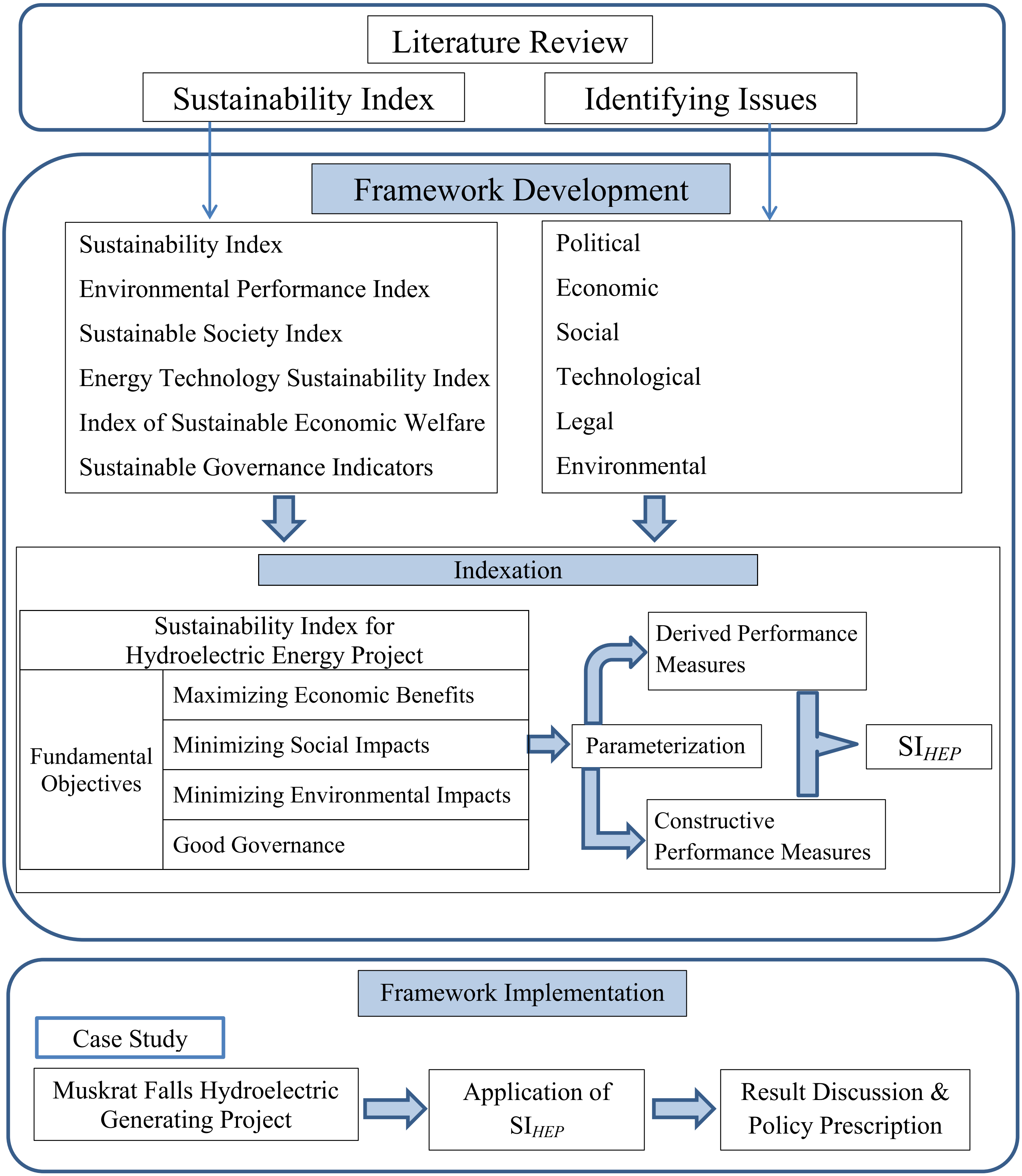

Figure 1: Research Methodology

minimizing social impacts, minimizing environmental impacts, maximizing economic benefits and good governance. This tool will provide the conceptual design based on extensive literature, as well as construction and execution procedures to measure sustainability. To extract all the relevant parameters, the operational framework includes the dynamic PESTLE analysis that encompasses all aspects related to a hydroelectric project. To obtain most accurate results, the proposed holistic tool requires both primary and secondary data. The tool includes both quantitative-data analysis and qualitative analysis; obtain by utilizing a participatory approach. The index can be calculated either by derived measures or by constructive measures or both. For indexation of some necessary qualitative data and to validate the SI_{HEP}, the methodology incorporates a sustainability workshop, called the constructive measure. The sustainability workshop will be organized with participation from local residents, stakeholders, government officials, energy experts, social scientists, etc. This will help to rank each indicator according to the sustainability scale. The average of the derived values (from secondary sources) of the indicators and constructed values from the workshop will be used to calculate the sub-indices and the SI_{HEP}. For the case study of the MF project, the sustainability workshop was not conducted and only the derived measure is used to calculate the SI_{HEP}.

The overall methodological framework is shown above in Figure 1. Here the first three phases are for framework development and the fourth phase includes the case study of the MF project. In phase one, a literature review will be conducted to explore all the existing sustainability indices. This will help to determine scope, boundaries, scaling and interpretation for the new tool. In phase two, an extensive PESTLE analysis will be conducted. The analytical tool PESTLE (Political, Economic, Socio-Cultural, Technological, Legal and Environmental) will determine the potential economic, environmental, social, and governance related impacts, as well as the uncertainties and the risks of hydroelectric project. Further, it will help to frame and contextualize the project. The application of this tool will allow us to identify and select all relevant parameters and their indicators necessary to compute the SI_{HEP}. In phase three, the values of indicators will be identified from the secondary sources for derived measurement, and the values of the indicators will be ranked in terms of the sustainability scale in the sustainability workshop as a constructive measure. Both derived and constructive values are used to compute the SI_{HEP}. In phase four, the developed methodological framework will be applied to MF hydroelectric project to determine its sustainability. In summary, this study will develop a tool, the Sustainability Index for Hydroelectric Energy Projects (SI_{HEP}), to measure the overall sustainability of any hydroelectric energy project. It will address the triple bottom line in decision-making (maximize economic, social and environmental values) along with the relevant governance issues.

The Driver Force-State-Response (DSR) framework will be used for policy prescription. The DSR framework was developed by the United Nations Commission on Sustainable Development (UNCSD) to provide a set of indicators that help to produce sustainable energy policies (Naimi and Zadeh, 2012). Figure 2 shows the DSR framework. The DSR framework is considered as an ideal tool for policy making in the energy sector because this framework addresses the complex web of socio-economic and environmental effects as well as the governance issues related to energy development. This tool is used frequently for policy prescription in energy research (Vera and Langlois 2007, IAEA et al. 2005 etc.)

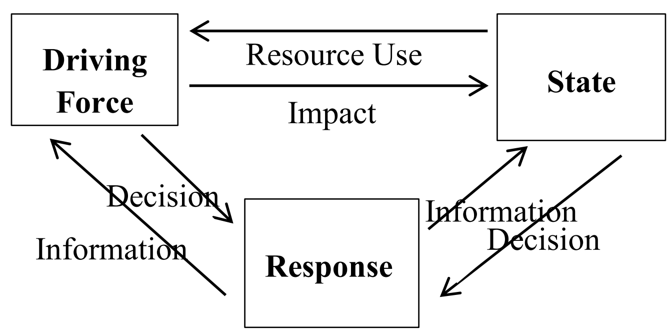

Figure 2: The DSR framework (DSD-UNDESA, 2001)

Chapter 3 Study Area Overview

Newfoundland and Labrador (NL) is the most easterly province of Canada. It is situated within the Atlantic region as shown in Figure 3. The province incorporates an island called Newfoundland and a part of main land Canada called Labrador. The combined land mass of the Province is 405,212 square kilometers (156,500 sq mi) (NL Community Account, 2015). The population of the province is very low compared to other provinces. In 2013, its population was 526,702; with almost 92 percent of the population living on the island of Newfoundland (NL Community Account, 2015). Historically, the province has experienced many changes in its socio-economic and governance patterns, and evolved through them.

Newfoundland has been home to aboriginal peoples for thousands of years. Europeans of Nordic decent first discovered the province around 1000 AD; however, these people did not colonize the region (GovNL, 2015). Newfoundland was rediscovered by the Italian navigator John Cabot in 1497 (GovNL, 2015). The region quickly became a lucrative port for settled fisher people from countries including; England, Portugal, France, and Spain (GovNL, 2015). The province was under British dominion for a long period of time from 1907-1949 (Earle, 1988) and gained significant internal control after the Balfour Declaration (1926). NL became part of Canada as an independent territory in the 20th century to bail out from its economic crisis (GovNL, 2015). Economic crisis was underway in the province during the Great Depression and the Second World War within a fifteen year period. People lost faith in British dominion as they refused to bail them out from this crisis and decided to join with Canada.

Canada Newfoundland and Labrador

Figure 3: Map of Newfoundland and Labrador

The Province of Newfoundland and Labrador became part of Canada in 1949. Because of the British legacy, 97.6 percent of its population's mother language is English. Apart from the English language, French and Irish languages are spoken in the province. This is because, historically, NL was also home for some French and Irish people. The extinct language of the Beothuk Native Peoples is not spoken anymore. In Labrador, local dialects of Innu-aimunand called Inuktitut are also spoken (DL, 2015).

Communities of the Province:

Historically, there are four groups of people, including both aboriginal communities and migrated communities in this province. They are: Inuit, Innu, Metis and Settlers. Each of them has their own culture and separate way of living. Migrated populations are considered non-aboriginal settlers and they were very few in number in the past. However, these non-aboriginal settlers make up the majority of people in the province now. Apart from the English speaking settlers, there are some migrated people from France who speak French in Labrador (DL, 2015).

First Inhabitants: Human civilization first came to NL province around 9000 years ago. They were mainly attracted to the abundance of fish resources (Tuck, 1991). After that, different groups of people settled on the island and around the coastal region of Labrador.

First Nations: The First Nations are formerly known as Indians and they include the Innu of Labrador and the Mi'kmaq. The Innu in Labrador live in two communities: Natuashish and Sheshatshiu. The Natuashish community was developed in 2002 and they call themselves the Mushuau Innu. The other group Sheshatshiu call themselves the Sheshatshiu Innu. The Ancient Innu inhabitants came to the province over 7000 years ago according to the available archeological evidence. Both Innu groups have many similarities. They have similar cultures, the same language- Innu-aimun, etc. The Innu population's main profession was hunting and mostly they were caribou hunters though this has changed now and their professions are diversified.

The Mi'kmaq live all over the island of Newfoundland but are concentrated mainly on the West and South Coasts and Central Newfoundland (Hanrahan, 2012). This group speaks like most other aboriginal groups in Canada. Only a few thousand people of Mi'kmaq ancestry are currently registered in the FNI (Federation of Newfoundland Indians) bands and their language is considered as a threatened language. In 2012, 23,877 people were registered in the Qalipu band with total applications over 101,000 currently being assessed.

Inuit: The Inuit, formerly known as Eskimo, never came under Indian Act. This group includes The Inuit of Nunatsiavut and The Southern Inuit of NunatuKavut. The Nunatsiavut heartland is the Northern Coast of Labrador. It consists of five communities as well as others in Central

Labrador. The NunatuKavut's heartland is the South Coast of Labrador from Lodge Bay to Paradise River although members live in Central Labrador and elsewhere (Hanrahan, 2012). Around 20 percent of the total population of Labrador is Inuit. In 2005, they have started to self-govern in the Northern Labrador and the region is now called Nunatsiavut 'our beautiful land.'

Labrador Metis: The Labrador Metis are the progenies of Aboriginal females and European male settlers. The females in this relation were mostly from the Inuit communities. The largest community of Labrador Metis is currently located along the southern coast of Labrador as well as in the Lake Melville area. They spend winter in sheltered bays and summer in harbors or on islands. This aboriginal community is not recognized by the provincial authority (Storey et al., 2011). The Metis community formed their separate council in 1981 and named it as NunatuKavut Community Council.

Settlers: Generally everyone who was non-aboriginal in Newfoundland and Labrador was known as settlers. Most of those who came to settle Newfoundland and Labrador subsisted as fisher people. In addition, the region also attracted persons interested in business and missionary work. The majority of early settlers were of European decent.

Among the communities living in Labrador, the Nunatsiavut and NunatuKavut communities are most affected, as they are living in, within and around the MF project area. The Inuit of Nunatsiavut are living downstream of the Lower Churchill River mostly in Happy Valley-Goose Bay. The Labrador Metis of NunatuKavut are living in the Lake Melville area. These native communities are most vulnerable to any social and environmental effects. Two probable impacts that these communities may face because of the MF project are related to its land acquisition and water management. Use of land for this project is regulated by the 'Muskrat Falls Land Use and Exploration Act, 2012'. This law is consistent with 'Labrador Inuit Land Claims Agreement Act, 2005' which was set out to protect aboriginal communities, land and archeological sites. Land use for both project construction and transmission line setup will follow the terms and conditions of the 'Labrador Inuit Land Claims Agreement Act' prior to the 'Muskrat Falls Land Use and Exploration Act'. But concerns exist among both the communities about hunting grounds and wildlife habitat. Similarly, there are water related concerns including: flooding, mercury levels in the water, etc.

3.1 The Energy Sector

NL is considered an energy warehouse in North America as it has rich supply of both renewable and nonrenewable energy resources. With the available energy supplies, the province can meet its own energy demand and also can export energy for years (Energy Plan, 2007). Proper energy policy support and strategic planning are needed to explore and exploit this potential. Policies for responsible development of both renewable and nonrenewable resources will boost the provincial economy and bring long term economic stability. Energy security is crucial for continued growth and development. The province formulated its energy sector development policy action plan in 2007 (Energy Plan, 2007). Every three years the province develops a strategic development plan for the next three years to secure its energy supply for the long term (DNR-NL, 2015). Two energy industries are prominent in NL: the oil and gas industry and the electric power industry.

Oil and gas industry: The oil and gas industry is the major energy industry in the province in terms of investment, employment generation and government revenue. This industry makes the largest contribution to the provincial economy (GovNL, 2012). The provincial economy largely depends on the revenue earned from this industry. Statistics shows that the oil and gas industry contributes more than 30 percent to the gross domestic product (GDP) of the province and provides employment to more than 5500 people in NL (GovNL, 2012). Thus, the oil and gas industry plays a major role in the provincial economy. This overreliance of the provincial economy on oil, can present a risk for social-economic sustainability, as the recent impact of the fall in oil prices has demonstrated.

Electricity: The electric power industry is a small industry with high potential for growth in the province. Overall activities in this industry, from power generation to distribution within the province, are done by two organizations. They are Newfoundland Power (NP) and NL Hydro. More than 280 thousand electricity customers in the province are jointly served by these two organizations. As the island of Newfoundland and Labrador are geographically separated, different power supply systems are used in the province. An interconnected power system is used on the island that has capacity of around 2000 megawatt (MW). Customers in Labrador are served by another similar interconnected system that receives power from the Upper Churchill project[3]. Apart from this, there are some (25) diesel based small power generation plants to serve customers in the remote and disconnected areas of the province. Statistical comparisons of power generation trends (according to the production source) for Canada and the province are shown in Appendix A. The data shows hydropower is the dominant source of renewable electricity production followed by wind sources.

A major portion of electric energy requirement of the province (92 percent) is supplied by NL Hydro. NP operates 23 small scale hydroelectric systems to serve the other customers. As a result, 80 percent of the total energy supply of the province comes from clean, hydroelectric generation systems. According to the Department of Natural Resources (2012), the power generation capacity of NL Hydro consists of nine hydroelectric plants, one oil-fired plant, four gas turbines, 25 diesel based power generation plants, and thousands of kilometers of transmission and distribution lines. The Churchill Falls Corporation is a subsidiary company of NL Hydro and it has the maximum share (75 percent) of plant operation. This is because the Upper Churchill Falls generating station has 11 turbines with a total generation capacity of 5428 MW and has the biggest underground powerhouses in the world. This plant produced more than 34 Terawatt hours (TWh) of electric energy in 2008. A major portion of this energy goes to Hydro-Québec (HQ) because of the long-term power purchase arrangement between the province of NL and the province of Quebec. This arrangement will be finished in 2041. Half of the obtained power from this project (150 MW) is used for two purposes: for mining operations in West Labrador and for the interconnection system in Labrador that is controlled by NL Hydro. NL Hydro also sells around 50 percent (150 MW) of electricity to external markets in Atlantic Canada and some parts of the United States (NRCan, 2012).

The provincial government has committed to a mega project requiring them to build two hydroelectric dams on the LC River. This LC Project is considered to be one of the most lucrative and embryonic hydroelectric projects in the recent history (Nalcor, 2015). The project has two installations: Gull Island and Muskrat Falls. Together they will have a capacity of over 3,074 MW. This mega project will have the ability to provide 16.7 TWh of electricity each year. The project is expected to displace over 16 megatons of CO_2 emissions every year by replacing

[3] The Upper Churchill generation facility is the biggest hydroelectric project of the province and second biggest project in Canada.

the fossil fuel based power production systems in the province. The government of NL is focusing on clean, stable, renewable energy with these policy actions and strategic decisions. The long term goal of this project is to meet domestic and industrial needs in the province and export remaining power to other jurisdictions. According to the investment agreement, 40 percent of the project production will be used domestically and 40 percent will be exported (Weil, 2012). For covering 20 percent of investment in transmission line setup, Emera Inc. will receive 20 percent of produced electricity for a 35 year period (Weil, 2012).

3.2 Socio-Economic Attributes

Socio-economic attributes indicate the health of a society as well as its economy. Improving the wellbeing of its people and maximizing economic efficiency are the two primary goals of every society. There are a few common economic and social indicators that are generally used to show the state and functionality of any socio-economic system. Some of the most commonly used economic indicators for NL are presented in Table 1 below. This table will help explain the socio-economic status of the province. All the economic policies are targeted to achieve the desired value of the following indicators.

GDP is considered to be one of the most basic and widely used indicators of economic activity. The GDP of the province has increased by 5.9% in 2013 while Canada grew just 2% in the same year (Stats Canada, 2015). Most of the growth is due to the oil and gas industry (30%) and this reflects strong gains in investment, exports and consumption. Investment also increased by 31.4 percent in the same year because of major project investments. Consumer price rose by 1.7 percent, employment grew by 1 percent and population remained unchanged compared to the previous years (DF, 2015). Table 1 show that the economy did perform well in 2013 compared to the previous year except in demographics.

Table 1: Provincial Economic Indicators

Indicators	Value
GDP at Market Prices ($ M)	35,094
Final Domestic Demand* ($ M)	36,275
Household Income ($ M)	23,096
Household Disposable Income ($ M)	17,495
Retail Sales ($ M)	8,883

Consumer Price Index (2002=100)	128.4
Capital Investment ($ M)	12,249
Housing Starts (Units)	2,119
Employment (000s)	238.6
Labor Force (000s)	270.9
Population (000s)	527

Source: Department of Finance– NL, 2015

A comparative study of the socio-economic features of NL and the whole country is shown in the Table 2 below. The first indicator is the population growth rate. In the last five years, there was only a 1.8 percent growth in population in NL, compared to 5.9 percent population growth in Canada. Similarly, indicators for migration rates, family income, per capita income, employment rater, life expectancy etc. are all lower for NL when compared to Canada as a whole. Only the percentage growth of population with ages above 65 is higher (16 percent) in NL when compared to Canada (14.8 percent). This indicates that the province's socio-economic condition is lower than the overall standard in Canada.

Table 2: Socio-Economic Profile

Attributes	**Canada**	**NL**
Population Change (5 year rate)	5.90%	1.80%
Migration Rate: Movers in the past 5 years	18.90%	14.00%
Average Family (2 member) Income	$100,200	$91,700
Personal Income per Capita	$32,800	$31,000
Employment Rate	82.60%	76.70%
High School Diploma or Higher	84.20%	74.90%
Life expectancy at birth	81.1	78.9
Percentage of population 65+	14.80%	16.00%

Source: Community Accounts – NL, 2015

The size of the economy is determined by it gross domestic product (GDP). The economy of NL is small compared to other provinces in Canada. The GDP of NL was around 35832 million dollars compared to 1893759 million dollar for whole country. Table 3 shows that the GDP of NL has been below 2 percent of the total Canadian GDP for the last seven years. The GDP of the province has also fluctuated over the period, which in not the sign of a healthy economy. Fluctuation indicates that there are governance and policy errors impacting the provincial economy.

