Community choices: Pathways to integrate renewable energy into indigenous remote community energy systems

by

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Author's declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Statement of contributions

With the exception of Chapters 5, 6, 7 and Appendix A, all writing in this dissertation is solely the author’s. These chapters have been co-authored with my dissertation advisor Dr. Paul Parker and published in refereed journals (Chapters 5, 6, 7 and Appendix A). I testify that I am the primary author of the manuscripts in my dissertation. Dr. Paul Parker provided contextual material and editing.

Abstract

Community owned renewable energy generation (electricity and heat) is often associated with improving reliability and affordability of supply, increasing local wellbeing, empowering through new revenues, business opportunities and capacity building, and reducing environmental impacts. Similar motivations for renewable energy projects are observed in the case of Canadian remote indigenous communities that target activities that improve their socioeconomic conditions and mitigate socioeconomic-political-cultural impacts resulting from colonization, while having minimal influence on the environment and traditional activities. However, the slow transformation of remote indigenous communities' diesel-powered electricity systems through the introduction of renewable energy technologies (RETs) between 1980 and 2016 called for an examination of factors that influence the transition to more sustainable electricity options.

The purpose of this dissertation was to improve understanding of the technical, contextual, and social complexity associated with the introduction of RETs into Canadian remote indigenous community electrical systems, explain the diffusion of RET projects within these systems to date, and examine the implemented governance processes and how these processes were modified to encompass indigenous perspectives. Improved understanding enables identification of pathways and development of policy recommendations for the transition to more sustainable energy systems. These objectives were achieved through: (a) a review of prior academic and non-academic documents on the introduction of RETs into remote communities, the examination of 133 community electrical systems in Yukon, NWT, Nunavut, British Columbia, Ontario, Quebec and Newfoundland and Labrador, and the identification of RET projects undertaken between 1980 and 2016, (b) an empirical study in the context of northern Ontario, Canada, and (c) an analysis of events related to the introduction of RETs through, first, the multi-level perspective (MLP) approach to explain the non-linear uptake of RET projects in remote indigenous communities and identify macro- and meso-level factors that influenced the deployment, and, second, the technological innovation system (TIS) approach to examine policy measures and activities in Northwest Territories and Ontario and generate insights on micro-level factors that led to the development of an increased number of mostly solar projects in these provinces between 2009 and 2016.

The key findings of the research suggest that the deployment of RET projects was influenced by the institutional complexity of indigenous electrical systems, the diversity of stakeholder perspectives (government, utilities and indigenous peoples) on community electricity generation and the challenges that the introduction of RETs is expected to address, and the uncertainty associated with both the future “long term” structure and governance of provincial and territorial electricity generation systems and the financial viability of small-scale off-grid applications. Furthermore, the shift from utility-driven to community-driven RET projects in the period examined was explained through the interplay between tensions developed from new legislation favouring indigenous aspirations and sustainability concerns, governmental and utility internal stresses expressed through governmental targets and supporting policies for renewable electricity alternatives, and pressures from technological advances. Governments engaged in a dialogue with indigenous people and other participants, which resulted in a policy shift from capital financing to capabilities improvements and network formation, and, finally, to regulatory and financial arrangements supporting indigenous demand for community owned electricity generation.

This research contributes to scholarship and provides insights to policy design. First, it improves understanding of the nature of the problem associated with the introduction of RETs into Canadian remote indigenous communities by providing a description of the origins, dynamics, extent, and pattern of transition and the associated technical, contextual, and social complexity. Furthermore, it contributes to the field of sustainability studies by providing research using both the MLP and TIS concepts in the context of remote Canadian indigenous communities and evidence, first, that the proposed complex causal mechanisms were present and performed as predicted, and second, that regional institutional structures and networks (or the lack of them) played an important role in the diffusion of RET projects. Finally, this research suggests that a transition management approach involving the co-development of policies supportive of indigenous aspirations, experimenting and learning, and evaluation and adjustment of policies based on the acquired knowledge, may lead to an increased number of RET projects in remote indigenous communities. Accordingly, policy related recommendations include the need for (a) establishing specific targets, policies, and programs for the reduction of diesel consumption and the introduction of RETs (b) policy development in a collaborative and negotiated way with indigenous people, and (c) effective coordination of interventions for the creation of networks that would improve interactions and learning.

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List of Abbreviations

AANDC	Aboriginal Affairs and Northern Development
AEA	Arctic Energy Alliance (AEA)
AED	Aboriginal Economic Development
AEPP	Aboriginal Energy Partnerships Program
ALGP	Aboriginal Loan Guarantee Program
ANCAP	Aboriginal and Northern Community Action Program
ANCCP	Aboriginal and Northern Climate Change Program
AREF	Aboriginal Renewable Energy Fund
ARI	Aurora Research Institute
ATF	Aboriginal Transmission Fund
BC	British Columbia
CCAP	Climate Change Adaptation Program
CED	Community Economic Development
CEEP	Community Energy Partnerships Program
GEGEA	Green Energy and Green Economy Act
CEP	Community Energy Plan
CPO	Causal Process Observation
CREF	Community Renewable Energy Fund
EANCP	Aboriginal and Northern Communities Program
GDP	Gross Domestic Product
GHG	Greenhouse gases
HORCI	Hydro One Remote Communities Inc
IESO	Independent Electricity System Operator
INAC	Indigenous and Northern Affairs Canada
IPA	Independent Power Authority
IPP	Independent Power Producer
kW	Kilowatt
kWh	Kilowatt-hour
LDC	Local Development Corporation
MLP	Multi-Level Perspective
MW	Megawatt
NAN	Nishnawbe Aski Nation
NFL	Newfoundland and Labrador
NGO	Non-Governmental Organization
NLH	Newfoundland and Labrador Hydro
NRCan	Natural Resources Canada
NTPC	Northwest Territories Power Corporation
NWT	Northwest Territories
OEB	Ontario Energy Board
PPA	Power Purchase Agreement

QEC	Qulliq Energy Corporation
RCAP	Royal Commission on Aboriginal Peoples
RCE	Remote Communities Electrification
RCI	Remote Communities Initiative
RETs	Renewable Electricity Technologies
RRRP	Rural or Remote Rate Protection
R & D	Research and Development
SCADA	Supervisory Control and Data Acquisition
SCC	Supreme Court of Canada
STS	Shibogama Technical Services
TIS	Technological Innovation System
YIS	Yukon Interconnected System

Chapter 1: Introduction

1.1 Research context and problem rationale

Remote communities in Canada are communities that are not connected to the North American electrical grid and are permanent settlements with at least 10 permanent dwellings (AANDC and NRCan, 2011). In 2011, there were 292 such communities in Canada with an approximate population of 195,000, of which 171 were indigenous communities[1] of approximately 126,000 people (AANDC and NRCan, 2011; AANDC, 2012). Several communities in NWT and Yukon are integrated within local territorial grids powered mainly by hydroelectricity, while 144 remote indigenous communities with a population of approximately 90,000, use exclusively diesel powered electricity (AANDC, 2012).

Diesel-generated electricity in these communities can limit economic development opportunities and result in poor quality services, increased production of CO_2 emissions, as well as associated spills and leakages from fuel storage facilities. Increased current and anticipated fuel prices lead to high electricity costs, which when combined with substantial transport costs (often air), lead to high expenses for electrification (AANDC, 2012). There is a need to transform the current fossil fuel based energy systems to low carbon sustainable systems that address both environmental and economic development issues, either through the connection of the communities to local or provincial grids, the introduction of renewable technologies to local energy systems, or a combination of both.

The rationale for research into pathways for the introduction of renewable electricity technologies (RETs) in remote indigenous communities in Canada stems from empirical results that point to a limited number of such projects between 1980 and 2016 (AANDC and NRCan, 2011; Arriaga, Canizares, & Kazerani, 2014; Weis, 2011). Pathways are understood as conceptualizations of different processes and patterns that explain the transition from a current sociotechnical

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[1] According to Crown-Indigenous Relations and Northern Affairs Canada "the Canadian Constitution recognizes three groups of Aboriginal peoples: Indians (more commonly referred to as First Nations), Inuit and Métis. These are three distinct peoples with unique histories, languages, cultural practices and spiritual beliefs" (GC, 2017b; AANDC, 2012a). Some indigenous people live on reserves. A reserve is a "tract of land, the legal title to which is held by the Crown, set apart for the use and benefit of an Indian band" (AANDC, 2012a). Some indigenous peoples have also adopted the term "First Nation" to replace the word "band" in the name of their community (AANDC, 2012a).

configuration to a more sustainable one. As such, stimulation of these processes and patterns can in turn stimulate the transition process (Rosenbloom, 2017).

Motivations for community participation in renewable energy generation (electricity and heat) include community social goals (such as distributional and procedural justice), increased local wellbeing through revitalization projects and community capacity development, as well as the opportunity to address environmental challenges (Wuestenhagen, Wolsink, & Buerer, 2007; Walker, Hunter, Devine-Wright, Evans, & Fay, 2007; Walker, 2008; Seyfang & Smith, 2007; Hicks & Ison, 2011). Furthermore, in the case of rural communities challenged by low population densities, lack of infrastructure, low levels of economic activity and restricted access to main centres due to physical terrain and long distances, residents' motivations for RET deployment relate to reliability, affordability, as well as independence and community empowerment through new revenues, jobs, business opportunities, and capacity building (OECD, 2012; Hicks & Ison, 2011; DelRıo & Burguillo, 2009; Slattery, Johnson, Swofford, & Pasqualetti, 2012; Giddings & Underwood, 2007).

Similar motivations for participation in renewable electricity generation are observed in Canadian indigenous communities focused on rebuilding their societies and mitigating the socioeconomic-political-cultural impacts resulting from colonization (Corntassel, 2012). Self-governance and self-reliance may also be attained through renewable energy ventures that have minimal impact on the environment and traditional activities while providing appropriate economic rents that could contribute to sustainable economic development (Kendal, 2001; Slowey, 2008). Revenue generation to support community self-sufficiency goals appears to be the main motivation for recent participation of indigenous communities in numerous community owned (or co-owned) *on-grid* large-scale hydroelectric, wind and solar projects (Henderson, 2013; Henderson, 2009; INAC, 2004; McLaughlin, McDonald, Nguyen, & Pearce, 2010). For example, Krupa (2012b) states revenue generation, employment during projects' construction phase, and the creation of two full time jobs for operations as the main outcomes of the Pic River First Nations' owned three hydroelectricity assets (see also AECOM, 2012). Similarly, Chief Keith "Keeter" Corston of the Chapleau Cree First Nation, identifies community self-reliance as the outcome of the Kapuskasing hydroelectricity project and states that "our goal and our destiny is to be self-governing, but to be self-governing you have to have an economic engine and the economic engine that we have is the resources on the land" (Landers, 2014, p. 1). Shawn Batise, executive director of the Wabun Tribal Council, sees RET projects as contributors to sustainable indigenous development, since the revenue generated provides “a regular flow of income over time, rather than mining, which is over once the ore is depleted” (Stewart, 2009, p. 1). Finally, compatibility with indigenous values is expressed in the words of Batchewana First Nation Chief Dean Sayers, stating that the community co-owned renewable energy project is “…perfectly aligned with our original expectations at Treaty time; those expectations were to benefit from our resources in sustainable ways” (Marketwired, 2013, p. 1).

However, despite the multiple potential benefits associated with community participation in renewable electricity projects, the deployment of RETs into *remote* indigenous community electricity systems between 1980 and 2016 has been limited (AANDC and NRCan, 2011; Arriaga, Canizares, & Kazerani, 2014; Weis, 2011). As discussed in Chapter 4, during this timeframe 71 RET projects were installed in 57 of the examined 133 diesel powered remote indigenous communities in Yukon, Northwest Territories (NWT), British Columbia, Ontario, Quebec, and Newfoundland and Labrador, with a total of 31.5 MW, or 13% of the total electricity capacity. If hydroelectricity is excluded, 63 of these projects were small-scale wind and solar applications with a total capacity of 1.6 MW, or less than 1% of the total electricity generation capacity.

This slow transformation of community electrical systems, despite the potential of RETs to address multiple concerns and provide numerous potential socioeconomic and environmental benefits (OECD, 2012; IEA, 2011), calls for an examination of factors that influence the transition process. As the responsibility for electricity generation in these communities is shared among the federal government, provincial/territorial governments, utilities, and local indigenous governments (OEB, 2008), it could be that differing stakeholder perspectives over the challenges that RETs are supposed to address, and the governance structures necessary to support their implementation contribute to inaction over the transition to green electricity generation. With this in mind, the introduction of RETs into community electrical systems exhibits characteristics similar to those of a “wicked problem” or a social problem that is difficult to define in terms of causal relationships surrounding the issue in question (Rittel & Webber, 1973). As Head and Alford (2015) observe, wicked problems are characterized by a variety of stakeholders that contribute to an “ill-definition” of the problem under consideration. This lack of “definitional clarity” results from stakeholders’ diverse perceptions arising from a variety of differing, often opposing, world views, backgrounds, cultures, moral, political and professional agendas (Weber & Khademian, 2008; Ritchey, 2013), as well as governance structures and political economy considerations (Fritz, Kaiser, & Levy, 2009), such as the existence of "redistributive implications for entrenched interests" (Rayner, 2006, p. 2). Rittel and Weber (1973) also refer to insufficient scientific knowledge, the problem's unique character, the existence of value laden conflict, and the fact that one wicked problem is usually part of a larger wicked problem.

Research contributions on wicked problems (including energy-related papers) refer extensively to the "challenge of identifying, defining and describing the nature" of the problem under consideration (Danken, Dribbisch, & Lange, 2016, p. 20). Understanding the problem's technical, contextual (wickedness associated with localized factors), and social (participating actors) complexity, is approached through examining the participating network, consisting of different actors, their backgrounds (educational and professional), worldviews, political agendas, cultural traditions, economic interests, and institutional and governance arrangements (Raisio, 2010). Furthermore, Fritz et al. (2009) argue that a governance and political economy analysis is necessary to understand "why the identified problem has not been addressed successfully and what the relative likelihood is of stakeholder support for various change options" (p. x). A second focus of studies on wicked problems also is to concentrate on approaches to cope with such complexities, examining the type of coping strategy selected and the actors' necessary skills for implementation (Danken, Dribbisch, & Lange, 2016).

1.2 Purpose of the study, rationale and study objectives

Accordingly, and given the suspected "wickedness" stemming from the participation of multiple stakeholders with diverse worldviews, the purpose of this doctoral study is to improve understanding and advance knowledge on the factors that influence the introduction of RETs into remote indigenous community electrical systems in Canada. Within this broader purpose there are three specific study objectives:

1. Develop a conceptual framework to examine the transformation of remote community electrical systems;
2. Use the conceptual framework to improve understanding of the “wickedness” (the technical, contextual, and social complexity) associated with the introduction of RETs into remote indigenous community electrical systems, and explain the diffusion of RET projects within these systems to date; and
3. Examine the processes implemented to cope with the wickedness of the problem (in the form of mechanisms and actor strategies) and how these processes were modified to encompass indigenous perspectives in order to identify pathways and develop policy recommendations for their transition to more sustainable systems.

1.3 Dissertation outline

This thesis was prepared in a manuscript style and includes three stand-alone articles written for publication in peer-reviewed journals. This introductory chapter outlines the problem rationale and research context, the problem statement, purpose, and objectives of the study.

Chapter two provides a literature review of energy-related research that examines sociotechnical, political, economic and environmental factors to explain change in multi-stakeholder settings, as well as past research contributions on the introduction of RETs in rural and remote communities. Since the goal of this study is to examine the transformation of indigenous community electrical systems, additional context to the study is provided through a review of changes in indigenous governance and political economy structures over recent years.

Chapter three addresses the first research objective by examining the theoretical background, methodological approaches and limitations of three subdisciplines, with the goal of identifying a conceptual framework for the study. The multi-level perspective (MLP) and the technological innovation system (TIS) are introduced as analytical tools for understanding and explaining the introduction of RETs in remote community electrical systems. Driven by the conceptual frameworks and research setting, the research approach, data collection methods, analysis process, and research limitations are presented, along with the researcher’s positionality.

Chapter four summarizes results from seven papers, which are presented in Appendix A and published in the journal *Papers in Canadian Economic Development*. The papers use internet searches and literature reviews of academic and governmental and utilities' policy documents and reports to describe the electrical systems of remote communities in Yukon, NWT, Nunavut, British Columbia, Ontario, Quebec and Newfoundland and Labrador. In addition, the papers identify RET projects installed between 1980 and 2016 and policies that supported their implementation. This chapter improves understanding of the contextual and technical complexity of the introduction of RETs into remote indigenous communities' electrical systems.

The three remaining chapters address the second and third objective of the study. Because of the stand-alone format of the dissertation, some contributions in chapter three and four are repeated in chapters five, and six, and seven. Each of these three manuscripts is a co-authored article with my dissertation advisor Dr. Paul Parker.

Chapter five presents a paper entitled "Technical solution or wicked problem?: Diverse perspectives on Indigenous community renewable electricity in northern Ontario". The manuscript addresses the second objective. It uses a literature review and semi-structured interviews with key informants of a remote community to improve understanding on the wickedness associated with the introduction of RETs into remote community systems. Findings indicate that technical and institutional complexity of the electricity system, diversity of stakeholders' perspectives, and uncertainty over the future of community electrical systems influence the deployment of RETs. The manuscript is published in the Journal of Enterprising Communities: People and Places in the Global Economy: Konstantinos Karanasios, Paul Parker, (2018). Technical solution or wicked problem?: Diverse perspectives on indigenous community renewable electricity in Northern Ontario. *Journal of Enterprising Communities: People and Places in the Global Economy*, Vol. 12 Issue: 3, 322-345.

Chapter six presents a paper entitled "Tracking the transition to renewable electricity in remote indigenous communities in Canada". The manuscript improves understanding of transitions within communities' electrical systems and addresses the second and third research objectives. An MLP-based framework is used to analyze and explain the non-linear deployment of RETs in remote indigenous communities and identify macro- and meso-level factors that influenced the development of projects in Yukon, Northwest Territories, British Columbia and Ontario. Factors include community interest in participating in local electricity generation, learning processes facilitated by multiple experiments, and the existence of supporting regulatory and fiscal policies that were negotiated and adapted to indigenous sustainability visions. The manuscript is published in the journal *Energy Policy*: Karanasios, K., & Parker, P. (2018). Tracking the transition to renewable electricity in remote indigenous communities in Canada. *Energy Policy*, Vol. 118, 169-181.

Chapter seven presents a paper entitled "Explaining the diffusion of renewable electricity technologies in Canadian remote indigenous communities in NWT and Ontario through the technological innovation system approach". The manuscript addresses the second and third research objectives. It identifies the systemic and transformational failures responsible for the functional performance of the innovation systems and applies the technological innovation system (TIS) approach and compares the NWT and Ontario TISs to generate insights into the main factors that have the potential to sustain the development of RETs by examining the policy measures and activities that led to an increased number of mostly solar projects developed between 2009 and 2016. The manuscript is published in the journal *Sustainability*: Explaining the diffusion of renewable electricity technologies in Canadian remote indigenous communities through the technological innovation system approach. *Sustainability*, 2018, 10, 3871.

Chapter eight summarizes the major research findings presented in chapters five, six, and seven, and outlines the strengths and weaknesses of the study, as well as potential areas for further research. Furthermore, it summarizes the contributions of the research and offers policy related recommendations for the design of pathways for the introduction of RETs into remote community electricity systems and their transition to more sustainable options.

Appendices at the end of the thesis include the seven papers published in the journal *Papers in Canadian Economic Development* described in chapter four, and a list of the RET projects developed in remote indigenous communities identified in this thesis.

1.4 Significance of the study

The potential of RET deployment to mitigate climate change has been extensively discussed in the literature (see for example Simns, 2004; Mathiesen, Lund, & Karlsson, 2011; IPCC, 2011; IPCC, 2014). In addition, numerous contributions document the environmental and socioeconomic benefits of distributed renewable generation for rural, remote, and isolated communities in developing countries that either lack access to electricity or use diesel powered electrical systems (UNDP, 2000; UNDP, 2004; UNDP-ESMAP, 2003; ESMAP, 2007; IRENA, 2015; Yadoo & Cruickshank, 2012).

However, in the case of Canadian remote indigenous communities there are limited studies that examine non-technical factors that influence the uptake of renewable applications. This study improves understanding of the challenges associated with the energy transition of Canadian remote indigenous communities, explains the transition until now, and identifies factors that have the potential to increase the deployment rates of RET projects. The 2017 Budget announcement of support for INAC's Northern Responsible Energy Approach for Community Heat and Electricity Program, as well as of additional funding over the coming years to reduce the reliance of remote communities on diesel affirms the renewed interest of federal and provincial governments in assisting indigenous communities to embrace renewable energy (INAC, 2018b; PI, 2018). In this direction, understanding the challenges associated with the introduction of RETs, explaining "what was done" (in terms of extent and transition patterns) and "how it was done" (how the transition was managed), and understanding the dynamics of the transition can inform policymakers, practitioners, and indigenous leaders, both in Canada and other countries, about potential pathways to the benefit of all parties involved in guiding the transition process.

Chapter 2: Literature review

2.1 Research context

Energy is the capacity to do work. Energy in its various forms, heat, radiation, electrical, chemical, nuclear energy, and gravitational (Peake, Everett, & Boyle, 2012), has been the focus of numerous studies that span from household dependence on lower forms of energy for daily meals (Leach, 1975; Barnes & Floor, 1996; Heltberg, 2004; Heltberg, 2005), to key energy technologies and renewable electricity alternatives (Brabec, 2004; Dincer, 2000; Midilli, Dincer, & Ay, 2006), public policies for decarbonization of energy systems (Gallant & Fox, 2011; Liming, Haque, & Barg, 2008), and household appliance and energy efficiency standards (Bansal, Vineyard, & Abdelaziz, 2011). Energy-related studies also examine the contribution of energy to economic development and the direction of causality in the energy-development relationship (Toman & Jemelkova, 2003; Stern, 2011; Omri, 2014).

This thematic and methodological variety of energy research across disciplines and subdisciplines is demonstrated by Agostino et al. (2011) in a 2011 review of 2,502 articles published between 1999 and 2008 in three major energy journals (*Energy Policy*, *The Energy Journal*, and *The Electricity Journal*). Engineering and sciences were identified as the main contributing disciplines to energy research, followed by social sciences, and, to a lesser extent, geography and planning. Thematically, most studies related to both conventional and renewable electricity supply, followed by transportation (conventional and renewable liquid fuels), energy efficiency, and heating and cooling. Methodologically, more than 40% of published articles within the *Energy Policy* journal employed engineering and economic methods, such as economic modelling, econometric modeling, scenario analysis, cost benefit analysis, financial analysis, input-output analysis, regression analysis and mathematical programming. There were a limited number of surveys, questionnaires or interviews/focus groups. A subsequent review of 4,444 articles published between 2009 and 2013 in the same journals found that only 12.6 % of studies used qualitative methods, with geography and issues relating to space and scale representing approximately 1% of the total number of articles (Sowacool, 2014).

Besides engineering, subdisciplines of economics, such as energy economics, environmental economics, and ecological economics, examine multiple themes and rely extensively on quantitative studies as their main methodological tool. Energy economics contributions investigate, among others, energy supply, energy markets, international trade, and economic development and use multivariate statistics, stochastic optimization modelling, investment impact analysis, time series analysis, and financial analysis as their methodologies. For example, Asafu-Adjaye (2000) used econometric modelling to examine relationships between energy and income in developing countries, Soytas & Sari (2003) used time series analysis to examine the causality relationship between energy and GDP in developed countries and emerging markets, while D'Ecclesia (2016) reviewed 27 papers that used a variety of quantitative methodologies to examine the role of fossil fuels and the role of renewable energy in power markets' dynamics.

Environmental (and resource) economics studies examine the management of public goods, the efficient allocation of resources, including energy in various forms, and the identification of an optimal level of (negative) externalities (Van den Bergh, 2001). According to Ma & Stern (2006), energy-related topics in environmental economics include mainly market valuation through the use of econometric modelling (see for example Kosenius & Ollikainen, 2013) and optimization modelling (for example Berrada, Loudiyi, & Zorkani, 2016; Ernsten & Boomsma, 2018; Obydenkova, Kouris, Hensen, Heeres, & Boot, 2017), and, to a lesser extent, environment and resources.

Finally, ecological economics examine the relationship between economic systems and ecosystems to investigate current global challenges, such as global warming and sustainability (Constanza, 1989). Ecological economics aims at sustainability and recognizes the complexity of managing economic and ecological systems, and, contrary to environmental economics, considers that complexity and uncertainty are not controlled through market prices and mechanisms (Van den Bergh, 2001). Early research concentrates on pollution control costs and policy instrument design, followed by discussions on the future of energy and resources (see Meadows, 1972), and their contribution to carbon emissions, and role in the transition to a low carbon future (Roepke, 2004). More recent research focuses primarily on green accounting and the environmental Kuznets curve (Ma & Stern, 2006). Energy and energy markets within ecological economics prior to deregulation are examined through optimization studies that examine the allocation and generation output of utilities emphasizing system cost minimization, while in deregulated markets computational methods and decision support tools (such as Multi-Criteria-Decision Analysis) inform the integration of renewable resources and policy making analysis (Georgopoulou, Sarafidis, Mirasgedis, Zaimi, & Lalas, 2003; Ribeiro, Ferreira, & Araujo, 2013; Balint, et al., 2017).

However, as Sovacool (2014) suggests, quantitative methodologies are unable to capture human dimensions related to energy use, such as habits, attitudes, experiences, different cultures and lifestyles. Exploring human-environment relationships through qualitative methodological approaches employed by political economy, political ecology, and geography, may lead to new conceptualizations of energy use and energy problems.

Political economy contributions to the study of energy include, among others, discussions about states' and corporations' use of power and violence to secure fossil fuel related operations, challenges associated with resource curse, and the connection between energy and national security (Sovacool & Brown, 2010). Furthermore, political economy examines energy-related distributional justice issues, such as the distribution of benefits and burdens to society members across countries and continents, energy poverty and the need for affordable energy (Bickerstaff, 2017; Burke & Stephens, 2018; Sovacool & Dworkin, 2015), and the role of institutional and political factors, such as markets, oil prices, and national interests, on fossil fuel exploitation (Matutinovic, 2009; Hancock & Vivoda, 2014).

In a similar vein, political ecologists argue that it is political and social power combined with the high complexity of environmental problems that influence understanding and solution finding of social-ecological problems. Political ecologists use both quantitative and qualitative methodologies and case studies to identify power relationships and explain linkages and changes in socioenvironmental systems (Walker, 2006). For example, Baka (2017) examines structural factors responsible for poverty, Zimmerer (2015) and Sovacool (2000) investigate the role of power and politics in the formation of energy patterns, and McDowell & Ford (2014) use key informant interviews to identify specific socio-economic, political, and biophysical issues resulting from hydrocarbon development activities in Greenland.

Finally, energy has been extensively studied within the geography discipline. Early studies examine energy development, supply, transportation, and use patterns, as well as their determinants from a spatial, regional, or resource management perspective. More recently, a variety of theories and, mostly, qualitative methodologies were employed to examine different fossil fuels and their impacts on human health and sustainability, expansion and integration of renewable technologies, energy consumption in buildings, industry, transportation, integration of transmission grids and electricity markets, decentralized electricity generation, and global energy networks (for a review of studies see Calvert, 2016; Salomon & Calvert, 2017).

A recent focus of geographers' research concentrates on transitions, a theoretical contribution aiming to address current complex environmental problems such as climate change, biodiversity, and resource depletion (Meadowcroft, 2005; Kemp & Loorbach, 2006). Within this strand, energy transitions examine the transformation of energy systems at a community, urban, regional, or national scale. A number of studies take a descriptive approach to illustrate the transforming nature of energy flows in the world's energy intensive regions (see for example Mabee, Cabral, & Webb, 2017; Tolmalsquim & Livino, 2017), or examine the nexus of energy, water and food and look into how their interrelated nature impacts community resilience (Loring & Gerlach, 2013; Hossain, Loring, & Marsik, 2016).

Another research strand in geography uses a sociotechnical transition approach to examine the transformation of large-scale infrastructural systems, such as energy, transportation or agri-food systems, towards more sustainable options (Geels, 2005). Changes in such systems necessitate new technological innovations as well as changes in user practices, policy and culture (Geels, 2010). Sociotechnical systems are unable to be restructured under market forces due to their inherent stability and vested interests, and political will, state intervention, and policy support are necessary for their radical transformation (Geels, 2011; Meadowcroft, 2011). The governance (steering) of energy transitions and energy resources is examined under the transitions management approach (Meadowcroft, 2005; Kemp & Loorbach, 2006; Smith, Stirling, & Berkhout, 2005; Loorbach, 2007) or resource management perspectives, such as adaptive management and co-management, participation, and stakeholder engagement (Mitchell & Parker, 2017). Furthermore, transition pathways are examined at the national level (McDowall, Radošević, & Zhang, 2013; Berkhout, Angel, & Wieczorek, 2009), regional level (Rosenbloom & Meadowcroft, 2014), or sectoral level (Jacobsson & Bergek, 2004; Labrinopoulou, Renwick, Klerkx, Hermans, & Roep, 2014), as well as at the community level, which will be discussed in the next section.

2.2 Energy research in remote and rural communities

Energy research in remote and rural communities in developing countries examines the energy transition of households from lower forms of fuel to modern fuels, household factors that induce the use of household-level small RET applications (such as solar homes), and community level electricity access though the deployment of RETs. In the case of rural settlements in developing countries that rely on fuelwood or charcoal as the main energy source, households make decisions to ascend the "energy ladder" by switching to modern fuel (e.g. propane) and electricity or use multiple fuels and technologies simultaneously (fuel stacking). Energy studies examine the environmental and health impacts of fuelwood use and the factors that influence households' energy and technology use choices (see for example Bhatt & Sachan, 2004; Chen, Heerick, & Van den Berg, 2006; Demourger & Fournier, 2007; Heltberg, 2004; Heltberg, 2005; Edwards & Langpap, 2012).

In rural communities that have access to electricity through small diesel generators and solar panels, or a combination of both, studies focus on the identification of household level factors (such as employment, income, and family status) that influence electricity consumption and household choices over electrical services (see for example Mainali & Silveira, 2013; Mandelli, Barbieri, Mereau, & Colombo, 2016; Kaundinya, Balachandra, & Ravindranath, 2009). Most of these studies rely on nationwide statistical data on household energy use and household data and surveys of household socioeconomic status.