Table 3: Gross Domestic Product (GDP) Current Prices, Millions of Dollars

	2007	2008	2009	2010	2011	2012	2013
Canada	1,565,900	1,645,974	1,567,007	1,662,757	1,770,014	1,831,228	1,893,759
Newfoundland	29,714	31,434	24,972	29,063	33,497	32,365	35,832
% of GDP	1.90	1.91	1.59	1.75	1.89	1.77	1.89

Source: Stat. Canada, 2015

The population growth rate in NL is not stable. Figure 4 below shows a comparison of the population growth trends NL compared to Canada. The country experienced a smooth growth of population because of international immigrants. The NL province on the other hand, experienced fluctuation in their population size. According to Figure 4, the province experienced a decline of population from 2001 to 2007 followed by a rise in population from 2008 to 2013. The population size again started to decline in 2014. One of the major reasons is the out migration of the people in the search of jobs.

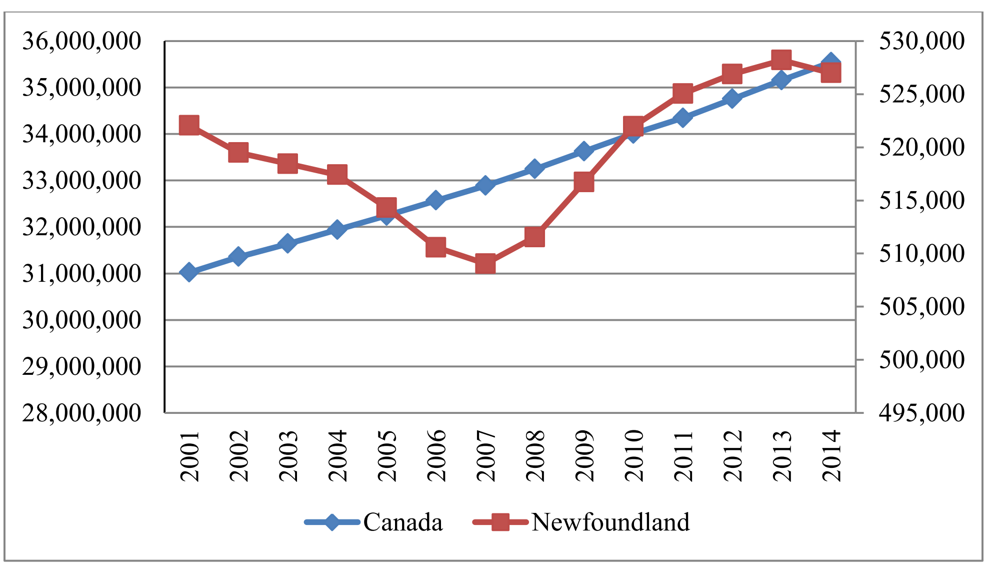

Figure 4: Population growth trend (Source: Community Accounts – NL, 2015)

One of the crucial social indicators is social security. Lack of economic activities results in unemployment and deteriorated social security. The performance of the province in terms of providing social security to its citizens is failing to meet national averages. In 2014, there were only 895 police officers for 0.5 million people living in the province. Thus, there are more than 550 people per police officer, which is very low compared to other parts of Canada. Moreover, the number of police officers in the province is declining while the crime rate, usually low, has been on the rise (Baird, 2013). The total number declined from 939 in 2010 to 895 in 2014. Table 4 below shows a comparison of total police officers in NL and in Canada for the last five years.

Table 4: Police officers

Place	**2010**	**2011**	**2012**	**2013**	**2014**
Canada	69,068	69,424	69,505	69,250	68,896
Newfoundland and Labrador	939	935	926	917	895

Source: Community Accounts – NL, 2015

Apart from this, both food and health security has been considered by ILO as essential components of social security (Delgado, 2012). Good food ensures good health of people in the society. Ensuring food security for the people in the province is also important for its SD. The province is not self-sufficient in food production as the majority of its food supply is shipped from outside of the province (FSN-NL, 2014). Access to health is another important social attribute that is essential for a sustainable and healthy society. The province does not have an extended health service that covers every citizen. The table 5 below shows that about 0.39 million people out of 0.53 million (73.5 percent) have access to medical services. There are only 1.37 physicians per one thousand people in the province. Improvements to health services are necessary for the province.

Table 5: Population with a regular medical service, by sex

	2009	**2010**	**2011**	**2012**	**2013**
Newfoundland and Labrador	387,194	397,799	405,024	405,633	391,833
Males	178,715	185,541	190,781	192,823	180,464
Females	208,480	212,258	214,243	212,810	211,369

Source: Community Accounts – NL, 2015

Socio-economic Conditions in Labrador: The communities living in Labrador are facing many socio-economic constraints and challenges. There are almost 27000 people living in Labrador and 35 percent of them are in aboriginal communities (GovNL, 2013). An important problem they are facing is access to power supplies. There is either no access to power supply or it is not affordable for the communities. The electricity that coastal communities do have is produced from diesel based power generation plants. This process is costly as well as environmentally polluting. The high price of power hinders business development and economic growth in Labrador. The second challenge that communities in Labrador are facing is the lack of educational facilities. This challenge includes lack of availability of early childhood education, aging of both primary and secondary school infrastructure, and the lack of accessible post-secondary offerings (GovNL, 2013).

The justice system is the next challenge for the communities in Labrador. This includes proper functioning of court and policing systems. It is very important for the system to take account of variations in cultural practice and social needs in Labrador. Providing adequate healthcare to all communities is another big challenge for Labrador because small populations are dispersed across a large geographic land area. Apart from this, there are many difficult issues like housing, employment, child care, access to clean water, violence and addiction prevention programs, culture and heritage protection program etc. (GovNL, 2013). The socio-economic condition of Labrador is thus not very sound compared to other parts of Canada.

3.3 The Environment in NL

Climatic Condition: NL experiences wide variations in the weather and climatic condition. The main reason for its diverse climate is the geographical location of the province. The geographic location of the island is parallel to the Great Lakes' location that covers 5 degree latitude. The ocean around NL mostly influences the island weather because no part of the island is more than 100 km away from the ocean. It lies in the Northern Atlantic Ocean at the confluence of two Atlantic currents: the Labrador Current (cold) and the Gulf Current (warm). Labrador is the most untouched and pristine part of the province with rough coastal area. The province is divided into six climate types. Winter is cold and typically the temperature ranges from -10ºC to -15ºC in January. Summer is short and relatively cooler in this province because of its close proximity to the ocean. In summer the temperature ranges from 8ºC to 10ºC in the coastal area but temperature rises by 3ºC to 5ºC in the interior area. The land remains covered by snow for 8 months in the north and more than 6 month in the south. The interior region of Labrador experiences continental climate, meaning long and cold winters with deep snow cover. The Upper Lake Melville area is very close to the MF project site has shorter winters and warmer summers. The northern region of Labrador experiences Tundra-like climatic conditions, while the southern portion is more subarctic.

Environmental Pollution: The energy sector is the main polluter within the province. The sector contributes around 90 percent of the overall greenhouse gases (GHG) emitted by the province (Table 6). The oil and gas industry is mainly responsible for that. Switching from nonrenewable fossil fuels to renewable environmentally friendly energies will help to eliminate the emissions of GHG. Table 6 shows that the GHG emissions in the province are declining at very slow rate.

Table 6: GHG Emissions (kt CO2 equivalent)

	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
TOTAL	9,430	11,400	10,900	10,500	9,860	9,480	10,600	9,910	9,680	9,280	9,310	8,740
ENERGY	8,650	10,600	10,100	9,500	9,000	8,650	9,810	9,090	8,810	8,450	8,450	7,750
% of ENERGY	91.73	92.98	92.66	90.48	91.28	91.24	92.55	91.73	91.01	91.06	90.76	88.67

Source: Stat. Canada, 2015

Emissions of GHG have long-term consequences upon all irrespective of who is responsible for them. NL is a coastal province with more than 90 percent of the population living near the Atlantic Ocean. Climate change because of continuous GHG emission could trigger natural disasters like sea-level rise, coastal erosion and increase frequency of storms and flooding (CCEE-NL, 2015). This significant impact of climate change will be on individuals, communities and on the environment Newfoundlanders and Labradoreans live in. Warmer weather and changes in patterns of precipitation may cause health hazards for humans, create scarcity of clean water and change patterns of food production. Good and sensible energy policy is important for the province to minimize the pollution, as well as hazardous impacts on its people.

The overall socio-economic and environmental status of the province is below average when compared to the rest of Canada. The provincial government is building the MF hydroelectric project as an initiative to improve the present situation. It is essential to determine how this project will alter the current scenario, and identify whether or not the MF dam will be sustainable. Answering these questions will require an integrated approach to measuring sustainability.

Chapter 4 Sustainability Assessment Framework

4.1 Conceptual Framework

4.1.1 Sustainable Development

The concept of sustainable development was provided by the World Conservation Strategy (WCS: IUCN, UNEP and WWF, 1980). WCS identified three sets of factors or indicators: social, economic and ecological, and prescribed that these indicators must be taken into account to ensure SD. The project titled 'Our Common Future' also known as the Brundtland Report (UN Documents, 1987) came up with the first formal definition of SD:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

- *the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and*
- *the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs."*

The Brundtland Report (UN Documents, 1987) tried to provide a comprehensive solution for SD. The Earth Summit in 1992 produced Agenda 21 for SD. This was further formalized in 2002 when the World Summit on Sustainable Development introduced the three pillar concept of sustainability: social, environment and economy. The Earth Summit in Reo 2012 raised the necessity of an institutional framework for integrating the three pillars and ensuring sustainability. SD and sustainability are not identical even though they have the same fundamental components. The notion of SD is pragmatic and anthropocentric; it focus is only on human well-being. Human beings are the prime concern of SD. Sustainability on the other hand is referred to as quality of system. It has dynamic and long-term features and takes fair distribution between present and future into account.

Environment Canada (2015) outlines SD as follows; “Sustainable development is about meeting the needs of today without compromising the needs of future generations. It is about improving the standard of living by protecting human health, conserving the environment, using resources efficiently and advancing long-term economic competitiveness. It requires the integration of environmental, economic and social priorities into policies and programs and requires action at all levels - citizens, industry, and governments.” In this research, the four-pillar concept of SD is introduced. In the following paragraphs, the four pillars (four fundamental objectives) are described and each pillar’s relevance to SD is explained.

4.1.2 Economic Sustainability

The most general definition of economic sustainability is the ability of the economy to have sufficient capital for producing a definite level of output indefinitely. There are four different types of capital in economics: man-made, natural, human and social. The goal of a sustainable economy is that those forms of capital are substitutable (Solow, 1970) and investment mainly in man-made capital is sufficient to sustain a growing economy for indefinite periods of time. This concept ignores the objective limits of economic activity imposed by availability of natural capital. There is divergence between economic efficiency and economic sustainability and it is difficult to ensure both at the same time. Economic efficiency needs to be compromised to some extent to ensure economic sustainability. According to Foy (1990) “Safe minimum standards for environmental assets constrain the efficiency criterion in order to ensure the sustainability of economic systems. It is argued that the ecological approach to sustainability should limit the economic approach for decisions involving the allocation of environmental assets.” Harris (2003) defines economic sustainability from an economist’s point of view as follows; “An economically sustainable system must be able to produce goods and services on a continuing basis, to maintain manageable levels of government and external debt, and to avoid extreme sectorial imbalances which damage agricultural or industrial production.”

The Neo-classical economic point of view is that economic sustainability will be obtained by maximizing the welfare of citizens over time. Economists sometime simplify sustainability by identifying welfare maximization with utility maximization from consumption. Neo-classical economics do not consider the sustainable use of environmental capitals or assets (Foy, 1990). Instead they assert that natural and man-made capitals are perfectly substitutable, and diminishing of natural capital is acceptable. This contradicts the sustainability concept. The idea obtained from the above definitions and explanations is that economic sustainability can be achieved through the conservation of critical ecosystems and natural resources, and by ensuring their sustainable use for production as well as their intergenerational equity. The market mechanism is not a sufficient tool to conserve natural capital and must be complemented by political decision-making targeting economic sustainability.

4.1.3 Social sustainability

The general idea of social sustainability is that a society is sustainable when all the activities and events ensure the wellbeing of the humans living in the society. Social sustainability is integrated with economic and environmental sustainability. Often, economic and environmental issues shape the state of social sustainability. Human wellbeing cannot be sustained without a healthy environment and is also unlikely in the absence of equitable distribution of economic wealth (Torjman, 2000). Gilbert et al. (1996) defines social sustainability using certain social goals. Social sustainability is obtained when people in a given society are united and work together to meet some common goal such as health and well-being, nutrition, shelter, education and cultural expression.

Dempsey et al, (2011) explained the social dimension of sustainability from the perspective of a country using the example of England. They showed that urban social sustainability mainly depends on social equity and sustainability of the communities. Social equity is a part of social justice for the citizens of a country and proper political will and policy support are required for ensuring equity in a society. The sustainability of community dimension on the other hand is a little unclear but is concerned mainly with the continued viability, health and functioning of society itself as a collective entity. Thus, social sustainability can be defined as a quality of a society that ensures humans' wellbeing, equity of access to key services and among generations, and citizens' participation in the political process. The indicators for social sustainability are identified in different reports as shown in the Table 7 below.

Table 7: Social classifications and objectives in social indicator sets

Author	Social Classification
UN Commission for Sustainable Development (UNCSD,1996)	Combating poverty Sustainable demographic dynamics Protecting human health Promoting human settlement Promoting education, public awareness, and training
UN Commission for Sustainable Development (UNDESA, 2001)	Equity Health Education Housing Security (combating crime) Population
UN Commission for Sustainable Development (UNDESA, 2007)	Poverty Governance Health Education Demographics
EU Sustainable Development Indicators (Eurostat, 2007)	Social inclusion Public health Demography Good governance
OECD Social Indicators (OECD, 2009)	Social "Organizing Dimension" Economic self-sufficiency Equity Health Social cohesion

Source: Quoted from Murphy K. (2012)

4.1.4 Environmental Sustainability

The third pillar that both directly and indirectly influences the well-being of humans is environmental sustainability. Every development initiative has an impact on the environment and the protection of the environment during any development activities is very important. The World Bank introduced this concept of development, which is "environmentally responsible development", in 1992 (Das, 1998). Serageldin and Streeter (1993) then used the term "environmentally sustainable development." Another concept of environmental sustainability was developed by Goodland (1995), according to him "environmental sustainability seeks to improve human welfare by protecting the sources of raw materials used for human needs and ensuring that the sinks for human waste are not exceeded, in order to prevent harm to humans."

Herman E. Daly (1990), one of the pioneers of ecological economics, defines sustainability from the viewpoint of natural capital maintenance. According to him, environmental sustainability is defined by the maximum allowable rates of harvesting renewable resources, as well as the creation of pollutants and depletion of non-renewable resources. If these rates cannot be continued indefinitely then they are not sustainable. The definition of environmental sustainability from a biophysical perspective came from Holdren et al. (1995). According to them, biophysical sustainability exists when the integrity of the life supporting systems of the earth are maintained or improved. The biosphere is sustainable when there are adequate provisions for both present and future generations to improve economic and social conditions within a framework of cultural diversity, while maintaining (a) biological diversity and (b) the biogeochemical integrity of the biosphere. The definition of environmental sustainability by the aforementioned scientists mainly focuses on six areas of the environment: climate systems, human settlements and habitats, energy systems, terrestrial systems, carbon and nitrogen cycles, and aquatic systems (Romero-Lankao et al., 2014). As most of these are environmental services, the environmental sustainability of any development can be obtained by maintaining these natural processes at a suitable level.

4.1.5 Good Governance

Governance has been defined in different ways by international organizations. One common idea that comes up from the definitions is that governance is the management of tasks or people to attain certain objectives. According to the World Bank [The World Bank [1992:1], governance refers to "[the] use of power in the management of a country's economic and social resources for development" (UNESCO, 2006). The concept is further explained [UNDP, 1997b:9] as "the exercise of political, economic and administrative authority to manage a nation's affairs" (UNESCO, 2006). In the same way, UNDP (1997) explained that appropriate governance is crucial for lasting development and it is very essential to ensure good governance from the very beginning of any development process; otherwise there will not be any sustainable development within the society. These articulate a clear cause-effect relationship between good governance and sustainable development. Good governance always works as a basis of overall sustainability.

The UNDP also identified nine core characteristics of good governance: participation, rule of law, transparency, responsiveness, consensus, equity, effectiveness and efficiency, accountability and strategic vision (EEG, 2015). A country needs to have all of these characteristics to achieve SD. These characteristics are all interconnected; good performance of one improves the performance of others and vice versa. A well-functioning legislative system ensures the rule of law in a country. According to Sachiko and Durwood (2007), “good governance always promotes accountability, transparency, efficiency, and rule of law in public institutions; that allows sound and efficient management of human, natural, economic, and financial resources for equitable and sustainable development.” Good governance improves the strategic decision making capacity of policy makers, increases the participation of civil society in the decision making process and develops a platform for SD (Sachiko and Durwood, 2007). Kabumba (2005) used Ghana and Egypt as examples to demonstrate that good governance and sustainable development are inter-related. Kabumba (2005) asserts that durable and lasting development can only be ensured through good governance. He argues for pursuing development activities and improving governance simultaneously, and prioritizes good governance above all else. Kabumba (2005) also pointed out that the aforementioned African countries are struggling to ensure their development in a sustainable manner. Poor governance is identified as systemic in those countries, which constrains SD. The EU (2015) considers the world summits to be the best opportunity to improve understanding about sustainable development among countries and provide effective guidance for SD. The EU went to the Earth Summit (2002) with a complete set of proposals to improve democratic practice and increase participation in decision making.

Good governance can be practiced both nationally and internationally. International good governance is important to deal with any international issue in a sustainable way. Hence globalization of good governance is equally important for SD. The importance of good governance and its necessity for SD was not considered in setting the millennium development goals (MDGs). UNU-IAS (2014) stated in their policy brief that governance should be included in the sustainable development goals (SDGs). The policy brief also highlighted three crucial aspects of governance that SDGs needs to consider: “good governance (the processes of decision making and their institutional foundations), effective governance (the capacity of countries to pursue sustainable development), and equitable governance (distributive outcomes).” The above definitions and explanations thus give clear indication that good governance is an essential precondition for SD both at the local and international levels.

Thus, all of the four pillars are essential and need to function well for SD to occur. Figure 5 highlights the four pillars sustainability concept. Now to measure these four fundamental objectives, proper parameters and their indicators must be identified.

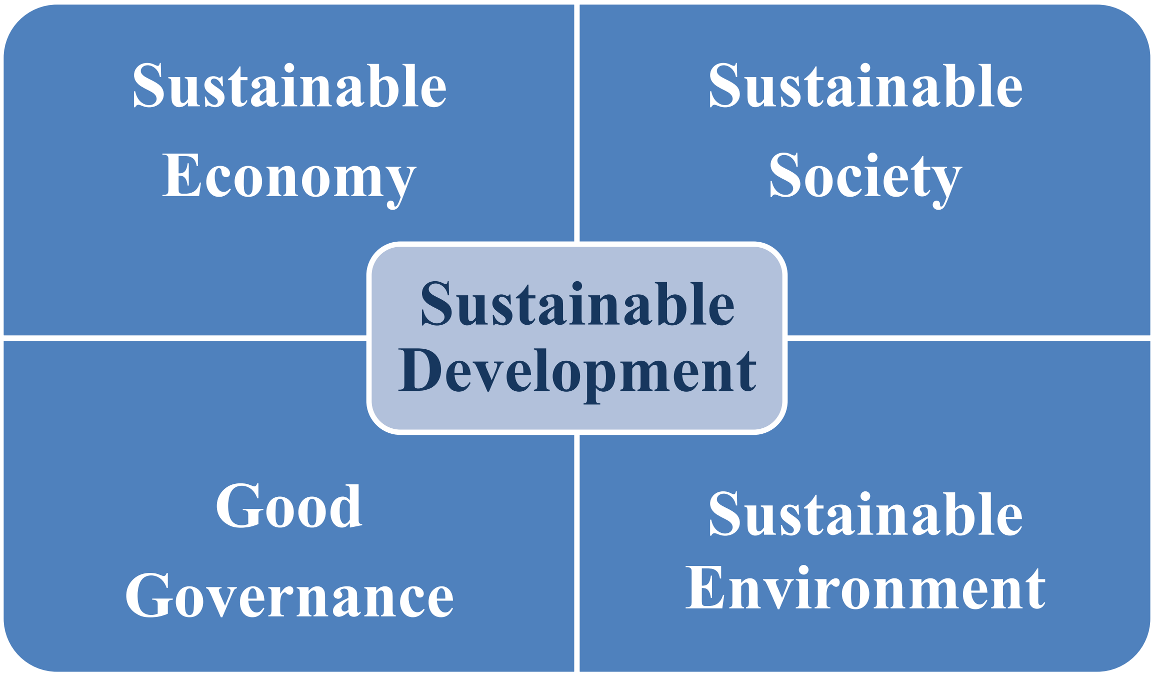

Figure 5: Four pillars for sustainable development

4.2 Identification of Key Issues: PESTLE Analysis

Sustainable development is a complex fact that depends on a range of variables. Sustainability of a hydroelectric project, in the same way, depends on many variables. This methodology uses a PESTLE analysis to identify those variables that are part of the four sustainability pillars. The PESTLE analysis is a framework used to scan the external macro environment of an organization or a project. The framework explains the political, economic, socio-cultural, technological, legal and environmental issues of an organization or project. Key issues for a hydroelectric project along with the probable risks and uncertainties are explained below.

Political Factors**:** The prime political obstacle for the development of any energy sector is the scarcity of comprehensive and harmonized policies. The energy policy structure of most developed countries centers on the use of non-renewable fossil fuels because of their high economic benefits; there is very little policy importance granted to the renewable energy sector.

Historically political will is always motivated by economic benefits. As such, current policies do not account for the social and environmental effects of fossil fuels (Onat and Bayar, 2010). The role of civil society in the political sphere is very important to the promotion of sustainability in the energy sector. In the same way, rights and equity for the people of a society are also vital to the SD of energy projects.

There is also concern about both national and international conflicts related to hydroelectric dams. The construction of dams and hydroelectric reservoirs on big rivers can trigger political conflict among communities, nations and regions that rely on those rivers for water. There are many examples worldwide of such conflicts. The Grand Renaissance dam on the Nile in Ethiopia created a political crisis among Ethiopia, Egypt and Sudan. There were allegations against Ethiopia about manipulating the water supply and reducing the efficiency of dams downstream (Eastwood and Elbagir, 2012). Similarly, there are political conflicts between India-Bangladesh and India-China with regard to hydroelectric power generation. Public participation in decision-making is another crucial political issue. People from all levels including: the local community, aboriginal group, and migrated people should have a right to be heard and decisions should be made in a democratic manner.

***Economic Factors*:** Economic analysis for any type of project starts with feasibility issues. Net present value (NPV), internal rate of return (IRR), return on equity (ROE) etc. are the prime indicators for measuring the financial feasibility of a project. To measure feasibility, costs and benefits related to the project are considered. Economic factors include mostly the costs and benefits that have monetary values. An investment must be able to produce goods and services in a stable manner and maintain manageable levels of government debt (both internal and external) to be economically sustainable. Izutsu et al. (2011) showed that a proper government policy for sustainable energy production would promote businesses in the local community and change lifestyles. Bracken et al. (2014) showed that micro-hydro power plant created the opportunity for game fishermen to invest in maintaining fish stock and improve riverine habitat; thereby involving the local community.

In Canada, 60% of electricity comes from hydropower sources, which translates into a fundamental contribution to the Canadian economy. In the last twenty years, about 1 million jobs have been created by this sector and boosted the Canadian economy. Hydropower has stimulated

Canadian economic growth, attracted many industries and investments, developed opportunities for nurture innovation, and created modern expertise over the years (Hydro Review, 2009).

Social Factors**:** Social sustainability mainly deals with the factors that directly influence the wellbeing of humans. A sustainable social system ensures fair distribution of resources and opportunities. It also allows for adequate social services like health and education, gender equity, political accountability and participation. The development of hydroelectric projects also influences the social life of humans in different ways. Hydroelectric project construction may require the relocation of people living within and nearby the construction site.

Project construction may also affect the community living in downstream and create health hazards for them. All of the victims of a project construction should be entitled to get compensation (IPCC, 2011). Cernea (2004) identified four potential social impacts of hydroelectric dam construction: "forced population displacement and impoverishment, 'boomtown' formation around major constructions, downstream unanticipated changes in agro-production systems; and loss of cultural heritage assets." Each of these impacts happens mainly during the dam construction period, while the latter occurs over a period of time. Increase in mercury levels in soil and water that is discharged for the reservoir may form methyl mercury, which causes health hazards for downstream communities upon entering the food web.

Cultural assets that are vulnerable to dam construction include, but are not limited to: the remains of historical important sites, and archeological structures that have significant cultural, spiritual, or religious importance. Apart from these impacts, there can be some other impacts like air pollution related health hazards, potential terroristic acts and accidental malfunction, downstream flooding as a result of faulty construction, natural catastrophes like earthquakes, landslides, etc. Any of these impacts can create severe social hampers for communities living in the region (Commerford, 2011).

Technological Factors**:** The application of advanced technologies is crucial to the development and sustenance of a community, state, or nation. Use of modern technologies in any hydroelectric power generation improves sustainability by reducing production cost, improving production efficiencies and ensuring a better environment. The prime challenge for a successful transfer of technology is the cultural and heritage barriers in the locality. Unavailability of modern technology is also a big concern. Policy initiatives and necessary finance are needed for the R & D (research and development) sector to develop new and more efficient technologies. Lack of technical knowledge is another barrier to introducing new technologies. Technical knowledge and trainings should be available in educational institutions to produce a technically skilled labor force. Research and development for technological innovation in hydroelectric generation will improve environmental performance and reduce operational costs. Even though hydroelectric generation technologies are almost mature, more improvements exist such as; bringing variation in speed, improving tunneling efficiency, modernizing river basin management and reducing environmental impacts like soil erosion, emissions etc. (IPCC, 2011). Finally, one of the most important technological factors in this case is that new technologies are always very expensive, and expensive investments are also very risky.

Environmental Factors**:** Environmental sustainability is the most important sustainability pillar as the overall sustainability is based on this. The environmental factors that are crucial to the SD of a hydroelectric project can be organized into two classes: natural resources and climatic conditions. Harris highlighted the important role that the sensible use of natural resources plays in environmental sustainability. According to Harris (2003), "a sustainable environmental system requires to maintain a stable resource base, without any over-exploitation of renewable resources or sink functions of environmental, and depleting non-renewable resources only to the extent that investment is made in adequate substitutes". Environmental sustainability also includes maintenance of biodiversity, atmospheric stability, and smooth functioning of ecosystems.

Considering both natural resources and climatic conditions, Moldan et al. (2012) came up with a holistic view point that includes most of the environmental factors that are very much relevant to hydroelectric project development. He highlighted that research measuring environmental sustainability explicitly focuses on: "Climate systems (covering climate and climate change, climate risk management, mitigation and adaptation), Human settlements and habitats (covering cities, urbanization and transport), Energy systems (covering energy use, energy conservation, renewable energy, energy efficiency and bioenergy), Terrestrial systems (covering natural and managed ecosystems, forestry, food systems, biodiversity and ecosystem services), Carbon and nitrogen cycles (covering sources and sinks, feedback processes and links to other systems), Aquatic systems (covering marine and fresh water ecosystems, fisheries, currents and biodiversity)". Thus, there are many environmental factors that need to be considered while measuring the environmental sustainability of a hydroelectric project.

Legal Factors**:** There are a limited numbers of legal factors that can create impediments for the plant's construction. Spicer (2014) emphasized that corruption related to the hydroelectric project can play a major role in any legal system. Apart from corruption, hydroelectric projects may result in some legal disputes. Legal disputes may include land that has other uses like agriculture, mineral extraction, esthetic values etc., including aboriginal rights to traditional land. Legal disputes may also arise for the water resources that are shared by states and countries. There are some legal regulations that can both positively and negatively influence hydroelectric project development. Legal regulation can affect tax and duties on new business that have developed in local communities, or technological equipment import to hydroelectric energy plants and the export of electricity. These legal regulations can increase investments in hydroelectric energy and the affordability of renewable energy for citizens (Zalengera, 2014). Legal regulations can be made in a manner that encourages the development of renewable energy resources. On the other hand, there may be an absence or lack of transparency in laws on renewable energy. Environmental laws also can be insufficient to deal with environmental problems created due to energy production. These are the main legal factors that need to be considered when developing a hydroelectric project sustainably.

Figure 6 below highlights the relevant parameters for hydroelectric energy projects that came out of PESTLE analysis. The next step is to develop an inclusive sustainability index that integrates all of these parameters and assess the sustainability of a hydroelectric project.

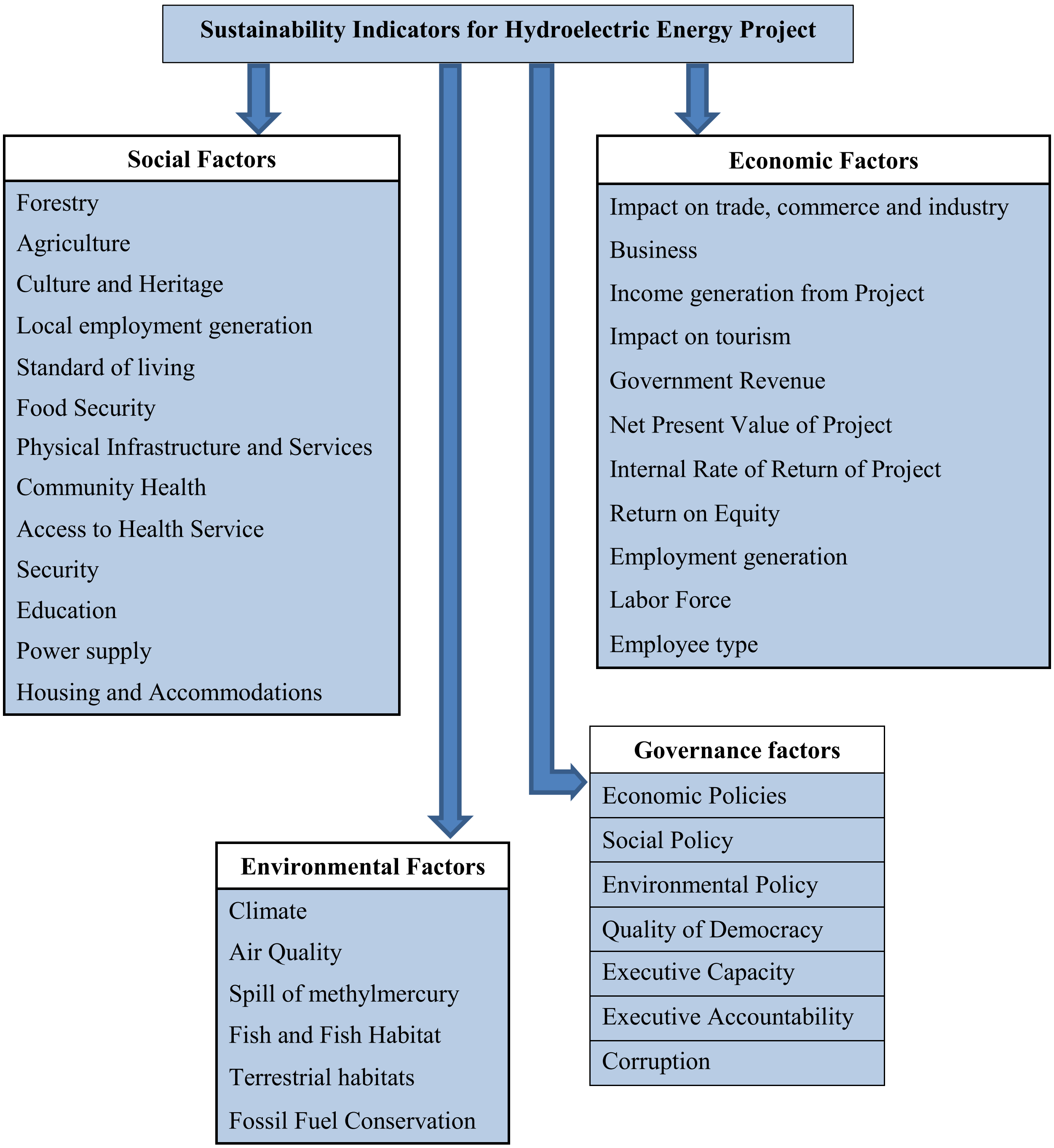

Figure 6: Identified issues related to sustainability of a hydroelectric project

4.3 Sustainability Index (SI_{HEP}) and Parameterization

4.3.1 Literature Review

Sustainable development or ensuring the sustainability of an activity or a system, either small or big, has been a prime objective for more than two decades. Over this period, different types of composite indices have been developed for measuring sustainability. These indexes have been successfully used and considered as powerful social, economic and environmental policy making tools. According to KEI (2005), "Indicators and composite indicators are increasingly recognized as a useful tool for policy making and public communication in conveying information on countries' performance in fields such as environment, economy, society, or technological development". In the same way, Nessa et al. (2007) stated that "The purpose of sustainability assessment is to provide decision-makers with an evaluation of global to local integrated nature–society systems in short and long term perspectives in order to assist them to determine which actions should or should not be taken in an attempt to make society sustainable." The study, therefore, demands exploration into the existing indices for measuring sustainability that are related to the four pillars. This will help to develop a holistic and inclusive sustainability index for hydroelectric energy projects.

Environmental sustainability is measured using the Environmental Performance Index (EPI), which was developed from the Wellbeing Index (Prescott-Allen, 2001). The EPI focuses on two environmental objectives: reducing environmental stresses on human health and promoting ecosystem vitality, and sound natural resource management. To measure these two objectives, the EPI uses twenty five indicators in six policy categories. The EPI calculates a proximity-to-target value for each country based on the gap between a country's current results and the policy target. These targets are drawn from four sources: (1) internationally established goals and treaties; (2) internationally set standards; (3) leading national regulatory requirements and (4) expert judgment based on the prevailing scientific consensus (Moldan et al., 2012). Onat and Bayar (2010) measured the sustainability of power production systems. They measured renewable energy resources such as wind, sun, hydrothermal and geothermal, along with fossil fuel, coal and natural gas power stations, nuclear power stations and fuel cells to examine their production sustainability. To index each production process, they used parameters including: unit energy cost, CO_2 emissions, availability, efficiency, fresh water consumption, land uses and social influences. Their findings show that wind, nuclear and hydroelectric energy are ranked first, second and third respectively, in terms of sustainability. Bosello et al. (2011) presented the composite sustainability index proposed by FEEM (Fondazione Eni Enrico Mattei) known as FEEM Sustainability Index (FSI) and used it within the framework of a dynamic Computable General Equilibrium (CGE) model. For indexation, they chose the 23 most commonly used indicators to measure sustainability. This list of indicators is mainly extracted from the lists compiled by the Lisbon Strategy and the EU Sustainable Development Strategy, and sub-grouped under three domains or sustainability pillars. Benchmark values of each indicator were set and normalized between the values 0 and 1. The non-additive measures approach (NAM) was used where they assigned different weight to different indicators.

Kerk and Manuel (2012) developed a social sustainability index (SSI) and applied it to rank social sustainability in 151 countries. They used three wellbeing dimensions: human wellbeing, environmental wellbeing and economic wellbeing. They sub-grouped these dimensions into eight categories and the values of these categories were measured using 21 indicators. The index used a 1-10 scale to rank each dimensions and derive the SSI score for each country. Good governance and sustainable development go hand-in-hand. Bertelsmann Stiftung (2015) introduced sustainable governance indicators (SGI) based upon three pillars: policy performance, democracy and governance. These pillars were sub-grouped into six dimensions and the values of these categories were measured using 32 indicators. The methodology required conducting a survey that includes both qualitative assessment and qualitative data to build up a high resolution profile for a country. The linear transformation method was used to standardize the quantitative indicators. In order to determine the highest and lowest values, time series data were used. Thus, there are different types of indexes that measure specific sustainability: social, environmental, governance etc. They use more or less similar techniques and have been successfully applied over a number of years.

4.3.2 Index development

Expanding on existing composite indexes, this research developed a new composite index for measuring sustainability of a hydroelectric energy project. This new sustainability index for hydroelectric energy will integrate four sub-indices: sustainability index for society, economy, environment and governance (Brown and Sovacool, 2007; Kerk and Manuel, 2012; Moldan et al., 2012; Wilkins et al., 2014). The functional form for this index is;

$$SI_{HEP} = f\,(\text{SocSI, EnvSI, EcoSI, GovSI})\ldots\ldots\ldots\ldots\ (1)$$

Where SocSI = f (Social Development, Community Health, Infrastructures and Services etc.)

EcoSI = f (Trade, Provincial Economy, Feasibility etc.)

EnvSI = f (Atmospheric Environment, Natural Resources, Aquatic Environment, etc.)

GovSI = f (Policy Performance, Democracy, Governance etc.)

SI_{HEP} is a function of four sub-indices with four fundamental objectives: minimizing social impacts, minimizing environmental impacts, maximizing economic benefits and ensuring good governance. Each fundamental objective has some means objectives (Appendix C) and each means objective has one or more parameters with natural or proxy indicators/performance measures. All the parameters relevant to the sustainability of a hydroelectric project have been captured from the PESTLE analysis in Figure 6.