Furthermore, energy studies examine electricity access and supply through renewable sources in isolated communities that use (or lack) diesel powerplants. An overview of energy planning models for decentralized systems is presented in Hiremath, Shikha, & Ravindranath (2007), while energy models of hybrid[2] systems, either in grid-connected or stand-alone mode, are presented in Kaundinya et al. (2009). Most of these studies are concerned with the technical configuration and the cost effectiveness of such systems and use techno-economic analysis (which may include environmental benefits) to calculate the system's net present value and payback period for different

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[2] According to Gupta et al. (2011, p. 459): "Hybrid Energy Systems (HES), or remote area power systems (RAPS), generally integrate renewable energy sources with fossil fuel powered diesel/petrol generator to provide electric power where the electricity is either fed directly into the grid or to batteries for energy storage. The role of integrating renewable energy in a hybrid energy system is primarily to save diesel fuel".

interest rates, diesel fuel prices, electricity prices and subsidy rates, or the levelized cost of energy, to compare the cost effectiveness of alternative renewable energy sources to established fossil fuel-based options (see also Bhattacharyya, 2012). Optimization techniques, such as linear programming, mixed integer linear and non-linear programming, and stochastic discrete dynamic programming among others (for an overview see Gupta, Saini, & Sharma, 2011) are used to optimally size hybrid systems. Software solutions, such as HOMER, for sizing and assessing the techno-economic performance of hybrid systems have contributed to the evaluation of multiple scale hybrid systems mostly in remote and rural areas (NREL, 2005; Bahramara, Moghaddam, & Haghifam, 2016).

Other studies use differing methods to assess RET alternatives, such as sustainability indicators, Multi-Criteria-Decision Analysis (MCDA), and Sustainability Impact Assessments (SIA) to introduce sustainability considerations and stakeholders' opinions in the decision-making process. Sustainability indicators (Ribeiro, Ferreira, & Araújo, 2011) consider technical, socioeconomical, environmental, social and strategic dimensions defined, weighted, and scored through interviews with local stakeholders, and, finally, evaluated by an MCDA method (e.g. analytic hierarchy process, multi-attribute utility theory, and outranking) (Georgopoulou, Sarafidis, & Diakoulaki, 1998; Wang, Jing, Zhang, & Zhao, 2009; Pohekar & Ramachandran, 2004; Huang, Keisler, & Linkov, 2011). Sustainability based assessments (Ness, Urbel-Piirsalu, Anderberg, & Olsson, 2007) may produce a variety of results depending on the participating actors, since sustainability represents different values for different people and is influenced by geographic location, local resource availability, local business strategies, special considerations (e.g. health concerns), local user practices and local cultures, objectives and visions (Gibson, Holtz, Tansey, & Whitelaw, 2005; Winfield, Gibson, Markvart, Gaudreau, & Taylor, 2010; Nathwani, et al., 2014; Alanne & Saari, 2006; Pope, Annandale, & Saunders, 2004; Afgan, Gobaisi, Carvalho, & Cumo, 1998).

However, several studies in developing countries move beyond the technology and finance perspective and use the sociotechnical approach and, to a limited extent, political aspects and common-pool resource management, to explain energy transitions (for an overview see Ockwell, Byrne, Hansen, Haselip, & Nyggard, 2018). Although the applicability of transition frameworks, such as the Multi-Level Perspective (MLP), Strategic Niche Management (SNM) and Technological Innovation System (TIS), in developing countries has been criticized due to the differing contexts (Jacobsson & Bergek, 2006; Lachmann, 2012), these frameworks have recently been applied, on their own or combined with other theories, to examine the deployment of innovative technologies. For example, Pedersen and Nygaard (2018) adopt the MLP approach and institutional theory to examine firms and the business models employed in Kenya's rural electrification. They identify niche experiments and potential for the upscaling of RETs through increasing institutionalization of niche rules, practices and norms. Hansen et al. (2015) use the TIS framework to review the development of photovoltaics in different segments in Kenya, Tanzania and Uganda and identify trends and factors that encourage the diffusion of solar home systems. Similarly, the TIS framework is used to identify market structure and dynamics for the diffusion of improved cookstoves in Ghana (Agbemabiese, Nkomo, & Sokona, 2012), actors, systemic problems and system building processes in the case of solar panels in Ethiopia (Kebede & Mitsufuji, 2014), and obstacles to the deployment of biodigesters in Rwanda and Kenya (Tigabu, Berkhout, & van Beukering, 2015). The TIS analysis is also used to evaluate RET supporting polices and programs in the case of photovoltaic deployment in the Maldives (VanAlphen, Hekkert, & VanSark, 2008).

Methodologically, these studies use case studies, ethnographic research, historical analysis of events, and interviews with participating stakeholders as their empirical data sources (Ockwell, et al., 2018). Besides the use of MLP and TIS, Ockwell et al. (2018) point to social theory (in combination with MLP and TIS) and political economy (in combination with MLP and transitions management) as important lenses for understanding energy transitions in developing countries. While adaptation of social group practices is considered a factor for the success of RETs in areas with no grid connection, political analysis focuses on the material interests, politics, and power involved in both the deployment of utility scale grid connected solar deployment (Rodríguez-Manotas, Bhamidipati, & Haselip, 2018), and small-scale photovoltaic applications (Byrne, Mbeva, & Ockwell, 2018) to identify enabling conditions and strategies of participating actors.

Canadian remote indigenous communities share some characteristics with developing countries. In both contexts, demand for electricity exceeds supply. Communities in both contexts also face the choice to expand their current unsustainable systems, to use hybrid solutions, or to look to connecting with the main grid. They also have weak local economies, lack of financial and human resources, and poor infrastructure (Lachmann, 2012; Graham, 2012; Swiderski, 1992; Southcott &

Irlbacher, 2009). However, Canadian indigenous communities have access to diesel-generated electricity and local technology as opposed to very small-scale diesel plants or lack of electricity and imported renewable technologies in communities in developing countries. Past and recent research on the transformation of Canadian remote indigenous community electrical systems will be discussed in the next section.

2.3 Research on the introduction of RETs into Canadian remote communities' electrical systems

Remote communities in Canada rely on diesel-generated electricity. Early studies on the potential of RETs to reduce diesel consumption by introducing hydroelectricity, wind, and solar applications were performed by the Saskatchewan Power Corporation and North Sask Electric in 1972. Research for electrification alternatives was driven by high diesel price increases that led to high electricity expenses, and considered line extensions, large units serving several communities, fuel cells, and small hydroelectric plants (Cooke, 1980; Ostrom, 1981). Subsequent studies on RET penetration in remote Canadian communities include the 1985 Sigma Engineering study and later updates by CanmetENERGY-Varennes in 1999, which estimated renewable energy deployment at 173 MW of hydroelectricity, 630 kW of wind, and 15.9 MW of biomass projects (Ah-You & Leng, 1999; AANDC and NRCan, 2011).

Recent studies in Alaska, Canada, and Australia on the introduction of RETs in remote indigenous communities' electrical systems concentrate on the identification of technical factors that influence deployment and financial viability (Baring-Gould & Corbus, 2007; Fay, Keith, & Schwörer, 2010a; 2010b; Tan, Meegahapola, & Muttaqi, 2014; Nathwani, et al., 2014). Technology factors include the choice over the extent of the renewable energy resource component (low, medium or high penetration RET integration), the architecture type of the hybrid system (single vs. a combination of renewable resources), economies of scale, the existence of trained personnel, availability of information systems (e.g. SCADA monitoring equipment), developers' expertise, availability of distribution infrastructure, smart grid considerations, lower cost storage technology, reliable, robust equipment, and packaged systems using plug-and-play control technologies.

Non-technical issues hindering the deployment of RETs are captured through interviews and surveys; findings include institutional weaknesses and capacity issues, vested interests and funding structures for energy services that act as disincentives, lack of capital and financial capacity, high capital costs, lack of expertise, missing infrastructure, and perceptions that RETs may damage the environment and significantly affect traditional practices (McDonald & Pearce, 2012; McDonald & Pearce, 2013; Ostrom, 1981; Parcher, 2004; Inglis, 2012; Weis, 2006; Weis, 2014; Krupa, 2012a; Senate Canada, 2014c; INAC, 2005; INAC, 2007; AFN, 2011b; Weis & Cobb, 2008; Fay & Udovyk, 2013).

Furthermore, numerous non-academic contributions concentrate on indigenous and governmental/utility concerns over diesel-generated electricity and their perspectives on renewable electricity generation as factors that influence the introduction of RETs in remote indigenous communities. Indigenous concerns over diesel-generated electricity include, *first*, electricity costs, influenced by rising fuel transportation and diesel fuel prices in addition to growing utilities' generation and operation, maintenance and administration costs (GNWT, 2008b; Hydro One, 2012; NTPC, 2012). High electricity costs result in higher electricity prices for both residential customers and local governments (GNWT, 2008b; Hydro One, 2012; NTPC, 2012; Knowles, 2016). These higher prices in turn increase residents' cost of living and local governments' electricity expenses, therefore limiting available funds for economic development opportunities (OEB, 2008; NWT, 2011).

Second, load restrictions posed by utilities and conditioned by the output of diesel generators, limit new housing development and business connections, leading to the overcrowding of existing houses, and hindering community potential to participate in resource projects (KLFN, 2013; NAN, 2012). Even if the diesel generators were to be upgraded, continuous community growth would lead to a new cycle of load restrictions within the next five to seven years. In addition, high variance of community electricity loads, and safety considerations lead to the use of multiple diesel generators and/or their frequent operation below capacity, which increases generations costs (Arriaga, Canizares, & Kazerani, 2014; Knowles, 2016).

Third, communities experience power outages, surges, and brownouts due to poorly serviced and outdated diesel generators (GNWT, 2009a; Senate Canada, 2014b; Bell, 2015). Power outages during winter conditions in northern communities may generate costs, damage community equipment and infrastructure, and threaten the safety of residents (GNWT, 2009b; AANDC, 2012). Maintenance and replacement of diesel generators is subject to budgets approved by different authorities leading to delays and, in some cases, operation of diesel generators beyond their recommended life expectancy (Senate Canada, 2014a).

Fourth, there are community environmental concerns over increasing direct and indirect carbon emissions, as well as black carbon emissions, caused by the burning and road or air transportation of diesel, fuel spills during transportation and storage, as well as fuel tank leakages (AANDC, 2012; GC, 2017a; Knowles, 2016). The per capita direct carbon emissions in Northern Ontario's HORCI-operated remote communities increased from 2.5 tonnes $CO_{2,eq}$ in 1991 to 4.4 tonnes $CO_{2,eq}$ in 2011 (HORCI, 2012), while direct emissions range between 9 tonnes $CO_{2,eq}$ annually per capita in British Columbia, to 3 tonnes $CO_{2,eq}$ annually per capita in Nunavut, and an average of 4,4 tonnes $CO_{2,eq}$ annually per capita for 133 remote indigenous communities (see also Chapter 4). In addition, the transportation and storage of millions of litres of diesel fuel annually results in fuel spills and contamination of soils in the majority of remote aboriginal communities. According to AANDC and the Federal Contaminated Sites Inventory, contaminated sites on reserve lands north of 60^o latitude represented a financial liability of approximately $1.5 billion in 2008 (AANDC, 2008; TBS, 2016; AANDC, 2012b), with the majority of these sites related to hydrocarbon contamination of soils caused by leakages from fuel storage tanks[3].

Government concerns over diesel dependency are associated with higher carbon emissions and increasing electricity cost subsidies as a result of higher diesel prices. In 2013, the 133 remote indigenous communities noted above were responsible for the consumption of approximately 151 million litres of diesel and direct emissions of 400,000 tonnes of $CO_{2, eq}$. (see Chapter 4), while additional indirect emissions caused by the transportation of diesel to remote communities represent almost 70% of direct emissions in the case of fly-in communities (see HORCI (2012)). In addition, direct electricity subsidies for residential customers in remote communities, ranged from $3.5 million in 2015-2016 in Yukon (GY, 2015a) to approximately $34 million in 2015 in both British Columbia and Ontario (see Chapter 4) (BC Hydro, 2015b; Hydro One, 2012; GN,

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[3] See also WP (2013c) for the projected costs of soil remediation in Ontario's remote communities.

2015a). Consequently, diesel displacement in remote communities through the introduction of electricity generation alternatives could contribute to Canada's recent commitments towards GHG emission reductions to 30% below 2005 levels by 2030 (GC, 2016; DSF, 2012), and could potentially be translated to lower subsidies provided by provincial and federal governments for the operation of remote diesel systems (OPA, 2014). Finally, government owned utilities' additional concerns over diesel dependency relate to rates affordability, the need to build redundancy into the systems through alternatives to diesel generation and increased reliability of supply, as well as the desire to increase self-sufficiency by reducing diesel consumption (GNWT, 2009a; Yukon Energy, 2012a).

Moreover, since 2000, numerous studies have employed quantitative methodologies, such as feasibility and optimization methods, to evaluate the performance of RET projects in remote indigenous communities (Table 1). These studies use wind speed and solar data acquired from local meteorological stations, installed wind measurement equipment, and installed demonstration projects to construct future meteorological profiles and perform a technoeconomic analysis to calculate the project's net present value or levelized cost of energy. Results indicate that there is a limited number of wind and solar projects that are financially viable in remote indigenous communities. Financial returns may vary among communities in the same province and territory and among communities in different locations, as they are highly dependent on the availability of the renewable resource component and local factors. The accuracy of results can be improved through the acquisition of high quality meteorological data based on locally deployed monitoring equipment, as well as good quality household data, which can be challenging in the context of indigenous communities (Fay, Keith, & Schwörer, 2010a; Weis, 2014). In addition, there is a need for accurate future meteorological and community load profiles, which can be developed through probabilistic and component modelling approaches, and then used in optimization studies for sizing the hybrid systems' components to meet cost and reliability targets under certain design constraints (Tan, Meegahapola, & Muttaqi, 2014).

Table 1: Feasibility and optimization studies for RETs in remote communities

Feasibility studies			
Communities	**Technology**	**Year**	**Source**
Sachs Harbour, Tuktoyaktuk, Holman, Paulatuk	Wind	2003	ARI (2003)
Sachs Harbour, Ulukhaktok, Paulatuk, Tuktoyaktuk, Yellowknife, Inuvik	Wind	2007	Pinard (2007)
31 communities in NWT 14 communities in Nunavik, Quebec 2 communities in Yukon (Destruction Bay, Old Crow)	Wind	2006	Maissan (2006a)
14 communities in Nunavik, Quebec	Wind	2005	Krohn (2005)
Colville Lake, NWT	Wind	2008	Pinard & Maissan (2008)
Deline, Jean Marie River, Trout Lake, Fort Providence	Wind/ solar	2008-2012	ARI (2016)
Storm Hills, Colville Lake, NWT, Lutselk'e, Norman Wells, Paulatuk, Sachs Harbour, Thor Lake, Tuktoyaktuk, Ulukhaktok, Wekweètì, Whati, Yellowknife, Inuvik	Wind/ solar	2008-2015	ARI (2016)
Optimization studies			
Cartwright (Labrador)	Wind/ solar	2007	Iqbal, n.d.(b)
12 communities in NWT 13 communities in Nunavut 2 communities in Yukon (Destruction Bay and Old Crow) 10 communities in Nunavik-Quebec 21 communities in Newfoundland and Labrador 3 communities in Manitoba 1 community in Ontario (Fort Severn)	Wind	2008	Weis & Ilinca (2008)
22 communities in Newfoundland and Labrador (with results for Cartwright, Charlottetown, Hopedale, Makkovik, Mary's Harbour, Nain and Port Hope Simpson)	Wind, solar, small hydro	2009	NFL Hydro (2009)
12 communities in NWT 19 communities in Nunavut 2 communities in Yukon (Destruction Bay and Old Crow) 14 communities in Nunavik-Quebec 22 communities in Newfoundland and Labrador 3 communities in Manitoba 16 communities in Ontario 2 communities in BC	Wind/storage	2010	Weis & Ilinca (2010)
Kasabonika Lake First Nation	Wind/ solar	2013 2017	Arriaga, Cañizares & Kazerani (2013); Karimi (2017)
Brochet (Manitoba)	Wind	2013	Bhattarai & Thompson (2016)
Ramea (non-aboriginal)	Wind/storage		Iqbal, n.d.(a)
13 communities in Nunavut	Wind, solar, battery storage	2016	Das & Canizares (2016)

In addition to quantitative studies a limited number of qualitative contributions provides insights into the deployment of RETs in remote indigenous communities. Best practices (INAC, 2004; INAC, 2005; INAC, 2007; INAC, 2010b) and guides (AEA, n.d.; OSEA, n.d.) use interviews with community members to identify critical success factors (CSFs) (Bullen & Rockart, 1981), in the form of technological, structural, and institutional factors, for the successful deployment of RET projects. Technological CSFs relate to both the need for understanding and monitoring of local renewable resources and the use of proven technologies in northern environments, since equipment failure may discourage the project implementation and affect financial performance. Institutional and structural CSFs relate to the existence of capable leadership teams (able to engage in collaborative action with governments and utilities), the potential of community equity participation, internal financial capacity to perform RET projects, the existence of governmental funding and financial incentives to overcome technical and financial barriers, and local infrastructure supporting RETs integration within local grids. Additional factors mentioned were the existence of a community energy plan (CEP) and learning and sharing experiences for the development of internal capacity to maximize benefits from the projects (Brookshire & Kaza, 2013; St.Denis & Parker, 2009; Krupa, 2012b). A significant number of community profiles and CEP plans have been conducted for remote indigenous communities from non-governmental organizations such as the Arctic Energy Alliance (AEA) in NWT (see for example AEA, 2016; AEA, n.d.) and Pembina Institute (see for example Cobb & Weis, 2007; Weis & Cobb, 2008). Furthermore, Keyte (2015) used a resilience theory-related framework and data from document reviews and interviews with key informants to examine a biomass application in a remote indigenous community in NWT. He identified willingness towards experimentation, leadership to form partnerships, and the ability to harness local resources as key success factors for improving remote communities' energy resilience.

Finally, a few qualitative studies focus on sociocultural and economic factors that have the potential to influence the transformation of indigenous electrical systems. Rezaei and Dowlatabadi (2015) argue that indigenous motivation for participation in new electricity generation through RETs is driven by self-reliance considerations and capacity development. In Ontario, ten remote indigenous communities act as Independent Power Authorities (IPAs) and own their electrical systems. These communities, despite higher costs and reduced subsidies in comparison to 15 Ontario remote indigenous communities serviced by Hydro One Remote Communities Inc. (HORCI), state that their motivation for ownership is local control through rate settings according to community needs, collection methods that support members facing poverty, opportunities for local job creation, and a sense of community pride (OEB, 2008). Furthermore, Jaffar (2015) uses the MLP framework and discourse analysis to understand how indigenous values, and their compatibility with renewable energy generation, influence politics and power relationships in energy transitions. The transition approach was also employed in the context of on-grid Canadian indigenous communities in Nova Scotia, Ontario and Saskatchewan: Martens (2015) employed a combined framework, consisting of the MLP and TIS frameworks and discourse coalition theory, and data from document reviews and interviews with key stakeholders to analyze the participation of indigenous people in on-grid large-scale renewable electricity generation and generate insights on the likelihood of indigenous participation in sustainable electricity transitions. He observed that successful First Nation participation in the transformation of energy systems is likely to occur where governments focus on reconciliation efforts and allow for new actors' participation in the electricity generation process. In addition to regulatory changes, Martens (2015) identifies supporting policies and financial resources that enable revenue generation activities through the sale of electricity to the provincial grid as important factors for the long-term success of indigenous participation in the electricity sector.

Since governance and revenue-generating arrangements are considered important to Canadian indigenous communities, the next section provides an overview of how these structures have evolved over recent years.

2.4 Indigenous governance and political economy considerations

Governance and political economy considerations provide understanding on how societies change over time and may lead to the identification of governance structures able to promote economic development (Fritz, Kaiser, & Levy, 2009). Understanding indigenous governance and political economy shifts over time may improve understanding of factors that (have the potential to) influence indigenous decision making for the transformation of indigenous communities' electrical systems. In addition, these changes may provide insights for the choice of the theoretical and conceptual frameworks that will drive research design (Grant & Osanloo, 2014).

Accordingly, the purpose of this section is to provide a brief description of changes in indigenous governance and political economy structures over the last century. Political economy is broadly defined as the analysis of linkages between politics and economics, stemming from the perspective that governance, in the form of political behavior (exercising power and authority) and institutions, influence economic outcomes (Weingast & Wittmann, 2015).

According to Frideres (2008) indigenous peoples encompass a diversity of groups of various linguistic and historical backgrounds, currently located in different socioeconomic and political contexts, and pursuing different goals. Indigenous people in Canada "do not make up a single-minded monolithic entity, speaking with one voice" (Frideres, 2008, p. 314). The relationship between indigenous and settler societies is captured in the indigenous governance literature that consists of topics related to self-determination, indigenous knowledge, legal and inherent rights, colonialism and Eurocentrism, environmental decision making, and decolonization (for an overview see von der Porten, 2012). However, the self-determination literature is most relevant to this study as it is closely associated with political economy considerations and the governance of indigenous lands and resources. According to Henricksen (2001) (cited in von der Porten, 2012, p.2) indigenous self-determination is "the right to exercise cultural, linguistic, religious, territorial or political autonomy within the boundaries of the existing state". The United Nations General Assembly (2007) states: "Indigenous peoples [may] freely determine their political status and freely pursue their economic, social and cultural development…[and] have the right to the lands, territories and resources which they have traditionally owned, occupied or otherwise used or acquired" (ibid.).

2.4.1 Changes in indigenous governance and political economy

The early relationship between indigenous people and newcomers was defined by agreements on sharing land and resources and was eventually succeeded by treaties that involved peaceful relations, trade agreements, military assistance, and, eventually, the surrendering of indigenous lands to Canada. European colonization proceeded within First Nation territories through the signing of Peace and Friendship Treaties from 1725-1779 and the numbered Treaties between 1870-1930, with the exception of what is today Labrador, the N.W.T., Yukon, and the Northern parts of British Columbia and Quebec (Hamley, 1995; Borrows, 2001; INAC, 2010a; AANDC, 2010). The numbered Treaties involved ceding title to indigenous land in return for the creation of protected spaces (reserves), certain rights, such as hunting and fishing within traditional territories, as well as material benefits in the form of education and financial support.

In an effort to assimilate indigenous populations to westernized and industrial society habits the newly formed Canadian state introduced the Indian Act in 1876. The Indian Act replaced traditional forms of governance and increased the authority of Indian Affairs over indigenous peoples through an elective system of Chiefs and Councillors, which allowed limited local authority for the care of communities, such as the creation of bylaws related to health, education, road maintenance and public and social housing (Milloy, 2008). Through control the administrative and political band structures the federal government controlled aboriginal education, employment, cultural values, and the management of aboriginal lands and resources (Coates, 2008). Land holding under the Indian Act between 1876 to 1951 was practiced through location tickets of reserve lands and a fee-simple interest for enfranchised indigenous people, and, after 1951, through two statutory property rights, the certificates of possession (CP) or proof of an individual’s possession of reserve land, and leases of band or CP holders land; both land holding mechanisms within reserve lands are associated with high transaction costs limiting the potential for on reserve economic development (Alcantara, 2013).

Between 1930 and 1950 indigenous people in Canada were able to improve their socioeconomic status through adaptation of traditional activities and participation in commercial activities and wage employment, especially during WWII that encouraged the move towards major industrial centres in search of stable economies (Craddock, 1997). However, indigenous economic conditions were ultimately affected by a changing economy and competition with the non-indigenous, higher skilled workforce (Hayter & Barnes, 2001). By the 1960s, it was clear that reserve economies were unable to support indigenous populations and the gap between indigenous economies and the rest of the Canadian economy increased. The lack of success of indigenous economies was attributed to a combination of (a) lack of workforce skills, lack of local competitiveness, lack of business experience, as well as limited financial support for indigenous business development from the Indian Affairs department, and (b) a difference in culture, with indigenous people favoring non-wage jobs and activities influenced by traditional hunting, fishing and gathering economies (Craddock, 1997). However, the Hawthorn report (1966-1967) (INAC, 2018c) that examined the problem of indigenous disadvantage continued to see assimilation policies as an appropriate method for improving indigenous socioeconomic conditions and indicated a "cultural barrier" as the main reason of their failure. According to Craddock (1997), the report failed to acknowledge the importance of land and resources to indigenous peoples and their effort to participate in a western economy (as their ancestors did by adapting to the fur-trading culture, the subsistence-wage culture, and the pre-war and post war wage cultures), cancelling therefore, arguments of "cultural barriers" on the side of indigenous people.

Between the 1970s and 1990s assimilation policies were questioned and amendments to the Indian Act in 1951 emphasized indigenous self-determination. As a result of these initiatives, Indigenous Affairs began decentralizing and devolving its operations to Band Councils between 1960 and 1970 and created an on-reserve indigenous bureaucracy that was able to absorb educated indigenous peoples (Craddock, 1997). The devolution was complemented with the establishment of numerous indigenous political organizations (such as the National Indian Brotherhood of the NWT, now known as the Assembly of First Nations (AFN), and the Union of BC Indian Chiefs in British Columbia) advocating for more indigenous government and a focus on land claims and treaties injustices. By the end of the 1970s indigenous governments and indigenous political organizations were the main source of employment for on-reserve indigenous people.

Furthermore, this period is also characterized by a shift towards more flexible production systems and an active global environmental movement (Hayter & Barnes, 2001). Political pressure from First Nation, environmentalists, and supporters of indigenous peoples during the 1970s resulted in legislation clarifying aboriginal rights (Coates & Crowley, 2013; AANDC, 2010). The Supreme Court of Canada decision in the Calder case in 1973 (Calder et al. v. Attorney-General of British Columbia, [1973] S.C.R. 313) represents a landmark decision, as it recognizes that aboriginal title exists in modern times. The decision initiated the establishment of the Native Claims office by the Government of Canada to negotiate with First Nations over comprehensive claims and specific claims (Slattery, 1987; Hamley, 2005).

In addition, changes in the mode of natural resource exploitation (from government-controlled projects for the provision of economic development through local processing, the creation of linkages and the procurement of local labor, to large-scale development employing economies of scale through the integration of private capital intensive equipment, and increasing environmental concerns) (see, for example, Gunton, 2003; Bridge, 2004; Di Boscio, 2010; NRCan, 2013a; NRCan, 2014) mobilized indigenous people to actively pursue participation in the benefits from resource extraction (Barnes & Hayter, 2005; Hipwell, Mamen, Weitzner, & Whiteman, 2002). During this period the first Community Impact Agreements (CIA), an early form of Impact and Benefit Agreements (IBAs), were introduced, by private proponents, as formal return of benefits from resource development projects to communities. Early CIAs were negotiated between Ontario Hydro and the community of Atikokan in northern Ontario (Reschny, 2007).

Finally, expansion of indigenous public administration on reserve land continued with local governments increasingly participating in education and social services. However public administration employment created a clear division between community members employed by local governments that enjoyed stable and relative high incomes and community members that had to rely on subsidies, traditional activities and seasonal wage employment. In some cases, this income gap and division between community members was further exaggerated through corruption, nepotism, favoritism and political gaming associated with the distribution of rents from land claims and impact agreements (mostly) in the form of public employment (Craddock, 1997; Graham, 2012).

The years after 1990 see the political economy of indigenous peoples continuing to be based on an expanding public sector due to further devolution of Indian Affairs services and legislation favoring indigenous rights. In some communities, the Indian Act was replaced by other forms of governance and self-government agreements introduced through the modern treaties process. In 1986, the Sechelt in British Columbia implemented the Sechelt Indian Band Self-Government Act of 1986 and the Band assumed complete responsibility for the management, administration and control of all Sechelt lands, which were no longer Indian Act reserves but instead fully owned by Band in fee simple title for “the use and benefit of the band and its members” (Schulze, 2008, p. 22). The 1990 R. v. Sparrow case in the Supreme Court of Canada (SCC) provided a broad interpretation to section 35(1) of the Constitution Act (1982) and recognized and affirmed the existence of aboriginal rights (R. v. Sparrow, [1990] 1 S.C.R. 1075). After 2000, governance and political economy of indigenous people was further transformed through the introduction of the Crown’s duty to consult and the judicial clarification of the fiduciary relationship of the Crown to Aboriginal people and the private sector’s Impact Benefits Agreements (IBAs) (Isaac & Knox, 2005). Furthermore, 22 self-government agreements, of which 18 are part of comprehensive land claims agreements, were signed between the federal government and indigenous governments. These agreements enabled 36 indigenous groups to be self-governed, provided ownership of approximately 600,000 km^2 of land, certainty over indigenous land rights to over 40 percent of Canada's land mass, and over $3.2 billion capital transfers (INAC, 2018e). Self-government agreements enabled indigenous people to structure their governments, to create laws, and provide services to their members (INAC, 2018f). Furthermore, in 2007 the government of Canada introduced the Specific Claims Action Plan to accelerate the specific claims process and take action on a growing number of claims accumulated after 1993. According to AANDC "specific claims snapshot", there are currently 390 concluded specific claims and 320 specific claims in progress (INAC, 2018a). Finally, further changes in indigenous governance structures and political economy were introduced through indigenous governments' access to "Indian moneys", and the introduction of various acts that allowed for alternative taxation systems, such as the First Nations Fiscal and Statistical Management Act and the First Nations Goods and Services Tax Act (Schulze, 2008).

As a result of the numerous changes in legal interpretation of aboriginal rights and title, and changes in indigenous political economy in terms of governance structures and revenue generation, the relationship between indigenous people and settler societies in Canada evolved in three distinct ways. *First*, through a series of legislative decisions, indigenous rights evolved from fishing rights in 1973 (in the Calder et al. v. Attorney-General of British Columbia) to sharing the wealth of the land rights in 2014 (see Tsilhqot'in Nation v. British Columbia and Keewatin v. Ontario (Natural Resources)). Because of this changing landscape in indigenous rights and title and the associated comprehensive and specific land claims, indigenous land base increased to 15 million hectares controlled by First Nations and 45 million hectares controlled by Inuit (AANDC, 2009).

Second, governance structures regulating the relationship between indigenous people and settler societies evolved from friendship treaties and alliances, to the creation of reserves and establishment of hunting and fishing rights, to the 1876 Indian Act, and, recently, to self-government agreements. Self-government agreements enable indigenous groups to create laws over a defined area based on their "inherent right to self-government" and decide on their membership basis, constitution structure of their governments, election rules, and the provision of services to their members. However, a number of provincial and federal laws (e.g. criminal law) continue to apply in the designated areas (Imai, 2008).

Third, both legislation on aboriginal rights and title and new governance structures led to changes in the sources of revenue for communities. During the period examined, indigenous peoples' sources of revenue shifted from federal transfers for education, health, administrations and treaties provisions, to indigenous control of lands under fee simple title, revenue authority over "Indian moneys", the establishment of tax regimes on indigenous lands, and alternatives to tax systems, such as the federal First Nations Fiscal and Statistical Management Act and the First Nations Goods and Services Tax Act. Further indigenous revenue generation systems include the federal First Nations Oil and Gas and Moneys Management Act and the First Nations Land Management Act, where local governments can have full control of the revenues collected for the use of their reserve lands other than for oil and gas (Schulze, 2008). In addition, new revenue sources were added to communities through the participation in land claims and self-government agreements, numerous resource development projects through IBAs or partnership agreements, and involvement in market-based activities (Loizides & Wuttunee, 2005; Loizides & Anderson, 2006; Sisco & Stewart, 2009; Bains & Ishkanian, 2016).