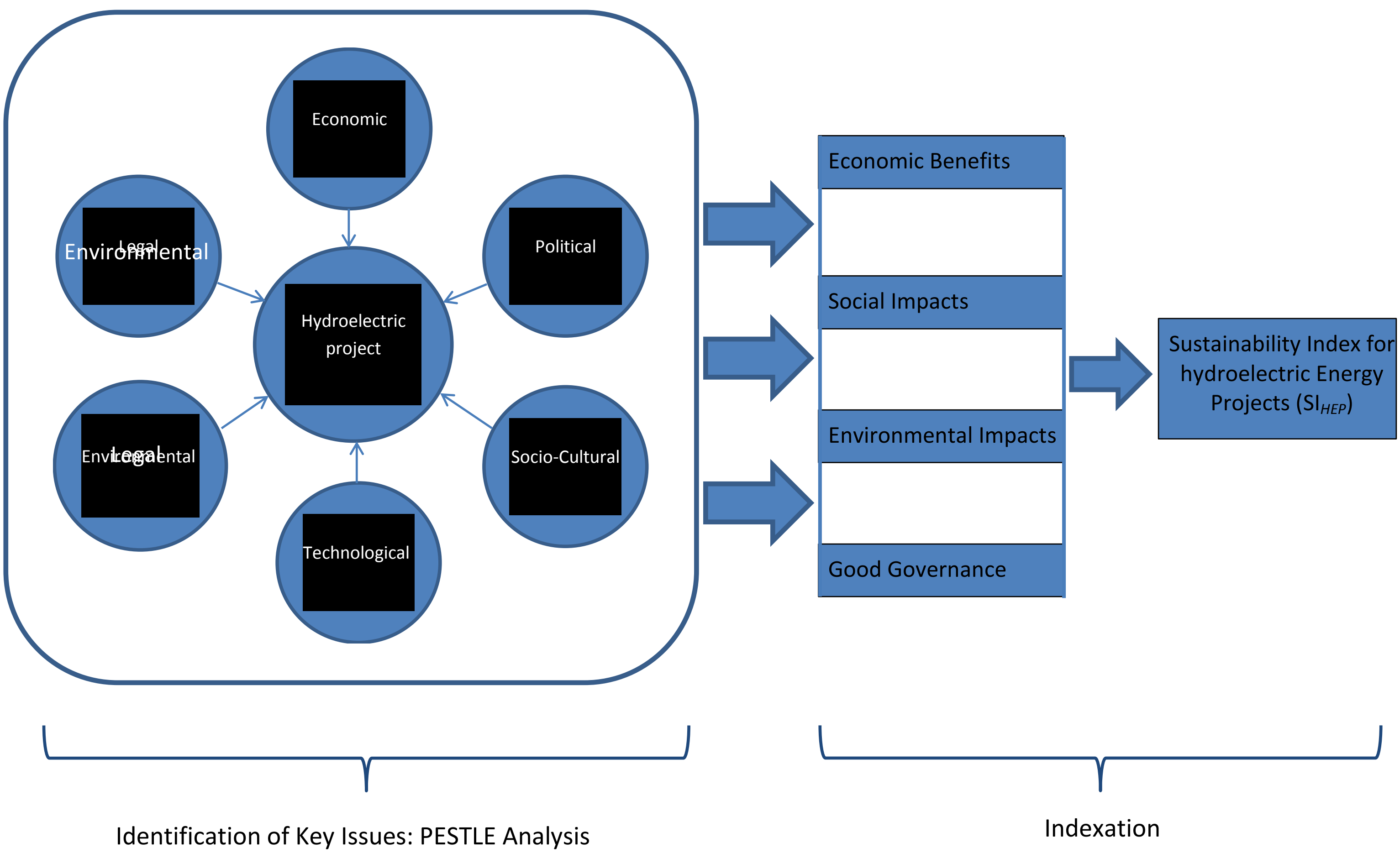

Figure 7: Derivation method of indicators

The value of these performance measures will be obtained from their natural and proxy measures. A sustainability workshop will help to identify any missing parameters and their indicators. The values of all indicators will be ranked according to the sustainability scale by the participant of the sustainability workshop. The sustainability workshop will serve three purposes: identify missing indicators, rank all the indicators in terms of the sustainability scale and validate the overall indexation process. Average values of the indicators will be used to calculate each sub-index and in turn, the sustainability index for the project will be established. Figure 7 shows how the indicators are obtained, categorized and indexed.

4.3.3 Normalization and Aggregating Indicators

Thirty seven parameters have been identified from the PESTLE analysis (in Figure 6) that is crucial for measuring the sustainability of a hydroelectric project. Some of the parameters require data that is specific to the hydroelectric project, while others require national or country level data. For example, the data on corruption, accountability, policy initiatives etc. is country level data, while housing, health, business etc. are all project specific data. Each parameter has a measurement indicator (either natural or proxy). Normalization of each indicator is essential since each of them has different measurement units. This study followed the normalization scale and weighting procedure utilized by Huang and Cai (2009) for their vulnerability index module. The normalization grid required for the module is shown in Table 8 below.

Table 8: Normalization Grid

Sustainability	**Normalized range**
Not Sustainable	0.0 – 0.2
Weak Sustainable	0.2 – 0.5
Moderate Sustainable	0.5 – 0.8
Strong Sustainable	0.8 – 1.0

Every indicator has a benchmark range of value (Appendix D) and every benchmark value corresponds to a normalized sustainability range (in Table 8). There are no internationally defined or standardized limits for all benchmark values under consideration. Benchmark limits for an indicator that has no internationally established standard are set by considering its performance in different countries in a given year. The indicators value for top 40%, 50%-60%, 40%-50% and bottom 40% countries are considered benchmark values for the indicator. Again, all the benchmark values derived in this way may not be appropriate if the project is in a province or state within a country. In case of a project in a state or province, benchmark values of the indicator can be set by comparing the region in question with other states or provinces in the country.

The derived indicators value will determine the class of benchmark range it falls in and identify the corresponding class of sustainability range. In order to calculate the overall sustainability, each indicator must present a unique sustainability value. To determine a unique sustainability value for each indicator within a sustainability class, the following formula must be applied:

$$Sustainability\ Value = X_l + \left(\frac{V - Y_l}{Y_u - Y_l}\right) \times (X_u - X_l) \ldots\ldots(2)$$

Where V is the derived value of the indicator, X_l and X_u are the lower and upper limits of the sustainability class, Y_l and Y_u are the lower and upper limits of benchmark class. The benchmark range for the thirty seven indicators along with their source is shown in Appendix D.

Before aggregating it is important to assign weights to each indicator. The equally weighted average (EWA) method is applied. It assigns each indicator the same weight so that indicators are comparable using the sustainability scale. This index has four fundamental objectives: Minimizing Social Impacts, Minimizing Environmental Impacts, Maximizing Economic Benefits and Ensuring Good Governance. Each of these objectives has a different number of parameters and measuring indicators. The assigned weight for each fundamental objective is one. Weights for the indicators will be determined by dividing one by the total number of parameters.

4.3.4 Calculation Procedure

The sustainability index for any hydroelectric energy project can be computed using the following formula that is developed from the vulnerability index formula used by Huang and Cai (2009):

$$SI_{HEP} = \sum_{i=1}^{n} \left[\left(\sum_{j=1}^{m_i} X_{ij} \times W_{ij} \right) \times W_i \right] \quad ....(3)$$

Where n = number of parameter categories (four in this assessment); m_i = the number of parameters in ith category; x_{ij} = the value of jth parameter in ith category; w_{ij} = the weight given to jth parameter in ith category; and W_i = the weight given to ith category. The conditions for assigning weights are;

1). Total of weights given to all parameters in each category should be equal to 1; and

2). Total of weights given to all categories should be equal to 1.

The four categories (four pillars) represented in the function (1) are weighted 0.25 each and parameters under each category are weighted differently depending on the number of parameter in each category based on the EWA method. Their weight is determined by dividing one by the total number of parameter under each fundamental objective. The overall calculation process is shown in Table 9 below.

Table 9: Calculation of sustainability index for hydroelectric energy projects

Categories	**Social Impacts**	**Environmental Impacts**	**Economic Benefits**	**Good Governance**
Parameters	$X_1, X_2, \ldots X_n$	$Y_1, Y_2, \ldots Y_n$	$Z_1, Z_2, \ldots Z_n$	$K_1, K_2, \ldots K_n$
Weight	1/n	1/n	1/n	1/n
Weighted Parameter	$X_{w1}, X_{w2}, \ldots X_{wn}$	$Y_{w1}, Y_{w2}, \ldots Y_{wn}$	$Z_{w1}, Z_{w2}, \ldots Z_{wn}$	$K_{w1}, K_{w2}, \ldots K_{wn}$
Category Total	$a = \sum_{i=1}^{n} X_{wi}$	$b = \sum_{i=1}^{n} Y_{wi}$	$c = \sum_{i=1}^{n} Z_{wi}$	$d = \sum_{i=1}^{n} K_{wi}$
Category Weight	0.25	0.25	0.25	0.25
Weighted Category	SSI (= a×0.25)	EnvSI (= b×0.25)	EcoSI (= c×0.25)	GovSI (= d×0.25)
Overall Score	SI_{HEP} (= SSI + EnvSI + EcoSI + GovSI)			

4.3.5 Explanation of the Results and Policy Recommendations

After calculating the overall sustainability score along with the scores of all sub-indices from the above Table 9, the next step is to give explanation of each score, identify the causes and their effects and provide the necessary policy recommendation required under different sustainability scenarios. Table 10 provides the interpretation of different sustainability score intervals. The steps for the policy recommendations are: identifying parameters with poor score, run a comprehensive policy scan on the identified parameters, detect the policy gaps and make policy prescriptions.

Table 10: Interpretation of sustainability score and policy status

Sustainability Index	Interpretation
Strong Sustainable (0.8 – 1.0)	This indicates that the hydroelectric project is perfectly sustainable in terms of the four pillars: social, economic, environmental and governance. Existing policies and long term strategic planning for the four pillars are sufficient. No major policy change is needed. It is possible to have a low or poor performance of one or two parameters that may require minor policy adjustment.
Moderate Sustainable (0.5 – 0.8)	This indicates that the project is moderately sustainable with regard to the four pillars. The score of one or two sub-indices is not very good. The project has some major challenges and concerns that need to be taken into account. Strengthening the policy structure is required. Long term integrated strategic planning is sufficient for this project.
Weak Sustainable (0.2 – 0.5)	This indicates that the project is not very sustainable with regards to the four pillars. Performance of each sub-index is very poor. Major policy correction and long term strategic planning is essential to improve the score of parameters under each sub-index.
Not Sustainable (0.0 – 0.2)	This indicates that the project is not sustainable with regards to the four pillars. The country is not ready for this project at this moment. There is no specific policy structure to address the issues of the project. There is also a lack of long term integrated strategic planning for this project.

4.3.6 Report Writing

The last part of the module is the report writing. The report will contain six chapters. It will start with an introduction that will present the study's rationale and the objectives behind measuring sustainability. The next chapter will describe the study area covering all aspects related to the four pillars. The third chapter will apply the PESTLE analysis and identify relevant parameters out of the given thirty seven parameters. The next chapter will apply the index and interpret the findings. The fifth chapter will identify the policy gap from policy scan and will recommend necessary policies. The last chapter will conclude with key findings of the research.

Chapter 5 Case Study: Sustainability of the Muskrat Falls Project

5.1 Project Background

Planning and development of the MF project started in the mid 1960's even before inauguration of the Upper Churchill generation facilities that started power generation in 1971. This planning, research and development process continued for a long period of time until the end of 2012 when the project was sanctioned by the provincial government. The Upper Churchill generation facility is the biggest hydroelectric project in the province with a capacity of 5428 MW. The province receives only a small proportion of power and benefit of this project. The major share of power and benefit is attributed to Hydro Quebec (HQ). NL has to wait until 2041 to gain full ownership of the project. This situation and the continuously rising power demand both at home and abroad stimulated policymakers to invest in the LC generation facilities.

The Lower Churchill project has two separate generation projects in two different locations. One is the Muskrat Falls (its capacity is 824 MW) and the other one is in Gull Island (its capacity is 2,250 MW). The construction of the MF project started in 2013. This project is considered to be one of the largest and most significant projects in NL, and requires more than $8 billion worth of investments. The construction cost for the project is $6.99 billion, while the interest costs along with other financing costs comprise the remaining $1.3 billion. Therefore, the estimated total cost of the project is $8.29 billion (GovNL, 2014).

The MF project consists of three sub-projects: generation facilities, the Labrador-Island 1,100 kilometer high voltage direct current (HVdc) transmission line from Muskrat Falls to Soldiers Pond on the Avalon Peninsula (along with an additional 250 kilometer, two high voltage alternating current (HVac) transmission line, between MF and Churchill Falls) and 480 km high voltage direct current (HVdc) maritime transmission line between the province and NS (Nalcor, 2015). The installed capacity of the project is 824 MW associated with firm energy on average about 4.9 TWh/yr. The plant consists of a concrete dam that closes the river from North and South of the powerhouse block as shown in the Figure 8.

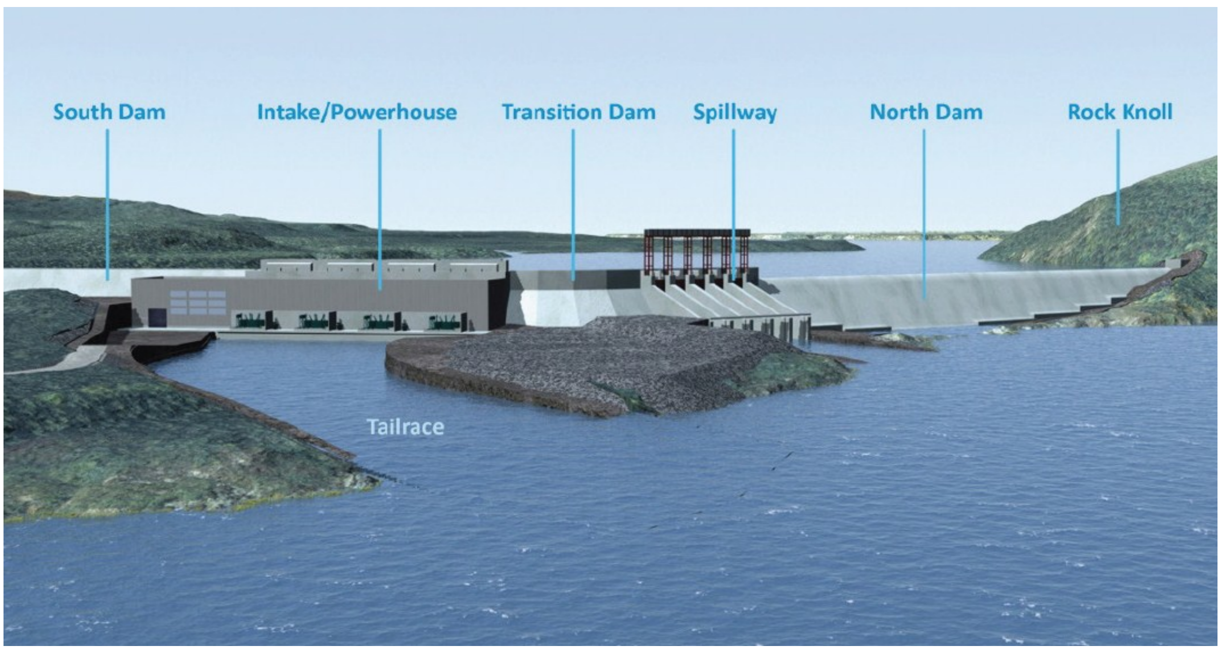

Figure 8: Muskrat Falls generation facilities

A spillway structure is included between the North dam and the powerhouse block. The powerhouse is designed with four turbine-generator units using a concrete spiral case arrangement. A switchyard will be located at the MF site for interconnection of the power station with the transmission system. The system is made up of a 345 kV switchyard at the MF station, as well as a 345 – 138 kV substation located about five kilometers from the station (PUB, 2014).

Nalcor Energy and Emera Inc., two public corporations of NL and Nova Scotia, are the main actors that signed the deal to construct the MF project (phase 1). According to the agreement, 40 percent of the total generated electricity will be used to meet the provincial power demand. For covering 20 percent of the project cost, Emera Inc. will purchase 20 percent of the electricity. The remaining 40 percent of generated power will be either; open for export to Atlantic Canadian and New England, or for meeting the growing domestic power demand (Nalcor, 2015). A more than $6 billion deal was signed between the two public corporations to develop the phase 1 of the whole project. According to the deal, Nalcor Energy did all the preliminary work and started the construction of the hydroelectric power station at Muskrat Falls. Alongside the project construction, the corporation is also installing the HVdc transmission line between Labrador and the Newfoundland Island. Emera Inc. is expected to install the maritime transmission link between Newfoundland and Nova Scotia. Emera Inc. will also finance the Labrador-Island Link. The investment of Emera Inc. will be 49% of the total transmission infrastructure investment. In return, Emera Inc. will receive one terawatt-hour of electricity per year for 35 years.

5.2 Identifying Key Issues: PESTLE Analysis

The MF project is a massive hydroelectric project under construction in the LC River. It took more than half a century for the stakeholders to start the actual work on the ground. This is because so many aspects needed to be taken into consideration before the start of construction. A Joint Review Panel was appointed by the NL government and the Ministry of Environment in the federal government to complete an environmental assessment of the project. They assessed the environmental impacts of the project and their chain impact on socio-economic life of the communities living in the project area. The assessment was done considering two kinds of project impacts: environmental impacts and socio-economic impacts. From the environment side, the assessment measured the atmospheric, aquatic and terrestrial environmental impacts. On the socio-economic side, the assessment measured all the social, cultural and economic aspects of the local area (CEAA, 2015). An economic analysis done by Natural Resources Canada (NRCan) also measured the economic feasibility by considering different economic aspects of the project (NRCan, 2015). The PESTLE analysis below explains the status of the province under six different criteria and identifies key issues with potential risks and uncertainties that are essential for measuring the sustainability of the project.

Political: Political issues have played and are still playing a major role in the MF project. More than fifty years of planning, research and development clearly highlight the importance of political factors and governance issues. In this case, political issues stretched from the local community to the provincial government, and even beyond the boundaries of the province. The estimated cost of building the hydroelectric dam increased over time and has become a political issue as the increased burden shifts onto the taxpaying voters. The imbalanced and ill-fated agreement of NL government with the government of Quebec about the Upper Churchill made their relationship sore. Additionally, HQ and the government of Quebec have continued to dispute the water management and sharing policies that govern the two mega hydroelectric projects. Water management and sharing is the most common problem that most countries face while constructing a hydroelectric dam. There are water sharing dispute between India-Bangladesh, China-India, Ethiopia-Egypt and many more (Mirumachi, 2013). The MF project is expected to release NL from the geographic stronghold of Quebec since the MF transmission line effectively bypasses Quebec. One positive aspect of trans-border politics is the strategic tie and cooperation of the province with Nova Scotia. The LC project is on the verge of reshaping the politics in Newfoundland and Nova Scotia even though it has yet to produce a single watt of power. Ruling parties always stay under immense pressure both from opposition and voters to be very cautious about investment and strategic ties. Another big political issue that has been ongoing for decades is the land dispute and the concerns for the cultural heritage of aboriginal and indigenous communities living in Labrador.

Economic: The MF project is expected to bring a revolutionary change to the oil and gas dependent (30% of GDP) Newfoundland economy. The power industries in Canada contribute only 2.2 percent of GDP (in 2010) and account for only 0.6 percent of total Canadian employment (NRCan, 2015). But, all of these are direct contributions. Power is the most essential factor input for all industrial products and, in this way, power supply has a huge indirect contribution to both national GDP and employment in Canada. An estimate of Nalcor (2015) shows that the construction phases of the MF project will enhance the provincial income by $2.1 billion, where $700 million will be gained by project labor and business people in Labrador. The project is also expected to generate 5600 person-years of direct employment in the province, mostly in the project location (NRCan, 2012).

Mega projects that require huge capital investment always come with some spill-over impacts. Infrastructural development is necessary as it supports the proper functioning of the project and transmission line construction processes, as well as operations and maintenance. The development of the project requires smooth communication facilities to the project site, and modern air, land and sea ports, highways and other transportation infrastructures are also needed. This will also benefit the communities living in Labrador. It is expected that this infrastructure development will leave long-term socio-economic impacts in the locality including: hotels and other accommodations, as well as the influx of new investments and businesses. Further, national and international companies may also expand their service to the localities. The development of the Trans Labrador Highway (TLH) already resulted in new commercial trading patterns, business expansions and tourism opportunities (Nalcor, 2014a). These changes will raise the land property values and provide local people with employment, with the end result being that the government will receive more revenue. Presently, major business activities in Labrador are tourism related. More than 25 percent of the businesses are connected to the tourism industry (Nalcor, 2014b). The presence of the dam and generation facilities is expected to attract more tourists each year. The communities around the project area are mostly wage employees and the project will expand employment opportunities for wage employees. The direct benefit from the project is determined by calculating its NPV, IRR and ROE. The values of these financial indicators are essential in order to determine whether the project is feasible or not.

Social: The MF project is expected to bring dynamic social impacts upon the communities in Labrador. The majority of the populations in the project area and in Labrador are aboriginal peoples. They have many cultural heritages and resources, with different types of values: prehistoric, historic, cultural, spiritual, natural, scientific and aesthetic. Their cultural resources are mainly archaeological, prehistoric, historic and natural sites; structures and objects; and burial, cultural, spiritual and other heritage sites. Investment in the MF project can have both positive and negative impacts on these cultural resources. It could either destroy them or financially benefit them by bringing in more tourists. The impact of the project on population is uncertain. Population decline is a major issue in Labrador and the province as a whole. Labrador experienced 13.2 percent decline in the population from 1991 to 2006 compared to 11.1 percent decline in the entire province. The impact of the project on community health is another big concern. Primary health impacts will come from environmental pollution due to project construction activities. Community health may also be affected indirectly through demographic change and, specifically, through any in-migration to and worker-community interactions within the Upper Lake Melville area. Construction of both the dam and reservoir demands heavy physical work, which may result health hazards for workers. There is also a possibility of mercury emission, which may pollute the water and raise mercury beyond tolerable levels in fish, thereby creating an indirect health hazard for humans.

Development of social infrastructure and services as described above may create employment and business opportunities for local people. This may also improve social security and education services, as well as housing and accommodation. Incremental power demand for local businesses and services, like consumers in Happy Valley-Goose Bay and elsewhere in Upper Lake Melville area, are expected to be met from the project without interrupting the supply.

Technological: The MF project is a high capital-intensive modern techno based investment project and most of the equipment for power generation and transmission are imported from different countries like France, Turkey, etc. Understandably, the unskilled and semi-skilled workers have minimum or no knowledge and expertise regarding the construction, installation, operation and maintenance of the technology. There is and will continue to be a shortage of skilled and knowledgeable persons meaning the project will not run efficiently if these workers are used in construction. Considering the similarity of the work, workers from the iron ore and mining sectors are employed on the project. This will not bring much efficiency. Colleges and technical institutions need to train students with modern applied technical education so they not only work on such projects; but develop technologies to make similar undertakings more efficient. Communities in rural areas usually do not like drastic changes and the NL province consists mostly of rural areas. In some cases, the rural people of NL are scared of the changes that are brought about by dynamic socio-economic and environmental impacts of such technological installations. Also, people in the communities are not well-informed about the pros and cons of this project.

Environmental: There are mixed opinions and research findings about the scale of environmental effects resulting from a hydroelectric dam and a reservoir. Hydroelectric energy is a renewable energy. It is also one of the cleanest sources of energy. Nonetheless, the construction stage of these projects causes greenhouse gas (GHG) emission and air pollution. The construction of the plant requires the clear-cutting of forest, as well as the demolition of hills and elevated regions. As a result, GHGs like CO_2 and CH_4 are emitted from the decay of organic matter on the forest floor. The remaining organic matter is either transported through wind or surface runoff to the Churchill River, resulting in both air and water pollution. Compared to a fossil fuel power plant, a hydroelectric project emits less GHGs. Counteraction activities, such as site preparation and the construction of site buildings (clearing, grubbing and blasting), excavation for and installation of generation components, concrete production, vehicular traffic onsite, quarrying and borrowing, and transportation and road maintenance pollute the surrounding air. Pollutants released in this way are PM, NOX and SO_2. They can have adverse environmental effects on the atmospheric environment.

Another potential source of environmental impact is the construction of the transmission line. This project can cause problems both for the aquatic and the terrestrial environment. The transmission line will pass under the ocean; that will hamper the normal activities of fish populations. The bulk of the overland transmission system located in NL can cause a decline in vulnerable species like caribou. Aquatic species can also be affected by the release of mercury into the Churchill River. The aboriginal group Innu reported that the Churchill Falls hydroelectric project affected how fish tasted and that they were told not to eat too many fish from the Smallwood Reservoir (Innu Nation Hydro Community Consultation Team 2000). Recent literature has found that hydroelectric dams have less effect on the magnitude of floods as well as their recurrence intervals. In USA, the estimated reduction in median annual flood for large rivers averages 29%, for medium rivers 15% and for small rivers 7% because of hydroelectric dams (Goudie, 2015). One major concern of such project is siltation and drying up of river due to a dam. Dam construction causes upstream sedimentation and erosion in the downstream (Poleto and Beier, 2012). Modern hydroelectric generation technology largely minimizes such environmental impacts.

Legal: The NL government and other project stakeholders had to face various legal issues both internal and external (with other provinces). The efficient operation of the MF project depends on the efficient operation of the Upper Churchill reservoir storage and generation station. Well-coordinated operation is required between these two adjacent projects mainly during the spring season. Coordinated effort will save energy as well as avoid waste. The upstream storage and generation project is legally bound to serve HQ under the agreement signed in 1969 that will expire in 2041. The NL government went on with the construction work relying on the provincial Water Management Agreement established in 2010. Still there exist legal disputes with HQ about the use and control of the Upper Churchill reservoir and generation assets for the MF project. Emera Inc. and Nalcor Energy have signed the final legal agreements about governing the MF power project but pricing of electricity is not fixed yet; that may cause problems and legal disputes in the future. The NL government needs to establish a reasonable pricing policy for the developed energy.

One major concern is that the province of NL does not have a proper renewable energy policy. The government published an energy sector development plan in 2007 (Energy Plan, 2007). Proper policy guidelines for renewable energy development and coordination among all relevant policies to ensure the sustainability of the sector are needed. Lack of integration of the renewable energy sector in existing policies can leave some important issues undetected and unaddressed. This may result in serious harm to humans and the environment. The environmental assessment that was done by a review panel appointed by NL government and Environment Canada was not directed to take a sustainable approach. According to Doelle (2012) "The panel was hampered in its efforts by lack of clarity in its mandate and by lack of information to implement a full sustainability assessment. The end result was a sustainability assessment framework for government decision makers." Good and effective governance is neither an automatic process nor a problem free process. It is shaped by traditions, cultures, and the social locations of all parties. It is essential to continue the path of devolution and ensure participatory governance, that will obtain the best outcome for the community, province and the country.

Using the PESTLE analysis we obtain a holistic picture of the project and screen-out all the necessary parameters (Table 11) for measuring the sustainability of the overall project.

Table 11: Key parameters for measuring sustainability of the MF hydroelectric project

Index	Fundamental Objectives (Sub-Indices)	Means Objectives (Categories)	Parameters
Sustainability Index for Hydroelectric Energy Projects (SI_{HEP})	**Minimizing Social Impacts**	Land and Resource Use	Forestry
			Agriculture
		Reduce Cultural Influences	Culture and Heritage
		Social Development	Standard of living
			Food Security
			Local employment generation
			Physical Infrastructure and Services
		Improve Community Health Standard	Community Health
			Access to Health Service
		Social Infrastructures and Services	Security
			Education
			Housing and Accommodations
	Minimizing Environmental Impacts	Atmospheric Environment	Climate
			Air Quality
		Aquatic Environment	Fish and Fish Habitat
		Terrestrial habitats	Animal biodiversity
		Natural Resources	Fossil Fuel Conservation
	Maximizing Economic Benefits	Improve Trade	Impact on trade, commerce and industry
			Business
		Vibrant Provincial Economy	Impact on tourism
			Income generation from Project
			Government Revenue
		Feasibility	Net Present Value
			Internal Rate of Return
			Return on Equity
		Employment	Employment generation
			Labor Force
			Employee type
	Good Governance	Policy Performance	Economic Policies
			Social Policy
			Environmental Policy
		Democracy	Quality of Democracy
		Governance	Executive Capacity
			Executive Accountability

5.3 Measurement of Sustainability

In order to ensure holistic sustainability and better management of any hydroelectric project, it is very important to apply the four pillars concept of sustainability to the project. The core objective of a mega project like the MF project should be to minimize its social and environmental impacts and to maximize economic benefits by ensuring good governance. The sustainability index for hydroelectric energy projects (SI_{HEP}) covers all these objectives to measure the sustainability of a project. This index develops four sub-indices to explain how efficiently the four fundamental objectives are met. The value of the parameters is derived from their natural or proxy indicators as shown in Appendix C. The data for these indicators are mainly obtained from the Environmental Impact Statement document and the Economic Feasibility Report for the project and few other provincial government documents. Due to a shortage of time and financial support, the sustainability workshop was not conducted.

5.3.1 Minimizing Social Impacts

The sustainable society index (sub-index for SI_{HEP}) shows that the project is moderately sustainable with a sustainability score of 0.6. Twelve parameters used to measure social sustainability as shown in Table 12. The project is not sustainable in terms of land and resources use. The parameters for measuring this 'means objective' are forestry and agricultural land area. The statistics show that there is 29% forestland in the province, which is lowest among all provinces (Stat. Canada, 2015). In the same way, agricultural land in NL declined 23% from 2001 to 2011 (Stat. Canada, 2015). The project construction and transmission line installation will result in the clear-cutting of forestland and enclosure of agricultural land. This further aggravates the poverty status. Apart from this, the physical infrastructure and services are very poor in Happy Valley Goose Bay and Labrador as a whole, when compared to other cities in Canada. Development of the project required further investment in infrastructure. There is a small domestic airport in Goose Bay with very few flight operations, which accommodates only 95,000 passengers a year. Another social concern is that the province does not have enough public service professionals. There are only 1.37 physicians per 1000 patient and one police officer for more than 550 people. The Provincial government needs to correct these weak social issues to ensure social sustainability.

Table 12: Social sustainability of the MF hydroelectric energy project

Fundamental Objective	Means Objective	Parameter	Weighted Index	Sub-Indices
Minimizing Social Impacts	Land and Resource Use	Forestry	0.04	0.6
		Agriculture	0.01	
	Reduce Cultural Influences	Culture and Heritage	0.04	
	Social Development	Standard of living	0.06	
		Food Security	0.08	
		Local employment generation	0.07	
		Physical Infrastructure and Services	0.01	
	Improve Community Health Standard	Community Health	0.08	
		Access to Health Service	0.02	
	Social Infrastructures and Services	Security	0.03	
		Education	0.08	
		Housing and Accommodations	0.07	

5.3.2 Minimizing Environmental Impacts

Environmental issues have been the biggest concerns in the literature on hydroelectric projects. The environmental sustainability index (sub-index of SI_{HEP}), with a modest sustainability score of 0.84 (Table 13), shows that the project is strongly sustainable from an environmental perspective. The sustainability of the project is measured with consideration given to atmospheric, aquatic and terrestrial environments. There can be some long run environmental changes such as change of river flow, micro climate, loss of biodiversity etc., but all of them are uncertain; they depend on the technology used and management procedures. An interesting fact is that the environmental impact of the project is very high in the first five years of the construction period. If only the initial five years were considered for measuring sustainability, the project would be unsustainable. When sustainability is measured for the project's lifetime of minimum 50 years, the project becomes highly environmentally sustainable. This is because the environmental impacts of this project in the operation and maintenance period are very low. The annual GHG emissions in the construction period could range from 50,000 to 200,000 tons, which equals about 1 million tons of CO_2 for the entire project. The emission of particulate matter (PM) would be around 1724 tons per year (EIS, 2009). Both the emissions of GHGs and PM occur during the project construction period for around 5 years. There will not be many emissions during the operation and maintenance period. Another strong aspect of the project is that it will reduce the use of environmental polluting fossil fuels. An estimate shows that the full capacity operation of the project reduces diesel use by 1645 barrels per day (Stat. Canada, 2015).

Table 13: Environmental sustainability of the MF hydroelectric energy project

Fundamental Objective	Means Objective	Parameter	Weighted Index	Sub-Indices
Minimizing Environmental Impacts	Atmospheric Environment	Climate	0.16	0.84
		Air Quality	0.16	
	Aquatic Environment	Fish and Fish Habitat	0.16	
	Terrestrial habitats	Animal biodiversity	0.16	
	Natural Resources	Fossil Fuel Conservation	0.19	

5.3.3 Maximizing Economic Benefits

The economic sustainability index (the third sub-index of SI_{HEP}) measured for the MF project shows that the project is moderately sustainable and has a sustainability score of 0.59 (Table 14). Findings of this sub-index identified some weak features of the project with regard to economic sustainability. According to the results, the project will not contribute a great deal to improving the provincial economy. Even though tourism is important to the Labrador economy, contributes much less to the provincial economy. Over the years, tourism's contribution to the provincial GDP has been less than 1 percent (Stat. Canada, 2015). In the same way, the project's contribution to household income is very little. The project will contribute only 2.7 percent to household income during the construction phase (Stat. Canada, 2015). The government taxes from the project will not generate a significant amount. The contribution to government revenue from the project is also less than 1 percent of GDP. Therefore, the project will have very minimal impact on the provincial economy. However, there will be some contributions, including improving trade and business in the province. The data shows that 39 percent of energy produced in the province was consumed by the industrial sector in 2012 (Stat. Canada, 2015). Furthermore, statistical data shows that the share of private investment for the province in 2012 was more than 80 percent. The private sector of the province is growing and this renewable power supply will support further growth in the sector. Both net present value (NPV = $2052 million) and internal rate of return (IRR = 7.45%) for the project are high enough to make it a feasible project (NRCan, 2012). All these economic indicators suggest that the project will be moderately sustainable in terms of maximizing economic benefits.

Table 14: Economic sustainability of the MF hydroelectric energy project

Fundamental Objective	Means Objective	Parameter	Weighted Index	Sub-Indices
Maximizing Economic Benefits	Improve Trade	Impact on trade, commerce and industry	0.09	0.59
		Business	0.09	
	Vibrant Provincial Economy	Impact on tourism	0.03	
		Income generation from Project	0.04	
		Government Revenue	0.02	
	Feasibility	Net Present Value	0.04	
		Internal Rate of Return	0.08	
		Return on Equity	0.06	
	Employment	Employment generation	0.06	
		Labor Force	0.04	
		Employee type	0.05	

5.3.4 Good Governance

The governance issues in the province are the most vulnerable for the sustainability of the MF project. The good governance index (fourth sub-index of SI_{HEP}) shows that poor governance in the province makes the MF project weakly sustainable, with a sustainability score 0.4 (Table 15). Both policy support and executive structure are not efficient or up to standards for the sustainable development of this mega project. Policy support in the province is determined by its economic, social and environmental policy performance. The provincial government invested only 1.12 percent of its GDP into research and development in 2012 (Stat. Canada, 2015). Moreover, there are many economic policy weaknesses related to the project. The project cost increased several times from $6.5 billion to $8 billion during the last two years. The government could not set a standard pricing policy for the produced energy of MF (relying on spot pricing), and the financial sources funding for this project are not clearly stated.

Social policy performance is measured by investigating the education and skills development policy of the province. The Conference Board of Canada (2015) graded the education and skill development policy of the provinces by considering 23 indicators. They graded the province's performance with a 'D-', the worst grade given to any province. Also, Corporate Knights (2012), a magazine on clean capitalism, graded the environmental policy of provinces and ranked them in terms of their green status. Seven indicators: Climate and air, water, nature, transportation, waste, energy, and innovation were analyzed to determine the green status of the provinces. They graded NL with a 'C+' and ranked it number 6^{th}. Thus, the social and environmental policy performance of the province is relatively poor.

The Executive Council of NL government is responsible for providing all the necessary support to the executives of the NL government. This support includes helping government make decisions, strategic planning, and the formulation of policies. They also provide advisory support to the government for all types of development activities. There are no separate strategic units for long term strategic planning and policy support. The Executive Council draws support from the Research and Development Corporation (RDC) for strategic planning and implementation. There is a lack of skilled and expert professionals in the government's bodies, which sometimes causes problems for long term policy planning. Many times there is a lack of coordination, which creates information gaps between the provincial government and local municipal governments.

Further, executive accountability is not properly ensured in NL. The reason behind this is that most of the government's policies and strategies are not disclosed to the citizens. Therefore, the general public has no knowledge of different issues of interest. Citizen's capacity to voice their opinions is very low as a result. Print and electronic media sources are very few and do not have full coverage throughout the province. People living in big cities are decreasingly aware of events that should interest them. Citizen participation in the democratic voting system (below 60%) is also low when compared to other Canadian provinces. The way that the government is dealing with the impact of the CETA (Comprehensive Economic and Trade Agreement) on the fishery and with hydraulic fracturing in western Newfoundland, further supports the conclusion that government bodies and policy makers are detached from the general public. There was also lack of consultations with aboriginals (especially Nunatukavut) in the MF area about land claim issues.

Table 15: Sustainable governance of the MF hydroelectric energy project

Fundamental Objective	Means Objective	Parameter	Weighted Index	Sub-Indices
Good Governance	Policy Performance	Economic Policies	0.03	0.40
		Social Policy	0.02	
		Environmental Policy	0.04	
	Democracy	Electoral process	0.13	
		Access to information	0.06	
		Rule of Law	0.06	
	Governance	Executive Capacity	0.04	
		Executive Accountability	0.02	

5.4 Discussion

The overall sustainability index for a hydroelectric energy project (SI_{HEP}) is determined by giving equal weights to each of the four components/pillars of the index: Social Impacts, Environmental Impacts, Economic Benefits and Good Governance. The sustainability rank of the project is determined by utilizing the sustainability grid in Table 8. The Table 16 shows that **the sustainability score for this MF project is 0.61, which means that the overall project is moderately sustainable.** The results for the four fundamental objectives demonstrate that the project is strongly sustainable in terms of its environmental impact, moderately sustainable in terms of its social and economic impacts and weakly sustainable in the category of good governance (The framework is in Appendix B). Apart from this, some key findings of this research that are explained below.

Good governance is considered to be the foundation of a balanced and inclusive development. Historically, the importance of good governance to sustainable development was not considered. For instance, if we go through the Millennium Development Goals (MDGs) that were set in 2000, we see that there are goals and targets for sustainable development but not for governance.

For economically, socially and environmentally sustainable development in future, the UN is considering political and technical issues that ensure good governance within its post-2015 development framework (UNDP, 2014). The General Assembly of United Nations further reaffirmed that good governance is essential for sustainable development (UN-GA, 2005). Thus, it is clear that there is a cause-effect relationship between good governance and social, economic and environmental sustainability. This supposition is also reaffirmed in the findings of this study. Poor strategic capacity and work coordination, along with low public participation levels and reduced access to information results in feeble governance. On the other hand, socio-economic and environmental sustainability requires a well-coordinated, balanced and holistic approach to development. Poor governance in the case of the MF project is made obvious by more than fifty years of delay s prior to the start of its actual construction. Moreover, the provincial government does not have a structured renewable energy policy framework. In the case of the MF project, governance issues influenced the sustainability of the other three pillars and the overall sustainability of the project.

Table 16: Sustainability index for the MF hydroelectric project

Sustainability Index for Hydroelectric Energy Projects (SI_{HEP})				
Fundamental Objective	Minimizing Social Impacts	Minimizing Environmental Impacts	Maximizing Economic Benefits	Good Governance
Sub-indices	**SSI**	**EnvSI**	**EcoSI**	**GovSI**
Indexed value	**0.60**	**0.84**	**0.59**	**0.40**
Weight	**0.25**	**0.25**	**0.25**	**0.25**
(SI_{HEP})	**0.61**			

The overall results indicate that this project is moderately sustainable; however, this does not tell the complete story. The project has two phases: the construction phase, and the operation and maintenance phase. The value of the sub-indices will be different in those two phases, thus the overall sustainability result will be different. In the case of the social sustainability index, most of the indicators perform well during the construction phase as lots of jobs are created, people get housing and all the public facilities work smoothly. This creates strong social sustainability with a high sustainability score. In the operation and maintenance phase, there will not be much employment. Rather, a big group of people could become unemployed, which may lead to a social crisis. This results in a weak or not sustainable project, with a very low sustainability score. The same thing may happen with regard to the environmental sustainability index. If only the construction period is considered, the project may be considered weak or not sustainable since most of the environmental pollution occurs during the project construction period. Conversely, since there is very little or no pollution during operation and maintenance period the project may become strongly sustainable in that period.

Therefore, proper policy support is required in the case of the MF project to ensure good governance and to bring balance between costs and benefits over the lifetime of the project.

Chapter 6 Policy Framework and Recommendations

6.1 The DSR Framework

Energy, most importantly environmental friendly clean energy, is considered an essential ingredient for the sustainable socio-economic development of both present and future generations. Strong and comprehensive energy policies and strategic guidelines are necessary for balanced and inclusive socio-economic development as well as for preserving a healthy environment. The energy sector of the province of NL has a very high potential for nonrenewable and renewable energies. The Newfoundland and Labrador Department of Natural Resources has formulated several comprehensive policy initiatives and development plans in its energy plan 2007 (Energy Plan, 2007). The MF project is a mega project and the province has its foundational development plan in its Energy Plan (2007). For holistic and inclusive development of the MF project, as well as to ensure its sustainability, the provincial government should consider introducing additional policies. The DSR framework is applied here to identify the driving forces that impact SD, as well as the present state of SD and related policy responses. The major driving forces and the present state of the project can be identified in the PESTLE analysis above. The driving forces and the present state of this project are summed up in Table 17.