2.4.2 Modelling indigenous political economy

The shifts in governance and revenue generation structures of indigenous peoples in Canada are explained through two, mainly, political economy models. *First*, the internal colony model, sees indigenous peoples as nations within the Canadian state that have been dispossessed from their traditional territories, driven by capitalism and settlers' endless desire for more land accumulation (Atleo, 2014) that led to "economic and social domination" over indigenous populations and their economic dependency on the state (Hicks, 2004, p. 3). Impacts of colonialism include the loss of lands and access to traditional resources, the erosion of indigenous cultures and practices, social inequalities between educated community members (bureaucrats) and those practicing traditional activities (see also Nadasdy, 2003), and a multitude of social problems caused by assimilationist policies (Hodgkins, 2009; Alfred, 2009).

Responses to colonialism include contradicting perspectives. Indigenous peoples argue for (a) the returning of land and resources as the basis for economic self-reliance and (b) establishing self-government agreements to improve the socioeconomic condition of indigenous people where prior assimilationist and integrationist policies failed (RCAP, 1996; Hodgkins, 2009; Kendal, 2001; Imai, 2008). For example, the 1986 Sechelt Indian Band Self-Government Act and the Westbank First Nation Self-Government Agreement of 2003, allowed for the full ownership of indigenous lands under "fee simple" by the local government for the benefit of community members, the establishment of own government structures, and (among others) taxation power for interests within their lands (Schulze, 2008).

However, indigenous scholars heavily criticize the surrendering of indigenous lands in exchange for a (smaller) defined area where indigenous groups will exercise self-government, and some ask for the invalidation of any governance structures and institutions that regulate relationships with the Canadian state, including self government and modern treaty agreements. They argue that such approaches extinguish aboriginal rights and title in exchange for monetary rewards and do not contribute to the revival of indigenous practices (Corntassel, 2008; Alfred, 2009). Corntassel (2008) expresses concerns over the sustainability of such agreements and calls for "sustainable self-determination", that goes beyond political/legal recognition, and includes the regeneration of indigenous communities and families and the building of local economies, "which are by definition inherently sustainable" (p. 119).

Alfred (2009) states that self- government and economic development are "ineffective ways of confronting colonialism" because "rather than attacking the roots of the problem, they perpetuate a dualistic and dependent relationship between First Nations and the state" (p. 47) and instead proposes the "resurgence of an indigenous consciousness" for the real transformation of indigenous communities (p.49). Furthermore, it is argued that self-government agreements contribute to "… the transfer of a certain degree of decision-making power from 'colonial' elites to an emerging layer of local elites, within a constrained constitutional framework that poses no serious threat to (and arguably advances the interests of) the capitalist state or the capitalist system" (Hicks, 2004, p.11). Coulthard (2007) (referring to Alfred, 2005) points to the creation of different income groups within communities, as self-government processes and economic development

> “produce Aboriginal capitalists whose thirst for profit comes to outweigh their ancestral obligations to the land and the others. And land claims processes…. are now threatening to produce a new breed of Aboriginal property owner, whose territories, and thus identities, risk becoming subject to expropriation and alienation. Whatever the method, … all of these approaches, even when carried out by sincere and well-intentioned individuals, threaten to erode the most traditionally egalitarian aspects of Indigenous ethical systems, ways of life, and forms of social organization” (p. 452).

The *second* model, proposed by Widdowson (2016), aims at explaining indigenous disadvantage as the result of lack of indigenous proletarianization rather than dispossession. She argues that colonization did not happen in the case of north American Indians (as was the case with third world colonies) and indigenous populations were dispossessed, creating a “fourth world” type of economy, because their participation in the labour market was not necessary for the development of settler societies. As a result, most of these communities are unable to contribute to the economy, and they “survive”, and will continue to survive, as the result of federal transfers, which constitute a form of aid or (semi-rent) (Widdowson, 2016). She proposes a model of “neotribal rentierism”, which builds on Rata’s framework of the political economy of neotribal capitalism (Rata, 2004) and the “rentier state” and “semi-rentier states” theories for development (Beblawi, 1987), to explain indigenous political economy through class structures, rather than land ownership structures, and the building of traditional economies proposed by the “internal colony” model.

According to this model, neotribes (local indigenous elites), brokers (lawyers, negotiators, consultants and bureaucracy), and rent distributors (corporations and the Canadian state) are the main interest group involved in the process of negotiated and distributed rents. Rents take the form of revenues from, first, the extraction of commodities within traditional territories, second, compensation from the Canadian state for past injustices, and third, negotiation of transfers and self-government agreements for the control of funds related to the administration and provision of services within reserves. It is then argued that rents (external sources of revenue rather than productive activities) “… are negotiated by brokers and then circulated unequally within neotribes…” (Widdowson, 2016, p. 22). Brokers benefit from negotiations about the rent (e.g. land claim agreements), while corporations and the Canadian state control rents as their focus remains the availability of funds for the productive economy.

However, governments have also to distribute rents to interest groups. In the case of indigenous communities, governments disperse rents (in the previously described ways) to promote natural resources development within traditional territories, to address demands from non-indigenous Canadians concerned about the socioeconomic conditions in indigenous communities, and to protect indigenous Canadians that are facing poverty and marginalization. However, rents are unequally distributed within the neotribes (between members of local elites, indigenous governments and their kinship relationships) reducing access to quality services for community members and contributing to the continuous dependency and disadvantage of indigenous peoples (Widdowson, 2016).

2.5 Concluding remarks

The review of these previous studies on the introduction of RETs into remote indigenous community electrical systems and the indigenous governance and political economy structures point to research gaps and a certain level of “wickedness” inherent within the problem of introducing RETs, which, in turn, drive the choice of the theoretical and conceptual framework of this study and, consequently, the study’s methodology (Leshem & Trafford, 2007; Grant & Osanloo, 2014).

First, the review suggests that research on the introduction of RETs into remote indigenous community electrical systems involves a limited number of studies, of which most used quantitative methods, such as deterministic modelling and optimization techniques that isolate a few variables to generate models of limited complexity, usually presenting net present values (NPV) for alternative projects’ evaluation. Few studies use qualitative methodologies (e.g. interviews) or consider interdependencies between variables. Co-evolving factors, such as (i) stakeholders’ preferences on the future of electricity systems and their ownership structures, (ii) indigenous, provincial, and federal governments’ expectations from natural resources developments that influence decisions on new infrastructure and connection of communities to provincial grids, and (iii) the existence (or lack of) and quality of governance structures in the form of RET supporting policies and programs, have the potential to impact the diffusion rates of RET projects into remote indigenous community electrical systems. These factors are influenced (and influence), in turn, by political settings, financial resources availability, volatility of energy and natural resources prices, and increased speed of technological transformation (Yi & Feiock, 2014). Accordingly, there is a need to examine such dynamic processes that have influenced the transition so far and have the potential to influence the transition further (Grin et al., 2010).

Second, the “wickedness” connected to the introduction of RETs into these systems stems from both the technical and social complexity of the issue. Technical complexity influences the financial viability of such projects. The financial performance of a project depends on its technical performance, which, in turn, depends on local renewable resource availability, prediction of their future intermittency level, the level of renewable electricity penetration in comparison to the size of the community load, type of load (residential, commercial, or community buildings), diesel engine type and number of operating units, load management, the existence of storage technology, and, finally, operational constraints (operation and maintenance) (Mc Gowan, Manwell, & Connors, 1988; Arriaga, Cañizares, & Kazerani, 2013; Karimi, 2017). The social complexity of the issue stems from the different perspectives of participating stakeholders on the role that RET projects may play in communities, or the problems that the introduction of RETs is supposed to address. Governments’ and utilities’ perspectives concentrate on carbon emissions, financial performance, subsidy reductions, as well as reliability issues (GNWT, 2009a; GNWT, 2009b; OPA, 2014). Indigenous expectations on the role of RETs range from reductions in electricity costs, carbon emissions, and spills and leakages, to improvements in electricity supply reliability and services (GNWT, 2009a; 2009b; McDonald & Pearce, 2013), to self-sufficiency, community pride, and improving community socioeconomic conditions (Rezaei & Dowlatabadi, 2015; OEB, 2008; NAN, 2014a; AANDC, 2012b). Furthermore, there is uncertainty about the potential benefits from community ownership of RET projects due to the existence of indigenous vested interest in the form of revenue and employment from diesel storage and distribution (GQ, 2014; Weis, 2014), and the inherent risk of such projects caused by the intermittency of renewable resources and technical complexity of these systems.

However, the diffusion of RET projects into remote indigenous communities, although limited, points to stakeholders’ converging (rather than diverging) views on the potential for environmental and socioeconomic improvements, and, therefore, the introduction of RETs exhibits characteristics of a “mess”, or a form of organized complexity rather than a non-solvable wicked problem, signaling the need for analysis through systemic approaches (King, 1993). Such approaches are characterized by the inclusion of multiple stakeholders, including state governments, the private sector, communities, and individuals, that address problem wickedness through the development of “clumsy” solutions, or solutions emerging from a “minimum requisite variety” of social actors (Rayner, 2006, p. 11). Clumsy solutions are policies that combine opposing perspectives based on different ways of organizing social relations that integrate scientific alternatives, good management and socioeconomic and political considerations (Khan & Neis, 2010; Verweji & Thompson, 2006).

Third, the review of changes in indigenous governance and political economy structures suggests that indigenous peoples, utilities, territorial, and federal governments have participated in events and shifted their identities and preferences over recent years. Events represent actions of actors or what happens to actors, as a result of interactions (Poole, van den Ven, Dooley, & Holmes, 2000). Because of numerous events, aboriginal rights and title evolved from hunting and fishing rights, established through the early Treaties processes, to the sharing of the wealth of natural resources within traditional territories. In addition, governance structures shifted from early versions of the Indian Act to governance outside the Indian Act, and the establishment of self-government agreements that provide significant powers and control over indigenous lands and resources to indigenous governments.

Based on the results of the literature review, the transformation of indigenous community electrical systems through the introduction of RETs would seem to occur within a changing social, historical, economic and political context and be influenced by a variety of actors’ actions and events that shape this transformation over time. From a research perspective, the shifting identities of actors, the problem of organized complexity, and the limited number of existing qualitative studies point to the need for a focus on process rather than variance theories (Poole et al., 2000). As a result, an exploratory and evolutionary world view may better explain the transition of remote community energy systems to more sustainable ones through the introduction of RETs. Exploratory research and process approaches will be discussed in the following section.

Chapter 3: Theoretical considerations and research approach

The purpose of this chapter is to present the theoretical and methodological approach of the study, the conceptual framework that drives the research methodology, and the research approach to achieve the study's objectives. Section 3.1 outlines process tracing as a method to examine and test causal inferences. Section 3.2 discusses three theoretical frameworks that have the potential to provide mechanisms that explain energy transitions, while section 3.3 identifies the MLP and TIS frameworks that will drive the research approach. Sections 3.4 and 3.5 present the research method and data collection process respectively. Finally, the researcher position is presented in section 3.6 followed by the study's limitations in section 3.7.

3.1 Research approach

Exploratory research is defined as research that aims at discovering, improving understanding, gaining new insights, and increasing knowledge about an understudied phenomenon (Stebins, 2011). It is used when there is reason to explore a group, activity or situation, despite the lack of scientific knowledge, high levels of uncertainty, and lack of understanding surrounding the case in point (Reiter, 2017). It is characterized by "flexibility" and "open mindedness" regarding methodologies and data collection and targets understanding human acts and inductively deriving generalizations about the group, process, activity, or situation under examination (Stebins, 2011). As such, exploratory and inductive research focuses on process theory and the causal mechanisms that "underlie and produce social phenomena" and allow for the development of knowledge on the "why" and "how" (Reiter, 2017, p.140).

Process theory, in contrast to variance theory, takes into consideration that entities (not variables) which change their identities over time, are responsible for outcomes. A variance approach is based on the deduction of causes (variables) from theory and the conducting of experiments where variables are manipulated, and results are compared based on the presence or absence of the variable investigated. The presence of cause (variable) is demonstrated through the relationship between inputs and outputs. These non-dynamic patterns are captured through quantitative and statistical analysis methods (Poole et al., 2000). By contrast, in the non-experimental approach defined as the process approach, the researcher observes an effect and identifies (suspects) causes. Since the researcher is unable to influence the causal variable (as in the case of an experiment), they draw on theory and experience to indicate the mechanism suspected to be responsible for the effect (Pentland, 1999; Morris, 2005).

Grin et al. (2010, p.94) focus on five main differences between variance and process approaches:

1) *Different character of entities investigated:* in variance theories entities possess a fixed set of variables and maintain their identities through time, while variables do the acting. For example, in the case of measuring the relationship between the number of clients served (dependent variable) and stakeholder participation (independent variable) in a new program start-up, measurements that occur at different time points assume that, first, client service means the same thing (no change over time) during these different time points, and second, that an increase in stakeholder participation (independent variable) will not change (influence) the character of the client service (see Poole et al., 2000, p.31). In process theories, subjects are entities (people, groups, organizations, artifacts) and do the acting. Events are what entities (the actors) do or what is done to them. Process theories examine events rather than variables.

2) *Stability of entities:* in variance theories attributes have one meaning causing change throughout the process. However, in process theories the unit of analysis under investigation is an entity that "evolves" and "makes things happen" and to which "events occur" (Poole et al., 2000, p. 39) and, as a result, it may change its identity ("undergo metamorphosis over time" (Grin et al., 2010, p.94)), define itself differently, or change its preferences as a result of experiences and learning.

3) *Time order of influence*: in variance theories the sequence of influence of different independent variables on dependent variables over time is not important for the outcome. On the contrary, in process theories, the temporal sequence of the independent variables is important since the order in which events happen, as well as their duration, determines the causes and how long the causes operate and influence the outcomes.

4) *Causation and explanation*: in variance theories variables act as forces on the unit of analysis and lead to its change (in terms of the outcome variable) signaling a "push-type causality" (Poole et al., 2000, p.33). In a process approach the narrative explanation is associated with "pull-type

causality" where "X [the precursor] does not imply Y [the outcome], but rather Y implies X" (p.42). Furthermore, process theories are "causally deep" (p.46), as they explain the development at different points based on prior events and influences. In addition, prior events become part of the entity's history and continue to exercise influence on the entity and shape its future. Accordingly, narrative explanations are formulated as distant to recent layers of temporal explanations and may incorporate structural changes and trends (Grin et al., 2010).

5) *Generality of explanation*: in variance theories, the evaluation of the theory's generality is based on its ability to explain causality across a broad range of contexts and measured through statistical methods. In the case of process theories, the generality of the narrative explanation "stems not from its uniformity and consistency, but from its versatility, the degree to which it can encompass a broad domain of developmental patterns without modification of its essential character. The broader the domain -the greater the variety of cases, context, events, and patterns the theory can adapt to- the more general the explanation" (Poole et al., 2000, p. 43).

The main method to establish knowledge on the "why" and "how" and causal sequences (mechanisms) involved in a case is process tracing (Collier, 2011; Bennet A. , 2010). Process tracing is used by qualitative researchers who investigate a limited number of cases (small-n methodologists), assume a complex world, and conceptualize causation as "a process involving the mechanisms and capacities that lead from a cause to an effect" (Bennet & Elman, 2006, p. 457). Accordingly, process tracing is defined as "an analytic tool for drawing *descriptive* and *causal inferences* (emphasis added) from diagnostic pieces of evidence-often understood as part of a temporal sequence of events or phenomena" (Collier, 2011, p.824). George and Bennett (2005, p. 206) state that process tracing is used to "identify the intervening causal process—the causal chain and causal mechanism—between an independent variable (or variables) and the outcome of the dependent variable". These causal mechanisms are defined as "unobservable physical, social, or psychological processes through which agents with causal capacities operate, but only in specific contexts or conditions, to transfer energy, information, or matter to other entities. In doing so, the causal agent changes the affected entities' characteristics, capacities, or propensities in ways that persist until subsequent causal mechanisms act upon them" (George & Bennett, 2005, p. 137).

Research purposes of process tracing variants in the literature include (i) theory testing, (ii) theory building, and (iii) case specific process tracing (Kay & Baker, 2015; Beach & Pedersen, 2013). Process tracing for theory testing involves the testing of causal mechanisms that a theory supports by asking if the causal mechanism is present in the case and if it functions as the theory suggests, or, otherwise said, if the theory proposed X mechanism explains Y outcome in the case examined. In theory-building, process tracing is used inductively by, first, asking what the causal mechanism between X and Y is and, second, building a theory that can be generalized to a population. Finally, process tracing in a "particular interesting and puzzling" case study (Beach & Pedersen, 2013, p.18) is not to build or test theory, but to generate an explanation of the outcome Y.

Since the focus of this study is on exploring, understanding, and explaining the transition of remote indigenous community electrical systems between 1980 and 2016, a theory testing process tracing approach will be used. Investigating the presence or absence of causal mechanisms predicted by existing theorization in the case of remote indigenous communities would then provide the foundation for further investigation of causal mechanisms through in-depth single case studies leading to theory building (Beach & Pedersen, 2013). Furthermore, testing prior theorized mechanisms contributes to theory building by improving a theory's validity, while findings may expand the theory's application context and identify consequences that were not present in the original theory (Colquitt & Zapata-Phelan, 2007).

In the case of theory-testing process tracing, the following methodological steps are involved (Beach & Pedersen, 2013, p. 14; Kay & Baker, 2015, p. 15):

(1) Identify a preexisting theory and the hypothesized mechanisms X and their empirical proxies (which we expect to observe if present in the specific case and which predict the cause of Y) and make clear the context to which they apply.
(2) Operationalize the theorized causal mechanisms and translate the theoretical expectations to case specific predictions.
(3) Collect empirical evidence that can be used to make causal inferences. Evidence collection is driven by the theory chosen in the previous step. Using the definition for mechanisms, causal process tracing takes the form of "X caused Y through the mechanistic sequence of A, B, C in the case Z" (Kay and Baker, 2015, p. 15).

The empirical evidence provides the basis for causal inferences by improving knowledge about (and confidence in) (a) whether the hypothesized causal variables were present or absent in the examined case, or X and Y actually took place (descriptive inference), and (b) whether the causal mechanism functioned as expected, or X caused Y (causal inference). The hypothesized relationship is "inductively confirmed if the probability of it being true is higher after the diagnostic evidence is known than its probability of being true prior to collecting the evidence" (Kay and Baker, 2015, p. 15).

Causal inference builds in careful description (Collier, 2011). It is the detailed descriptive component capturing "good snapshots at a series of specific moments" (Collier, 2011, p.824) that provides evidence that (i) the events really occurred (the hypothesized variables were present) (ii) how they unfolded (their sequence and extent), and (iii) if the anticipated reaction was present (the hypothesized mechanisms performed as the theory predicts) (Mahoney, 2012). The theoretical hypothesis is evaluated using two types of empirical tests, the hoop test and the smoking gun test, which are developed based on the causal inferences made when, using process tracing, (a) we find the predicted evidence, and (b) we do not find the predicted evidence, respectively (Beach & Pedersen, 2013). A hoop test would involve a hypothesis that is certain (evidence is present), but the outcome is not unique (an alternative hypothesis may produce the same outcome). Failing such a test (no evidence present) reduces our confidence in the hypothesis. However, if both the uniqueness and the certainty about the hypothesis is increased (e.g. by hypothesizing a complicated mechanism and providing evidence that the components of the complex mechanism are present, and that the causal mechanism functioned as expected), then the strength of the hoop test is increased, and the confidence in the validity, and hence the importance, of the hypothesis is improved (Collier, 2011; Mahoney 2012; Kay & Baker, 2015). In the case of a "smoking gun test" it is hypothesized that an unobserved cause or outcome took place and its traces, for which the cause or outcome is a necessary condition, are captured by the researcher. The presence of such traces infers that the cause or outcome took place and the validity of the hypothesis is confirmed (Mahoney, 2012).

Data collection of empirical observations that form the evidence in process tracing is guided and, therefore, influenced by the chosen theoretical concept. Empirical observations (called causal process observations (CPOs)) may take the form of a narrative data set and, to be considered diagnostic evidence, must be evaluated in terms of their relevance to the process examined (Kay & Baker, 2015). Beach and Petersen (2013) argue that CPOs are considered evidence when they have "any tendency to make the existence of any fact that is of consequence to the determination of that action more probable or less probable than it would be without evidence" (p.99). Kay and Baker (2015), quoting Collier, Brady, & Seawright (2004), state that evidence is "information about context, process, or mechanism", which "… contributes distinctive leverage to causal inference" (p. 12).

Evidence in process tracing includes pattern, sequence, trace, and account evidence (Beach & Pedersen, 2013). Pattern evidence takes the form of predictions of statistical patterns in the evidence set, while sequence evidence captures the "temporal sequences and events and the conjunctures of event chains" (Grin et al., 2010, p. 93) predicted by the hypothesized causal mechanism. Trace evidence provides proof that the suggested mechanisms exist, and finally, account evidence considers the content of the empirical material used as evidence. Furthermore, evidence also consists of primary CPOs, such as documents produced by participants prior or during events, as well as documented events themselves, which are subject to bias generated by the actors that produced them. Secondary CPOs used as evidence would build on, and interpret, primary evidence and may include historical analysis, articles, manuscripts, and interviews with participants that provide information on events or, in the case of participants with different worldviews, their motivation for events (Beach and Pedersen, 2013; Kay and Baker, 2015). Secondary evidence should also be examined for potential bias. In addition, evidence may also be assigned a weighting factor depending on their contribution to the hypothesis promoted (Mahoney, 2012).

Criticism towards process tracing as a research methodology in social sciences comes from supporters of quantitative approaches. They argue, first, that the existence of an "infinite number of causal steps between any independent and dependent variable" leads to "infinite regress", and, second, that research that examines a large number of variables using a small number of cases is unable to "truly link the independent variable with the dependent variable" (Mahoney, 2010, p. 123; Bennet, 2010). Furthermore, since in theory-testing process tracing inferences are drawn about whether a set of mechanisms hypothesized by an existing theory was present, and whether the mechanism functioned as expected, another limitation relates to the researcher's bias towards the selection of a specific theory. Such errors can be avoided by using multiple theories or a combination of theoretical approaches (Kay and Baker, 2015). A further limitation relates to the inability of theory-testing process tracing to test the explanations provided by alternative, or competing, mechanisms, or to compare mechanisms (Beach and Pedersen, 2013). Moreover, since the outcome of a process is not the result of the presence of the mechanisms (a mechanism does not cause an outcome, but "causation resides in the interaction between the mechanism and the context within which it operates" (Kay and Baker, 2015, p.7)), it is possible that the same outcome is the result of different mechanisms and processes (equifinality) and that the same mechanisms and processes can produce different outcomes (pathways) in different contexts (multifinality) (Kay and Baker, 2015).

3.2 Towards a theoretical framework of the study

In the next sections, I review three sub-disciplines involved in energy research, political ecology, political economy, and transitions management, which use political, economic, sociotechnical, and environmental factors to explain change in multi-stakeholder settings. Their theoretical backgrounds, methodological approaches, and limitations are highlighted, with the goal of providing insights for the identification of a theoretical framework to be used for this study. In a second step, I introduce the conceptual framework and the hypothesized mechanisms that explain the deployment of RETs. The framework, in turn, drives the study's data collection, and interpretation of results (Leshem & Trafford, 2007; Grant & Osanloo, 2014), which will provide the basis for causal inferences and knowledge development on the "why" and "how" of the transformation, and achieve the study's second and third objectives, namely: to improve understanding of the "wickedness" (the technical, contextual, and social complexity) associated with the introduction of RETs into remote indigenous community electrical systems; to explain the diffusion to date of RET projects into these systems; and to examine how these implemented processes for coping with the wickedness levels (the mechanisms and actors' strategies) were modified to encompass indigenous perspectives, with the goal of identifying pathways and developing policy recommendations.

3.2.1 Political ecology

Political ecology is rooted in critical theory and Marxian political economy to analyze relationships between economy and the environment (Greenberg & Park, 1994). Bryant (1992, p. 12) defines political ecology as a method to develop understanding "of how environmental and political forces interact to mediate social and environmental change". Over time political ecologists' interests shifted from ecological processes to the definition of power relationships involved in control and access of resources, and the influence of multiple scales and global policies to local environmental challenges (Nygren & Rikoon, 2008). This focus is captured through research questions that ask, "how and to what degree do control over the environment and knowledge of the environment, along with the distribution of environmental access and authority, influence environmental conditions and change?" (Turner & Robbins, 2008, p. 300). Political ecologists argue that it is politics and social power on top of environmental problems' social complexity that influence the capacity to address social-ecological problems (Zimmerer, 2015). Furthermore, political ecology research "tends to reveal winners and losers, hidden costs, and the differential power that produces social and environmental outcomes" (Sovacool, 2000, p. 530).

Over recent decades, political ecology has expanded in terms of worldviews, topics, and research directions with studies ranging from Marxian theoretical critiques, to assessments of the global biotechnology industry, and sustainable livelihoods in rural communities (Walker, 2006). Key energy-related political ecology topics include conflict, armed violence, and access to land and participation in decision making in the case of natural resources and fossil fuels exploitation (Watts, 1998; Billon, 2001; Bebbington, 2009), disputes between exploitation of marginal lands for biofuel production and risks for populations depending on such lands (Bailis & Baka, 2011), conflict between expansion of biofuel production and forest preservation (Orsato, Clegg, & Falcao, 2013), or environmental costs of biofuels to rural communities (Baka, 2017). In the case of renewable energy, topics include the influence of energy security and national security, and justice and equity issues to spatial energy configurations (Zimmerer & Basset, 2003), environmental impacts, changes in resource management practices, and impoverishment of people from large hydroelectricity generation to the benefit of private actors and the state (Martinez & Castillo, 2016), or modern core-periphery conflicts to the benefit (again) of the core (Zografos & Martinez-Alier, 2009).

Moreover, political ecology examines the struggle of indigenous populations around the protection of forests, rivers and natural resources from state, mining and other development interests (Escobar, 1998), their right to economic, cultural and ecological perspective difference from mainstream models (Escobar, 2006), and the right for implementation of natural resource management practices that meet the economic, social and cultural practices of indigenous community members (Natcher, Hickey, & Davis, 2004).

The diversity of objectives, epistemologies and methods employed by political ecologists have been criticized for their inability to engage policy makers. Walker (2006) argues that the large theoretical base and multitude of research under the political ecology discipline "poses an obstacle to the ability of the field to mount coordinated efforts to resolve tangible problems in the world outside" (p.392). Methodologically, political economy uses case studies that examine multiple themes, variants of ethnography, document research, and qualitative and quantitative analysis, including Marxian analytical methods and comparative analysis, to identify power relationships to explain linkages and changes in socioenvironmental systems (Walker, 2006; Baka, 2017). Another criticism to political ecology focuses on the use of theoretical frameworks to assume the relationships between political economic systems and environmental change. Vayda and Walters (1999) argue that the concentration on politics and power events to establish causal relationships may lead to the neglect of other events, and thus to a research agenda focusing on politics rather than ecology (see also Walker, 2005). Such an approach also overlooks complex interactions among factors that could be responsible for environmental change: the increased focus on sociopolitical factors impacting the environment diminishes the importance of ecological and cultural processes involved in complex change (Nygren & Rikoon, 2008). Alternatively, Walters and Vayda (2009) propose event ecology, or a causal historical research and analysis of events, where events are environmental changes. Event ecology, based on a process approach, explains why specific environmental changes have occurred by establishing causal connections to prior events through the use of socioeconomic and biophysical information relevant to the subject of interest, thus focusing on situation causes rather than theoretical prescriptions (Walters & Vayda, 2009; Vayda, 2006; Walters, 2017).

Accordingly, a political ecology investigation of the transformation of remote indigenous community electrical systems through RETs would examine the influence of political economy decisions, energy security, and justice and equity issues associated with RET deployment. Political ecology considerations that would be valuable for a conceptual framework examining RETs deployment would focus on: (a) the historic processes that shape socioeconomic relationships between participants, (b) the views and role of local users on local resources exploitation and their participation in the decision making process, and (c) the identification of benefits from renewable resources exploitation and the analysis of mechanisms used by participants to "gain, control, or maintain access within particular political and cultural circumstances" (Ribot & Peluso, 2003, p. 161).

3.2.2 Political economy

Political economy is broadly defined as the analysis of linkages between politics and economics, stemming from the perspective that governance, in the form of political behavior (exercising power and authority) and institutions, influences economic outcomes (Weingast & Wittmann, 2015). Rhodes (2000) illustrates the interplay between economy and governance by defining governance as a new political economy; governance is both "the political and economic processes that coordinate activity among economic actors" and "the complex art of steering multiple agencies, institutions and systems which are both operationally autonomous from one another and structurally coupled through various forms of reciprocal interdependence" (Rhodes, 2000, p. 59). Accordingly, political economy questions examine the interactions between political and economic processes, the distribution patterns of power and wealth between participating institutions and individual actors, as well as the processes responsible for the creation and transformation of these patterns (Collinson, 2003).

The broad focus of political economy calls for various approaches and methodologies to examine political and economic processes. Quantitative methods include, for example, input-output analysis (Watkins, 1963), statistical analysis (Bullock, Imai, & Shapiro, 2011) and statistical inference for causal effects (Bowers, Fredrickson, & Panagopoulos, 2013). These methods are complemented by qualitative methods, such as institutional analysis used for the analysis of regional or national economies (Ostrom, 2011), as well as, more recently, bottom-up institutional economics that study individual interactions (Greif, 2006) and case studies (Odell, 2001). In addition, commodity chain analysis examines control of commodities in given settings, while livelihoods analysis aims at identifying economic, political, social and cultural factors that define and influence the livelihoods of individuals, at multiple levels (local, national and international) (Collinson, 2003). Finally, a governance and political economy (GPE) analysis examines interactions among structure, actors, and institutions, and the likelihood of success of actions promoting system changes (Fritz, Kaiser, & Levy, 2009).

Political economy investigations related to natural resources and energy in the Canadian context (see also Wellstead, 2007) focus on the different perspectives between non-renewable staples developers, territorial governments, and local actors that use the land's traditional resources (Hutton, 2007). Since such perspectives depend on location, resource scarcity or abundance, and national strategies (Veltmeyer, 2013; Bebbington, Bornschlegl, & Johnson, 2013; Collinson, 2003), political economists explore new complex forms of governance based on more flexible and inclusive regulatory approaches (Fitzpatrick, 2007). For example, Carroll, Stephenson, & Shaw (2011) examined the post staples economy of British Columbia and the need for regulatory models that promote sustainable development to address resistance from various actors (including indigenous communities) to shale gas development. However, sustainability interpretations are also subject to political economy analysis based on the ideologies and arguments of participating actors on markets, technology, and focus on power relationships (Davidson, 2014).