Table 17: Driving forces and State of the MF project

Driving Forces	State
Energy Environment Governance Economy	Renewable Energy Geopolitics Air Quality Climate Change Accountability Democracy Industry and Business Employment Culture and Heritage

Demand for energy is the major driver in this case. This is because the MF project is expected to produce 824 MW of clean, renewable energy i.e. 98% sustainable energy (GovNL, 2015). This capacity can easily replace the 25 non-renewable diesel based power generation plants in the province. There is growing demand and export potential for clean renewable energies in other provinces and countries. That being said, bad geopolitics surrounding energy use and exportation from the Upper Churchill project (second largest hydroelectric plant in the world), is having a negative impact on the province's ability to enjoy that project's expected benefits. To meet the clean energy demand both at home and abroad, the provincial government invested in the MF project. Federal government also provided financial support by guaranteeing the loan needed for the start of the project. The federal government loan guarantee was capped at $6.3 billion for MF which increased the economic sustainability of the MF project (Gov.Canada, 2012). The environment is another big driver for this hydroelectric project development. There are concerns that a project of such scale may cause climatic changes, and create problems for various aquatic and terrestrial species. The findings of the study show there will not be any major impact on aquatic and terrestrial species and the climatic impacts will be limited to the construction phase of the project. The GHG emissions from the project are mainly CO_2, CH_4. Possible air pollutants are PM, NOX and SO_2. The annual GHG emissions during the construction phase could range from 50,000 to 200,000 tons, resulting in about 1 million tons of CO_2 for the whole project (EIS, 2009). The PM emission will be 15.32 tons per year during the construction period (EIS, 2009).

Governance is another very important driver for the MF project. The NL Government's efficient and productive decision making, as well as coordination among ministries and works are questionable. Further, its budget management and long-term comprehensive policy making capacity are not up to the proper standards to ensure the sustainability of such a mega project. The Office of Executive Council (OEC) itself identified three priority issues to address by 2017, which are: policy capacity, planning and coordination, and form Governance and Oversight of Agencies, Boards and Commissions (OEC, 2014). Apart from this, the democratic process is not properly functional at all levels of the province and many important issues fail to receive media coverage. As a result, the affected population cannot raise their concerns. Even if they raise their voice, it appears to fall short of government and policymakers. Additionally, the accountability of those people at the decision making level is not fully ensured. The last important driver is the economy. The MF project is expected to have substantial effects on the economy of Labrador as well as on the provincial economy by increasing employment and business development (EIS, 2009). It is expected that the newly developed infrastructure and consistent power supply will attract many industries and add to the inflow of investment. Many aboriginal and indigenous groups call Labrador home. They have their own unique cultural heritage that attracts thousands of tourists every year. There are real concerns that the MF project construction might affect their historical and archeological sites.

The current situation (the drivers and states) suggests there is need for corrections within the government system itself to ensure good governance. After the effectiveness of the governing system is fixed, it will identify whatever policies are needed for achieving the overall sustainability of the project. The following section will scan the existing policies and suggest required policy improvements.

6.2 Hydroelectric Energy Development: Policy Scan

The province of NL is considered an energy warehouse because of its abundance of natural resources both renewable and nonrenewable resources. The province is using water to produce electric energy and meet most of its power demand. There are 45 large scale (more than 40 MW) hydroelectric dams and 145 small scale dams in the province (DEC, 1992). On the other hand, the province is highly reliant on environment polluting fossil fuels for energy production. The pace of development in the renewable energy sector has changed since 2007 when the provincial government developed an energy policy strategy, which gave consideration to the nonrenewable features of fossil fuels. They decided to invest the wealth and revenues obtained from the nonrenewable energy sector into renewable energy development (Energy Plan, 2007). Moreover, the government decided to work closely with their development partners to improve investments in the renewable energy sector. The Energy Corporation Act was passed in 2008 and a provincial energy corporation was formed. The objective of the corporation was to invest in the development, production, transmission and distribution of energy in the province. The corporation also invests in research and development in the energy sector.

The provincial Energy Plan (2007) provided the following policy actions to develop the Lower Churchill projects and to accommodate the Upper Churchill project after the expiration of the agreement with HQ. “The Government of Newfoundland and Labrador will:

1) Lead the development of the Lower Churchill Hydroelectric Project, through the Energy Corporation.

2) Ensure that first consideration for employment will be given to qualified personnel adjacent to the resource.

3) Conduct a comprehensive study of all potential long-term electricity supply options in the event that the Lower Churchill project does not proceed.

4) Ensure CF(L) Co. continues to maintain the Upper Churchill facility to a proper operating standard.

5) Position the province to take full advantage of Upper Churchill power for provincial and export customers after the power contract expires.

6) Explore opportunities for Upper Churchill to make a greater economic contribution to the province” (Energy Plan, 2007).

The provincial policymakers projected that the energy investment will spin-off a significant amount of employment and business in the province. The government also established a strategic backup plan to meet the energy demand in case the production of the MF project is delayed. The standby option was an economically and environmentally sustainable combination of thermal, wind and small hydro developments (Boksh, 2013). The government energy strategies also included the continuous exploration of potential hydroelectric development projects as well as further feasibility and environmental studies. The government authorized the Energy Corporation to have full control of exploring, investing, developing and transmitting energies from small hydroelectric projects. The policy actions taken by the government for the new hydroelectric project development are articulated as follows; "The Government of Newfoundland and Labrador will:

1) Maintain the moratorium on small hydro developments, subject to a review in 2009 concurrent with a decision on proceeding with the Lower Churchill project.

2) Ensure the Energy Corporation continues to work on feasibility and environmental studies of additional hydroelectric prospects.

3) Implement a new policy on the issuance of water rights for new hydroelectric developments, making the Energy Corporation responsible for coordinating and controlling all new hydroelectric developments in Newfoundland and Labrador" (Energy Plan, 2007).

The development of the transmission network is crucial for the province for two reasons: to evade the land blockade presented by Quebec, and to provide access to both national and international power export markets. Nalcor Energy and Emera Inc. signed agreements pertaining to the development of the project and transmission line in 2012 (in Figure 9). The policy strategy of the government is to provide low cost and reliable electricity supplies, while attracting new industrial development to the province and expanding the transmission line to potential markets in Canada and the U.S.A. (Energy Plan, 2007).

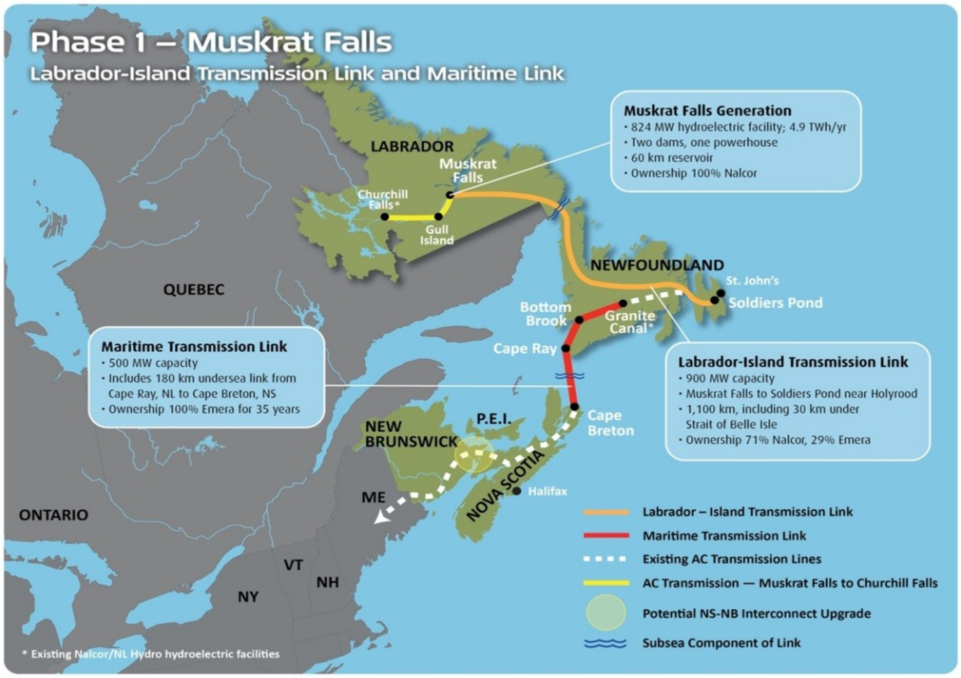

Figure 9: Transmission line for phase 1

There are some indirect policies introduced by the NL government to support the development of renewable energy. According to 'Canada's Regulatory Framework for Air Emissions' all provinces need to develop a technology fund and invest it into the development of renewable energy (Energy Plan, 2007). This fund will be developed by taking penalties from industries or organization that cannot reduce their emissions. The LC project has the potential to reduce GHG emissions by nearly 13 million tons every year if it replaces or avoids oil-fired generation. The air pollution control policy of the province is integrated with this hydroelectric project. The policy states: "the government of NL will

- by 2015, target the elimination of 1.3 million tons of GHG emissions per year, as well as all other pollutants from Holyrood, by building LC and the Labrador-Island Transmission link. This will ensure more than 98 per cent of electricity generated for our own use comes from renewable sources" (Energy Plan, 2007).

In order to improve energy efficiency and eliminate waste by people and businesses in day-to-day life, the government has developed a strategy aiming to change the culture of power consumption pattern. The strategy will apply education to alter this culture. According to the Energy Plan (2007), "the government will

1) Continue to support the Climate Change Education Centre as a way to provide effective public education on energy conservation and efficiency opportunities.
2) Establish and implement a comprehensive energy efficiency and conservation marketing strategy.
3) Support programs that focus on engaging young people through outreach and education through an innovative annual $200,000 education fund.
4) Continue updating and expanding the environmental science component in the K to 12 curriculum.
5) Continue to support our initiatives outlined in the Council of the Federation's "Climate Change: Leading Practices by Provinces and Territories in Canada," and considers implementation of best practices from other jurisdictions in the country."

The provincial government has taken on a number of initiatives to produce skilled and professional workers and integrated them with its Poverty Reduction Strategy. This strategy also placed more importance on improving the participation of aboriginal populations in educational institutions, and recruiting first peoples into employment in the energy sector. According to the Energy Plan (2007), "the provincial government will

1) Support and implement the recommendations of the Skills Task Force.
2) Continue to update the labor demand and supply analysis of the Skills Task
3) Force for current and future energy projects.
4) Working with the Nunatsiavut Government and Aboriginal groups to identify potential employment and training opportunities.
5) Identifying and facilitating programs to increase the participation of Aboriginal peoples in professional and skilled trades in the energy sector."

The provincial government outlined some specific strategic guidelines in its Strategic Plan (2011-14, 2013-14). It includes responsible resource development, where development of new clean and renewable energies is encouraged, and a Social License was granted for communities including aboriginal groups to ensure the marketing, sale and distribution of renewable energies. The responsible resource development plan also aims to build a culture of worker safety and environmental sustainability. The goal of this strategy is to advance renewable energy use in the province, focusing on the LC project. The second strategic directive is aimed to ensure a stable and competitive energy supply. The focus is on creating alternative energy, setting competitive prices and exporting surplus energy.

To establish the financing structure for the LC project, two bills: Bill 60 and Bill 61 were proclaimed in the House of Assembly in 2013. Bill 60 includes land related issues along with taxation and the creation of emissions permits. Bill 61 includes a number of finance- related amendments to the provincial legislation. The provincial government has taken a number of legislative measures (see Table 18) that both directly and indirectly focused on the development of the LC project.

Table 18: Legislative measures taken for hydroelectric energy development

Acts	Description
Muskrat Falls Project Land Use and Expropriation Act, 2013	This legislation establishes a lands related act to govern the acquisition of land and land interests that are necessary for the Muskrat Falls Project.
Muskrat Falls Project Land Use and Appropriation Act	This legislation creates a statutory easement, expropriating authority, assigns tax liability of land holder and approves the use of land by a proponent in the transmission corridor.
Amendment of Hydro Corporation Act 2007	This amendment sets out the mandate, powers and management structure of the Newfoundland and Labrador Hydro-Electric Corporation as a crown agency. Amendment of the act was done in 2012 to facilitate project financing, protection of non-project assets, and sufficient borrowing limits for Nalcor Energy.
Amendment of Electrical Power Control Act 1994	This amendment sets policy with regard to electric power rates and establishes provisions for the determination of such power rates by the Public Utilities Board. Amendments to the act were carried out in 2012 for granting of exclusive, wholesale electricity supply rights and Crown equity payments to NL Hydro.
Lower Churchill Development Act 2001	This act authorizes the Minister of Natural Resources to enter into an option agreement with the Lower Churchill Development Corporation (LCDC) guaranteeing the corporation’s executive water rights, rights to flood land and a sole option to purchase the Gull Island hydro assets.
Newfoundland and Labrador Power Commission (Water Power) Act, 1965	This act extinguishes certain water power rights held at the time by BRINCO and provides for their assignment to Newfoundland and Labrador Hydro (Power Commission) to

	facilitate financing of the Bay d'Espoir hydroelectric project.
Miscellaneous Financial Provisions Act, 1975	This act nullifies any provincial legislation that prevents government from assigning the Newfoundland and Labrador Hydro Electric Corporation a right, title or interest in royalties and rentals in clauses 1 and 8 of Part II of the lease between government and CF(L) Co.
Energy Corporation of Newfoundland and Labrador Water Rights Act, 2009	An act to enable the issuance of water rights to the Energy Corporation of Newfoundland and Labrador for the LC River.
Electrical Power Control Act, 1994	Sets policy with regard to electric power rates and establishes provisions for the determination of such power rates by the Public Utilities Board.

Source: Quoted from Strategic Plan 2014-17, DNR, NL

The policy scan above clearly states that the policy actions and strategic measures of the government for the hydroelectric project development are very specific and target oriented. The general focus of the policy action is to invest more in this renewable energy, increase use of this energy in the province, and export the excess energy. Those policies are mostly motivated by economic benefits. The DSR metrics below (Table 19) sums up the overall project scenario with the most relevant indicators.

Table 19: The DSR Metrics

	Social	**Economic**	**Environmental**	**Governance**
Driving Forces		Economy Energy	Environment	Governance
State	Employment Culture and Heritage	Renewable Energy Industry and Business	Air Quality Climate Change	Geopolitics Accountability Democracy
Responses	Skills dev. program	Increase Investment	Policy coordination	Work distribution

6.3 Policy Recommendations

Phase 1 of the LC project, the MF project, is already under construction and the hydropower plant is expected to come into operation by 2017. The present policy structure is enough to finish the construction work and add the desired MW into the grid, if the formulated policies are properly implemented. When the formulated policies stay only on paper, they do not bring any good. The general idea is that for development of any project, a set of necessary policies needs to be formulated and implemented. Otherwise, the project will not work efficiently and the investment will not be sustainable. On the other side of the coin, there are many different variables related to the four pillars of sustainability that need to be considered and calculated while making policies. Based on the PESTLE analysis, the results of SI_{HEP} and DSR framework, this study recommends the following policy suggestions. The suggestions are made separately for each sustainability pillar to meet the fundamental objectives set for overall sustainability.

Social**:** The MF project is moderately sustainable with regard to its social impacts. The project has already boosted social development in Labrador. Infrastructure is developed, accommodation facilities are modernized and youth employment has been generated. Nonetheless, there is concern that after the completion of the construction stage, hundreds of people will become unemployed. To avoid this undesirable consequence and sustain the development process, the provincial and municipal governments - along with the aboriginal groups, should generate integrated and inclusive development policies. Investment in social assets can be a good long-term policy for the government.

The province needs to have a strong policy promoting the preservation of culture and heritage within aboriginal communities. Aboriginal historic and archeological sites attract thousands of tourists every year. They are a source of employment for locals, as well as source of revenue for the government. The integration of employment generation and, tourism policies with cultural heritage protection legislation is essential for alleviating the probable social impacts of mega projects like the MF project.

The health and safety of all citizens is important, especially for those citizens who are working on the MF project construction. Most of the employees are unskilled or semiskilled and are working with heavy machineries, and this may result sudden unfortunate incident. Nalcor (2014) has taken safety to be the number one goal, with the promise of sustainable safety excellence by 2017. This study suggests initiating a policy of training the employees before employing them. The provincial government should create more technical institutes and include courses on energy technology in the curriculum of existing educational institutions. Health services in Labrador are not in a satisfactory state. The number of people per physician is very high. The Department of

Health and Community needs to make strategic plans to incorporate the health and safety issues of communities living near the project area.

Environmental**:** The project is strongly sustainable considering its environmental impacts. Even though the project is not harmful for the environment in the long-term, it has some serious short-term environmental consequences that need to be dealt with by appropriate policies. Clear-cutting hundreds of hectares of forest for project construction and transmission line installation can cause environmental imbalances and the extinction of vulnerable animals and plants including; various caribou herds, small game, medicinal plants and berries. Policy makers should develop strategies to ensure the planned replantation of forests, thereby mitigating the forest losses. Additionally, they should also utilize the timber obtained from clear cutting and develop a recovery strategy for endangered animals. The recovery process should include policies to protect the Red Wine Mountain caribou herd that is most vulnerable to the impacts of the project.

Methylmercury levels in the water can be a great concern. It is a significant issue with the MF project since there are two mega hydroelectric projects on the same river, within few kilometers of each other. Compounding this issue is the fact that the MF project has 740 hectares of fish habitat area that can be affected. There is a need for frequent monitoring activities to measure methylmercury levels in the water, including all possible pathways throughout the food web.

Atmospheric monitoring is also very important during the construction period of the project. There will be emissions of GHGs and particulate matter that are harmful to humans and the environment. Proper monitoring and regulatory measures are required to deal with this problem. The best policy would be to use modern technologies that will create less air, noise pollution, and GHGs emissions.

Economic**:** The project is moderately sustainable from an economic point of view according to the SI_{HEP}. That being said, such a project has the scope to be strongly sustainable if all the necessary policy actions and strategic decisions are made at the right time. Even though this project has very high initial investment ($8 billion), expenditures for operation and maintenance are relatively minimal. The output of the project can be beneficially used in two ways: use the energy for domestic business and industrial development, and export all additional units of power. In either case, the right policy support from the government is required.

The provincial government is considering spot pricing policy for electricity export. This may constrain domestic economic development and result in an unfair distribution of resources. A fair and competitive pricing policy is essential, with lower rates for domestic businesses and industrial use and a modest rate to expand into the export market. An efficient and visionary pricing policy will improve the economic feasibility of the project. Proper marketing policy is also essential to ensure each unit of electricity allotted for export is sold. Electricity market analysis is crucial before the constructing of the Gull island project. If there is a large market demand for electricity, the government should construct this project soon.

Power is the most essential ingredient for economic development. In addition to uninterrupted power supply, infrastructural support is needed to attract both private and foreign investment. Government should be required to evaluate how new policies will influence the province's ability to attract new investment. Establishing a technical training institution in Labrador to train people in modern hydroelectric energy technology, construction procedures and operation and maintenance activities would contribute to the economic sustainability of the project. This will generate a skilled work force, not only for the MF project but also for other upcoming hydroelectric projects including the Gull Island project.

A policy to compensate the communities affected by the project, and construction of the transmission line, should be initiated. Increasing investment in research and development on issues related to the beneficial and adverse impacts of such mega projects would be another valuable policy initiative.

***Governance*:** This project is weakly sustainable from a governance point of view according to the SI_{HEP}. The provincial government and its relevant departments are lacking good governance capacity. This is most apparent concerning the strategic capacity, ministerial coordination, and the necessary policy communications. This is backed up by citizens' participatory capacity, and the strength of media. The government's decision making should be based on proper evidence, strategic planning and advice from scholars. All the decisions should be made by consulting and coordinating with relevant ministries and departments. Proper implementation of 'the right to access information regulation' is essential so citizens are fully aware of the government's actions and they can raise their voice to help the government make the right decisions. A strong media is crucial to inform the citizens of the broader public policy issues. There should not be any restriction imposed on the activities of printed and electronic media. These policies will help the government make right decisions and will improve its accountability to the citizens.

The MF project is already under construction and these policy suggestions may not help in the construction stage a great deal, but the learnt lessons will definitely help to develop a more sustainable operation and maintenance stage. They can also be useful for developing Phase 2- the Gull Island project- in a more sustainable way.

Chapter 7 Conclusion

7.1 Summary and Conclusion

The MF project in the LC River is the second largest hydroelectric project in the province and there has been lots of emphasis placed on the outcomes of this billion-dollar project. This research tried to measure how well this project will serve to meet expectation through a structured decision making approach. A sustainability measurement tool SI_{HEP} was developed through consideration of the four pillars of sustainability (social, economic, environmental and governance) and applied to the MF project. The findings show that the project is moderately sustainable with a sustainability score of 0.61. In relation to the pillars, the project was strongly sustainable in environmental aspects, moderately sustainable in economic and social aspects and weakly sustainable in governance aspects. The results suggest that poor governance is making it difficult to maintain strong sustainability in economic, social and environmental aspects. To formulate and implement a good policy strategy which involves all economic, social, and environmental aspects, the coordinated effort of a group of skilled people is required. The provincial government needs to identify the core factors preventing the project's sustainability and work to solve them in order to ensure the sustainable development of the Muskrat Falls project and all other future hydroelectric projects.

7.2 Research Achievement

This research developed a new indexation methodology that can be used to measure the sustainability of a hydroelectric energy project anywhere in the world. This tool has the flexibility to scale up and down depending on size and the number of the projects under consideration. Introducing a four pillars concept of sustainability, the indexation methodology attempted to measure the holistic sustainability of a hydroelectric project. PESTLE analysis has been integrated with this methodology that identified 37 crucial parameters for measuring sustainability. This tool has been applied to measure the sustainability of the MF hydroelectric project. A DSR analysis has been performed to identify policy gaps and recommend policy adjustments.

7.3 Research Limitation

There are a few limitations that this research has faced over the research and writing period. The main limitation is that the researcher was unable to conduct the sustainability workshop because of time and financial constraints. The sustainability workshop is an important part of the methodology as it would help to identify essential parameters that are missing from the current study. Further, it would also provide an additional performance measure for each parameter within the sustainability ranking. The parameters would help to obtain more accurate results. Analysis has not been done to measure risk and uncertainty associated with each parameter. Due to these research limitations, the results of the analysis must be cautiously interpreted. The research employed the following sustainability scale: (1) 1.0-0.8 as strong sustainable, (2) 0.5-0.8 as moderate sustainable, (3) 0.2-0.5 as weak sustainable and (4) 0.0-0.2 as not sustainable. However, other scales can be used for future works.

7.4 Scope for further research

There are several avenues for further work building on the framework presented here. The methodological framework can be applied to the LC project that includes both the MF project and the Gull Island project. Sensitivity analysis can be completed by measuring sustainability once for the construction period and once for the operation and maintenance period. Similar methodological tools can be developed for other renewable energy projects including; wind energy, solar energy, biogas etc. Project specific new parameters can be added for more accurate results. Apart from this, the Sustainability Index for Hydroelectric Energy Projects (SI_{HEP}) can be used in other research, both at micro and macro levels to study other diverse aspects of hydroelectric projects.

References

Akyurek, G., (2005), Impact of Ataturk Dam on social and environmental aspects of the south eastern Anatolia project, The Graduate School of Natural and Applied Sciences of Middle East Technical University. Ankara.

Baird, T., (2013), Is crime getting worse? The Independent. Available at <http://theindependent.ca/2013/07/29/is-crime-getting-worse/> accessed on May 2015.

Banos, R., Manzano-Agugliaro, F., Montoya, FG., Gil, C., Alcayde, A., Gomez, J., (2011), Optimization methods applied to renewable and sustainable energy: A review, Renewable and Sustainable Energy Reviews, 15: 1753–1766

Berkun, M., (2010), Hydroelectric potential and environmental effects of multi-dam hydropower projectsin Turkey, Energy for Sustainable Development, 14: 320–329

Bertelsmann Stiftung, (2015), Sustainable Governance Indicators (SGI), Available at <https://www.bertelsmann-stiftung.de/en/our-projects/sustainable-governance-indicators-sgi/> accessed on April 2015

Boksh, FIMM., (2013), Renewable Energy for Newfoundland and Labrador: Policy Formulation and Decision Making, Journal of Environmental Management and Tourism, 2(8): 91-100

Bosello, F., Portale, E., Campagnolo, L., Eboli, F., Parrado, R., (2011), Costs of sustainability (general equilibrium analysis), Available at <http://in-stream.eu/download/D6.6a_sensitivity_%20FSI.pdf> accessed on February 2015

Bracken, LJ., Bulkeley, HA., Maynard, C., (2014), Micro-hydro power in the UK: The role of communities in an emerging energy resource, Energy Policy, 68: 92-101

Brown, MA., Sovacool, BK., (2007), Developing an "Energy Sustainability Index" to Evaluate American Energy Policy, Working Paper: 18, Georgia Institute of Technology. Available at: http://www.google.ca/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0CCUQFjAB&url=http%3A%2F%2Fwww.researchgate.net%2Fpublication%2F27539016_Developing_an_Energy_Sustainability_Index_to_Evaluate_American_Energy_Policy%2Flinks%2F00b7d52662272a14aa000000&ei=fn9WVLrVGpSnyASzp4C4Dg&usg=AFQjCNEbhbwG5CFlmN0eocQM3CQ9v38v_Q&sig2=XTf9zSwbmdDGIpc2NhMekg accessed: September 25, 2014

Canadian Environmental Assessment Agency (CEAA), (2015), Lower Churchill Hydroelectric Generation Project. Available at <http://www.ceaa.gc.ca/052/details-eng.cfm?pid=26178> accessed February 2015

CCEE-NL, (2015), Climate Change. Available at <http://www.exec.gov.nl.ca/exec/ccee/issues/climatechange.html> accessed on April 2015

Chakrabarty, S., Boksh, FIMM., Chakrabarty, A., (2013), Economic viability of biogas and green self-employment opportunities, Renewable and Sustainable Energy Reviews, 28: 757–766

Choy, Yee, K., (2005), Dam-induced development and environmental and social sustainability: The Bakun industrialization strategy revisited, Journal of Economic Issues, 39(1): 123–150

Cernea, MM., (2004), Social Impacts and Social Risks in Hydropower Programs: Preemptive Planning and Counter-risk Measures, Keynote address: Session on Social Aspects of Hydropower Development United Nations Symposium on Hydropower and Sustainable Development Beijing, China. Available at <http://www.un.org/esa/sustdev/sdissues/energy/op/hydro_cernea_social%20impacts_backgroundpaper.pdf> accessed April 2015

Clarke, AR., (2015), Transboundary Hydropower Projects Seen Through The Lens of Three International Legal Regimes – Foreign Investment, Environmental Protection and Human Rights, International Journal of Water Governance, 3(1)

Commerford, M., (2011), Hydroelectricity: The Negative Ecological and Social Impact and the Policy That Should Govern It, Energy Economics and Policy, Available at <http://www.files.ethz.ch/cepe/Top10/Commerford.pdf> accessed on May 2015

Community Account-NL, (2015), Available at <http://nl.communityaccounts.ca/> accessed on February 2015

Conference board of Canada, (2015), Education and Skills, Available at <http://www.conferenceboard.ca/hcp/provincial/education.aspx> accessed on December 2014

Corporate Knights, (2012), Green provinces of Canada, Available at <http://www.corporateknights.com/channels/leadership/canadas-greenest-province/> accessed on June 2014

Daly, HE., (1990), Boundless bull. Gannett Center Journal 4(3):113–118

Das, RC., (1998), The Environmental Divide: The Dilemma of Developing Countries, Delhi: Ashish

DEC, (1992), Water Use, Available at <http://www.canal.gov.nl.ca/reports/Water_Resources_Atlas/Water_Resources_Atlas_of_Newfoundland_1992_06_WATER_USES.pdf> accessed on November 2014

DF (Department of Finance), (2015), Economics and Statistics. Available at <http://www.fin.gov.nl.ca/fin/publications/index.html#7> accessed on March 2015

Delgado, GC., (2012), Social security and food security Successful policy experiences in Brazil, ESS Paper 30, Geneva: ILO.

Dempsey, N., Bramley, G., Power, S., Brown, C., (2011), The Social Dimension of Sustainable Development: Defi ning Urban Social Sustainability, Sustainable Development, 19(5): 289–300

DNR-NL, (2012), Electricity. Available at <http://www.nr.gov.nl.ca/nr/energy/electricity/> accessed on May 2015

DNR-NL, (2015), Strategic Plans. Available at

<http://www.nr.gov.nl.ca/nr/publications/index.html> accessed on May 2015

Diduck, AP., Pratap, P., Sinclair, AJ., Deane, S., (2013), Perceptions of impacts, public participation, and learning in the planning, assessment and mitigation of two hydroelectric projects in Uttarakhand, India, Land Use Policy, 33: 170– 182

DL, (2015), Destination Labrador: History and Culture. Available at <http://www.destinationlabrador.com/guide/history_and_cultures.htm> accessed on May 2015

Doelle, M., (2012), he Role of EA in Achieving a Sustainable Energy Future in Canada: A Case Study of the Lower Churchill Panel Review, Journal of Environmental Law and Practice 113. Available at <http://ssrn.com/abstract=2070708> accessed on April 2015

DSD-UNDESA, (2001), Indicators of Sustainable Development, Framework and Methodologies, Background Paper 3, New York, USA: United Nations

Dursun, B., Gokcol, C., (2011), The role of hydroelectric power and contribution of small hydropower plants for sustainable development in Turkey, Renewable Energy, 36: 1227-1235

Earle, KM., (1998), Cousins of a Kind: The Newfoundland and Labrador Relationship with the United States, American Review of Canadian Studies, 28

Eastwood, V., (2012), Ethiopia powers on with controversial dam project. CNN, Available at <http://www.cnn.com/2012/05/31/business/ethiopia-grand-renaissance-dam/index.html> accessed on November 2014

EEG, (2015), An Introduction to Governance, Good Governance and the process of Engendering Economic Governance, Available at <http://www1.aucegypt.edu/src/engendering/good_governance.html> accessed on January 2015

Environment Canada, (2015), Sustainable Development, Available at < http://www.ec.gc.ca/dd-sd/> accessed on May 2015

Environmental Impact Statement (EIS), (2009), Lower Churchill Hydroelectric Generation Project Environmental Assessment, Nalcor Energy. Available at <http://nalcorenergy.com/lower-churchill-project-environmental-assessment.asp> accessed on January 2015

Eisgruber, L., (2013), The resource curse: Analysis of the applicability to the large-scale export of electricity from renewable resources, Energy Policy, 57: 429–440

Emiroglu, N., (2009), Environmental cost analysis of Yusufeli hydropower dam. MSc Thesis, Graduate school of natural and applied sciences, Karadeniz Technical University, Trabzon.

EU, (2015), Good governance for sustainable development. Available from <http://ec.europa.eu/environment/archives/wssd/pdf/good_governance.pdf> accessed on March 2015

FSN-NL, (2014), Annual Report 2013-2014. Available from <http://www.foodsecuritynews.com/Publications/FSN_2014_Annual_Report.pdf> accessed on May 2015.

Foy, G., (1990), Economic sustainability and the preservation of environmental assets, Environmental Management, 14(6): 771-778

Frey, G.W., Linke, D.J., (2002), Hydropower as a renewable and sustainable energyresource meeting global energy challenges in a reasonable way, Energy Policy, 30: 1261-1265

Gilbert, R. Stevenson, D. Girardet, H., Stren, R., (1996), Making cities work: The role of local authorities in the urban environment. London: Earthscan

Gov.Canada, (2012), Federal loan guarantee by her majesty the queen in right of canada for the debt financing of the lower churchill river projects, Available at <https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/www/files/2012-11-29-TL-Churchill-Projects-eng.pdf> accessed May 2015

GovNL, (2013), Muskrat Falls: Our project, our benefits, Available at <http://economics.gov.nl.ca/E2013/LowerChurchillProject.pdf> accessed on November 2014

GovNL, (2014), Muskrat Falls Project Oversight Committee, Available at <http://www.gov.nl.ca/MFoversight/pdf/report_sept_2014.pdf> accessed on May 2015

GovNL, (2013), Status of development in Labrador, Available at <http://www.laa.gov.nl.ca/laa/northern_strategic_plan/status.pdf> accessed in May 2015

GovNL, (2012), Newfoundland and Labrador's Energy Sector to Sustain the Provincial Economy for Generations to Come, Available at <http://www.releases.gov.nl.ca/releases/2012/nr/1231n03.htm> accessed on May 2015

GovNL, (2015), History of Newfoundland and Labrador, Available at <http://www.newfoundlandlabrador.com/AboutThisPlace/History> accessed on May 2015

Goodland, R., (1995), The concept of environmental sustainability, Annual Review of Ecology and Systematics 26: 1–24

Goudie, N., (2015), The Human Impact on the Natural Environment: Past, Present, and Future (7th ed.), Sussex: Wiley-Blackwell

Grumbine, RE., Dore, J., Xu, J., (2012), Mekong hydropower: drivers of change and governance challenges, Front Ecol Environ, 10(2): 91–98

Hanrahan, M., (2012), Who are the aboriginal peoples of Newfoundland and Labrador? Available at <http://staff.library.mun.ca/staff/staffdir/acadcouncil/feb12/WhoAreAboriginalPeoplesNewfoundlandLabrador.pdf> accessed on May 2015

Harris, JM., (2003), Sustainability and Sustainable Development, International Society for Ecological Economics. Available at <http://isecoeco.org/pdf/susdev.pdf> accessed on May 2015

Hashim, H., Ho, WS., (2011), Renewable energy policies and initiatives for a sustainable energy future in Malaysia, Renewable and Sustainable Energy Reviews, 15: 4780– 4787

HDR, Inc., (2014), Available at <http://www.hdrinc.com/about-hdr/sustainability/sustainable-return-on-investment> accessed on January 2015

Helston, C., (2012), Large Hydro, Energy BC, Available at: <http://www.energybc.ca/profiles/largehydro.html#lhenvironment> accessed on June 2015

Holdren, JP., Daily, GC., Ehrlich, PR., (1995), The Meaning of Sustainability: Biogeophysical aspects. In: Munasingha, M., Shearer, W. (Eds.): Defining and Measuring Sustainability, The World Bank: Washington, D.C.

Huang, Y., Cai, M., (2009), METHODOLOGIES GUIDELINES - Vulnerability Assessment of Freshwater Resources to Environmental Change, Nairobi: UNEP

Hydro Review, (2009), Resource Overview: Hydropower in Canada: Past, Present, and Future, Available at <http://www.hydroworld.com/articles/hr/print/volume-28/issue-7/articles/resource-overview.html> accessed on May 2015

IAEA, UNDESA, IEA, EEA, (2005), Energy Indicators for Sustainable Development: Guidelines and Methodologies. IAEA Publishing Section, Vienna, Austria. Available at <http://www-pub.iaea.org/MTCD/publications/PDF/Pub1222_web.pdf> accessed on May 2015

IPCC, (2011), Hydropower, Available at <http://srren.ipcc-wg3.de/report/IPCC_SRREN_Ch05.pdf> accessed on November 2014

Izutsu, K., Takano, M., Furuya, S., Iida, T., (2012), Driving actors to promote sustainable energy policies and businesses in local communities: A case study in Bizen city, Japan, Renewable Energy, 39: 107-113

Jorgenson, AK., Alekseyko, A., Giedraitis, V., (2014), Energy consumption, human well-being and economic development in central and eastern European nations: A cautionary tale of sustainability, Energy Policy, 66: 419–427

Kabumba, I., (2005), Good governance and sustainable development in Africa: meaning, relationship, problems and strategies, African association for public administration and management, Available from <http://unpan1.un.org/intradoc/groups/public/documents/AAPAM/UNPAN025764.pdf> accessed on April 2015

Kerk, GVD., Manuel, A., (2012), Sustainable Society Index 2012, Sustainable Society Foundation, Available at: <http://www.google.ca/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0CCMQFjAB&url=http%3A%2F%2Fwww.ssfindex.com%2Fcms%2Fwp-content%2Fuploads%2Fssi2012.pdf&ei=vIBWVJ7nFpWjyATaioCwDA&usg=AFQjCNGZYSRdSjx4IeZbg0xuDTFbbgxvWg&sig2=GdCcf5Pc2M-rKjw519DBBA&bvm=bv.78677474,d.aWw> accessed: September 25, 2014.

Knowledge Economy Indicators (KEI), (2005), Work Package 7, State of the Art Report on Simulation and Indicators. Pages 1-2, Available at <http://www.unirier.de/ fi leadmin/fb4/projekte/SurveyStatisticsNet/KEI-WP7-D7.1.pdf> accessed on May 2015

Loney, M., (1995), Social problems, community trauma and hydro project impacts, Canadian Journal of Native Studies 15(2): 231–254.

Mirumachi, N., (2013), Securitizing shared water: an analysis of hydro-political context of Tanakpur barrage project between India and Nepal, The Geographical Journal, 179(4): 309-319

Moldan, B., Janouskova, S., Hak, T., (2012), How to understand and measure environmental sustainability: Indicators and targets, Ecological Indicators, 17: 4-13

Murphy K. (2012), The social pillar of sustainable development: A literature review and framework for policy analysis, Sustainability: Science, Practice, & Policy, 8: 15–29

Naimi, HM., Zadeh, SV., (2012), Sustainable development based energy policy making frameworks, a critical review, Energy Policy, 43: 351–361

Nalcor Energy, (2015), Our Operations - Lower Churchill Project, Available at <http://www.nalcorenergy.com/our-operations---lower-churchill-project.asp> accessed on June 2015

Nalcor Energy, (2014), Strategic Plan 2014-2016 Transparency and Accountability. Available at <http://www.assembly.nl.ca/business/electronicdocuments/Nalcor-Hydro2014-16StrategicPlan.pdf> accessed on January 2015

Nalcor Energy, (2014a), LCP Socioeconomic Environmental Effects Monitoring Plan, Available at <http://muskratfalls.nalcorenergy.com/wp-content/uploads/2014/08/Socioeconomic-Environmental-Effects-Monitoring-Plan.pdf> accessed on May 2015

Nalcor Energy, (2014b), Lower Churchill Hydroelectric Generation Project A description of the proposed project and its potential effects on the environment. Available at <http://www.ceaa.gc.ca/050/documents/43686/43686e.pdf> accessed on May 2015

Nessa, B., Piirsalua, EU., Anderbergd, S., Olsson, L., (2007), Categorising tools for sustainability assessment, Ecological Economics, 60: 498 – 508

NRCan, (2015), Electricity, Available at <http://www.nr.gov.nl.ca/nr/energy/electricity/index.html> accessed on March 2015

NRCan, (2012), Economic Analysis Lower Churchill Hydroelectric Generation Project, Available at <https://www.nrcan.gc.ca/media-room/backgrounders/2012/3247#toc319473547> accessed on January 2015

OECD, (2014), OECD and post-2015 reflections, Element 4, paper 2. Available at: http://www.google.ca/url?sa=t&rct=j&q=&esrc=s&source=web&cd=6&cad=rja&uact=8&ved=0CFMQFjAF&url=http%3A%2F%2Fwww.oecd.org%2Fdac%2FPOST-2015%2520sustainable%2520energy.pdf&ei=RABJVPWLH9eBygTY0oDwBA&usg=AFQjCNGHGFtpPyyxxYLc4_R_YldbxDVCQw&sig2=r6jF8z_smfs_HBG0P5nW1g&bvm=bv.77880786,d.b2U accessed: September 26, 2014.

Oyedepo, SO., (2012), Energy and sustainable development in Nigeria: the way forward, Energy, Sustainability and Society, 2: 15

Office of Executive Council (OEC), (2014), Activity Plan. Available at <http://www.assembly.nl.ca/business/electronicdocuments/OfficeoftheExecutiveCouncil2014-17ActivityPlan.pdf> accessed on January 2015

Onat, N., Bayar, H., (2010), The sustainability indicators of power production systems, Renew. Sustain. Energy Rev., 14 (9): 3108-3115.