Political economy studies in the case of renewable energy development in Canada examine the structural changes of electricity generation producers to identify factors that may influence future expansion of renewable sources. Netherton (2007) used a staples analysis to identify the shifting structures of electricity regimes through changes in the distribution of electricity generated rents (industry subsidization, to mass production facilitation, to sustainable development), shifts in technology (from available resources, to mass hydroelectricity, to multiple renewable technologies), and trade networks (from fixed borders, to provincial grids and northern extensions, to integration to the North-American interconnected grid). Furthermore, Haley (2011) used a staples political economy analysis to examine Canada's new staple trap and identified strategies, such as fiscal linkages between the fossil fuels industry and the green industry, to address political demand for transition to a low carbon economy (Haley, 2011). Finally, MacArthur (2017) identified policy intervention, financial resources, and political will towards renewables as important factors for the uptake of small-scale community energy projects.

In the case of renewable energy deployment in developing countries, political economy has examined the coalition formed by policy makers and incumbent regimes in the form of multiple arrangements among fossil fuel corporations, industry, military, and governments under concepts such as the "carbon lock-in" (Unruh, 2000), the "mineral-energy complex", the "carbon capital", and the "fossil fuel historical bloc" (Geels, 2014). Forms of power used by regimes to resist change include instrumental power (e.g. authority and money), discursive strategies (controlling "what" and "how" issues are discussed), improvements and adaptations of existing sociotechnical configurations, and institutional power (culture, ideology and governance structures) (Geels, 2014). For example, overinvestment in electricity infrastructure from the mineral-energy complex in combination with privatization initiatives, shape the energy landscape and the transition to sustainable alternatives in a socially and spatially uneven way in South Africa and Mozambique (Baker, Newell, & Philips, 2014; Power, et al., 2016), while powerful political vested interests in coal generation act as barriers to the uptake of RETs despite societal pressures for clean electricity in India and China (Isoaho, Goritz, & Schultz, 2016).

Accordingly, similarly to political ecology, the integration of political economy considerations into a conceptual framework that examines RET deployment would focus on: (a) historical legacies and economic processes that create the current economic and political situation under consideration, (b) institutional structures, related to laws, regulations and formal and informal rules and cultural obligations, and (c) the creation and allocation of rents, which create winners and losers in a given economy, and influence governance structures and economic growth (Fritz, et al., 2009).

3.2.3 Sustainability transitions

Sustainability transitions represent "fundamental transformation towards more sustainable modes of production and consumption" of established large-scale sociotechnical systems that are unable to address current sustainability challenges (Markard, Raven, & Truffer, 2012, p. 955). A sociotechnical transition is defined as a set of processes (initiated by technological innovations) that radically change a sociotechnical system “along different dimensions: technological, material, organizational, institutional, political, economic, and socio-cultural” (Markard, Raven, & Truffer, 2012, p. 956). These processes involve technological innovations generated by “multiple trial and error processes” and involving “social and cultural dimensions” (Geels, 2010, p.498). Sociotechnical transitions are examined under four different approaches (a) the multi-level perspective (b) strategic niche management; (c) transition management; and (d) technological innovation system (Markard, Raven, & Truffer, 2012, p. 956).

The first three approaches are closely related and rely on a “transitions perspective”, defined through the multi-level perspective (MLP), which introduces transitions as the results of interactions between meso-level socio-technical regimes, micro-level niche innovations, and macro-level landscape pressures. Strategic niche management focuses on the role of technological niches (articulation of expectations and visions, building of social networks, learning processes) and how they, eventually, compete with the current sociotechnical regimes’ technologies (Schot & Geels, 2008). Transition management was developed as a systemic approach to examine large-scale and complex environmental problems in energy, transport and agrifood systems (Geels, 2005) and understand and orient change (Meadowcroft, 2005, p. 483). It introduces “system innovation” and radical restructuring (rather than incremental innovations), as well as reflexive governance for “steering” the transformation of current unsustainable systems to more sustainable ones (Kemp & Loorbach, 2006; Loorbach, 2007).

The fourth approach, the technological innovation system (TIS), adopts an “emerging technological perspective” and focuses on the identification of important drivers, barriers, and interactions responsible for the uptake of specific technological innovations (Markard & Truffer, 2008, p. 596). All approaches aim to identify factors that influence the transition process, either at an aggregate level (e.g. sectoral), or at the technology or product level.

The multi-level perspective and the technological innovation system approaches will be detailed next.

3.2.3.1 The multi-level perspective (MLP) approach

The technological transition approach, or the multi-level perspective (MLP) approach, conceptualizes the transition process through the interaction of three levels, namely technological niches, socio-technical regimes, and landscapes (Geels, 2005; Geels & Schot, 2007). *Landscape* (macro-level) factors represent broader overarching political and social institutions, while *socio-technical regimes* consist of the practices of actors and institutions that establish and maintain a technological system (meso-level); finally, *technological niches* are the spaces where new innovations are created (micro-level), protected from market intervention until they reach maturity and build the necessary networks for market integration (Foxon, Hammond, & Pearson, 2010).

The main component of the framework is the meso-level with sociotechnical systems consisting of human beings and machines interacting for the provision of services; examples are infrastructural projects, such as electricity generation and provision, where humans, institutions and infrastructural components operate together for the provision of electricity services (Geels, 2005). Within the system the sociotechnical regimes are defined as “stable configurations of institutions, techniques and artefacts, as well as rules, practices and networks that determine the ‘normal’ development and use of technologies” (Smith, Stirling, & Berkhout, 2005, p. 1493). They experience high inertia (rigidity) due to interactions with user practices, technologies, business models and regulations, as well as institutional and political structures, with changes taking place in an incremental rather than a radical way. The MLP identifies transition pathways towards new sustainable systems as a result of “interactions between the internal regime dynamics and wider landscape factors and niche alternatives, which destabilize the incumbent regime and eventually give rise to a new regime” (Foxon, 2011, p. 1207). Landscape factors include political and business cycles, changing demographics, or shifts in environmental awareness, cultural preferences and public opinion (Geels, 2004; Sorell, 2018). Regime level stresses occur when regimes are inadequate and unable to provide the societal needs they are supposed to support and take the form of “mis-matches between certain rules”, such as, for example, policies not aligned with societal problems or incentives and subsidies that do not contribute to problem solving (Geels, 2004, p. 914; de Haan & Rotmans, 2011). Finally, micro- level pressures take the form of alternatives to the functioning of current regimes in the form of, for example, technological alternatives (electronic vs. telefax technology vs. traditional mail) or new organizational forms (private health care vs. regular healthcare) (deHaan & Rotmans, 2011).

3.2.3.2 The technological innovation system approach

In the "emerging *technological perspective*", sociotechnical change is the result of emerging technological innovation systems. A technological innovation system (TIS) distinguishes itself from geographically (national systems of innovation) or industrially (sectoral innovation systems) focused systems through its specific technological focus (Vidican, McElvaney, Samulewicz, & Al-Saleh, 2012) and is defined as:

> "a dynamic network of agents interacting in a specific economic/ industrial area under a particular institutional infrastructure and involved in the generation, diffusion and utilization of technology (Carlsson and Stankiewicz, 1991, p. 111)" (quoted in Markard and Truffer 2008, p.599).

In this case, the innovation system and its components, actors, institutions and interactions (relationships) between them, become the unit of analysis (Markard & Truffer, 2008; Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008). Actors are the private consumers, firms, governmental agencies, universities, non-governmental organizations (NGOs) and a multitude of other organizations participating in any given technological innovation. Institutions are considered the laws and regulations, technical, formal and informal rules and norms, visions, expectations that shape the interactions between actors (Markard & Truffer, 2008). Finally, interactions (or relationships) are means of transfer of codified and tacit knowledge at the individual or organizational levels; interactions are developed and exchanged between the elements of the system through cooperative relationships or the establishment of networks between different actors, between actors and institutions and among institutions (Wieczorek & Hekkert, 2012). Examples of interactions that influence and shape the uptake of a TIS, are the development of business associations, coalitions, research communities, political advocacy and business networks, since actors may compete or collaborate, may use existing institutional arrangements or create new institutions, and different institutional settings may reinforce or displace innovation potential. The constant interplay between the system’s elements, coordination mechanisms and the development of interrelations defines the dynamic character of the TIS that may or may not lead to the uptake of certain innovative products within a specific environment (Bergek, et al., 2008; Markard & Truffer, 2008).

Examining the uptake of a TIS can be done through the analysis of both the structural and the functional components that form the TIS. A structural analysis maps the TIS elements and evaluates their capacity to encourage innovation (Bergek, et al., 2008; Wieczorek & Hekkert, 2012). A structural analysis will examine if actors, institutions, networks (as operationalization of interactions of cooperative relationships) are present in a given setting as well as their capacity to perform and stimulate the TIS. Wieczorek and Hekkert (2012) add infrastructure in the form of physical (artefacts, machines, roads, buildings), financial (financial programs, subsidies, grants), and knowledge (expertise, know how, strategic information) infrastructure as an important structural component, the existence and performance of which influences the uptake of a certain TIS. The dynamic component of the TIS is related to the “processes” that are important for the TIS performance, which are categorized as functions of the innovation system. According to Johnson (1998), Jacobsson & Bergek (2004), Bergek, et al., (2008), and Hekkert, Suurs, Negro, Kuhlmann, & Smits (2007) the functions are: F1 (entrepreneurial activities), F2 (knowledge development), F3 (knowledge diffusion), F4 (guidance of the search), F5 (market formation), F6 (mobilization of resources), and F7 (creation of legitimacy/ support from advocacy coalitions). Their definitions are presented in Table 2.

Table 2: Functions of TIS

F1. Entrepreneurial Activities	Entrepreneurs are essential for the function of the TIS. They can be new or existing firms; they take advantage of opportunities and engage in experiments. Lack of entrepreneurial activity is caused by the underperformance of the other function.
F2. Knowledge Development	Includes learning mechanisms and captures the current knowledge of the TIS, and includes scientific, research, technology, market, deployment, and design knowledge.
F3. Knowledge Diffusion	Knowledge networks facilitate information exchange and promote further knowledge development through interactions.
F4. Guidance of the Search	Guidance of the search represents the selection process that is necessary to facilitate a convergence in development. It includes long-term targets, policy options, outcomes of technical or economic studies and technological expectations.
F5. Market Formation	Since new technologies often cannot compete with established ones, niche markets are formulated to provide the opportunity for new technologies to grow. They take the form of incentives, favorable tax policies and new environmental regulations.
F6. Resource Mobilization	Financial, material and human capital are necessary inputs for the development of knowledge, new markets and experiments. This function represents input for other functions.
F7. Support from advocacy coalitions/ legitimization	The emergence of a new technology often finds resistance from established actors. For an innovation system to develop, actors lobby for resources (F6), incentives (F5) and new knowledge (F2) to counteract the incumbent system's inertia.

Source: Adapted from Hekkert et al. (2007); Bergek et al. (2008); Suurs & Hekkert (2009)

Empirically, operationalization of the functional patterns is achieved through a set of indicators or diagnostic questions, which can be both qualitative and quantitative, describing the content of the function (Bergek et al., 2008). For example, entrepreneurial activities (F1) can be measured through the number of new firms established or new projects undertaken; the function guidance of the search (F4) can be measured through the targets developed by governments or press releases that set expectations and future policy goals (Table 3) (Markard & Truffer, 2008). Mapping of TIS functions through activities (their operationalizations) over a time period can additionally create an evolutionary pattern of the innovation under examination (Negro et al., 2007).

Table 3: Functions of innovation and operationalization indicators

System function	**Indicators**
F1. Entrepreneurial Activities	Number of new entrants and diversifying established firms; number of different types of applications; breadth of technologies used.
F2. Knowledge Development	Bibliometric; number, size and orientation of R&D projects; patents.
F3. Knowledge Diffusion	Number of workshops; conferences; network size and intensity.
F4. Guidance of the Search	Belief in growth potential; incentives from taxes (factor prices); regulatory pressure; expression of interest of leading customers; targets set by governments; number of press articles that raise expectations.
F5. Market Formation	Market size; customer groups; actor strategies; role of standards; purchasing processes; lead users.
F6. Resource Mobilization	Volume of capital and venture capital; volume and quality of human resources; complementary assets.
F7. Support from advocacy coalitions/ legitimization	Alignment with current legislation; standards; visions and expectations; depiction in newspapers.

Source: Adapted from Markard & Truffer (2008, p. 604).

3.2.3.3 Transitions and policy intervention

Both the MLP and TIS frameworks allow for actors participating in the transition process to “steer” the direction of the transformation through policy or governance interventions. “Steering” within the “transition perspective” leads to the transition management process (Kemp & Loorbach, 2006). The process is initiated by developing shared understanding of the problem through a problem structuring and envisioning process that examines the culture of a system (or subsystem) and components such as norms, values, ethics and sustainability. Subsequently, a sequence of tactical, operational and reflexive activities for the transformation of a societal system, or a subsystem (energy system and energy supply), is introduced. First, tactical activities such as rules, regulations, institutions and networks development related to the structure of a societal system (or subsystem, or project) are introduced as “steering” activities. Second, operational activities consisting of actions, practices and experiments introduce new structures, culture, routines and actors and are driven by entrepreneurial ventures and innovative social and technical solutions created at the niche level. Finally, reflexive activities monitor, assess and evaluate the transition process and transition management components (problem structuring and envisioning, transition agendas, and experiments) to improve learning through the interaction and cooperation of involved actors and to stimulate action towards the long-term goal of the transition process (Loorbach, 2007; Loorbach, 2010; Grin, Rotmans, & Schot, 2010). The factors that influence the sociotechnical regime transformation include (a) the articulation of a pressure targeting social change (addressing a sustainability problem), (b) the existence within the regime of adequate resources (physical and capabilities) for the regime transformation or the ability to acquire them, and (c) the effective coordination of resources to address the change (Smith, Stirling, & Berkhout, 2005).

Similarly, "steering" and policy related issues with the TIS approach result from the proposition that the structure and functions of a TIS are influenced by the existence and capabilities of different actors and institutions, as well as the existence and quality of the interactions. Both structure and function can be influenced by "inducement" and "blocking" mechanisms, which are responsible for the shaping of the TIS dynamics. Targeted policies may affect the mechanisms that induce the transformation process creating the "virtuous cycles" of successful activities, resulting in the moving of the key processes and the diffusion of the specific technological innovation and the transition from one sociotechnical regime to the desired next one (Bergek et al., 2008; Elzen & Wieczorek, 2005).

3.2.3.4 Critique on transition approaches

Both the MLP and the TIS frameworks have been criticized for various deficiencies. Critique on the MLP framework concentrates on issues of operationalization and specification of regimes, its focus on elite actors, a bias towards bottom up change in the form of niche-level mostly technological artifacts, its heuristic rather than positivist character and methodological lack of statistical regression techniques to offer solutions, and issues of agency and power (Geels, 2011). Further critique of the MLP focuses on the lack of geographical factors that may also influence the transition process (Hansen & Coenen, 2015; Coenen, Benneworth, & Truffer, 2012). Similarly, critique on the TIS approach concentrates on the lack of political power as an important contributor to agency issues (Kern, 2015), and lack of a spatial component and interactions between sectors explaining differences in TIS diffusion (Coenen, 2015; Bergek, et al., 2015; Markard, Hekkert, & Jacobsson, 2015).

Accordingly, and similar to political ecology and political economy considerations, the impact of power and politics on transitions represent the main criticism to the MLP and TIS. The political ecology perspective is summarized by Lawhon and Murphy (2011) who draw attention to four specific points related to power and how power is exercised within the transition literature, namely (a) the definition of the problem, or "how the terms of change are defined and by whom" (p. 365), since who decides the type, extent and direction of the sustainability transition influences the problem definition in a specific way and indicates a particular solution favoring some groups over others; (b) the inclusion or exclusion of actors from "transition arenas"; (c) the shaping of the sustainability direction though language and discourses used by transition experts; and (d) the adoption of niche-technology options that would lead to electrical systems beneficial for the local social systems. In a similar way Hillman et al. (2011) ask about the "who, how, and what" of the governance arrangements within the TIS that have the potential to influence the transition process.

The political economy perspective of power and how it is exercised in transitions involves regulatory and fiscal arrangements that may influence landscape factors (e.g. the economic climate), regime actors (through e.g. regulations and policies providing financial incentives), and niches (through e.g. policies that support or discourage innovations) (Avelino & Rotmans, 2009; Meadowcroft, 2011). These arrangements, supporting the deployment of RETs, create a significant "pool of economic rents" in the form of subsidies, tax reductions, financial assistance, permits, and political and administrative power that influences the transition process (Helm, 2010; Strunz, Gawel, & Lehmann, 2016). These rents, in turn, have the potential to influence actors' relationships and strategies, shape the transition process and create winners and losers among participating stakeholders (Shove & Walker, 2007; Smith, Stirling, & Berkhout, 2005). As May & Jochim (2013) state, "[policies] …shape politics by allocating winners and losers, by sending signals about who is deserving and undeserving, and by setting in place feedback processes that affect political participation and future policy demands. […] public policies are key components of governing" (p. 426). In the case of developing countries, as well as in the case of remote indigenous communities, the fact that regulations and financial rents associated with energy transitions can be important for economic development and political stability may complicate the process further (Khan & Jomo, 2000; Fritz, Kaiser, & Levy, 2009).

3.2.4 Concluding remarks

Despite the analytical strength of political ecology and political economy approaches on power related issues, this study will use the MLP and TIS frameworks for the following reasons. *First*, the MLP and TIS are process approaches (Grin, et al. 2010; Suurs, Hekkert, Kieboom, & Smits, 2010), and, therefore, better equipped than a variance approach to explain the transformation of communities' electrical systems (see section 3.1). A variance approach and a focus on a number of factors as independent variables responsible for the community energy transitions would be unable to capture dynamic interactions that influenced their transformation (for example, the establishment (or lack of) electricity rates structures or indigenous vested interests) in the period under examination. All participants involved in the remote communities' electricity generation process changed their identities and governance structures between 1980 and 2016 as result of participation and interactions within a changing social, historical, economic and political context. The MLP and TIS are able to capture these long-term processes and complex dynamics that involve co-evolutionary interactions between actors, different trajectories (e.g. rate structures and regulations), technical innovations, and broader societal transformations influenced by markets and social movements (Grin et al., 2010).

Second, the MLP and TIS are able to accommodate (to a certain extent) the main concerns of political ecology and political economy power and politics challenges that influence the transitions. Geels (2011) argues that although certain types of power, such as power struggles, are less developed, power and politics are captured in MLP through agency that is accommodated "in the form of bounded rationality (routines, search activities, trial-and-error learning) and interpretive activities" (p. 30). Political and cultural aspects, which are shaped by landscape level factors, can also be captured (to a certain extent) in the perspectives of regime and niche level actors that adjust their discursive activities. Furthermore, Geels (2014) acknowledges that regime actors are actively involved in political gaming, either resisting or supporting transitions for political and economic benefits and proposes that MLP analysis should be enriched by focusing on regime dynamics rather than niche innovations.

Similarly, the TIS framework allows agency and political aspects to be captured through its functions. Community visions and multiple roles of local governments, such as exercising power for increased self-reliance and respect for aboriginal rights, treaties negotiation, investment attraction, provision of social services, environmental licensing (Public Policy Forum, 2006), as well as promotion of certain innovations as "compatible" with aboriginal values and beneficial for the community, are captured through the "guidance of the search" and "legitimization" functions in the TIS approach (Markard, et al., 2015). Furthermore, politics, besides influencing regulation that supports "market formation" and, consequently, the "legitimization" function, have also the potential to influence academic research funding and impact both the "knowledge development" and "knowledge diffusion" functions. In this sense, participation, agency and power struggles between participants involved in producing change, will be reflected as changes observed in the TIS functions (Kern, 2015).

Third, geographical factors that may influence the transition process take the form of location, landscapes, territoriality, spatial differentiation and uneven development patterns, the scale of the energy systems, and, finally, the spatial path dependency (Bridge, Bouzarowski, Bradshaw, & Eyre, 2013). To identify geographical factors influencing transitions, Coenen et al. (2012) ask for comparative analysis of different TIS that explicitly focus on "institutional socio-spatial configurations" (p. 973) and introduce the concepts of "comparative institutional advantage" and "institutional thickness" to connect economic geography and transitions research. Similarly, Markard et al. (2015) argue that regional TIS comparisons would be able to capture differences in structures, including institutions and regional professional cultures. Finally, Coenen (2015) argues that TIS empirical research could benefit from existing theories on spatial proximity and agglomeration economies that explain why innovative entrepreneurs concentrate in space.

Fourth, both the MLP and TIS have been developed with the purpose to provide policy insights, and both frameworks, unlike political ecology, have been adopted by policy makers that seek to induce energy transitions (Alkemade, Hekkert, & Negro, 2011; Jacobsson & Bergek, 2011). The MLP and transition management approaches were developed as "a framework for considering portfolios of policy measures that nurture low carbon niche developments, putting pressure on emissions from incumbent regimes and facilitating processes for niches to inform regime transformation" (Scrace & Smith, 2009, p. 712). These policy frameworks take different forms during the different transition phases ranging from promoting variation in the pre-development phase, to stimulating learning and experimenting during acceleration, mobilizing actors and networks during take-off, and, finally, controlling the transition during the stabilizing phase. The main policy goal is to achieve “gradual” social change and socioeconomic and environmental objectives, while minimizing social resistance (Rotmans, Kemp, & VanAsselt, 2001). Similarly, the TIS framework was initially developed as a tool to identify system weaknesses and the development of policy recommendations for specific technologies (Jacobsson & Bergek, 2011; Markard, Hekkert, & Jacobsson, 2015). More recently Markard et al. (2015) argue that the framework was developed to improve understanding rather than deliver policy recipes for policy makers by identifying systemic problems and the mechanisms that block innovation and social change and developing policy relevant insights, so that poor TIS functionality is improved (Bergek et al., 2008).

Finally, neither the MLP nor TIS frameworks have been used for explaining the introduction of RETs in Canadian remote indigenous communities, although they have been applied in similar contexts in developing countries. The application of these frameworks in the Canadian context would, first, complement variance-based methodologies in the form of feasibility and optimization studies, and, second, allow for identification and exploration of new pathways and patterns that have not been previously considered through the inclusion of cultural and social goals of indigenous people, which, in turn, influence the outcome of the process to the benefit of the communities. In addition, a process approach, in a similar vein to indigenous methodologies, focuses on relationships between living things and their environment versus a “western individualism” focus of variance approaches on characteristics of individuals or communities to explain causality (Weber-Pilwax, 2004; Wilson, 2001; Cohen, 2001). Indigenous methodologies favour “research (that) has to benefit the community… (and) serve the community” (Hart, 2010, p. 11; Weber-Pilwax, 2004). Furthermore, besides achieving the study’s objectives, the application and testing of the MLP and TIS in the context of Canadian remote indigenous communities may provide useful policy insights relevant to other indigenous communities in similar contexts.

3.3 Theoretical framework of the study

Both the MLP and the TIS frameworks have been extensively used for the study of the diffusion of renewable energy technological innovations. Both frameworks are based on evolutionary economics and include concepts of non-linearity and path dependence, praise the importance of learning processes, institutions and networks, and were developed with a view to informing policy (Markard & Truffer, 2008; Meelen & Farla, 2013).

The two frameworks also complement each other: analytical weaknesses of the MLP framework can be covered by the TIS framework and vice versa. The MLP explains the success of innovation and the transition process as the result of an interplay among stabilizing mechanisms at the regime level, destabilizing landscape pressures applied to regimes, and the emergence of radical innovations at the niche level. However, the MLP is unable to elaborate in detail how, for example, changing policies (governance structures) that influence the transition process, come about. This level of detail is provided through a TIS analysis and the use of functions and functional interactions (Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007, p. 418). Furthermore, the MLP framework offers limited details on the roles and strategies of participating actors, interactions between actors and institutions, and resource distribution and their role in the development of networks and actors' capacity (Markard & Truffer, 2008; Smith, Stirling, & Berkhout, 2005).

Conversely, the TIS approach is unable to capture broader landscape factors that influence the transition process or inertia of incumbent sociotechnical regimes, but is able to deal with strategies, resources, and agency through the use of a combined structural and functional analysis. By providing a clear distinction between structure and functions, it also allows the analysis of interactions between actors participating in a specific institutional infrastructure, responsible for the generation, diffusion, and use of the technological innovation, which, in turn, reveals how specific policies and governance structures come about (Hekkert, et al., 2007). Furthermore, the TIS approach identifies underlying systemic problems, such as ineffective working networks, and institutional and infrastructure failures responsible for blocking and inducement mechanisms, which in turn influence the innovation functions (Wieczorek & Hekkert, 2012; Markard, Hekkert, & Jacobsson, 2015). Finally, the TIS analysis can capture spatial issues (different dynamics between nations or regions) and variety, such as economic drivers, institutional settings, and cultures, through comparative TIS studies between nations, or regions (Markard, Hekkert, & Jacobsson, 2015), or local levels (Ulsrud, Rohracher, Winther, Muchunku, & Palit, 2018).

The complementary nature of the MLP and TIS frameworks was investigated by Markard and Truffer (2008) who proposed an integrated framework. In the integrated framework a TIS would be influenced (both positively and negatively) by landscape factors, existing regimes, other TIS, and technological niches. Based on this integrated approach, Meelen and Farla (2013) proposed the integration of policy approaches related to MLP (and the associated transitions management and strategic niche management) with the policy recommendations resulting from the TIS literature into one framework for policy analysis. Furthermore, as mentioned in Chapter 2, both the MLP and TIS frameworks have been combined with other theories to examine the transformation of electrical systems in developing countries and in the context of on-grid Canadian indigenous communities.

This study will employ the MLP and TIS frameworks at different scales to examine the transformation of remote indigenous community electrical systems through RETs and address the study's second and third objectives. In a *first* step, a modified MLP framework that includes governance structures (Smith et al., 2005) is applied at a national scale to analyze the transition dynamics in Canadian remote indigenous communities between 1980 and 2016 (Chapter 6). The analysis identifies transformation patterns and regime shifts and provides an explanation of the diffusion of RETs into communities' electrical systems. However, the MLP framework is unable to explain in detail how (and why) the supporting policies came about, the roles and strategies of participating actors, the interactions between actors and institutions, or the distribution of resources and their role in the development of networks and actors' capacity (Markard & Truffer, 2008; Smith, Stirling, & Berkhout, 2005; Hekkert, et al., 2007). In a *second* step, therefore, a combined structural and functional analysis of the NWT and Ontario TISs, where the majority of RET projects were deployed between 2000 and 2016, will examine and compare the diffusion of RET in these remote communities and further address the study's second and third objectives (Chapter 7). In addition, this within nation sub-national level comparison (at the provincial level) (Snyder, 2001) may illustrate similarities and differences based on cultural, historical, institutional, and socioeconomic dimensions and demonstrate the importance of geographical factors in the transition process.

The next section outlines the conceptual frameworks to be used in the study, and, based on the framework components, the methodology for achieving the study's remaining objectives.

3.3.1 Modified MLP framework

The modified MLP framework (Figure 1) conceptualizes the transformation of communities' electrical systems through the introduction of three main subsystems (constellations or regimes) of the sociotechnical system that contribute to the system's functioning and influence the transition process: first, the incumbent regime that currently dominates the functions of the sociotechnical system that meets societal needs; second, novel constellations called niches that are able to provide system functions, but lack the power to become the dominant regime; finally, niche-regimes that provide, or are able to provide, system functions due to their power and are situated between the previous actors. Accordingly, the transition from the current system to a more sustainable one is conceptualized through the emergence of a niche-regime, either existing or developed out of a niche, that applies a different way (in terms of structure, culture and practices) of fulfilling societal needs, competes with the incumbent regime, and, eventually, takes over its functions, thus becoming the main provider of the system's functioning (deHaan & Rotmans, 2011; Grin, Rotmans, & Schot, 2010).

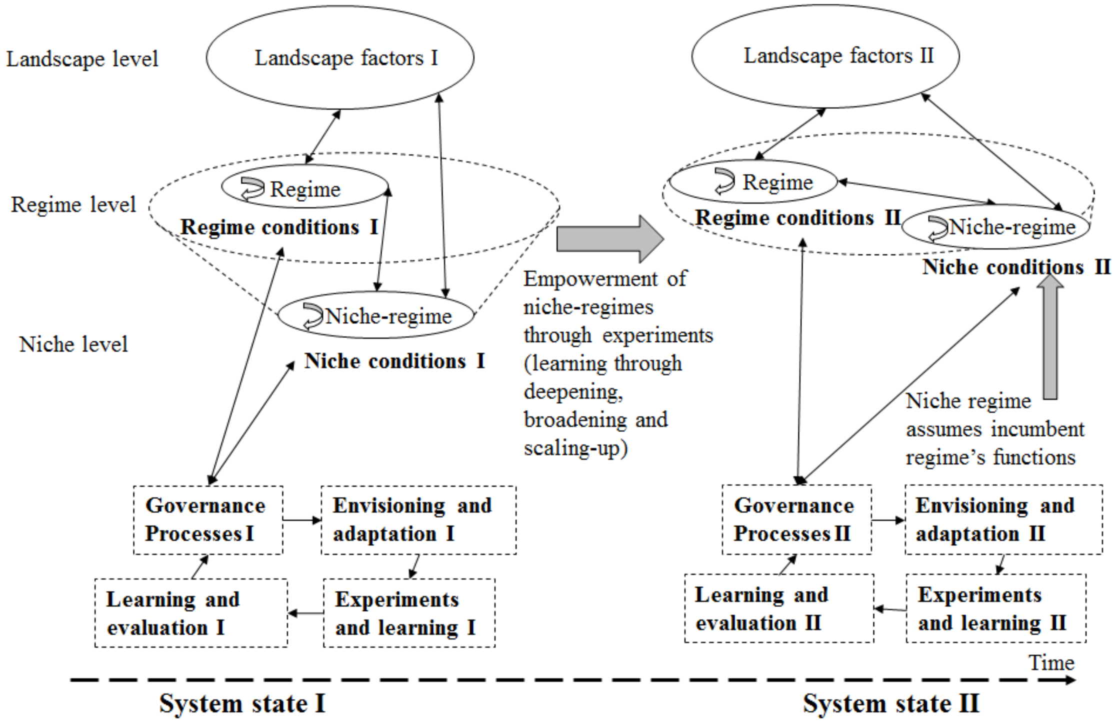

Figure 1: MLP modified framework: regime and niche-regime conditions and governance processes of the transition

Transformative change in the system occurs through: (a) tensions, or misalignment of the incumbent regime's functioning as a response to new developments at the broader landscape level of economic, cultural, political or ecological nature, (b) stresses, defined as internal misalignments of the incumbent regime's functioning that are either inadequate or inconsistent with the societal needs, and (c) pressures, developed towards incumbent regimes from new technologies and/or the existence of niches or niche-regimes (deHaan & Rotmans, 2011). When the regime conditions (tensions, stresses and pressures) reinforce each other towards a certain direction, then the introduction of transition experiments in the form of technological innovative projects aimed at societal change, allow for learning processes and the empowerment of niches and their transformation to niche-regimes which challenge the incumbent regime (deHaan & Rotmans, 2011; Grin, Rotmans, & Schot, 2010; van den Bosch & Rotmans, 2008). Learning processes include learning from transition experiments implemented in a specific context (deepening), in different contexts (broadening), as well experiments that are integrated and embedded (scaling-up) into mainstream activities and practices (van den Bosch & Rotmans, 2008; Grin, Rotmans, & Schot, 2010).

Van den Bosch & Rotmans (2008) add four niche related conditions for the success of transition experiments, namely (a) the internal alignment of the niche, (b) the ability of the niche to exercise power on the incumbent regime locally, (c) the existence of a cooperative regime that is responsive to experiments and the existence of key actors that assist in transforming experiments to practices that address societal needs, and (d) the alignment of the niche with trends and developments at the broader landscape level. The transition contains "slow" phases (pre-development and stabilization), resulting from negative feedback mechanisms caused by the incumbent regime in charge during the specific period, and "fast" phases (take-off and acceleration), where regime and niche regime conditions create positive feedback mechanisms that move the innovation forward (Grin, Rotmans, & Schot, 2010).

Because a transition process (or transition pathway) covers periods of (slow and fast) transformation, it could be represented as a sequence of transition patterns, or a sequence of transformations from a current system state to a new system state, involving changes in the system's functioning (deHaan & Rotmans, 2011). This transformative change can be "managed" by creating supporting mechanisms that create positive feedbacks, thereby influencing the transition.

Accordingly, transition pathways can be represented through a series of successive transition patterns, with the dynamics of each stage depending on (1) the current system state (system composition), (2) the system conditions, in terms of regime tensions, stresses, and pressures, and niche conditions, and (3) the governance processes negotiated between different regime members that seek to influence the transition process (Smith, Stirling, & Berkhout, 2005; deHaan & Rotmans, 2011; Haxeltime, Whitmarsh, & Bergman, 2008). As a result of the dynamic processes involved, niches can grow to niche regimes and eventually replace the incumbent regime, or they can be incorporated into, or co-exist with, the incumbent regime (Schot & Geels, 2008).

The analysis will indicate the extent to which RETs have emerged as a viable electricity generation alternative in remote communities in terms of regime shifts (which indicate a transition), the speed, size, period of change, and the phase (pre-development, take-off, etc.) of the transition, as well as the origin of the transition, in terms of where (which level and which constellation), when (in terms of tensions, stresses and pressures, niche related conditions and governance processes), and how (what type of experiments and learning processes). The dynamics of the process are elaborated through the articulation of expectations, learning processes, the creation of networks, building of institution (including governance structures), and experimenting (Schot & Geels, 2008; Smith & Raven, 2012). Furthermore, the transition patterns, as indicated by the extent of regime shifts, will also provide information on the effectiveness of strategies and instruments, and indicate targets and levers that could be the object of policies for influencing transitions.

3.3.2 TIS framework and TISs comparison

Based on the TIS analytical framework (see the process proposed by Bergek et al., 2008, and Wieczorek & Hekkert, 2012), the NWT and Ontario TISs are defined as networks of actors that interact within each province’s institutional infrastructure for the diffusion and use of RET technologies into remote communities’ systems. New RET technologies, such as wind and solar, “emerge” as electricity generation options as they co-evolve with the communities’ social contexts and are adopted if they align with community sociocultural and economic practices (Ockwell, et al., 2018). Methodologically, first, the structure, functional pattern, and the main blocking mechanisms and underlying systemic problems that induce or hinder the fulfilment of the functions in both TISs will be identified using the analytical framework presented in Table 4. Second, the systemic problems responsible for the poor functional performance of both the NWT and Ontario TISs will be "precisely identified" and analyzed (Wieczorek & Hekkert, 2012, p. 85). Third, the functional performances of the NWT and Ontario TISs during the 2000-2016 period will be analyzed and compared in order to, first, explain the diffusion of the TISs, and, second, generate insights concerning the main factors that influence the deployment.

Table 4: Framework for the analysis of the TIS in remote indigenous communities

Functions	Evaluation of functions based on diagnostic questions	Identification of the reasons affecting function performance	Identification of systemic (actors, institutions, networks, infrastructure), and transformational (directionality, demand articulation, policy coordination and reflexivity) failures responsible for the blocking/inducement mechanisms
Fn with n= 1,…,7	………..	Blocking /inducement mechanisms) affecting Fn	• Actors: Presence? Capabilities? • Institutions: Presence? Capacity/quality? • Interactions: Presence? Intensity/quality? • Infrastructure: Presence? Capacity/quality? • Presence and quality (effectiveness) of directionality measures? • Presence and quality (effectiveness) of demand articulation measures? • Presence and quality (effectiveness) of policy coordination measures? • Presence and quality (effectiveness) of reflexivity measures?

Adapted from Wieczorek and Hekkert (2012) and Weber and Rohracher (2012). See also Labrinopoulou, Renwick, Klerkx, Hermans, & Roep (2014).

Functional performance during the period investigated is assessed through mapping actors' activities (events) that changed institutions, influenced interactions and modified infrastructure, and, therefore, addressed systemic problems and contributed to TIS function changes and fulfillment. Events are then allocated to functions based on operationalization indicators (Suurs et al., 2010) described in Table 5. Findings will follow in the form of a narrative that will explain the historic development of both TISs through changes in the structure and functions' interactions.

The aim of the TIS analysis is to offer additional explanation of the diffusion process by examining interactions (the functional pattern), the reflexivity of governance processes (why certain policies and programs came into existence), and differences in context and institutional settings that may influence the diffusion process.

Table 5: Functions and operationalization indicators for the NWT and Ontario TIS

System function	Operationalization indicators
F1. Entrepreneurial activities	• Development of remote community owned RET projects.
F2. Knowledge development	• Conducting renewable resource surveys, monitoring studies, feasibility studies. • Community energy plans. Small-scale RET experiments. Participation in research projects.
F3. Knowledge diffusion	• Training of community members. Promoting energy-related education, developing energy campaigns, organizing and participating in conferences, exhibitions, workshops, charrettes, seminars, meetings.
F4. Guidance of the search	• Establishing targets for RETs. Design of policies and regulations that favor RET solutions. Design of policies and regulations that favor RET solutions in remote indigenous communities. Establishing expectations from RETs projects on indigenous lands. Providing direction and expressing interest in RETs options. • Publication of results from studies involving RETs in remote communities.
F5. Market formation	• Regulatory arrangements that allow local governments and their organizations to participate in the electricity generation process as Independent Power Producers (IPP). Power purchase agreements (PPAs). Net metering agreements.
F6. Resource mobilization	• Providing financial incentives (for project capital, technical training, and electricity generation). Providing loans. Providing loan guarantees. Financing research projects. Mobilizing cooperation with the private sector.
F7. Support from advocacy coalitions/ legitimization	• Advocating for indigenous RETs projects in remote communities. Statements of indigenous leadership on the cultural fit of RETs projects. Community visions and expectations favoring RETs deployment.

3.4 Methods

The choice of analytical frameworks and their components offers a visualization of the transformation of indigenous community electrical systems and aims, first, to improve understanding of the technical, contextual, and social complexities associated with the introduction of RETs into these systems and, second, to explain the diffusion of RET projects to date. A conceptual framework additionally provides information on the (i) the relationships that the study will examine, and hence the data to be collected and analyzed, (ii) the literature that should be the focus of the study, and (iii) the methods that need to be applied in order to study the phenomenon (Leshem & Trafford, 2007).

The study uses process tracing as its research methodology (see section 3.1). As George and Bennet (2005, p.6) state “in process tracing, the researcher examines histories, archival documents, interview transcripts, and other sources to see whether the causal process a theory hypothesizes or implies in a case is in fact evident in the sequence and values of the intervening variables in that case”. Data on event sequences in transitions’ studies that use the MLP in both developed (see for example, Raven, 2005; Verbong & Geels, 2007; Rosenbloom & Meadowcroft, 2014) and developing countries (see for example, Verbong, Christiaens, Raven, & Balkema, 2010; Nygaard & Hansen, 2016; Hansen, Pedersen, & Nygaard, 2015) are collected mainly from printed documents and literature reviews and interviews with actors participating in different regimes, as well as, to a lesser extent, from observations.

Similarly, empirical studies that use the TIS approach identify events, which are mapped to functions, and trend and interaction patterns, and construct a narrative that captures the development of the TIS (Bergek et al., 2008; Suurs and Hekkert 2009). Data on events in both developed countries (Negro et al., 2007; Negro et al., 2008; Hekkert & Negro 2009; Suurs and Hekkert 2009; 2010; VanAlphen et al., 2009; Wieczorek et al., 2015) and developing countries (VanAlphen et al., 2008; Kebede et al., 2015; Kebede & Mitsufuji, 2014; Agbemabiese, Nkomo, & Sokona, 2012; Tigabu, Berkhout, & van Beukering, 2015; Blum, Bening, & Schmidt, 2015) are collected mainly from literature reviews of secondary data (including technical and grey literature) and interviews with actors from various participating groups, as well as field observations (Blum et al., 2015). Interviews may additionally be used to rate functions’ performance (see VanAlphen et al., 2009) and as expert feedback for triangulation of the interaction patterns and the narrative’s content (Suurs and Hekkert, 2010).

3.5 Research process and data collection

The data collection and data analysis process and manuscripts’ writing and submission proceeded in three phases.

During the first phase (January 2014 to July 2016) the aim of the research was identifying the remote indigenous communities to be investigated, understanding community electrical systems and the technical problem associated with the introduction of RETs in isolated electrical systems, as well documenting the RET projects undertaken in these communities. Data collection involved internet searches that led to documents published by provincial governments and utilities, the federal government, academia, indigenous organizations, non-governmental organizations, and professional associations. However, most of the documents were unable to provide details on remote communities' electrical systems, except for the AANDC and NRCan (2011) initial study and provincial policy documents and utilities' annual reports. As a result, further searches involved "backward snowballing" and "forward snowballing" (Wohlin, 2014; Lecy & Beatty, 2012) based on the initial documents and searches. Results included additional provincial and territorial policy documents and utilities' annual reports to identify descriptions of current electrical systems, future plans for electrical system expansion, and information on past and current renewable electricity targets and programs. Searches were terminated once new documents were unable to produce any further insights relevant to the literature review scope (Wohlin, 2014). Data on RET projects in 133 of the 144 remote indigenous communities located in seven provinces and territories (Yukon, Northwest Territories, Nunavut, British Columbia, Ontario, Quebec, and Newfoundland and Labrador) were gathered through reviews of provincial policy documents, utilities annual reports and grey literature, and online searches using the name of the specific remote indigenous community and combinations of keywords, such as "renewable electricity", "solar", "wind", and "hybrid electrical systems". The documents are referenced in the papers presented in Appendix A.

Findings from the first phase indicated that the introduction of RETs in remote indigenous communities exhibits similarities to a wicked problem, involving participants that changed their identities and perspectives over time, and, therefore, necessitated the use of a process approach that considered systemic sociotechnical frameworks involving collaborative actions in multi-stakeholder settings (King, 1993). Accordingly, and following the choice of the MLP and TIS as analytical frameworks of the study, research during the second phase (September 2015 to July 2017) concentrated on, first, exploring indigenous and non-indigenous perspectives on the roles and challenges associated with the current community diesel powered systems, the future of electricity generation, the expectations from RET applications, as well as barriers to their implementation, and, second, examining the events that influenced the transformation of remote communities' electrical systems between 1980 and 2016.

Furthermore, the MLP-based analysis required the collection of data on (1) the current status of the Canadian remote indigenous communities' electrical systems and the RET projects developed to date; (2) the communities' electrical systems conditions in terms of regime tensions (landscape macro-level factors), stresses (regime meso-level factors), and pressures (niche micro-level factors), as well as niche level conditions, influenced by the relationship between federal government, provincial and territorial governments, indigenous governments, utilities, and other participating actors; and, finally, (3) governance processes, which aimed at influencing the transition process, that may have been negotiated between participants. In a similar way, the TIS-based analysis required the collection of data on (1) the structure (including infrastructure) of the NWT and Ontario TISs, and the main inducement and blocking mechanisms, as well as the underlying systemic problems that influenced functional performance and interactions between actors and between actors and institutions, and (2) actors' activities (captured as events) that changed institutions, influenced interactions and modified infrastructure.

Data collection during this phase involved a combination of literature reviews of academic, non-academic, policy and utilities' documents, interviews with key informants in a remote indigenous community, and discussions with participants during various conferences and thematic events. Although documents and internet sources are easily retrievable, can be reviewed by others, and may contain facts and specific details, they may also be inaccurate and biased due to the author's personal stance. In addition, important documents may also be missing (selectivity bias). Therefore, multiple document types from multiple sources were employed to improve information quality and corroborate facts (Yin, 2003). The following document types were used:

- Articles from scientific journals
- Articles from newspapers and industry journals
- Conference proceedings and conference reports
- Studies and reports from research institutes, universities, government agencies, non-governmental organizations, indigenous organizations
- Books on energy and energy policy, and indigenous governance
- Government (federal, provincial and territorial, and indigenous) internet sites
- Provincial and territorial utilities' reports

- Provincial and territorial reports related to energy and natural resources
- Federal, provincial and territorial and indigenous governments' policy documents and reports
- Statistical reports from Statistics Canada.

The documents used for data retrieval and analysis are referenced in Chapters 5, 6 and 7.

Interviews can be used as an important source of primary information about structures, behaviors, experiences, and events and to verify, corroborate, and augment other evidence (Yin, 2003; Hay, 2000). However, drawbacks of interviews include interviewee selection and problems with interviewee responses related to bias and poor recall (Yin, 2003). Due to time and financial constraints, interviews were conducted with ten community members in one northern Ontario remote indigenous community in October 2014. This community is typical of northern Ontario's 25 remote indigenous communities, in terms of language, common values, and traditional practices, population (approximately 1,000), building stock (residential, community and infrastructure), and electricity generation facilities. Interview participants were identified by the Band Council, were over 18 years old and consented in writing and orally to be interviewed. Interviews aimed at collecting information on niche level conditions (the internal alignment of the niche, its ability to exercise power on the incumbent regime locally, the existence of a cooperative regime, the existence of key actors participating in experiments, and the alignment of the niche with trends and developments at the broader landscape level) and blocking and inducement mechanisms to the deployment of RETs. The semi-structured interviews included qualitative, open-ended questions on the current electricity system governance structure, motivations for participating in renewable electricity generation, barriers to RETs deployment, and potential community benefits from the implementation of RET projects. Research in the community was undertaken following the Tri-Council policy requirements and received ethics clearance from the Office of Research Ethics at the University of Waterloo (ORE#19350). The interview questions are presented in Appendix B.

In addition, information for data triangulation (Yin, 2003) was collected through informal conversations with sixteen indigenous communities' leaders, members, energy managers, economic development officers, representatives of indigenous organizations, and federal government employees during the following public and thematic events: the Toronto Remote

Microgrids Conference (2013), the Northern Ontario First Nations Environmental Conference (NOFNEC) (2014), the Rise of the Fourth World Conference (2014), and the Energy Council of Canada Energy Summit (2015), and various Waterloo Institute for Social Innovation and Resilience (WISIR) workshops that included the participation of indigenous leaders at the University of Waterloo.

Finally, during a third phase (September 2016 to July 2018) data was analyzed using the techniques detailed in Chapters 5, 6 and 7, while manuscripts were written and submitted between February 2017 and July 2018.

3.6 Researcher's position

Besides the research problem, additional factors that affect the choice of research approach are associated with the personal experiences of the researcher, the audience, and the advisors' views (Creswell, 2014; Brown & Tandon, 1983). Moreover, both the researcher's and the research participants' identities influence the research process (Bourke, 2014). The concept of positionality includes the researcher's personal attributes (race, nationality and gender), and his or her personal life and experiences, philosophical and theoretical beliefs, perspectives, and cultural background, which are expected to influence (to different extents) the research design and methods used, including data acquisition (Chiseri-Strater, 1996; Bourke, 2014). In this sense, positionality would refer to the position of the researcher in relation to the research problem, the participants and the research process itself.

I entered into this research, involving the introduction of RETs in remote indigenous communities in Canada, with limited knowledge of Canadian history and historical treaties, acquired only through my high school history education and personal interest in indigenous peoples. During the research process, I improved my understanding of the continuous effort of indigenous people for self-governance by reviewing documents about Canadian history, treaties, indigenous governance and aboriginal rights and title. Furthermore, as (originally) a non-Canadian, I consider that my relation to indigenous participants and my research approach is not influenced by a "settler society" mentality or "guilt" for injustices to indigenous people of Canada. However, although my limited contact with indigenous people of Canada through this research would still certainly position me as an “outsider”, I found myself sometimes sharing their perspectives on resisting westernized economic development approaches to preserve traditional practices and cultures.

Accordingly, throughout my research and during my visits to a remote indigenous community and through conversations with indigenous people I have used a reflexive approach, constantly thinking about the way I think, where I am, and how I interpret things, and have remained critical of my position as an educated, middle class, white male, trained in engineering and business, and the way that these attributes affect my research approach. Throughout the process I aimed at understanding and reflecting on both indigenous and non-indigenous governance perspectives and viewing the introduction of renewable electricity systems through a sociotechnical lens rather than an engineering lens that “focuses too much on reducing unsustainability through optimization, thereby (unwillingly) adding to the lock-in of societal systems” (Loorbach, Frantzeskaki, & Avelino, 2017, p. 602).

3.7 Limitations of the study

Besides the limitations of the process tracing methodology described in section 3.1, additional limitations are associated with the choice of the theoretical frameworks and the quantity/quality of the data collected. First, the MLP is a middle range theory and its explanatory strength is that of a “heuristic” device that “guides the analyst’s attention to relevant questions and problems” and “helps the analyst ‘see’ interesting patterns and mechanisms” and “identify the relevant variables ….to develop conclusions tailored to a particular industry or company” (Geels, 2011, p. 34). Furthermore, the MLP, as a process theory, produces narrative explanation that captures complex interactions and explains outcomes in terms of event sequences (Grin et al., 2010, Geels, 2011). In a similar way, the TIS framework is unable to capture all potential interactions influencing a TIS, such as interactions between multiple technologies in the form of competing TIS or political strategies (Markard et al., 2015).

As a result, the narrative causality, defined through the “morphogenetic cycles” in the MLP or “motors of innovation” in the TIS (Grin et al., 2010, p.99; Suurs & Hekkert, 2009), is probabilistic. The MLP and TIS capture broader landscape level changes that influence the transition and provide information on the important actors and rules of the game, actors’ resources, interests, motivations, available alternatives and possibilities for action, as well as interactions between actors and the impacts of their strategies. Both the MLP and TIS analysis may specify the general form of the transition but the specific transition patterns are subject to local events and consequences, as actors may, or may not, take advantage of opportunities, change, or modify their strategies, which, in turn, may lead to new forms of interactions and may generate an alternative sequence of events.

Second, the quantity and quality of data necessary for the structure of indigenous electrical systems and the event analysis are important. Data on remote communities' electrical systems were limited, and there is limited academic research capturing indigenous peoples' perspectives on new off-grid renewable electricity generation. In addition, most information on the future of electrical systems is based on governmental and utilities documents, which include perspectives of current electricity generation regimes, including the perspectives of Band Councils, which may not be representative of all indigenous people within a community. Furthermore, financial and time constraints of the study allowed visits and interviews with key informants in one northern Ontario remote community. Community members within each community may have different opinions on electricity generation and integration of renewable options; some may favor local generation, others would see benefits in a transmission connection to local grids, and others may oppose both grid expansions and new off-grid renewable electricity generation that may potentially impact traditional activities. Moreover, perspectives of indigenous and non-indigenous authors on indigenous governance structures are not representative of all indigenous people; some are in favor of development (see for example Slowey, 2008), while others may oppose any development seen to impact traditional activities (Alfred, 2005; 2009), or others may favour a "midway" solution involving community based social entrepreneurial forms (Atleo, 2008).

Chapter 4: Electrical systems in remote indigenous communities in Canada

Chapter 4 summarizes the research results on the electrical systems of 133 Canadian remote diesel power communities and aims at improving understanding of the complexity associated with the introduction of RETs in remote indigenous communities. Analytical results are presented in Appendices A and B and include community population, power plant size and electricity generation output, diesel consumption, carbon emissions, electricity costs and subsidies, alternatives to diesel generation and utilities future electricity generation plans, and RET projects installed, as well as federal and provincial/territorial targets, policies, and programs supporting their deployment between 1980 and 2016.

4.1 Electricity generation in Canadian remote indigenous communities

Electrification of the remote communities began in the 1960s and 1970s, following arrangements with the federal and provincial governments (OEB, 2008). During this time the energy systems of the provinces and territories were developed with hydroelectricity and diesel as the main methods for electrification, and provincial utilities were formed through acquisition of private electricity generation assets and the development of new large-scale hydroelectricity projects.

In British Columbia, BC Hydro was formed in 1962 and by 1984 owned approximately 10,700 MW of hydroelectricity and 1,000 MW of diesel capacity (OPC, 2010). In Northwest Territories (NWT), Nunavut and Yukon, the Northwest Territories Power Commission (later Northern Canada Power Commission (NCPC)) was established by the federal government in 1948 to provide electricity to the developing mining sector; between 1950 and 1984 NCPC expanded the current hydroelectric projects in Yukon and NWT creating local grids and providing electricity through hydro and diesel to the territories' remote communities. In 1987 NCPC transferred its assets to the Yukon Government (its newly formed Yukon Energy), and to the government owned Northwest Territories Power Corporation (NTPC). In 2001, following the Creation of Nunavut in 1999, assets were transferred to the Government of Nunavut's Nunavut Power Corporation (NTPC, 2016a). In

Ontario, electrification of remote indigenous communities began in the 1960s by Ontario Hydro following electrification agreements with the federal and provincial governments. After 1998 electricity was provided under the new Electricity Act by Hydro One Remote Communities Inc (HORCI), a daughter company of Hydro One (OEB, 2008). In Quebec, between 1944 and 1971 the Quebec Hydro-Electric Commission (later Hydro-Quebec) acquired private and cooperative existing hydroelectric stations, added 6,200 MW new hydroelectric capacity, and in 1971 initiated the construction of the La Grande hydroelectric projects (Hydro Quebec, 2016a). Finally, in Newfoundland and Labrador (NFL), the Newfoundland Power Commission (NPC) (after 2007 named Newfoundland and Labrador Hydro (NLH), a subsidiary of Nalcor Energy) was established by the government in 1954 to extend electrification within the province to rural areas, build transmission lines and install diesel plants in remote communities (Baker , 1990; PA-Hatch , 2015).

Electricity generation in Canada is highly fragmented. According to s. 92, 92A of the Constitution Act (1867) and s.109 of the Constitution Act (1982) electricity generation is under provincial/territorial jurisdiction, and provincial governments are responsible for the development and regulation of energy projects within their borders (Valentine, 2010). This fragmentation results in both a lack of provincial interconnections that could take advantage of the abundance of hydroelectricity resources in some provinces, and the lack of unified policy towards electricity grid integration and collaboration to take advantage of RET potential in different areas (Liming, Haque, & Barg, 2008). In the case of remote indigenous communities, responsibility for communities' electricity systems is divided between the federal government, which is responsible for the capital cost of electricity systems' upgrades, and provincial governments and utilities, which are responsible for providing electricity at a reasonable cost and for the operation and maintenance of community power plants (OEB, 2008). With most of the federal funding being devolved to aboriginal communities, this division creates friction between local band councils and utilities regarding future electricity system upgrades (NAN-HORCI, March 2013).

Diesel-generated electricity is the main source of electricity for 144 of the 171 remote indigenous communities, with the remaining powered by hydroelectricity plants and backed-up by diesel generators. Diesel power plants offer a number of operational advantages in the environment of remote communities, such as simple design and layout of facilities, mature technology and reduced number of operating staff, low initial capital costs, short purchasing and installation time period, and reliable operation for 20-25 years (Edwards & Negnevitsky, 2008; Usher, Jean, & Howell, 1994; ICF, 2015). The disadvantages of diesel powered electricity are the high consumption and cost of fuel, which can be more than ten times the initial capital cost within a year, poor quality services, increased production of CO_2 emissions, which may affect the health of the local population, and spills and leakages from the fuel storage facilities (AANDC, 2012b). Load restrictions posed by utilities limit new housing and business connections, and communities' potential for successful participation in resource projects (KLFN, 2013). Additionally, increased current and anticipated fuel prices in combination with high (mostly air) transport costs, lead to high electricity costs influencing local government expenses and cost of food (NWT, 2011).

Available data on 133 out of the 144 diesel powered aboriginal remote communities (5 in Yukon, 25 in NWT, 25 in Nunavut, 23 in BC, 25 in Ontario, 14 in Quebec, and 16 in NFL), indicate a population of approximately 90,000, of which 36,000 are in 25 communities in Nunavut (Table 6). Population in these communities ranges from as low as 13 people of the Gwawaenuk Tribe in British Columbia to over 7,500 people in Iqaluit, with most of the communities in NWT, Ontario, Quebec and NFL having a population between 300 and 1,200. Depending on location, communities are accessed by all-weather road networks or winter roads available during the period of mid-January to late March and remote airports, while a few can be accessed by barge.

Table 6: Population, electricity capacity, generation and emissions in diesel powered remote aboriginal communities

Province/ Territory	**Number of commu-nities**	**Population (Year)**	**Generation Capacity**		**Electricity Generated**		**Fuels**	**Emissions**
			MW	**Year**	**MWh**	**Year**	**lit/year**	**tonnes/year $CO_{2,eq}$**
Yukon	5	2,009 *	8.5	2012	21,263	2012	5,970,000	17,000
NWT	25	13, 788 *	40.9	2013	83,884	2013	23,300,000	67,000
Nunavut	25	36,556 *	54.0	2013	174,000	2013	48,000,000	116,000
BC	23	5,586 **	41.0	2011a	67,500	2011a	18,750,000 b	50,250 d
Ontario	25	14,900 **	22.8	2011a	78,960	2011a	23,950,000 c	64,200 d
Quebec	14	12,090 **	24.3	2000[1]	85,500	2013 [2]	23,700,000 b	63,500d
NFL	16	5,719 **	15.6	2011a	28,148	2011a	7,900,000 b	21,200 d
TOTAL	**133**	**90,648**	**207.1**		**539,255**		**151,570,000**	**399,150**

* Population in 2014, ** population in 2011, [1] Hydro Quebec (2002, p.11), [2] GQ (2014, p.16).

a: according to AANDC and NRCan (2011); b: estimated, based on an average efficiency of 1 lit diesel=3.6 kWh; c: estimated, based on HORCI (2012) data and OEB (2008); d: estimated, based on average emissions 2.88 kg $CO_{2,eq}$/ lit diesel

Source: Statistics Canada (2011); AANDC and NRCan (2011); Karanasios & Parker (2016a-g).

Systems in 112 communities are operated by provincial owned utilities operating at arm's length from provincial and territorial governments under provincial budgeting and regulations, while the remaining 21 communities own and operate their own systems as Independent Power Authorities (IPAs) (10 in Ontario, 10 in British Columbia and one in Newfoundland and Labrador). Utilities' size, generation and distribution assets, and business structure differ between provinces and territories (Yukon Energy, 2012a; NT Energy, 2013; QEC, 2013; OPA, 2014; BC Hydro, 2015b; COGUA, 2016). The size of communities' power systems varies between 20 kW in small communities to 15,000 kW in Iqaluit, Nunavut. There are 23 systems with a capacity below 500 kW, and 36 systems with a capacity above 1,500 kW, while more than half of the electricity systems in remote communities (71 out of 132 systems[4]) range between 500 kW and 1,500 kW. Based on available data, the installed capacity of the 133 remote electricity systems is approximately 207 MW, with an estimated[5] electricity generation of 547,000 MWh for 2013, and an estimated average electricity consumption of approximately 6,000 kWh/capita per year. In 2013 the 133 remote aboriginal communities were responsible for the consumption of approximately 151 million liters of diesel and direct emissions of 400,000 tonnes of $CO_{2,\ eq}$, while additional indirect emissions caused by the transportation of diesel to remote communities represent almost 70% of direct emissions in the case of fly-in communities (see HORCI (2012)).

Electricity generation costs in remote indigenous communities consist of a fuel cost and an administrative and operational component (Hydro One, 2012) and is influenced by utilities' economies of scale, location and access to markets. Costs differ among provinces and territories and among communities within the same province or territory, ranging from 26 c/kWh to as high as 215 c/kWh in Yukon (Table 7) in comparison to 5-18 c/kWh in southern Canada (IESO, 2016; Hydro Quebec, 2016b; BC Hydro, 2015b).

These high electricity costs are subsidized through the creation of special rates and the allocation of cross-subsidies. Rate design takes into consideration cost categories (residential, governmental and commercial buildings, and street lighting), and cost differentiations due to location, access (road or air access), and electricity generation sources (hydroelectricity or thermal generation).

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[4] The communities of Destruction Bay and Burwash Landing in Yukon share the same power plant.

[5] The 2013 electricity generation, fuel consumption, and $CO_{2,\ eq}$ emissions are estimated using the 2011 and 2012 available data and an average annual electricity generation increase of 2%.

Such subsidies are justified through arguments promoting energy affordability, poverty reduction, enhanced security and energy supply, and economic growth (IEA, 2010). Lower rates for residential consumers in remote aboriginal communities are supported by direct governmental subsidies from Indigenous and Northern Affairs Canada (INAC)[6], cross subsidies in the form of higher rates (at the full electricity cost) for provincial and federal governmental customers operating within remote aboriginal communities, and financial transfers from provincial ratepayers through funding mechanisms supporting rural and remote electrification (OPA, 2014; SNC Lavalin, 2007). Direct electricity subsidies for residential customers in remote communities, ranged from $3.5 million in 2015-2016 in Yukon (GY, 2015a), to $34 million in 2015 in British Columbia (BC Hydro, 2015b), approximately $ 34 million in 2013 for Rural or Remote Rate Protection (RRRP) contributions in Ontario (Hydro One, 2012), and $30 million in 2012-2013 in Nunavut (GN, 2015a).