Panwar, NL., Kaushik, SC., Kothari, S., (2011), Role of renewable energy sources in environmental protection: A review, Renewable and Sustainable Energy Reviews, 15: 1513–1524

Poleto, C., Beier, EV., (2012), Siltation and erosion processes on a tributary of lake itaipu due a dam reservoir, Lakes, reservoirs and ponds, 6(2): 108-119.

Prescott-Allen, R., (2001), The wellbeing of nations. In: A Country-by-Country Index of Quality of Life and the Environment, Washington, DC: Island Press.

PUB, (2014), Muskrat Falls Project, Newfoundland and Labrador Board of Commissioners for Public Utilities, Available at <http://www.pub.nf.ca/applications/MuskratFalls2011/files/mhi/MHI-Report-VolumeII-Muskrat.pdf> accessed on January 2015

PUB, (2012), Reference to the board: Review of two generation expansion options for the least-cost supply of power to island interconnected customers for the period 2011 – 2067. Available at <http://www.gov.nl.ca/lowerchurchillproject/muskrat_falls_pub_final_report.pdf> accessed February 2015.

Romero-Lankao, P., Gurney, KR., Seto, KC., Chester, M., Duren, RM., Hughes, S., Hutyra, LR., Marcotullio, P., Baker, L., Grimm, NB., Kennedy, C., Larson, E., Pincetl, S., Runfola, D., Sanchez, L., Shrestha, G., Feddema, J., Sarzynski, A., Sperling, J., Stokes, E., (2014), A critical knowledge pathway to low-carbon, sustainable futures: Integrated understanding of urbanization, urban areas, and carbon, Earth's Future, 2(10): 515–532

Sachiko, M., Durwood, Z., (2007), Rule of law, good governance, and sustainable development, Washington, DC: INECE

Scanlon, A., Kile, R., Blumstein, B. (2004), Sustainable hydropower – guidelines, compliance standards and certification, paper presented at United Nations Symposium on Hydropower and Sustainable Development, Beijing, 27-29 October.

Sovacool, B.J., Bulan, L.C., (2011), Behind an ambitious mega-project in Asia: The history and implications of the Bakun hydroelectric dam in Borneo, Energy Policy, 39: 4842–4859

Stambouli, AB., Khiat, Z., Flazi, S., Kitamura, Y., (2012), A review on the renewable energy development in Algeria: Current perspective, energy scenario and sustainability issues, Renewable and Sustainable Energy Reviews, 16: 4445–4460

Stat. Canada, (2015), Available at <http://www.statcan.gc.ca/start-debut-eng.html> accessed on April 2015

Serageldin, I., Streeter, A. (eds.), (1993), Valuing the environment: proceedings of the First Annual Conference on Environmentally Sustainable Development, Environmentally Sustainable Development Proceedings Series No. 2, Washington, DC: The World Bank

Spicer, S., (2014), A Strategic Analysis for Small Hydro Power (SHP) Development in Himachal Pradesh, India, Undergraduate Review, 10: 171-177

Storey, K., Felt, L., Vardy, D., (2011), Labrador Mining, Aboriginal Governance and Muskrat Falls, The Harris Centre, Memorial University. Available at <http://www.mun.ca/harriscentre/reports/research/2011/ActionCanadaReportOct2011Web.pdf> accessed on May 2015

Stat. Canada, (2015), Available at <http://www.statcan.gc.ca/start-debut-eng.html> accessed on January 2015

The 2007 Energy Plan: Focusing Our Energy (2007), Government of Newfoundland and Labrador. Available at <http://www.nr.gov.nl.ca/energyplan/EnergyReport.pdf> accessed on January 2014

Torjman, R., (2000), The Social Dimension of Sustainable Development, Caledon Institute of Social Policy. Available at <http://www.caledoninst.org/Publications/PDF/1-894598-00-8.pdf> accessed on January 2015

Tuck, J.A., (1991), Museum Notes – The Maritime Archaic Tradition. The Rooms Provincial museum. Available at <http://www.therooms.ca/museum/mnotes12.asp> accessed on March 2015

Sustainable Energy, (2013), Sustainable Energy, Available at: <http://www.penguinsonthinice.com/Sustainable%20Energy%20and%20Development%20fact%20sheet.pdf> accessed on Jun 2015

UN Documents, (1987), Report of the World Commission on Environment and Development: Our Common Future. Available at <http://www.un-documents.net/our-common-future.pdf> accessed on May 2015

UN General Assembly, (2005), 60/1. 2005 World Summit Outcome, Resolution adopted by the General Assembly (16th Session). Available at <http://www.un.org/womenwatch/ods/A-RES-60-1-E.pdf> accessed on November 2014

United Nations Development Programme [UNDP] [1997b] - Reconceptualising Governance. Discussion Paper 2. New York, Management Development and Governance Division, Bureau for Policy and Programme Support, United Nations Development Programme [UNDP]

United Nations Development Programme [UNDP], (1997) Governance for sustainable human development, New York: UNDP policy document

United Nations Development Programme [UNDP], (2014), Governance for Sustainable Development Integrating Governance in the Post-2015 Development Framework. Available at <http://www.undp.org/content/dam/undp/library/Democratic%20Governance/Discussion-Paper--Governance-for-Sustainable-Development.pdf> accessed on December 2014

UNESCO, (2006), Definition of basic concepts and terminologies in governance and public administration, Available at <http://unpan1.un.org/intradoc/groups/public/documents/un/unpan022332.pdf> accessed on January 2015

UNU-IAS, (2014), Integrating Governance into the Sustainable Development Goals, Post2015 Policy Brief #3, Available at <http://www.earthsystemgovernance.org/sites/default/files/publications/files/Policy-Brief-3.pdf> accessed on December 2014

Vera, IA., Langlois, L., (2007), Energy indicators for sustainable development, Energy, 32: 875–882.

Weil, G.L., (2012), The Muskrat Falls Hydro Project Opportunities and Risks, Atlantic Institute for Market Studies. Available at <http://www.aims.ca/site/media/aims/Muskrat%20Falls.pdf> accessed May 2015

Wilkins, R., Dieter, H., Croissant, A., (2014), SGI: 2014 Australia Report, Available at <http://www.sgi-network.org/docs/2014/country/SGI2014_Australia.pdf> accessed January 2015

Wilson, R.S., Arvai, J.L., (2011), Structured Decision Making Using decision research to improve stakeholder participation and results, Oregon: Oregon State University

WPDC, (2013), Hydropower promise in Nepal, Water power and dam development, Available at <http://www.waterpowermagazine.com/features/featurehydropower-promise-in-nepal/> accessed on May 2015

Yuksel, I., (2012), Global warming and environmental benefits of hydroelectric for sustainable energy in Turkey, Renewable and Sustainable Energy Reviews, 16: 3816– 3825

Zalengera, C., Blanchard, RE., Eames, PC., Juma AM., Chitawob, ML., Gondwe, KT., (2014), Overview of the Malawi energy situation and A PESTLE analysis for sustainable development of renewable energy, Renewable and Sustainable Energy Reviews, 38: 335–347

APPENDIX A: Electric Power Generation (Annual Megawatt Hour)

Geography	Class of electricity producer	Type of electricity generation	2009	2010	2011	2012	2013
Canada	Total all classes of electricity producer	Total electricity generation	595537304	588,016,955	618550162	617,088,777	620444277
		Hydraulic turbine 3	365110421	347,980,845	372076377	376,574,355	387980873
		Tidal power turbine 4	29954	27680	26095	27128	14830
		Wind power turbine 5	6575235	8,636,950	10086688	11198373	11478684
		Solar 10	4502	115,745	256935	315,843	360478
		Other electricity generation	1918497	2975953	2509521	2723937	2441392
		Total thermal generation	221898695	228,279,782	233594546	226,249,141	218168020
	Electricity producer, electric utilities 1	Total electricity generation	545723020	541,845,459	568,460,462	562,828,271	565209964
		Hydraulic turbine 3	333679223	321,043,643	341,863,826	344,857,733	357044341
		Tidal power turbine 4	29954	27680	26095	27128	14830
		Wind power turbine 5	6573375	8,635,405	10085267	11194493	11461246
		Solar 10	4502	115,745	256935	315,843	360478
		Other electricity generation	1918497	2975953	2509521	2723937	2441392
		Total thermal generation	203517469	209,047,033	213,718,818	203,709,137	193887677

	Electricity producer, industries 2	Total electricity generation	49814284	46,171,496	50,089,700	54,260,506	55234313
		Hydraulic turbine 3	31431198	26,937,202	30,212,551	31716622	30936532
		Wind power turbine 5	1860	1545	1421	3880	17438
		Total thermal generation	18381226	19,232,749	19,875,728	22,540,004	24280343
Newfoundland and Labrador	Total all classes of electricity producer	Total electricity generation	38168660	41,742,835	41604016	43702506	43077139
		Hydraulic turbine 3	36728175	40,278,706	40016895	42186461	41424414
		Wind power turbine 5	102365	183379	197964	195044	191904
		Total thermal generation	1338120	1,280,750	1389157	1321001	1460821
	Electricity producer, electric utilities 1	Total electricity generation	37062952	40,484,527	40328986	42486532	41809855
		Hydraulic turbine 3	35899337	39,385,383	39121918	41321064	40532674
		Wind power turbine 5	102365	183379	197964	195044	191904
		Total thermal generation	1061250	915,765	1009104	970424	1085277
	Electricity producer, industries 2	Total electricity generation	1105708	1258308	1275030	1215974	1267284
		Hydraulic turbine 3	828838	893323	894977	865397	891740
		Total thermal generation	276870	364985	380053	350577	375544

APPENDIX B: Sustainability Index measurement procedure

Index	Fundamental Objectives (Sub-Indices)	Means Objectives (Categories)	Parameters	Derived Performance Measures							Constructive Performance Measures				Sub-Indices	SI_{HEP}
				Natural Measure			Proxy Measures			Weighted Index	Strong Sustainable (0.8 – 1.0)	Moderate Sustainable (0.5 – 0.8)	Weak Sustainable (0.2 – 0.5)	Not Sustainable (0.0 – 0.2)		
				Indicators	Value	Indexed Value	Indicators	Value	Indexed Value							
Sustainability Index for Hydro Energy Project (SI_{HEP})	Minimizing Social Impacts														SSI	
	Minimizing Environmental Impacts														EnvSI	
	Maximizing Economic Benefits														EcoSI	
	Good Governance														GovSI	

APPENDIX C: Parameters and their measures (natural and proxy)

Means Objectives (Categories)	Parameters	Derived Performance Measures	
		Natural Indicators	Proxy Indicators
Land and Resource Use	Forestry	change in land base	
	Agriculture	change in quantity of lands	
Reduce Cultural Influences	Culture and Heritage	government expenditures on culture	
Social Development	Local employment generation	Employment Rate	
	Standard of living		Income per capita
	Food Security	Household yearly food expenditure	
	Physical Infrastructure and Services	Airport passengers per annum	
Improve Community Health Standard	Community Health	Self-Assessed Health	
	Access to Health Service	Physician per Person	
Social Infrastructures and Services	Security	Police Officer/population ratio	
	Education	Teacher/student ratio	
	Power supply	per capita power generation	
	Housing and Accommodations	Homeownership rate	
Atmospheric Environment	Climate	Greenhouse gas emissions	
	Air Quality	Air Pollutant	
Aquatic Environment	Spill of methylmercury	Methylmercury level in water	
	Fish and Fish Habitat	Hectares of river and standing water	
Terrestrial habitats	Terrestrial habitats	Fatalities as a proportion of population	
Natural Resources	Fossil Fuel Conservation	Quantity of diesel replaced by electricity	

Improve Trade	Impact on trade, commerce and industry		Industrial energy use
	Business	Private Investment Proportion	
Vibrant Provincial Economy	Income generation from Project	% of total household income	
	Impact on tourism		% of GDP
	Government Revenue	% of tax revenue from this sector	
Feasibility	Net Present Value of Project	NPV	
	Internal Rate of Return of Project	IRR	
	Return on Equity	ROE	
Employment	Employment generation	Project employment % of labor force	
	Labor Force	Labor Force participation rate	
	Employee type	Gender and Aboriginal status	
Policy Performance	Economic Policy	Research and innovation	
	Social Policy	Education	
	Environmental Policy	Environment	
Democracy		Electoral process	
	Quality of Democracy	Access to information	
		Rule of Law	
Governance	Executive Capacity	Strategic Capacity	
	Corruption	CPI	
	Executive Accountability	Citizens' Participatory Competence	

APPENDIX D: Benchmarking and indexing criteria for indicator

Sustainability Scale		Benchmark Value		Value	Source
0-0.2		% of forest lands	<10		FAO
0.2-0.5			10≤x<25		
0.5-0.8			25≤x<30		
0.8-1			≥30		
0-0.2		% change in lands quantity	<(-10)		FAO
0.2-0.5			(-10)≤x<(-5)		
0.5-0.8			(-5)≤x<1		
0.8-1			≥1		
0-0.2		Government expenditures on culture (million)	<50		Stat. Canada & OECD
0.2-0.5			50≤x<250		
0.5-0.8			250≤x<400		
0.8-1			≥400		
0-0.2		Employment Rate	<50		OECD
0.2-0.5			50≤x<60		
0.5-0.8			60≤x<70		
0.8-1			≥70		
0-0.2		Income per capita (1000)	<20		OECD
0.2-0.5			20≤x<30		
0.5-0.8			30≤x<40		
0.8-1			≥40		
0-0.2		Household yearly food expenditure 000'	x>25, x<0.5		WB
0.2-0.5			25≥x>20, 0.5<x<5		
0.5-0.8			20≥x>18, 5≤x<12		
0.8-1			x≤18, x≥12		
0-0.2		Passengers (million)	<0.1		AIC
0.2-0.5			0.1≤x<1		
0.5-0.8			1≤x<10		
0.8-1			≥10		
0-0.2		Good Self-Assessed Health	<45		WHO
0.2-0.5			45≤x<52		
0.5-0.8			52≤x<60		
0.8-1			≥60		
0-0.2		Physician per 1000	>9		WHO
0.2-0.5			9≥x>8		

0.5-0.8			8≥x>7		
0.8-1			≤7		
0-0.2		Police officer per population (000)	<1		IACP
0.2-0.5			1≤x<2		
0.5-0.8			2≤x<2.5		
0.8-1			≥2.5		
0-0.2		Student-educator ratio	>30		OECD
0.2-0.5			30≥x>25		
0.5-0.8			25≥x>20		
0.8-1			≤20		
0-0.2		Per capita power consumption (MW H)	<3		World Bank
0.2-0.5			3≤x<5		
0.5-0.8			5≤x7		
0.8-1			≥7		
0-0.2		Homeownership rate	<65		OECD & The Atlantic
0.2-0.5			65≤x<70		
0.5-0.8			70≤x<75		
0.8-1			≥75		
0-0.2		Per capita GHG Emissions	>20		IPCC
0.2-0.5			20≥x>10		
0.5-0.8			10≥x>4		
0.8-1			≤4		
0-0.2		PM_{10} ((µg/m^3))	>150		WHO
0.2-0.5			150≥x>100		
0.5-0.8			100≥x>50		
0.8-1			≤50		
0-0.2		Methylmercury level in water (µg/litre)	>2		WHO
0.2-0.5			1.5≥x>1		
0.5-0.8			1≥x>0.5		
0.8-1			≤0.5		
0-0.2		Growth of fish population	<0		FAO
0.2-0.5			0≤x<2		
0.5-0.8			2≤x<3		
0.8-1			≥3		
0-0.2		% of Endangered animals	>20		IUCN
0.2-0.5			20≥x>12		
0.5-0.8			12≥x>6		
0.8-1			≤6		

0-0.2		Quantity of diesel replaced (Berrel/hr)	<500		ANDRITZ
0.2-0.5		Quantity of diesel replaced (Berrel/hr)	500≤x<1000		ANDRITZ
0.5-0.8		Quantity of diesel replaced (Berrel/hr)	1000≤x<1500		ANDRITZ
0.8-1		Quantity of diesel replaced (Berrel/hr)	≥1500		ANDRITZ
0-0.2		Industrial energy use (%)	<25		UNIDO
0.2-0.5		Industrial energy use (%)	25≤x<30		UNIDO
0.5-0.8		Industrial energy use (%)	30≤x<35		UNIDO
0.8-1		Industrial energy use (%)	≥35		UNIDO
0-0.2		Private Investment Proportion	<70		WEO
0.2-0.5		Private Investment Proportion	70≤x<73		WEO
0.5-0.8		Private Investment Proportion	73≤x<78		WEO
0.8-1		Private Investment Proportion	≥78		WEO
0-0.2		% of total household income	<1		OECD
0.2-0.5		% of total household income	1≤x<5		OECD
0.5-0.8		% of total household income	5≤x<10		OECD
0.8-1		% of total household income	≥10		OECD
0-0.2		% of GDP	<0.5		WB
0.2-0.5		% of GDP	0.5≤x<2		WB
0.5-0.8		% of GDP	2≤x<5		WB
0.8-1		% of GDP	≥5		WB
0-0.2		% of tax revenue from this sector	<1		Stat. Canada
0.2-0.5		% of tax revenue from this sector	1≤x<5		Stat. Canada
0.5-0.8		% of tax revenue from this sector	5≤x<10		Stat. Canada
0.8-1		% of tax revenue from this sector	≥10		Stat. Canada
0-0.2		NPV (million USD)	<0		MWH
0.2-0.5		NPV (million USD)	0≤x<500		MWH
0.5-0.8		NPV (million USD)	500≤x<1000		MWH
0.8-1		NPV (million USD)	≥1000		MWH
0-0.2		IRR	<0		UNFCCC
0.2-0.5		IRR	0≤x<1		UNFCCC
0.5-0.8		IRR	1≤x<10		UNFCCC
0.8-1		IRR	≥10		UNFCCC
0-0.2		ROE	<3		BC Hydro
0.2-0.5		ROE	3≤x<5		BC Hydro
0.5-0.8		ROE	5≤x<9		BC Hydro
0.8-1		ROE	≥9		BC Hydro
0-0.2		Project Employment % of labor force	<0.5		ESDC
0.2-0.5		Project Employment % of labor force	0.5≤x<1		ESDC

0.5-0.8			1≤x<2		
0.8-1			≥2		
0-0.2		Labor Force participation rate %	<60		ILO
0.2-0.5			60≤x<84		
0.5-0.8			75≤x<84		
0.8-1			≥90		
0-0.2		% of Aboriginal labor employed	<50		ESDC
0.2-0.5			50≤x<52		
0.5-0.8			52≤x<58		
0.8-1			≥58		
0-0.2		R&D % of GDP	<1		OECD
0.2-0.5			1≤x<1.5		
0.5-0.8			1.5≤x<3		
0.8-1			≥3		
0-0.2		Education and Skills Grade	<6		UNDP
0.2-0.5			6≤x<7.5		
0.5-0.8			7.5≤x<0.9		
0.8-1			≥0.9		
0-0.2		Environmental Performance	<50		EPI
0.2-0.5			50≤x<60		
0.5-0.8			60≤x<70		
0.8-1			≥70		
0-0.2		Voter Turnout Rate	<60		IDEA
0.2-0.5			60≤x<67		
0.5-0.8			67≤x<72		
0.8-1			≥80		
0-0.2		EGDI	<0.5		UNPACS
0.2-0.5			0.5≤x<0.7		
0.5-0.8			0.7≤x<0.9		
0.8-1			≥0.9		
0-0.2		Rule of Law	<40		WB
0.2-0.5			40≤x<60		
0.5-0.8			60≤x<80		
0.8-1			≥80		
0-0.2		Strategic Capacity	<3		SGI
0.2-0.5			3≤x<6		
0.5-0.8			6≤x<8		
0.8-1			≥8		

0-0.2		CPI	<50		TI
0.2-0.5			50≤x<60		
0.5-0.8			60≤x<70		
0.8-1			≥70		
0-0.2		Citizens' Participatory Competence	<3		SGI
0.2-0.5			3≤x<6		
0.5-0.8			6≤x<8		
0.8-1			≥8		