Table 7: Cost of electricity generation in remote aboriginal communities

Province/ Territory	Cost of electricity generation
Yukon	2009: Diesel electricity cost between 26.4 c/kWh and 57.3 c/kWh (for Old Crow) (Osler, 2011). 2012: Diesel electricity cost between 97 c/kWh and 215 c/kWh (Cherniak, Dufresne, Keyte, Mallett, & Scott, 2015).
NWT	2008-2009: An average cost of 64.9 c/kWh in 2007/2008 fiscal year (GNWT, 2008b; GNWT, 2009a; GNWT, 2009b). 2015: Cost of electricity for 2015 is between 58 c/kWh and 70 c/kWh (Cherniak et al., 2015). 2016: Cost of electricity for 2016 is between 21 c/kWh and 60.83 c/kWh (NTPC, 2016d).
Nunavut	2012-2013: Cost of electricity for 2012-2013 is between 50 c/kWh and 101 c/kWh (Cherniak et al., 2015).
BC	No data available.
Ontario	2014: For HORCI communities, equals the Standard A rate of 94.17 c/kWh (Hydro One, 2013). No data available for IPA communities, but is assumed 2-3% higher than the cost in HORCI communities (OPA, 2014).
Quebec	2013: Diesel electricity cost between 65 c/kWh and 132.4 c/kWh (GQ, 2014; Cherniak et al., 2015).
NFL	No data available.

Electricity consumption has increased in all remote communities due to population growth, an increase in homes and community buildings, and changes in household electricity use. For example, the electricity consumption in HORCI's serviced northern Ontario remote communities increased by an average of 4.2% per year from approximately 24,500 MWh in 1990 to

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[6] Former ministry of Aboriginal Affairs and Northern Development (AANDC). The name was changed to Indigenous and Northern Affairs Canada (INAC) in 2015.

approximately 59,000 MWh in 2011, while the per capita electricity consumption doubled from 2,800 kWh/capita in 1991 to 5,800 kWh/capita in 2011 (HORCI, 2012). This continuous increase in electricity demand has been addressed mainly through diesel generator upgrades. Further non-industrial electricity load growth ranging from 0.5% to 3.9 % is forecast for all remote aboriginal communities (Table 8), thereby raising concerns for governments, utilities and aboriginal communities over the continued high dependence on diesel-generated electricity.

Table 8: Forecast non-industrial electricity demand growth in remote communities

Province/ Territory	**Forecasted non-industrial electricity demand growth in remote communities**	**Source**
Yukon	0.5 % annually until 2030	Yukon Energy (2012a)
NWT	2.26 % annually	NT Energy (2013)
Nunavut	3-4% annually, significant growth is expected in Cambridge Bay due to the creation of the Canadian High Arctic Research Station (CHARS) campus	QEC (2015a)
BC	2% over the next 5 years, 1.2% over the next 11 years, 0.7% over the next 21 years	BC Hydro (2012b)
Ontario	3.9 % annually between 2013 and 2053	OPA (2014)
Quebec	2-4 % annually between 2005 and 2024	Hydro Quebec (2003)
NFL	3.4 % annually since 2007	PA-Hatch (2015)

4.2 Alternatives to diesel-generated electricity in remote indigenous communities

The main alternatives to address future industrial and residential electricity demand growth include connection to provincial interconnected or local grids, conservation initiatives and the use of alternative fuels, and the introduction of RETs into communities' systems (Table 9).

Table 9: Future provincial and territorial power requirements and resource alternatives

Province/ Territory	**Future power requirements**	**Alternatives to address future load growth**	**Source**
Yukon	-Increase of non-industrial loads -Diesel load is forecasted to increase from off-grid mines	-Short term, enhancements of current hydroelectric facilities. -Long term, development of new hydroelectric projects. -Development of Demand/Supply Side Management (DSM/SSE) programs. -RETs: solar applications. -Natural gas developments. -Connection to the Alaska Highway Pipeline. -Extending the current grid and connect to the BC or Alaska electrical grid.	Yukon Energy (2012a; 2012b)
NWT	-Residential load increase -Commercial and industrial load increases	-Development of medium (on the 10 MW scale) hydroelectric projects, such as the La Martre Falls, Snare Site 7, and the Taltson Expansion.	NT Energy (2013)

	due to mining and oil exploration	-RETS: solar, wind, biomass. -Diesel and liquefied natural gas (LNG) development. -Expansion of the hydroelectricity-based transmission system to connect the remote communities and mines to the provincial grid. -Interconnection of the NWT transmission system with one or more of the Saskatchewan, Alberta or British Columbia provincial grids.	BC Hydro (2013f)
Nunavut	-Residential load increase (new housing building) -Load increase due to territorial and federal government driven major projects -Load increase due to exploration activities in the mining sector	-Replacement and updates of QEC diesel plants, since 17 out of 25 facilities have reached the end of their designed service life. -Infrastructure investments in hydroelectricity projects to power Nunavut's potential mining operations, while at the same time reducing diesel consumption. -The connection of five Nunavut's Kivalliq region communities (Arviat, Whale Cove, Rankin Inlet, Chesterfield Inlet and Baker Lake) to Manitoba's electrical grid.	Senate Canada, (2014a); Murray (2015); Bell (2015); Senate Canada (2014b); QEC (2015a)
BC	-Load increase due to population growth and residential demand -Increase in commercial and industrial loads due to economic activity, mining and liquefied natural gas developments	-Conservation measures. -Supply from major hydroelectricity projects (such as the Site C on the Peace river). -RET supply from biomass, run-of-river hydro and wind projects developed in cooperation with Independent Power Producers (IPP).	BC Hydro, (2013a); BC Hydro (2013b); WEL (2009)
Ontario	-Load increase form population growth and residential demand -Future mining projects in remote communities	-Conservation measures introduced by HORCI. -RET projects development for the supply of clean electricity. -Connection to the provincial grid.	OME (2013); OPA (2014)
Quebec	-Load increase from population growth and residential demand -Future mining projects in remote communities	-RET projects development for the supply of clean electricity. -Connection to the provincial grid.	GQ (2006a); NRBHSS, (2013); NRBHSS, (2014); KRG (2012)
NFL	-New industrial demand	-Interconnection to Labrador via a High-Voltage direct current link bringing power from the Muskrat Falls hydroelectric generating station as the least-cost option. -Renewal of aging infrastructure and upgrades for the integration of Muskrat Falls energy. -Energy conservation. -RETs including solar, wind and mini-hydroelectric facilities for remote Labrador communities, and advancement of the Ramea Wind-Hydrogen-Diesel energy research and development project.	NE (2014)

4.2.1 Grid extensions

The extension of national or local grids for the connection of most remote communities and interconnection to other electrical grids is the main option examined by provinces and territories to address future residential and commercial/industrial sector electricity demand, due to low price affordability, potential for clean hydroelectricity generation and export of local generated renewable electricity (Table 9) (GY, 2009a; NT Energy, 2013; GQ, 2006a; Rogers, 2015; Cherniak et al., 2015). Yukon is considering the interconnection to Alaska and BC grids (Yukon Energy, 2012a; 2012b), and NWT is examining the expansion and interconnection of its two hydroelectricity grids and, finally, the connection to the Alberta, BC or Saskatchewan interconnected provincial grids (BC Hydro, 2013f). In Nunavut, the Kivalliq region communities (Arviat, Whale Cove, Rankin Inlet, Chesterfield Inlet and Baker Lake) have investigated a connection to the Manitoba hydroelectric grid (Rogers, 2015). Ontario is currently considering the connection of 21 out of 25 remote communities (OME, 2013; OPA, 2014), with 22 aboriginal communities participating in the creation of the transmission line (WP, 2012; WP, 2013a). Finally, in Quebec the connection of the 14 Nunavik communities to the provincial grid is being examined as an alternative for regional hydroelectricity generation powering resource development in the area (GQ, 2006a; KRG, 2012).

Governments, industry and indigenous communities anticipate an increase in natural resources exploitation in Canada’s remote areas (TCM, 2014; Eyford, 2013; NRCan, 2013b; NRCan, 2014; Rheaume & Caron-Vuatari, 2013). Mining and oil and gas projects are being considered in Yukon (YEC, 2015; Yukon Energy, 2012a), and NWT (NT Energy, 2013). In British Columbia increased mining and natural gas activity is expected in northwest British Columbia (MABC, 2008; STAC, 2011), while in Ontario and Quebec mining projects include the development of chromite deposits in the Ring of Fire area (Dadgostar, Garofalo, Gradojevic, Lento, & Peterson , 2012; TB-CEDC, 2013), and expansion of the Raglan mine and new developments in Nunavik (KRG, 2012). Potential future developments include more than 600 resource projects planned for the next 10 years with a total value of more than $650 billion (Eyford, 2013; Bains, 2013; NRCan, 2014). Many projects are to be located within 100 km of aboriginal communities, while 110 out of 111 projects currently under review involve aboriginal rights or interests (Bains, 2013; Rheaume & Caron-Vuatari, 2013; NRCan, 2013b).

However, resource development in the north is shaped, besides investor expectations of financial gains, by the continuous change in institutional relationships between indigenous people and resource exploitation (TCM, 2014), which in turn are influenced by changes in the legislation supporting indigenous rights (Isaac & Knox, 2005; Morellato, 2008; AFN, 2011a; BC-AFN, 2009).

Indigenous people anticipate long term opportunities for indigenous communities through participation in transmission connection infrastructure, ownership of renewable electricity generation assets (mainly hydroelectricity), supply of electricity to power natural resource projects, and Impact Benefit Agreements (IBAs) from the development of natural resources within traditional territories to maximize revenue and employment benefits and create sustainable regional economies (see for example NAN, 2012; KRG, 2012; OEB, 2008).

Examples of past combined resources and electricity infrastructure development projects impacting remote aboriginal communities include (a) the connection of Fort Albany, Kashechewan, and Attawapiskat to Ontario's electrical grid between 2001 and 2003 (Five Nations Energy Inc., 2006), (b) the 2008 connection of Minto copper-gold mine to the Yukon hydroelectricity powered electrical grid, which benefitted Little Salmon Carmacks First Nation, Selkirk First Nation and Na-Cho Nyak Dun First Nation along the path of the transmission line (CMC, 2008; Ragsdale, 2010), (c) the development of the Carmacks Stewart Transmission project in 2011, dictated by new demand generated by current and future mining projects, which led to the creation of the Yukon Interconnected System (YIS), and the connection of the community of Pelly Crossing (Yukon Energy, 2012), (d) the development of the Northwest Transmission line in BC in 2014, which provided electricity for eleven potential mining projects from newly constructed hydroelectricity projects in the area, connected the remote communities of Eddontenajon and Telegraph Creek, and led to the generation of over $ 1.8 billion of benefits for the Tahltan First Nation (RWB, 2011; BC Hydro, 2016).

4.2.2 Electricity conservation initiatives

Grid extension is considered a long-term option and unable to address short term electricity needs of remote communities. Electricity conservation initiatives to reduce diesel consumption and emissions, took the form of technological upgrades and demand side management (DSM) programs implemented after 1995 in Yukon, British Columbia and Ontario (HORCI, 2012; Yukon Energy, 2011; Yukon Energy, 2012a). However, conservation is not prioritized by some remote communities' consumers, since reductions in electricity use are rewarded with electricity bill increases when utilities aim at recovering electricity generation costs, formed by both fuel costs and fixed costs, from the existing customer base, leading to higher rates (GNWT, 2009a).

4.2.3 Introduction of alternative fuels

Alternative fuels have been used in Ontario, with biodiesel replacing diesel and leading to lower GHG emissions (HORCI, 2012), and natural gas use in the communities of Norman Wells and Inuvik (NT Energy, 2013). Both Yukon and NWT examined the use of local natural gas production to power remote communities (GNWT, 2011a; PRN, 2013; Yukon Energy, 2012a; 2012b).

4.2.4 The introduction of RETs into community electrical systems

Aboriginal driven electricity generation to achieve reliability (protection from diesel fuel price volatility, security of supply, and low electricity prices) and sustainability (environmental and economic development) goals can be achieved to different extents through the deployment of small hydro, wind, and solar technologies in remote communities, depending on long term and short term community electricity needs, availability of natural and financial resources, project deployment costs and electricity generation costs.

4.2.4.1 Small hydroelectricity

Small hydroelectricity projects are the best electricity generation option for achieving reliability and sustainability goals. Hydroelectricity projects are able to displace diesel completely and eliminate diesel related carbon emissions; they offer security of supply, due to the lack of intermittency, and despite higher capital costs they usually provide lower electricity costs than diesel, wind and solar applications (see Hatch, 2013; NFL Hydro, 2009). Successful examples of complete diesel displacement are the communities of Atlin (Taku Tlingit FN) (Kirby, 2009) and Kitasoo FN (GEA, 2016), while Deer Lake FN displaces a significant amount of diesel based on a hybrid hydro-diesel system (HORCI, 2012).

Although hydroelectricity may displace diesel and maximize community benefits, hydroelectricity resources are not always available in the proximity of remote communities. In addition, hydroelectricity projects have longer implementation timeframes than wind and solar applications. Solar applications, although still expensive, offer the advantage of faster deployment, easy siting, higher predictability than wind, decreasing solar panel prices, ease of maintenance, and simple installation, and, in combination with wind and storage applications, may lead to environmental and socioeconomic benefits for communities (Das & Canizares, 2016).

4.2.4.2 Wind and solar applications

Wind, solar, or a combination of both technologies, have the potential to displace diesel based on the level of renewable resource penetration: low penetration projects could displace up to 15% of diesel consumption, and high penetration systems could reduce up to 90%, under high wind resources availability (Fay, et al., 2010a; 2010b; Baring-Gould & Dabo, 2009).

However, one of the main technical issues increasing the technical complexity of introducing RETs in remote communities is associated with the levels of renewable energy penetration from intermittent resources. Using the case of a wind turbine project, *instantaneous penetration* would be defined as the Wind Turbine Power Output (kW) divided by the Primary Electrical Load (kW), and *average penetration* would be defined as the Total Wind Turbine Energy Output (kWh) divided by the total Primary Electrical Load (kWh) over a given time period, typically a month or year. Based on the definitions, three penetrations classes are distinguished (Table 10), namely low, medium and high penetration levels (Baring-Gould & Dabo, 2009; Fay, Keith, & Schwoerer, 2010; Ibrahim, Younes, Ilinca, Dimitrova, & Perron, 2010).

Table 10: Penetration classes based on instantaneous penetration and average penetration

Penetration Class	Operating Characteristics	Penetration level	
		Peak Instantaneous	Annual Average
Low	Diesel(s) run full time Wind power reduces net load on diesel All wind energy goes to primary load No supervisory control system	< 50%	< 20%
Medium	Diesel(s) run full time At high wind power levels, secondary loads dispatched to ensure sufficient diesel loading or wind generation are curtailed Requires relatively simple control system	50%-100%	20%-50%
High	Diesel(s) may be shut down during high wind availability Auxiliary components required to regulate voltage and frequency Requires sophisticated control system	100%-400%	50%-150%

Source: Baring-Gould & Corbus (2007, p. 4)

In the case of hybrid systems with low instantaneous wind penetration, there is limited need for system controls, since system control is provided by devices integrated into the diesel generator hardware. When instantaneous penetration levels increase additional control must be put in place to maximize system performance and stability. In the case of medium penetration systems with renewable energy contributing significantly for certain periods, some diesel generators must be turned off, or a smaller unit must be switched on, causing power imbalances. Finally, in the case of high penetration systems diesel engines are to be shut down, since the intermittent resources provide a large amount of the load, therefore the diesel engines are unable to control frequency, voltage, and reactive power. In this case, use of additional control systems in the form of synchronous condensers, dispatchable loads, and storage, in the form of batteries or flywheel systems, are to be introduced to ensure energy and power balance (Baring-Gould & Dabo, 2009; Mc Gowan, Manwell, & Connors, 1988) .

In the case of medium to high penetration systems, short term energy and power balance (balancing supply and demand) can be done by controlling energy supply, demand and storage. The microgrid central controller assumes the role of controlling the actions of all microgrid components, which provide real power or absorb the instantaneous real power difference between generation and loads (in the case of excess power generated), and provide or absorb the reactive power, while controlling local voltage and frequency (Kroposki, et al., 2008). Power balance can be achieved through dump loads (e.g. power is used to provide domestic hot water heating), which have to be integrated for protection in the case of excess power generation. Energy storage is another way used for balancing the difference between excess electricity generation caused by the intermittency of renewable sources and fluctuating demand: electricity can be stored during excess generation and released when demanded (Nigim, Ahmed, Reiser, Ramani, & Mousa, 2010). Storage technologies consist of batteries, hydrogen fuel storage (HFS), super capacitors (SCES), flywheels, superconducting magnetic energy storage (SMES), compressed air energy systems (CAES) and pumped storage (Diaz-Gonzalez, Sumper, Gomis-Bellmunt, & Villafáfila-Robles, 2012). Another option for balancing supply and demand and reducing total energy demand is the manipulation of demand through Demand Side Management (DSM), using techniques such as peak clipping, conservation and load shifting (Rae & Bradley, 2012).

Higher penetration wind, or solar applications, or a combination of both, represent high cost alternatives that may offer low cost electricity, depending on the availability of wind and solar resources (Fay, Keith, & Schwörer, 2010b; Maissan, 2006b; Das & Canizares, 2016). High wind or solar penetration options can achieve significant carbon reductions, although these solutions necessitate higher capital costs, higher subsidies in the form of capital requirements and generation incentives and are associated with higher operational risks. Finally, revenue generation, or reducing outflow of cash for the communities, and community employment are best accomplished through hydroelectricity projects, backed by larger lifespans of generation incentives (40 years) and favorable power purchase agreements (PPAs) (AECOM, 2012; Kirby, 2009), while only limited employment opportunities are expected from high penetration wind-diesel applications (Fay, Keith, & Schwörer, 2010a). In some cases, hydroelectricity projects have higher capacities that allow for increased community self-sufficiency, the potential for exporting excess electricity, as in the case of the Atlin project (Morrin, 2016; Kirby, 2009). Alternatively, the additional capacity could support local manufacturing, as in the case of the Kitasoo project that powers the community owned seafood production plant and employs most of the community (Sisco & Stewart, 2009).

In the case of remote aboriginal communities, lower penetration systems are associated with lower capital costs, simplicity of operations and lower operational costs, and consequently low overall project risks. Higher penetration levels necessitate higher levels of system integration, increased technological complexity and advanced controls, increasing project costs and require the employment of qualified operators, who may be difficult to attract and retain in remote locations

(Fay, Keith, & Schwoerer, 2010a). The higher costs of high renewable energy penetration levels have to be compared to reduced fuel consumption, reduced diesel operation time, reduced fuel storage and handling, as well as possible financial gains from carbon offsets, while non-monetary environmental benefits, employment opportunities, or issues of energy self-reliance could also be considered in microgrid related decision making (Weis & Ilinca, 2010; Rolland & Glania, 2011).

A considerable number of RETs projects in the form of wind, solar and small hydro has been installed in aboriginal remote and grid connected communities during the last years. A list of RETs projects in remote aboriginal communities is presented in Appendix C. There are limited empirical results on the performance of installed RETs in remote aboriginal communities. Low penetration hybrid wind-diesel systems installed in the communities during the 1987-2000 period experienced mechanical failures, high servicing and maintenance costs and poor performance, resulting in failures by 2006 (Weis and Ilinca, 2008), while existing assets exhibit poor performance[7] (HORCI, 2012). However, it should be noted that although the results on the efficiency of wind diesel systems integrated in remote communities' microgrids are not encouraging, each microgrid has unique characteristics and hybrid system design should be adjusted accordingly.

4.3 Renewable electricity policies, targets and programs

Decision on the introduction of RETs into remote indigenous communities' electrical systems are also influenced by policy support. Early policy objectives evolved from oil and fossil fuel substitution targets in the late 1970s to energy self-reliance, security of energy supply, energy diversity, and, more recently, sustainable development and climate change (Gingras & Dalp, 1993; Pneumatikos, 2003). RET policy was influenced by residential and industrial demand growth, availability of renewable resources, financial capacity, the changing structure of the electricity industry and the increasing role of the private sector in the generation, transmission and distribution of electricity, and the interests of market players, such as investors, bankers, project developers and indigenous people (NRCan, 2016a; PA-Hatch , 2015; WEL, 2009; Enzenberger, Wietschel, &

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[7] The three 10 KW wind turbines in Kasabonika Lake First Nation remote community generated 11,730 kWh for 2011, displacing approximately 3,300 liters diesel from a total of 1,126,943 liters of diesel consumed in the community (or 0.3% of total community's fuel consumption) and reducing CO_2 emissions by 8.5 tonnes (HORCI, 2012).

Rentz, 2002; Yi & Feiock, 2014). Thus, RET support policies differentiated between provinces and territories, and took the form of renewable electricity targets, supply push approaches in the form of feed-in tariffs, as well as demand-pull approaches with different quota models. Furthermore, federal programs and provincial targets and programs supporting RET deployment differentiated in terms of technologies, project scale, indigenous participation and focus on diesel substitution.

In the case of BC, Ontario, Quebec and NFL, provincial targets focused on large-scale expansion of renewable electricity, mainly through hydroelectricity and wind. In Yukon and NWT, new hydroelectricity generation and extension of local grids, due to the lack of connection to the North-American interconnected grid, were the primary aims. Conservation and alternative energy were mentioned as energy-related targets in Nunavut's Ikummatiit strategy, but no specific technologies were identified. Targets and programs also differed between provinces in terms of private sector and indigenous participation. In British Columbia, future electricity production (mostly hydroelectricity and wind) is being developed by private proponents (including communities) (WEL, 2009), while indigenous communities are supported by revenue sharing agreements, specific programs for capacity building, and equity funding through the First Nations Clean Energy Business Fund (FNCEBF) (GBC, 2016). Quebec's targets for hydroelectricity and wind expansion included requests for proposals designated specifically for First Nations (GQ, 2006b). In Ontario, private proponents' involvement in generation, transmission and conservation projects was promoted through a feed-in tariff (FIT) mechanism, which included additional selection points for projects which included First Nation and Metis partners. These programs led to indigenous participation in approximately 240 projects with over 1,000 MW of clean electricity capacity connected to the main grid (OME, 2013).

However, specific targets promoting RETs for diesel substitution in remote communities were developed only in NWT and Yukon. In NWT, policies aimed at supplying up to 20% of the average load of the 25 diesel powered communities through solar photovoltaic applications and displacing 10% of annual diesel-generated electricity (GNWT, 2012b). In Yukon, recent policies target a 20% increase in renewable energy supply (Yukon Government, 2015).

4.4 Concluding remarks

The goal of this chapter was to improve understanding of the contextual and technical complexity of the introduction of RETs into remote indigenous communities' electrical systems. Alternatives to diesel-generated electricity are expected to address utilities and indigenous communities' concerns over diesel dependency, rates affordability, reliability of supply, as well as the desire to increase self-sufficiency by reducing diesel consumption (GNWT, 2009a; Yukon Energy, 2012a). Furthermore, diesel displacement in remote communities could contribute to Canada's recent commitments towards GHG emissions reductions and reduce provincial and federal governments' subsidies for the operation of remote diesel systems (GC, 2016; DSF, 2012; OPA, 2014).

However, decisions on the future design of indigenous electrical systems are influenced by natural resources development and the availability and integration of large-scale provincial and territorial renewable hydroelectricity resources into provincial electricity generation systems and the potential connection of remote communities with provincial grids. Communities in the proximity of future natural resources development expect multiple benefits from transmission connections that could eliminate carbon emissions and improve both electricity supply availability and price affordability.

Decisions on the introduction of small-scale RETs into communities' electrical systems are influenced by the size of communities' power plants, availability of renewable resources, high capital costs and the associated technical complexity of the integration of RETs into local systems, electricity cost, rates, and service quality comparisons between diesel generators and intermittent sources, such as wind and solar. Furthermore, the complicated nature of electricity generation funding and rates subsidization influences RET acceptance as it may increase rather than decrease the cost of electricity in the north, while the risky nature of renewable electricity generation may threaten community budgets in the case of community owned project failures, as past practices indicate. As high penetration RET projects lead to higher electricity prices, further rates subsidization would be necessary for utilities revenues to remain at levels able to technically support the generation process and the quality of electricity services.

Furthermore, economies of scale favor the introduction of RET in larger diesel systems powering indigenous communities with larger populations and rich renewable resources, such as hydroelectricity, wind and solar.

Chapter 5: Technical solution or wicked problem?: Diverse perspectives on Indigenous community renewable electricity in Ontario, Canada

The purpose of this chapter is to understand the issues related to the deployment of renewable electricity technologies (RETs) in remote indigenous communities by examining the views of key informants in a remote northern Ontario community through the lens of a wicked problem approach, with the goal to identify policy direction and strategies for the further development of renewable electricity projects. The chapter uses semi-structured interviews with community key informants, informed discussions with community members and energy conference participants, and literature reviews of academic, policy, and utility documents as complementary data sources for triangulation of results.

According to informants, the complexity surrounding the deployment of RETs in remote Canadian indigenous communities is the result of different stakeholder perspectives on the issues that RETs are expected to address. Furthermore, institutional challenges of the electricity generation system, and uncertainty over both the choice of off-grid renewable technology and the future of electricity generation systems structure and governance add to this complexity. Given the government's legal obligation to consult with indigenous peoples for projects within their territories, community perspectives provide insights for policy design to support both the deployment of RET and address indigenous communities' sustainability goals.

5.1 Introduction

Historically, Canadian indigenous communities have relied on mixed economies with incomes supported by employment in resource based businesses, federal financial support and a subsistence component based on hunting and gathering (Usher, et al., 2003; Southcott & Walker, 2009). Recently, however, this economic model is being challenged by an increasingly young population, low educational attainment, health issues, high unemployment, as well as reduced state financial

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assistance (Loppie & Wien, 2009; Wilson & Macdonald, 2010). In order to mitigate socioeconomic, political and cultural impacts arising from these challenges, some indigenous communities aim to achieve self-governance and self-reliance through economic independence based on their lands, resources and the creation of entrepreneurial ventures with indigenous and/or non-indigenous partners (Anderson & Bone, 1995; Anderson, Dana, & Dana , 2006). Such ventures are expected to have minimal impact on the environment, traditional activities, and community way of life, and provide appropriate economic rents, thus contributing to sustainable economic development (Kendal, 2001; Slowey, 2008).

Improving local sustainability could be a complex process, as there is always tension between "sustainability and development, between environmental requirements and sociocultural needs and desires, between needs of the present generation and those of future generations" (Murphy, 2012, p.1). At the same time, indigenous community entrepreneurial ventures emerging out of economic, environmental and community vulnerability, call for innovative solutions (Peredo & Chrisman, 2006) that have to perform within a complex (wicked) environment (Dorado & Ventresca, 2013) characterized by distinct property rights, lands that are subject to claims by indigenous peoples, and multiple economic development barriers (OAG, 2003). In this sense, advancing community sustainability agendas that aim at addressing climate change issues and sustainable development through entrepreneurial ventures, exhibit characteristics similar to those of a "wicked problem". It is constrained by the complexity generated through the engagement of different stakeholders with different perspectives and subject to specific multi-layered institutional environments (Rittel & Webber, 1973).

One sector with potential for the development of indigenous owned ventures is community energy and electricity generation based on renewable resources (AFN, 2011a; BC-AFN, 2009). Motivations for community energy ventures include gaining financial support for community revitalization projects and capacity development, rent seeking, social justice and environmental oversight (Walker, 2008; Wuestenhagen, Wolsink, & Buerer, 2007; Walker, Hunter, Devine-Wright, Evans, & Fay, 2007; Walker & Devine-Wright, 2008). In the case of Canadian on-grid indigenous communities, recent research indicates that participation in large-scale renewable

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electricity generation projects is primarily motivated by the desire for self-sufficiency through the establishment of new revenue streams (Henderson, 2013; INAC, 2004; McLaughlin, McDonald, Nguyen, & Pearce, 2010; Krupa, 2012b; Landers, 2014; Stewart, 2009).

However, participation in renewable electricity technologies (RET) projects (hydroelectricity, wind and solar applications) was limited in the 140 indigenous remote communities in Canada that are powered by diesel plants. Remote off-grid communities are permanent or long term (five years or more) settlements with at least ten dwellings that are not connected to the North American electricity grid or piped natural gas network. In 2011 293 communities in Canada were still considered remote with an approximate population of 198,000 people, 328 MW estimated diesel capacity, 132 MW renewable energy capacity, and an estimated consumption of 230 million liters of diesel per year (AANDC and NRCan, 2011). In 2011, 171 of these communities were indigenous, of which 144 were powered solely by diesel generators (Table 11).

Table 11: Remote communities in Canada

	British Columbia	**Alberta, Saskatchewan Manitoba**	**Ontario**	**Quebec**	**Yukon**	**Northwest Territories**	**Nunavut**	**Newfoundland and Labrador**	**Total**
Remote indigenous communities (2011) (a)	25	5	25	16	25	33	26	16	**171**
Diesel powered indigenous communities	25	5	25	19	5	23	26	16	**144**[8]
Non-indigenous communities (b)	61	5	13	25	1	5	0	12	**122**
Total (a)+(b)	86	10	38	41	26	38	26	28	**293**
Indigenous population	7,619	2,217	14,236	15,452	7,705	22,410	29,453	5,634	**104,726**
Non-indigenous population	16,449	1,436	7,106	19,277	26,192	19,540	0	3,276	**67,420**
Total population[9]	**24,068**	**3,653**	**21,342**	**34,729**	**33.897**	**41,950**	**29,453**	**8,910**	**198.002**

Source: AANDC & NRCan (2011) (modified) and AANDC (2012b).

Research on 133 of the 144 indigenous remote indigenous diesel powered communities indicates that 71 RET projects were deployed in 57 communities in Yukon, NWT, Nunavut, British Columbia, Ontario, Quebec and Newfoundland and Labrador between 1980-2016, or

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[8] Some communities are now connected to provincial or local electrical grids, reducing the number of diesel powered communities to 140. See Appendices 1-7.

[9] Population data are based on 2006 Canadian Census as reported in AANDC & NRCan (2011), except the population of Yukon that was modified based on the 2011 National Household Survey (NHS) (Statistics Canada, 2016b).

approximately 13% of the total installed capacity (Karanasios and Parker, 2016a-g). In comparison, hydroelectricity represented 56% of Canada's total electricity capacity (EMMC, 2013). However, if hydroelectricity projects are excluded, 63 of the 71 projects were small-scale wind and solar applications with a total capacity of approximately 1,660 kW, or less than 1% of total installed capacity.

Contrary to the clarity of motivation for on-grid indigenous renewable electricity generation ventures, the drivers for the introduction of RETs into remote indigenous communities vary. For example, in NWT's and Nunavut's isolated local grids, community members examine the introduction of RETs to reduce high electricity costs (GNWT, 2009a; McDonald & Pearce, 2013), while Ontario's Independent Power Authorities (IPAs), which own electricity systems in ten remote communities in northern Ontario, prioritize local control through rate settings according to community needs, collection methods that support members facing poverty issues, opportunities for local job creation, and a sense of community pride as the main motivations for running their own power systems, despite higher costs and reduced subsidies in comparison to 15 Ontario remote communities serviced Hydro One Remote Communities Inc. (HORCI) (OEB, 2008).

The variety of community motivations and the slow diffusion rates of RETs applications in remote Canadian indigenous communities, despite public policy support (Bailie et al., 2009; Karanasios and Parker, 2016a-g) indicate that the RETs deployment process may represent a "wicked problem". Wicked problems lack a clear definition of challenges to be addressed, are "messy, circular, aggressive and intrinsically complex" (Hunter, 2007, p. 36), and, unlike "tamed" problems which, although technologically complex, are well defined and thus solvable through an established solution methodology (Conklin, 2005; Roberts, 2000), they lack an identifiable solution (Rittel & Webber, 1973). In a recent review of contributions examining modern policy-making challenges through a "wicked problems" approach, Danken et al. (2016) identify insufficient and contested knowledge, the need for building new knowledge due to the uniqueness of the problem, the nesting of the problem within overarching problems, and the existence of value-laden conflict between stakeholders, as the main factors for the lack of definitional clarity in the case of a wicked problem.

Accordingly, the purpose of this study is to advance understanding of the introduction of RETs into remote Canadian indigenous communities' electrical systems by (a) identifying the main stakeholders' perspectives on the challenges of diesel systems and the potential role of RET to address them, and (b) exploring the "wickedness" of the problem. A deeper understanding of the problem and assessment of its wickedness degree in terms of complexity, uncertainty, and divergence of opinions (Head, 2008), may provide policy direction for developing coping strategies (Roberts, 2000; APSC, 2007; Head & Alford, 2015). In the next section, the "wicked problem" approach is examined, followed by the research setting and methodology in section three. Section four presents the results, followed by the discussion in section five and concluding remarks in section six.

5.2 Wicked problems

The concept of "wicked problems" was introduced by Rittel and Weber (1973) to describe social problems that were difficult to define in terms of causal relationships surrounding the issue in question. This lack of definitional clarity results from stakeholders' diverse perceptions arising from a variety of differing, often opposing, world views, backgrounds, cultures, moral, political and professional agendas (Weber & Khademian, 2008; Ritchey, 2013), as well as the existence of "redistributive implications for entrenched interests" (Rayner, 2006, p. 2). Lack of definition acts as a barrier to an end-of-searching-rule and prevents the formulation of potential solutions (Rittel & Webber, 1973). Additionally, wicked problems are almost always unique, and solutions identified for one set of problems, may not be applicable to similar situations in other contexts. Such problems are never completely "solved", merely "resolved", as they tend to reappear in other forms, since each wicked problem may only be a symptom of another "higher level" wicked problem (Rittel & Weber, 1973). Finally, and perhaps most significantly, due to changes in resources, constraints and political will, wicked problems are in a constant state of flux and need to be continually redefined (Hunter, 2007; Roberts, 2000). However, as these problems are part of "multiple, overlapping, interconnected subsets of problems that cut across multiple policy domains and levels of government" (Weber and Khademian, 2008, p.336), any effort to solve them may

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have a knock-on effect adding to the complexity of related policy agendas. For this reason, despite good intentions and resource availability, these problems often defy solution and persist over time.

Addressing wicked problems necessitates understanding the nature of the problem, the identification of possible solution(s), and an implementation approach (Roberts, 2000; APSC, 2007). To further describe and understand the "wickedness" of a problem, Head (2008) introduced three dimensions, namely *complexity* (both technical and social complexity related to system's elements and interdependencies), *uncertainty* (related to risks, consequences, and future changes), and *divergence* (related to values, viewpoints, and stakeholder strategies to address the problem). For a problem to be characterized as "wicked", it would have to score high in all three dimensions, since technical uncertainty or social complexity alone could be addressed through scientific and technical analysis, and divergence of stakeholder opinion in itself does not necessarily make a problem wicked (Head, 2008).

Approaches for the governance of wicked problems often focus on the reduction of social complexity, since it is this social complexity, rather than the technical challenges, that allows for possible solution identification and a management approach to implementation. Such approaches examine the views and visions of multiple stakeholders with competing interests, thereby moving towards, first, a shared understanding of the problem and commitment to the possible solutions, and, second, the development of solutions to "tame the problem" in the form of criteria identification to "lock down" the problem statement (Conklin, 2005). Next steps involve "coping" with the issue through the identification, examination and selection of a limited number of alternatives, and experimenting through learning by doing (Conklin, 2005; Valkenburg & Cotella, 2016; Loorbach, 2007). Rogers (2000) suggested three generic coping strategies, authoritative, competitive, and collaborative, based on the level of conflict present in problem definition and solutions and power structures among stakeholders. Authoritative strategies are to be employed when power is concentrated in the hands of a few stakeholders that define the problem and seek appropriate solutions from a position of power. Competitive strategies have their roots in power conflicts that develop between stakeholders in their fight to define the problem and move towards a solution. Finally, collaborative strategies (Roberts, 2000), "clumsy solutions" (Khan & Neis, 2010; Verweji & Thompson, 2006), or a “transitions management” approach in the case of sociotechnical systems (Loorbach, 2007), combine opposing perspectives to develop a “win-win” view on problem definition and potential solution, in the form of alliances, partnership and joint ventures, and aim at “enlarging the pie” to the long-term benefit of all stakeholders involved (APSC, 2007). This paper will use the wicked problem framework to examine whether the three dimensions of complexity, uncertainty and divergence are found in the case of RETs in remote indigenous communities.

5.3 Research methodology

The purpose of this paper is to advance understanding of the introduction of RETs into remote Canadian indigenous communities’ electrical systems by identifying the main stakeholders’ perspectives on electricity generation in remote communities and exploring the “wickedness” of the problem. Main stakeholders in the remote communities’ electricity generation process include the federal government, provincial and territorial governments, community governments, utilities, and community members (Karanasios & Parker, 2016a-g; Knowles, 2016). To improve understanding on the “wickedness”, we combined a review of academic and non-academic literature, policy and utilities’ documents, with interviews with members of a remote northern Ontario community, and discussions with energy conference participants, to explore stakeholders’ opinions on the roles and challenges associated with the current communities’ diesel powered systems, the future of electricity generation, the expectations from RET applications, as well as barriers to their implementation.

For the literature search process, we used the electronic databases Scopus, Web of Science and ABI/INFORM and multiple combinations and variations of the following keywords: "Indigenous" AND "renewable" AND "electricity" AND "remote" AND "Canada". Results in Scopus peer reviewed journals ranged between 430 documents for the search string "aboriginal" AND "energy" AND "remote" AND "Canada", to 28 results for the search string “indigenous” AND “renewable” AND “energy” AND “electricity” AND “wind” AND “remote” and “Canada”. After eliminating studies irrelevant to Canadian context, sixteen articles related to

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indigenous communities and renewable electricity generation, of which only three were related to remote indigenous communities and involved interviews with stakeholders of the electricity generation process. The first of these involved opinions from government and utilities representatives and community leaders for RET projects in British Columbia's remote communities (Rezaei & Dowlatabadi, 2015). The second documented the perspectives of Inuit and non-Inuit residents on the acceptability of RET in three Nunavut communities (McDonald & Pearce, 2013). Finally, Weis, et al. (2008) surveyed multiple stakeholders, including governments and utilities, but not community members, on barriers to RET implementation.

We then extended the search to non-scholarly journals and the internet and included stakeholders' perspectives on renewable electricity generation and the future of remote communities' electrical systems as expressed in energy conferences and meetings (4 documents), and indigenous perspectives expressed by remote indigenous communities (3 documents), and indigenous organizations, such as the AFN, BC-assembly of First Nation, NWT Aboriginal Governments, Council of Yukon First Nations, and Ontario's Nishnawbe Aski Nation (NAN) (7 documents), as well as documents created by indigenous organizations for the federal government (4 documents). We then included energy policy documents and utilities reports (14 documents) capturing the perspectives of provincial and territorial governments and utilities (see Table 12)

These sources were also used for a review of technical and non-technical barriers to implementation of RETs in remote indigenous communities to improve understanding of the associated technical and social complexity.

Table 12: Systematic literature review documents

Scholarly articles
Rezaei & Dowlatabadi (2015); McDonald & Pearce (2013); Weis et al., 2008
Stakeholders' perspectives from energy conferences and meetings
NTPC (2007); YE (2011); GNWT (2012b); GNWT (2014)
Indigenous perspectives (remote communities)
VGFN (2002); HFN-ED (n.d.); KFN (n.d.)
Indigenous organizations' perspectives
AFN (2011a; 2011b); NAN-HORCI (2013); NAN (2012); OEB (2008); BC-AFN (2009); BC-AFN (n.d.)
Indigenous organizations (for the federal government)
INAC (2004; 2005; 2007; 2010)
Perspectives of provincial /territorial governments and utilities
AANDC (2012b); Yukon Energy (2012); NT Energy (2013); GNWT(2008b; 2009a; 2009b); GN (2007); Northern Vision (2014); BC-Hydro, 2013a-f; OME (2013; 2017); IESO (2014); GQ (2016); Hydro Quebec (2013); GNFL, (2015a)

The secondary research data were complemented with primary data from semi-structured interviews with key informants in a remote community in northern Ontario[10]. The community is typical of northern Ontario's 25 remote indigenous communities (Flyvbjerg, 2006), in terms of language, common values, and traditional practices, population (approximately 1,000), building stock (residential, community and infrastructure), and electricity generation facilities. Economic activities include fuel supply, diesel storage, and tourist services, but employment is primarily provided through the local government/band council services and the local store. The community is a member of the Nishnawbe Aski Nation (NAN), the political territorial organization that represents 49 northern Ontario First Nation communities, signatories of the James Bay Treaty No. 9 and Ontario's portion of Treaty No. 5 (NAN, 2014).

Research in the community was undertaken following the Tri-Council policy requirements and received ethics clearance from the Office of Research Ethics at the University of Waterloo. Participants were identified by the Band Council, were over 18 years old and consented in writing and orally to be interviewed. The semi-structured interviews with ten key informants were conducted in October 2014. Interviews were conducted in a respectful manner, were on average 20 minutes in length, and included qualitative, open ended questions to explore views on the current electricity system governance structure, their motivations for participating in renewable

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[10] The name of the community is not disclosed to protect the informants' anonymity.

electricity generation, and their opinion on potential community benefits from the implementation of RET projects. Interviewee responses were written down and subsequently analyzed by topic. The qualitative, semi-structured and open-ended question interview approach is aligned with indigenous worldviews on knowledge transfer through oral history and storytelling (Wilson, 2001; Kovach, 2010; Smith, 2001) and indigenous qualitative research methods that include talking circles, interviews and personal narratives (Weber-Pilwax, 2004). It is worth noting, however, that although the community is typical among northern Ontario remote community served by HORCI in terms of population, buildings, and local economy, interview results cannot be considered representative of either the community's whole population or the rest of Ontario's remote community populations.

Finally, triangulation data were collected through informal conversations with indigenous communities' leaders, members, energy managers, economic development officers, representatives of indigenous organizations, and federal government employees during the following public and thematic events: the Toronto Remote Microgrids Conference (2013), the Northern Ontario First Nations Environmental Conference (NOFNEC) (2014), the Rise of the Fourth World Conference (2014), the Energy Council of Canada Energy Summit (2015), and various Waterloo Institute for Social Innovation and Resilience (WISIR) workshops that included the participation by indigenous leaders at the University of Waterloo.

All data was analyzed using pattern coding to identify overarching concepts within the documents and interview results. In a second step, findings were compared to identify commonalities and differences and, finally, using the "wicked problem" lens, organized under complexity, uncertainty, and divergence of opinions categories.

5.4 Findings

Table 13 summarizes the findings from the literature review and key informant interviews regarding challenges associated with the current communities' diesel powered systems, the future

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of electricity generation, and, finally, the expectations from RET applications, as well as challenges to their implementation.

Table 13: Stakeholders perspectives on community electrical systems and RETs

	Perspectives of indigenous remote communities' members (scholarly literature)	Indigenous perspectives as expressed in -conferences and meetings -remote communities -indigenous organizations	Perspectives of federal and provincial /territorial governments and utilities	Perspectives of key informant interviews
Challenges associated with the current systems	**Environmental** -Carbon emissions **Economic** -High cost of electricity **Reliability issues** -Frequent interruptions **Diesel dependency** -Community acceptance of diesel as a necessity **Technical skills** -Lack of community knowledge about energy	**Environmental** -Environmental (responsibility) **Economic** -Affordability (minimize cost for power) **Reliability issues** -Reliability (reliable capacity) -Flexibility (new resources to be planned for load uncertainties)	**Environmental** -Environmental (carbon emissions, fuel transport, spills, noise, health issues) **Economic** -High electricity expenses, limits to economic development -Key issues: small customer base, isolation, high fixed and operating costs, limited economies of scale **Reliability issues** -Reliability and redundancy issues	**Environmental** -Environmental (carbon emissions, black carbon, leaks and spills, soil contamination) **Economic** -Limits to economic development **Reliability issues** -Reliability (power interruptions, surges, brownouts) -Maintenance issues **Diesel dependency** -Increased consumption (diesel dependency)
Issues associated with the institutional set-up and governance structures	**System complexity** -Fear for higher electricity rates from alternative electricity options -Lack of communication on community energy issues **Indigenous control** -Need for indigenous control over electricity systems -Need for indigenous supply of electricity	**System complexity** -High complexity of electrical system -Electrical system isolation (loss of major loads leads to rate increases) **Indigenous control** -Community participation in electricity generation -Need for partnerships development in electricity generation	**System complexity** -Regulated vs. non-regulated utilities -Complexity and high cost of the regulatory environment -Complexity of rates systems -Residential subsidies create market distortions -Lack of economies of scale increase electricity costs - "Use less, pay more" because of the isolated nature of the remote systems	**System complexity** -High complexity of electrical system -Bureaucratic, red tape, unionized procedures in electricity generation limit community participation **Indigenous control** -Improve participation in governance of the electricity system (influence electricity cost decisions, bills collection, economic development) -Improve community technical and managerial capacity issues
Future of communities' electrical systems	**Off grid RET as an option** -Increase RET share without increasing	**Off grid and on grid RET as options** -Engage in clean/ renewable initiatives and	**Off grid and on grid RET as options** -Focus on clean technologies and capture	**Off grid and on grid RET as options** -Small-scale RETs

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	Perspectives of indigenous remote communities' members (scholarly literature)	**Indigenous perspectives as expressed in -conferences and meetings -remote communities -indigenous organizations**	**Perspectives of federal and provincial /territorial governments and utilities**	**Perspectives of key informant interviews**
	community electricity costs	reduce carbon emissions (mainly hydroelectricity) -Connect to interconnected grid to address long term community electricity demand and economic development -Create indigenous utilities -Renewable and mining opportunities to be exploited under indigenous governance and participation	local alternatives (multiple mini hydro plants) -Reduce carbon emissions -Connect to interconnected grids engage large-scale hydroelectricity as the most affordable and clean option to support mining development	-Connect to the provincial grid to address long term community electricity demand and economic development -On-grid hydroelectricity generation is associated with multiple socioeconomic benefits
Potential community benefits of off-grid indigenous RET projects	**Socioeconomic** -Community economic development -Lower cost for electricity -Revenue potential **Political** -Self sufficiency	**Socioeconomic** -Green economy as key to indigenous prosperity -Economic benefits -Capacity building and employment -Financial savings -Use of local waste **Political** -Self sufficiency -Local control		**Socioeconomic** -Financial benefits (revenue, reduction of expenses) -Improve learning, management skills, local control -Partnership development **Political** -Improve self reliance (self sufficiency) to combat anticipated fiscal cuts
Challenges of off-grid indigenous RET projects	**Technical** -High upfront capital costs -System sizing issues **Institutional** -Bureaucratic barriers hinder RET implementation -Lack of governmental funding -Community acceptance -Lack of community technical and managerial capacity -Need for community control of assets	**Technical** -High capital costs **Institutional** -Need for electricity generation incentives -Need for cooperation, commitment between utilities and communities -Need for leadership -Risk minimization -Establishment of a supportive policy framework	**Technical** -Technical challenges (financial viability, technical integration) -Resources availability -System redundancy	**Technical** -Technical challenges (capital costs, capacity issues) **Institutional** -Ownership challenges (full community ownership vs. partnerships)

The wickedness associated with the introduction of RETs into communities' electrical systems can be explored as the result of four interrelated factors, namely: 1) the institutional complexity of the electricity system, 2) the diversity of stakeholder perspectives (government, utilities and indigenous peoples) on community electricity generation and the challenges that the introduction of RETs is expected to address, 3) "long term" uncertainty over the future of the electricity generation systems structure and governance, and 4)"short term" uncertainty over the choice of off-grid renewable technology. These factors are explored in detail next.

5.4.1 Complexity of the governing system

Complexity over remote indigenous communities' electrical systems stems from the joint responsibility of federal and provincial governments for electrical services. Under electrification agreements developed in the 1970s, the provincial government and utilities are responsible for funding the ongoing operation and maintenance of the electricity generation and distribution system, while the federal government, through Aboriginal Affairs and Northern Development (AANDC), is responsible for funding capital upgrades and the expansion of the electricity system (OEB, 2008; NAN-HORCI, 2013). However, since the 1990's, the devolution of almost 85% of AANDC's funding to local governments has complicated the process of capital funding for diesel system upgrades. In Ontario, HORCI claims that diesel upgrades are no longer under its control, and aboriginal governments express concerns over the apportionment of shares among the three parties involved for capital cost of generation, distribution and maintenance (NAN-HORCI, 2013).

In addition, informants criticized regulatory arrangements and bureaucratic procedures that further complicate the management of the generation process thus hindering community participation. Various departmental policies and "red tape procedures and increased bureaucracy", community members' lack of understanding of electricity issues, and the existence of technical regulations and unionized procedures were referred to as barriers limiting community voices in electricity system investment decision processes and participation in generation and distribution processes.

The existence of different subsidy structures for residential and governmental electricity rates further complicates the governance of electricity generation. The high electricity cost in remote communities (five to six times the average rate of grid connected customers, see for example Hydro One, 2012, pp. 679-681; GNWT, 2009b; Hydro Quebec, 2016; NLH, 2017) is heavily subsidized for residential use. Residential customers are billed at lower rates subsidized by provincial governments (for example, Ontario remote communities' rates are subsidized through the Rural or Remote Rate Protection (RRRP) program (IESO, 2017)). However, community buildings are billed at the full cost of electricity generation, and paid out of community budgets, which are subsidized through direct and indirect funding from federal and provincial governments. Accordingly, rising electricity costs coupled with population and per capita usage growth, increase both indigenous governments' expenses for the electrification of community buildings (paid through indirect funding), as well as federal and provincial direct and indirect subsidies (IESO, 2014). The introduction of community owned RETs "behind the meter" further compounds the issue by reducing electricity consumption billed at full rates. The installation of a RET project, e.g. solar electricity, on a community building under a net metering agreement will reduce 'full cost' electricity consumption, thereby reducing community expenses, that were subsidized indirectly by the federal government, and potentially making those funds available for other pressing community needs. However, these projects also reduce revenues for utilities and may necessitate an increase in either electricity rates, or provincial direct subsidies, or potentially both.

Finally, local government's vested interest in diesel-generated electricity in the form of revenue and employment through diesel fuel transportation and storage adds another layer of complexity, since revenues from RET projects are expected to compensate for financial losses related to the diesel fuel displaced (Weis, 2014).

5.4.2 Diversity of issues that the introduction of RETs is expected to address

Governments and utilities shared similar views on the need to improve supply reliability and reduce diesel consumption, and consequently, carbon emissions and subsidies, while at the same time use local resources. Utilities' mandate is to provide reliable electricity and at the same time the main goal is to reduce cost, ensure affordability, and distribute costs equally (GNWT, 2009a; 2009b; IESO, 2014).

Indigenous peoples' perspectives on the main challenges associated with the current diesel systems were similar and included environmental concerns related to diesel dependency, carbon emissions, spills, leakages, and soil contamination, as well as the need for reliability (providing uninterrupted quality services) at a low and affordable cost. Informants noted that the increase in electricity consumption since the 1970s was largely due to population growth and household appliance use, and also referred to increased numbers of youth and their daily use of electronic devices to explain the recent growth in household electricity consumption. It is worth noting that in 2011 young people under 24 years old accounted for 56% of the population in northern Ontario's remote communities, (see Statistics Canada, 2011; 2016a).

However, besides these shared concerns over diesel dependency, reliability of supply, and environmental impacts expressed by both community members and governments, indigenous perspectives prioritize communities as active participants in the ownership of RET projects and governance of the electricity generation process to control its economic, social and cultural impacts (OEB, 2008; KFN, n.d.; HFN-ED, n.d.).

Informants also stated that the community (through the Band Council) should play a more central role in controlling electricity generation assets in order to influence electricity cost, bills collection, and community development. One informant said "… the community should have a say on decisions regarding electricity, because they live here, so they have to say about the high cost of living here, the cost of food, and how it is to live in an isolated community". Another informant confirmed that the community wants both more electricity and to "have a saying to it" adding that "I want to see someone take the payments and see where the money goes" thereby connecting electricity expenses with out-of-community administrative costs and leaking of potential local spending. Another informant stated that community motivation for participating in decisions regarding electricity generation is "ownership (of electricity assets) and self-sufficiency". In further conversations, the concept of self-sufficiency, originating from the principles of "self-reliant" indigenous societies living from their traditional pursuits before western contact (IISD, 1992), was associated with increased control over community electricity systems, and control of electricity generation and distribution costs and associated financial flows (see INAC, 2004; 2007; OEB, 2008; McDonald & Pearce, 2013; Rezaei & Dowlatabadi, 2015; KFN. n.d.).

Furthermore, informants agreed that despite the devolution of funding giving the opportunity to the community (through the Band Council) to engage in conversations with HORCI and AANDC[11] on updates and upgrades to the electricity system, community views were not taken into consideration due to differential power relationships. Another participant stated that asset ownership by HORCI gives authority over generation and distribution and sets community views in second place.

5.4.3 Uncertainty over the future of community electricity systems and RET technology choice

The wickedness of the introduction of RETs into community electrical systems is further increased through the dilemma a community faces: whether or not to be in favor of off-grid RET projects. This decision is influenced by the possibility of a future extension of provincial grids and a potential connection of remote communities and further complicated by the inherent uncertainty surrounding the financial performance of off-grid RET projects.

Indigenous peoples see large-scale on-grid renewable electricity generation combined with future natural resources development as opportunities for the creation of local economies to the benefit of the communities involved. For example, such a future direction is encompassed within Ontario's Nishnawbe Aski Nation (NAN) four energy-related priorities: transmission expansion, connection of remote communities, renewable electricity generation, and supply of renewable electricity to communities and prospective (mining) developments in the north (OEB, 2008; OME, 2013; IESO, 2014) (see also WP, 2012; PWC, 2015; TB-CEDC, 2013).

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[11] The ministry of Aboriginal Affairs and Northern Development Canada (AANDC) was renamed Indigenous and Northern Affairs Canada (INAC) in 2015.

Informants also expressed their interest in future connection to the provincial grid as an option to change the current electricity governance structure and address long-term community electricity demand and economic development through ownership of large-scale transmission and renewable electricity generation entrepreneurial ventures. Hydroelectricity generation was referred to by three of the ten informants as the main alternative that will maximize revenue and employment opportunities. Five informants discussed large-scale grid-connected hydroelectricity generation projects developed in partnership with the private sector as a means to increase revenues, training, and qualifications for community youth. In total, seven out of ten informants mentioned employment benefits, four out of ten mentioned revenue generation and one informant additionally referenced the availability of affordable electricity to support community expansion and new business development. Finally, one informant pointed out the long-term importance of grid connected large-scale RET investments in association with potential electricity demand from future resource development projects in northern Ontario.

Furthermore, a decision in favor of small-scale off-grid projects is influenced by the inherent technical complexity and scientific uncertainty of off-grid RET projects, since their financial viability depends on the availability of the renewable resource, be it wind, solar, or hydro, future community electricity loads, and future diesel fuel prices (Mc Gowan, Manwell, & Connors, 1988; Tan, Meegahapola, & Muttaqi, 2014). These parameters define the choice of RET technology and the penetration level of the renewable component, which, in turn, define the participation and cooperation level between indigenous governments and utilities, the extent to which the previously mentioned challenges related to diesel systems are addressed, and the financial risks of the venture.

Low penetration solar or wind hybrid projects require low capital costs, displace up to 20% of diesel consumption and carbon emissions, and are associated with low financial risk, as well as low levels of revenue generation (Baring-Gould & Dabo, 2009; Mc Gowan, Manwell, & Connors, 1988). On the other hand, higher penetration solar or wind hybrid projects in resource rich locations may result in improved reliability of electricity supply, up to 90% fuel displacement and emission reductions, and provide higher, but riskier, financial returns. Additionally, high penetration projects equipped with advanced controls require trained system operators, who may be difficult to find and retain in remote locations, as well as close cooperation with utilities for operational and technical expertise, therefore resulting in higher project and electricity generation costs (Fay, Keith, & Schwoerer, 2010a; 2010b). In contrast to such solar or wind hybrid projects, hydroelectricity plants exhibit less technical complexity and scientific uncertainty and have the greatest potential to improve reliability, reduce or eliminate emissions, and generate revenue and community employment. Such advantages are largely achieved through the mature technology associated with hydro power, the low or non-intermittent nature of the renewable source, and longer lifespans of generation assets (40 years) in addition to favorable power purchase agreements (PPAs) (AECOM, 2012; Kirby, 2009).

Uncertainty regarding the choice of off-grid renewable application was reflected in informants' opinions on the financial benefits of RETs projects. Informants expressed different opinions about revenue generation or employment numbers stemming from off-grid small-scale RET projects and were cautious on the potential impacts on local governments' budgets of community investment decisions for off-grid RET applications. One informant expected financial benefits through the creation of multiple small solar projects under "net metering" agreements that will allow for community savings from energy intensive buildings, and private consumer savings though installations on residential buildings. Two informants mentioned that off-grid RETs were welcomed as a means of establishing partnerships and improving management skills. Two informants did not foresee any positive financial contribution through off-grid RET projects. These divergent opinions highlight the complexity and wicked nature of the issue and will be discussed further in the next section.

5.5 Discussion

5.5.1 RETs as a wicked problem

The slow diffusion of RET projects in remote indigenous communities demonstrates the following characteristics of a wicked problem.

First, there is high institutional complexity in communities' electrical systems, as expressed through the presence of different institutional arrangements (type of utilities, rates, subsidies structures and funding sources, technical regulations that define power relationships and limit community's ability to participate in the governance of the electricity system, and vested interests in diesel) (see for example GNWT, 2009b; Hydro One, 2012; Hydro Quebec, 2016; NLH, 2017; GN, 2015). The systems' complexity leads to numerous issues to be addressed, such as diesel dependency and reliability of electricity supply, high electricity costs, poor quality services, increased subsidies expenditures, carbon emissions, diesel spills and leakages, economic development constraints due to the size of the electrical systems, and improvement of community socioeconomic and political conditions (AANDC, 2012b).

Second, there is a lack of a clear definition of the challenges that the introduction of RETs is supposed to address, and, consequently, lack of identification of a solution acceptable by all parties involved, because of the co-existence of a variety of actors (state and indigenous governments, utilities, and community members), with different and competing current and future interests and sustainability views on the future of community electrical systems. Findings suggest that indigenous expectations from RETs implementation go beyond the initial concerns (impacts of diesel-generated electricity on current electricity costs, improvement in system reliability, emission reductions, and environmental performance), which are shared by indigenous peoples, governments and utilities. Indigenous preferences point to community participation in the governance of the electricity generation process and renewable electricity generation to control community socioeconomic development and increase self-sufficiency and community autonomy by reducing dependence on external sources of electricity.

Third, the introduction of RETs into remote electricity systems could be considered a non-stable problem (APSC, 2007) of high uncertainty, since it depends on interdependent factors, such as changing legislation on aboriginal title (Osler, 2017), financial resources availability, political will at the federal, state, and community level, and future natural resources developments. These factors are evolving at the same time that the problem is being addressed. For example, natural resources prices influence decisions over future electricity demand, grid extensions and investment on new

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mining operations in the area of remote communities (NT Energy, 2013; Hall & Coates, 2017). Accordingly, indigenous perspectives are divided regarding uncertain outcomes of off-grid RET applications that could potentially endanger community restricted budgets, and the potential benefits from a future community connection to the provincial electrical grids. Such a strategic perspective increases uncertainty over small-scale off-grid RET implementation benefits, since access to affordable and low emission electricity through a transmission connection to the provincial grid could secure long-term economic development benefits through participation in both large-scale renewable electricity generation and natural resource development within traditional territories.

Finally, limited participation by indigenous communities in renewable electricity generation within indigenous reserves can be considered a symptom of the broader wicked problem of indigenous economic development, rooted in distinct property rights, culture and traditions, previous problematic governmental interventions, existing institutional arrangements promoting sustainable economic development within indigenous reserves, and the lack of governmental support to address infrastructural, technical, managerial and financial barriers (OAG, 2003; Alcantara, 2003; Hunter, 2007; Senate Committee, 2007).

5.5.2 Policy implications

Policy implications stem from governmental obligations to consult with indigenous peoples over the development of projects (including electricity generation) within traditional territories (Sterling & Landmann, 2011; Morellato, 2008). Therefore, considering indigenous perspectives is crucial for improving understanding of the problem's wickedness and developing coping strategies.

Our interviews suggest that to cope with the "wickedness" of the off-grid RET introduction and to gain more control over local electrical generation, as well as the long-term transformation of the electrical system, informants pointed to both collaborative and competitive approaches (Roberts, 2000). Specifically, they point to cooperation with local utilities, other indigenous communities,

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state and federal governments and private proponents, as well as community entrepreneurial ventures in electricity generation and transmission assets.

Competitive approaches are evident in the joint venturing of 22 northern Ontario remote indigenous communities with a private proponent to form Wataynikaneyap Power, an indigenous co-owned licensed transmission company competing for the Wataynikaneyap Transmission Project, which would connect 21 of the 25 remote communities to the provincial grid, and supply power to both communities and mining developments in the Ring of Fire area through indigenous owned large-scale renewable electricity generation and transmission (WP, 2012; WP, 2013b; IESO, 2014). Similar views focusing on local control, community benefits, and entrepreneurial ventures and community ownership of electricity generation and transmission assets combined with natural resource development within traditional territories have been expressed by remote indigenous communities in Quebec (GQ, 2006a; KRG, 2012), and Nunavut (Rogers, 2015) and have been successfully implemented by communities in British Columbia (RWB, 2011; BC Hydro, 2016).

Both types of these entrepreneurial ventures (off-grid and on-grid RETs) are consistent with indigenous aspirations for local control and sustainable development through the creation of a reliable economic base that is driven by the people themselves, directed with community consent, able to provide localized socioeconomic benefits and lead to ownership opportunities, and, thus, self-sufficiency and self-reliance (OAG, 2003; Anderson, Dana, & Dana, 2006; Senate Committee, 2007; Slocombe, 2008; AAWG, 2010). It is apparent that such visions of active participation diverge significantly from governmental, utilities and environmentalist market-based approaches that see indigenous remote communities as passive receivers of technological solutions and simply as part of the renewable application implementation and experimentation market (Ibrahim, Younes, Ilinca, Dimitrova, & Perron, 2010; Rezaei & Dowlatabadi, 2015).

Accordingly, policies supporting RET implementation will have to take the form of "variable sum" collaborative and negotiated agreements between indigenous and state governments and utilities that promote benefits for all parties involved (Head, 2008; Roberts, 2000). Negotiated agreements (such as the Impacts and Benefit Agreements in mining projects) are an established method for

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indigenous peoples to define their development ideas and concerns and gain economic independence (Fidler, 2010; Sosa & Keenan, 2001; Dylan, et al., 2013).

In addition, a collaborative approach to policy co-development supporting the deployment of both off-grid RET projects and the connection to provincial grids would need to engage competing stakeholders, experienced researchers, policy analysts, and non-governmental stakeholders with expertise in delivering services and evaluating performance, to understand the problem (including political and economic development targets pursued by indigenous communities), resolve conflicts, provide options, and implement policies (Enzenberger, et al., 2002; Head & Alford, 2015). The effectiveness of these networks, and their potential for the creation of virtuous reinforcing cycles that will enable further collaboration between stakeholders (Loorbach, 2007; Head & Alford, 2015), will depend on, first, the development and sharing of new knowledge on the potential of RET solutions (Weber & Khademian, 2008), and, second, the co-development of regulatory and fiscal policies that are both supportive of provincial, private, and indigenous development interests, as well as tailored to address electricity demand, local electricity generation, community barriers to participation, and economic development goals of particular indigenous communities (Enzenberger, et al., 2002).

Tailored negotiated policies are necessary since state governments, utilities, and indigenous perspectives may differ among communities within the same province, and among different provinces and territories, as they are shaped by indigenous self-governance agreements (e.g. Nunavut and Yukon) (AANDC, 2017), the presence of different institutional arrangements (type of utilities, electricity rates and federal and provincial subsidies structures), and local factors (e.g. infrastructural deficiencies and renewable resources availability) (see for example GNWT, 2009b; Hydro One, 2012; McDonald & Pearce, 2013). Problem definition, and identification of coping strategies is further complicated by the existence of local vested interest, competing community priorities (e.g. housing needs), competing interests supporting new fuels (such as biodiesel or natural gas), natural resource development, and future grid extensions (NT Energy, 2013; OEB, 2008; Yukon Energy, 2012a; NT Energy, 2013; Weis, 2014).

Furthermore, not all indigenous peoples see participation in large-scale projects as culturally appropriate. Critiques concentrate mainly on the potential danger of low quality governance, and rent dissipation and appropriation (Vining & Richards, 2016), through the exercise of culturally insensitive capitalistic practices (Atleo, 2008, p. 24) by local elites that use a neo-traditionalist ideology of “revived leadership” (Rata, 2004, p. 56) to personally benefit from deals with the corporate sector at the expense of the community (Slowey, 2008; Atleo, 2014).

Finally, policy implementation should be constantly evaluated and re-evaluated, since there is always potential for negotiated arrangements to be shaped by political priorities and the “gaming” behavior of competing participants aimed at rent extraction at the expense of indigenous peoples and the broader public interest (Head & Alford, 2015).

5.6 Conclusion

The objective of this paper was to examine the slow deployment of RETs in remote indigenous communities through the lens of the “wicked problem” planning literature. Wicked problems are characterized by the lack of a shared understanding by participating stakeholders of the causal relationships surrounding the issue in question. In the case of the introduction of RET into remote indigenous’ communities electrical systems, the wickedness of the problem is seen to stem from the diversity of stakeholders’ perspectives on exactly which challenges the use of RETs is expected to address, including governmental cost considerations, utilities reliability of electricity supply, environmental commitments, sustainability, as well as indigenous targets of increasing local control and community socioeconomic benefits within traditional territories. In addition, the institutional complexity of current electrical systems, uncertainty over RET technology choices, and future governance structures of provincial/territorial and community electricity systems further deepen the wickedness of the problem.

Strategies to cope with the problem wickedness result from developing improved understanding of the problem, which, in the case of RETs deployment, necessitates the integration of indigenous viewpoints due to the legal obligations of the duty to consult and accommodate indigenous peoples

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for projects within their traditional territories. Indigenous perspectives were therefore examined to help describe the issues that the use of RETs is supposed to address, as without this much needed clarity, it is unlikely that appropriate coping strategies can be identified. Both literature and interviews findings suggest that indigenous peoples want to participate and control local electricity systems and new renewable electricity generation, and cope with the aforementioned wickedness by aiming at both long-term competitive (indigenous ownership of transmission and generation assets) and short-term collaborative (development of alliances and partnerships with utilities and private sector) entrepreneurial ventures.

Accordingly, further research on the governance structures and mechanisms that may steer indigenous RET entrepreneurial ventures and participation in the electricity generation process, should focus on both market model (competitive) approaches, as well as interactive (reflexive) and negotiated policy approaches for the co-development of solutions tailored to actors with different views and values (Geels, et al., 2004; Voss & Bornemann, 2011). Potentially, such solutions may also contribute to the identification of coping strategies for addressing the broader wicked issue of indigenous economic development.

Chapter 6: Tracking the transition to renewable electricity in remote indigenous communities in Canada

Diesel-generated electricity in 144 Canadian remote indigenous communities is responsible for carbon emissions, spills, leakages, poor quality services, and potentially restricts community development. Introducing renewable electricity technologies (RETs) into community electrical systems could address both environmental and socioeconomic development issues. This chapter identifies 71 RET projects developed in remote communities between 1980 and 2016 and uses the multi-level perspective (MLP) to examine the diffusion and governance processes influencing the transformation of these systems. The MLP framework explains the non-linear deployment of RETs through the shift from a utility driven phase focusing on hydroelectricity and small wind applications to a community driven phase concentrating on solar projects. Reasons for the development of projects in Yukon, Northwest Territories, British Columbia and Ontario include community interest in participating in local electricity generation, learning processes facilitated by multiple experiments, and the existence of supporting regulatory and fiscal policies that were negotiated and adapted to indigenous sustainability visions. The MLP framework indicates that remote indigenous communities now reject the role of passive recipients of technologies promoted by non-aboriginal interests. Instead, active participation in transforming electrical systems is sought, based on local sustainability agendas which further their goals of economic development and self-governance.

6.1 Introduction

In 2015, 193 member states of the United Nations adopted the 17 Sustainable Development Goals including goal number 7: “Ensure access to affordable, reliable, sustainable and modern energy for all” (UN, 2016). Although renewable sources account for over half of all electricity generated in

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Canada (NRCan, 2016a), there are 144 remote indigenous communities[12] with a population of approximately 100,000 that are powered by isolated diesel systems (AANDC and NRCan, 2011; AANDC, 2012). Alternatives to diesel-generated electricity include the connection to electrical grids, the use of alternative fuels (such as natural gas), and the introduction of renewable electricity technologies (RETs) into the communities' electrical systems. Despite the availability of renewable resources in remote indigenous communities, and research on the potential for integration of RETs, the shift to increased renewable electricity generation has only just begun. Seventy-one small RET projects over the 1980-2016 period serve as transition experiments to generate valuable learnings for a broader transition toward distributed and locally/indigenous owned RETs in remote communities.

Analytical tools for studying the diffusion of RETs include the STEP and AKTESP frameworks, which are used to identify agreement (A), knowledge (K), technical (T), economic (E), social (S), and political (P) factors influencing deployment. These frameworks have previously been used to identify and examine the deployment of grid connected large-scale RETs in Saskatchewan (Richards, Noble, & Belcher, 2012) and Canada as a whole (Valentine, 2010). In the case of Canadian remote indigenous communities, non-technical barriers to communities' participation in RETs include institutional weaknesses and capacity issues, vested interests in diesel-generated electricity, lack of capital, high capital costs, lack of expertise, missing infrastructure, and limited community acceptance (Ostrom, 1981; Parcher, 2004; INAC, 2005; INAC, 2007; Inglis, 2012). Technological constraints include, the need for developer, installer and operator expertise, the availability of distribution infrastructure, information systems, smart grids, lower cost storage, packaged systems control technologies, and robust equipment able to operate in extreme climatic conditions and variable load configurations (Fay, Keith, & Schwörer, 2010b; Baring-Gould & Dabo, 2009; Weis, Ilinca, & Pinard, 2008). Another strand of research examines the financial performance of RET projects through feasibility and optimization studies, conducted between 2003 and 2015 for 96 remote indigenous communities (ARI, 2003; Krohn, 2005; Maissan, 2006a;

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[12] According to AANDC and NRCan (2011) remote or off-grid communities are permanent or long-term (five years or more) settlements with at least ten dwellings that are not connected to the North American electricity grid or the piped natural gas network.

Pinard, 2007; Weis and Ilinca, 2008, NFL Hydro, 2009; ARI, 2016). Results indicate, under numerous assumptions, that a limited number of RET projects are financially viable, due to the high cost of RET generated electricity and limited economies of scale. Finally, a number of studies point to communities' sustainability concerns in the form of lack of economic benefits and assets control (OEB, 2008; INAC, 2004; Rezaei & Dowlatabadi, 2016), and high residential electricity costs (McDonald & Pearce, 2013; GNWT, 2008b) as factors responsible for limited community participation in renewable electricity generation.

Overall, these studies fail to take into consideration the functional dynamics of transforming electrical systems in the form of interactions between participating actors' structures, cultures, and practices that may drive non-linear behaviors, and the existence of positive and negative feedback mechanisms that may accelerate or slow the diffusion of new technologies (Grin, Rotmans, & Schot, 2010). For example, the establishment of new institutions and relationships may give rise to new policies, which in turn, supported by appropriate technologies, may define new institutions and relationships, create new interest groups and new institutions in electricity markets (Yi & Feiock, 2014; Smith, Stirling, & Berkhout, 2005). An alternative means of analyzing technological change and the diffusion of innovative solutions is the technological transitions approach, or the multi-level perspective (MLP) framework. The MLP analysis includes economic factors (such as costs, profitability and technological knowledge), but additionally considers interactions between broader overarching political and social institutions (landscapes-macro level), the functional relationships between actors participating in the technological system (regimes-meso level), as well as the influence of technological niches, to conceptualize the transition process towards more sustainable options (Geels, 2005; Geels & Schot, 2007; Smith, Stirling, & Berkhout, 2005).

Based on available data for 133 remote Canadian indigenous communities in seven provinces and territories that rely on diesel-generated electricity, this paper seeks to apply the MLP framework to examine the development of RETs in these communities between 1980 and 2016. More specifically, the paper examines the extent to which RETs have emerged as a viable electricity generation alternative in remote communities and identifies governance processes responsible for transition patterns, with the goal to provide (i) insights on the effectiveness of governance processes and instruments, and (ii) levers influencing the transition.

The paper is structured as follows: section 6.2 presents the analytical framework, while section 6.3 describes the methodology followed. Section 6.4 presents the findings, followed by a discussion in section 6.5 and concluding remarks in section 6.6.

6.2 Analytical framework

Sustainability transitions examine the transformation of sociotechnical systems into more sustainable alternatives through the interaction of three levels, landscapes, socio-technical regimes, and technological niches (Geels, 2005; Geels & Schot, 2007). Landscape (macro-level) factors represent broader overarching political and social institutions, while socio-technical regimes consist of the structures, cultures and practices of actors that establish and maintain a technological system (meso-level); finally, niches are the spaces where new innovations are created (micro-level), protected from market intervention until they reach maturity and build the necessary networks for market integration (Grin, Rotmans, & Schot, 2010).

DeHaan and Rotmans (2011) conceptualize sociotechnical change by introducing three main subsystems (constellations or regimes) of the sociotechnical system that contribute to the system's functioning and influence the transition process: first, the incumbent regime that currently dominates the functions of the sociotechnical system that meets societal needs; second, novel constellations called niches that are able to provide system functions, but they are not powerful enough to become the dominant regime; finally, niche-regimes that provide, or are able to provide, system functions due to their power and are situated between the previous actors. Accordingly, the transition from the current system to a more sustainable one is conceptualized through the emergence of a niche-regime, either existing or developed out of a niche, that applies a different way (in terms of structure, culture and practices) of fulfilling societal needs, competes with the incumbent regime, and, eventually, takes over its functions, thus becoming the main provider of the system's functioning (deHaan & Rotmans, 2011; Grin, Rotmans, & Schot, 2010).

Transformative change in the system occurs through (a) tensions, or misalignment of the incumbent regime's functioning as a response to new developments at the broader landscape level of economic, cultural, political or ecological nature, (b) stresses, defined as internal misalignments of

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incumbent regime's functioning that is either inadequate or inconsistent with the societal needs, and (c) pressures, developed towards incumbent regimes from new technologies and/or the existence of niches or niche-regimes (deHaan & Rotmans, 2011). When the regime conditions (tensions, stresses and pressures) reinforce each other towards a certain direction, then the introduction of transition experiments in the form of technological innovative projects aiming at societal change, allow for learning processes and the empowerment of niches and their transformation to niche-regimes that challenge the incumbent regime (deHaan & Rotmans, 2011; Grin, Rotmans, & Schot, 2010; van den Bosch & Rotmans, 2008). Learning processes include learning from transition experiments implemented in a specific context (deepening), in different contexts (broadening), as well experiments that are integrated and embedded (scaling-up) into mainstream activities and practices (van den Bosch & Rotmans, 2008; Grin, Rotmans, & Schot, 2010). Van den Bosch & Rotmans (2008) add four niche-related conditions for the success of transition experiments, namely (a) the internal alignment of the niche, (b) the ability of the niche to exercise power on the incumbent regime locally, (c) the existence of a cooperative regime that is responsive to experiments and the existence of key actors that assist in transforming experiments to practices that address societal needs, and (d) the alignment of the niche with trends and developments at the broader landscape level. The transition contains "slow" phases (pre-development and stabilization), resulting from negative feedback mechanisms caused by the incumbent regime in charge during the specific period, and "fast" phases (take-off and acceleration), where regime and niche regime conditions create positive feedback mechanisms that move the innovation forward (Grin, Rotmans, & Schot, 2010).

Because a transition process (or transition pathway) covers periods of (slow and fast) transformation, it could be represented as a sequence of transition patterns, or a sequence of transformations from a current system state to a new system state, involving changes in the system's functioning (deHaan & Rotmans, 2011). This transformative change can be "managed" by creating supporting mechanisms that create positive feedbacks, thereby influencing the transition. According to Loorbach (2007), transitions governance uses a cyclical process starting at the strategic level by envisioning a solution to a societal problem (problem structuring phase). At a second step, actions at the tactical level (policies and regulations) are negotiated (development

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of transition agendas). The next phase (implementation) is concerned with transition experiments, where policies and innovative projects and practices are transformed into action, coalitions are formed, and implementation initiated. The final phase (process evaluation) includes monitoring, evaluating, and learning from the implemented experiments and, based on the knowledge acquired, the adjustment of the visions, agendas, experiments and coalitions, initiating an iterative cycle of actions (development rounds), until the system transformation is completed (see also Voss & Bornemann, 2011; Schot & Geels, 2008; Grin, Rotmans, & Schot,2010). The emphasis on participation, collaboration, collective learning and "shared rule making and agreements between interdependent actors with diverging actors and beliefs" (Elzen & Wieczorek, 2005, p. 658) situate transition management as a reflexive governance approach of social regulation between top down and bottom up (or market) governance paradigms (Voss & Bornemann, 2011; Elzen & Wieczorek, 2005).

Depending on the changes in structure, culture and practices observed in the sub-system and the origin of resources supporting the transformation, DeHaan and Rotmans (2011) distinguish between transformation and adaptation transition patterns. A transformation of a niche or niche-regime to regime (empowerment pattern) results when niches or niche-regimes gain power supported by inside and/or outside influences (bottom up and top-down pressures and resources respectively) and assume part of the incumbent regime's functioning. The incumbent regime either adapts to the new state by incorporating new processes within its system's functions or is eventually replaced by the niche-regime (regime shift). A regime change (reconstellation pattern) describes a system transformation through large-scale, mostly infrastructural type, fast changes at the landscape level that are exerted on the incumbent regime (top down pressures rather than niche related pressures). Finally, incumbent regimes under tensions, stresses and pressures, may adopt innovative solutions leading to an internal transformation (adaptation pattern), as opposed to a transition.

Accordingly, transition pathways can be represented through a series of successive transition patterns, with the dynamics of each stage depending on (1) the current system state (system composition), (2) the system conditions, in terms of regime tensions, stresses, and pressures, and niche conditions, and (3) the governance processes negotiated between different regime members that seek to influence the transition process (Smith, Stirling, & Berkhout, 2005; deHaan & Rotmans, 2011; Haxeltime, Whitmarsh, & Bergman, 2008). As a result of the dynamic processes involved, niches can grow to niche regimes and eventually replace the incumbent regime, or they can be incorporated into, or co-exist with, the incumbent regime (Schot & Geels, 2008).

6.3 Research approach

The application of the MLP framework described in section two in the remote community context explores whether the transition from the initial utilities operated diesel systems to low carbon renewable systems under communities' full or partial ownership (a change in structures, cultures and practices) would be the result of successive transition patterns defined through regime and niche related conditions, as well as governance processes (Figure 2). These governance processes take the form of interventions influencing (a) the selection pressures that apply on target regimes, and (b) the adaptive capacity (resources, capabilities, knowledge) of target regimes so that they respond to the applied selection pressures. They take the form of:

1. policies that shape the selection pressures (e.g. environmental regulations, electricity regulations, renewable electricity generation targets, independent power producer (IPP) policies) and
2. policies and programs that support the innovation system (e.g. R&D programs), and influence regimes' adaptive capacity (e.g. capital grants and technical assistance, community energy planning programs and electricity generation incentives) (Smith, Stirling, & Berkhout, 2005).

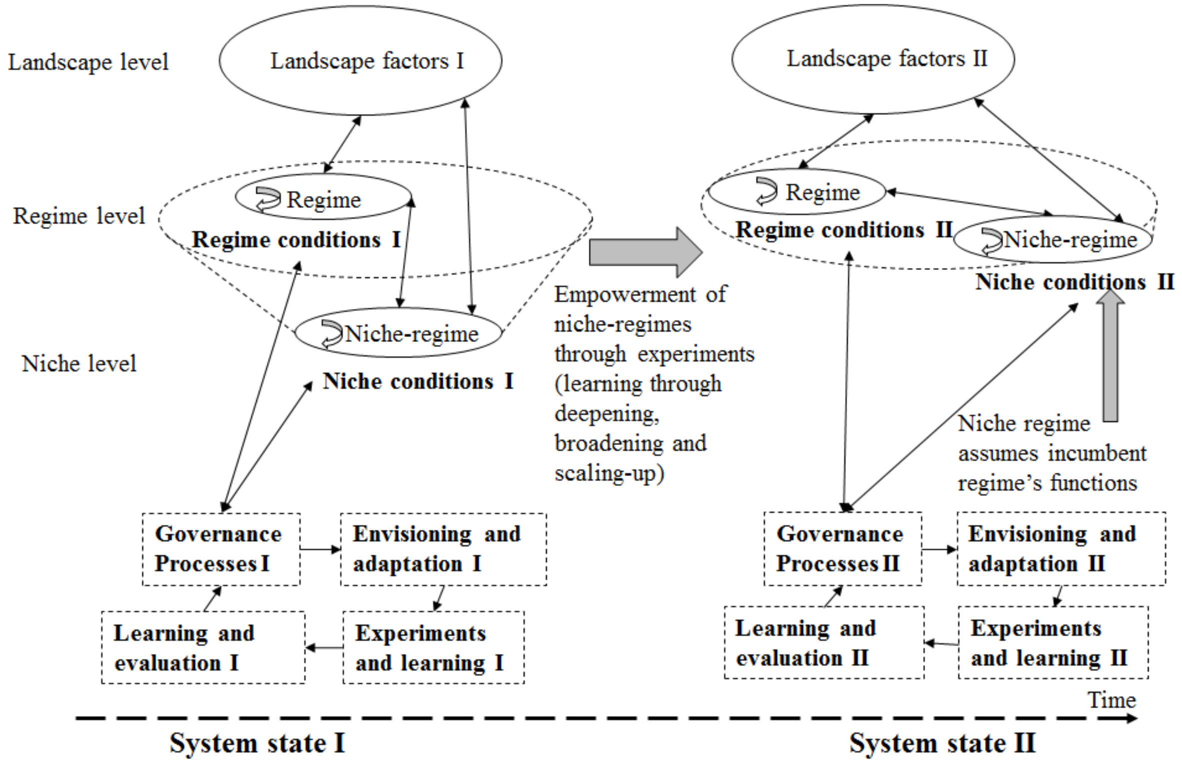

Figure 2: MLP modified framework: regime and niche-regime conditions and governance processes of the transition

According to the MLP based conceptual framework described in Figure 2, these policies and programs may influence the problem structuring and envisioning process towards more sustainable electricity systems desired by local governments and band councils, mobilize resources to address barriers to project deployment, create transition experiments and actor networks, and lead to learning processes through the mechanisms of deepening, broadening and scaling-up. Learning is also informed by similar projects developed in different communities in different provinces, as well as globally, leading to solution standardization and the formulation of best practices (Geels & Raven, 2006). Learning processes may shift indigenous leaderships and other participating actors' perspectives on local electricity generation; such enhanced perspectives, in turn, lead to adaptation of local government responses to selection pressures and the negotiation of new regulatory and

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fiscal arrangements, which lead to new experiments, and, over time, shape the transition pathway towards sustainable electricity options in remote communities.

Our analysis uses the MLP modified framework (Figure 2) to examine changes in remote community electricity systems. The analysis aims to identify:

1. the extent to which RETs have emerged as a viable electricity generation alternative in remote communities in terms of (i) speed, size, period of change, and the phase (pre-development, take-off, etc.) of the transition, and (ii) the origin of the transition, in terms of where (which level and which constellation), when (in terms of tensions, stresses and pressures, niche related conditions, and governance processes), and how (what type of experiments and learning processes), and,
2. transition patterns, that provide information on the effectiveness of strategies and instruments and indicate targets and levers that could be the object of policies for influencing transitions.

Accordingly, first the RET experiments deployed in remote communities between 1980 and 2016 were identified. Most projects are in NWT, Yukon, British Columbia and Ontario, and include hydroelectric, wind and solar applications of different capacities (see Table 14). Second, academic and non-academic literature was reviewed to identify factors that influenced changes in community electricity systems during the period examined. Finally, federal, provincial and utility policy reports on electricity generation, renewable energy targets, policies and programs were examined to identify the governance processes that "steered" the deployment of experimental RET projects in remote indigenous communities. Based on the data, historical narratives for the 1980-2000 and 2001-2016 periods were developed that include the tensions, stresses and pressures on the system, the niche conditions, the governance structures that drove the transition experiments, and the transition patterns observed.

6.4 Results

6.4.1 The utility driven phase (1980-2000)

6.4.1.1 Regime and niche related conditions

The electrification of remote indigenous communities through hydroelectricity and diesel plants was initiated in the 1960s and 1970s following the formation and expansion of provincial utilities (Valentine, 2010; Liming, Haque, & Barg, 2008). Electrification responsibilities were shared between the federal government, which was typically responsible for the capital cost of electricity system upgrades, and provincial governments and utilities, which were responsible for providing electricity at a reasonable cost and for the operation and maintenance of community power plants (OEB, 2008).

According to the MLP based conceptual framework, tensions influencing utilities between 1980 and 1990 were marked by oil price increases during the first and second oil crisis in 1973 and 1979, and the subsequent 1986 oil price fall to previous levels. Following the publication of the Brundtland report (WCED, 1987) and Canada's adoption of the Kyoto Protocol in 1998 (OAG, 2016; GC, 2003), utilities were pressured towards sound environmental practices and implementation of alternative solutions to diesel electrification in indigenous communities. During the same period, following the 1973 Supreme Court of Canada decision on the Calder case (INAC, 2003; Coates, 1995), the federal government initiated a lengthy procedure to settle comprehensive land claim agreements with Indigenous Peoples (Slattery, 2007). In 1982, aboriginal and treaty rights were recognized and affirmed in the Canadian Constitution Act. By 2004 sixteen comprehensive land claims had been settled in Canada, including the Nisga'a Agreement, Tlicho Agreement and Yukon Umbrella Final Agreement, which provided indigenous governments with rights to self-government, land ownership, surface rights and royalties from resource developments, and significant roles in the management of renewable and non-renewable resources within their territories (AANDC, 2015). These pressures led to increased friction among governments, utilities and indigenous governments regarding electricity generation upgrades and new generation assets (OEB, 2008). Additional internal stresses during this period resulted from transformations within utilities, such as the transfer of NCPC assets to Yukon Energy, Northwest

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Territories Power Corporation (NTPC), and Nunavut Power Corporation, and the restructuring of Ontario Hydro in 1998, as a response to structural changes at the provincial level (NTPC, 2016a; OEB, 2008).

Additionally, the continuous increase in electricity consumption due to population, residential, and community buildings growth, as well as changes in household electricity use (HORCI, 2012), and the resulting increased demand for diesel, led governments and utilities to examine other options to diesel-generated electricity. The first electrification alternatives considered by utilities were small hydroelectric plants, transmission line extensions, large generation units serving several communities, and fuel cells (Cooke, 1980). Small-scale hydroelectricity was developed initially in Newfoundland and Ontario (Ostrom, 1981), followed by experimental wind turbines deployed initially in Quebec (Adamek & Tudor, 2009). Lack of indigenous governments' direct participation in new renewable electricity generation during this period can be attributed to competing priorities, high cost and risk of RET alternatives, and numerous barriers to the development of projects within reserve lands (Parcher, 2004; OAG, 2003; INAC, 2005).

6.4.1.2 Governance processes

Governmental support for the deployment of RET projects in remote communities was initiated in the late 1970s as part of policy objectives evolving from oil and fossil fuel substitution to energy self-reliance, security of energy supply, energy diversity, sustainable development and climate change (Pneumatikos, 2003). Federal policies between 1978 and 1983 included capital support and tax write offs for hydroelectricity demonstration projects (Ostrom, 1981), the establishment of research institutes for the development of wind turbine prototypes between 1974 and 1984, and the implementation of wind demonstration projects in remote communities (AWTS, 1999; Green, Clark, Brothers, & Saulnier, 1994). Policies were implemented in a "top down" mode (Gingras & Dalp, 1993) facilitated by governmental ownership of utilities, while the participation of local governments was limited to cooperation with utilities on the siting of renewable projects (Nunavut Power, n.d.).

6.4.1.3 Experiments and transition patterns

Transition patterns in remote indigenous communities during this period take the form of utilities adaptation to mainstream and niche technologies through emission reduction measures (fuel switching, higher efficiency generators and demand response systems) after 1995 (see for example (HORCI, 2012), and the deployment of medium and small-scale hydroelectricity, wind and solar applications into community systems (Table 14). In British Columbia, BC-Hydro purchased electricity generated by four privately owned hydroelectric plants[13] to electrify larger geographical areas with multiple communities and settlements. Utility-owned small hydro-diesel hybrid systems were installed in Mary's Harbour in 1987 and Deer Lake in 1998. Finally, experimentation with innovative technologies in the form of wind turbines and solar photovoltaic by NTPC, Hydro One, and Hydro Quebec led to the development of eleven wind turbine projects and one 3.2 kW solar system in Iqaluit.

Table 14: Development of RETs in remote indigenous communities between 1980 and 2016

Province/Territory		**YU**	**NWT**	**NU**	**BC**	**ON**	**QU**	**NFL**	**Total**
Number of remote communities		**5**	**25**	**25**	**23**	**25**	**14**	**16**	**133**
1st period: 1980-2000	Hydro > 10 MW				1				1
	Hydro ≤ 10 MW				3	1		1	5
	Wind >100 kW			1					1
	Wind ≤ 100 kW		1	4		4	1		10
	Solar >10 kW								
	Solar ≤ 10 kW			1					1
Total		0	1	6	4	5	1	1	18
2nd period: 2001-2016	Hydro> 10 MW								
	Hydro≤ 10 MW				2				2
	Wind >100 kW								
	Wind ≤ 100 kW					1			1
	Solar >10 kW	1	10		1	9			21
	Solar ≤ 10 kW	3	19	1		3			26
	Other				3				3
Total		4	29	1	6	13	0	0	53

Source: Karanasios and Parker (2016a-g)

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[13] Ocean Falls in Bella Bella, Clayton Falls in Bella Coola, Queen Charlotte in Haida Gwaii (Skidate), and Dease Lake.

6.4.2 The community driven phase (2001-2016)

6.4.2.1 Regime and niche related conditions

Using the MLP-based conceptual framework, the main tensions surrounding utilities during the 2001-2016 period were identified as a series of legislative and court decisions favoring indigenous participation in projects within traditional territories, and the priority of governments to promote indigenous development and climate change mitigation. First, the 1996 RCAP report on indigenous economic development (RCAP, 1996), the 1997 Delgamuukw decision on the existence and constitutionally protected status of aboriginal title in Canada (Hurley, 1998), and the 2004 Supreme Court of Canada Haida decision on the Crown's "duty to consult" with indigenous people (Sterling & Landmann, 2011), initiated a new relationship between indigenous and state governments (Nacher, 2001). These decisions impacted institutional relationships and investor and community financial expectations regarding the exploitation of natural resources in northern Canada (Benoit, 2012). Moreover, they provided the background for indigenous participation in natural resources development either in full, through self-governance agreements, or partially, through revenue sharing agreements (RSA) and impact and benefit agreements (IBA) (Isaac & Knox, 2005; Morellato, 2008; AFN, 2011a). By 2006, following the settlement of comprehensive land claims agreements initiated in 1973, First Nations owned and controlled 15 million hectares of land and Inuit controlled over 45 million of hectares of land in Canada (MIAND, 2009). Second, during this period the federal government targeted indigenous economic development through a series of policy actions that supported labor market and business development, indigenous entrepreneurship, human capital development, partnerships and the development of indigenous assets (MIAND, 2009; AANDC, 2014c). Finally, in the context of the Copenhagen Accord in 2009, the Cancun Agreement in 2010, and the Paris Climate Conference in 2015, the government of Canada committed to reduce greenhouse gas emissions by 30% below 2005 levels by 2030 (GC, 2016; ME, 2014). Provincial governments also introduced targets and policies and established joint action plans and cooperation frameworks to meet emission targets (GC, 2016; DSF, 2012).

Internal stresses during this period take the form of utilities and federal and provincial governments' joint concerns regarding emissions and subsidy reductions. Federal and provincial

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governments aimed to reduce diesel fuel consumption because of the continuous increase in electricity cost subsidies due to community growth and increasing diesel fuel prices (OPA, 2014; GY, 2015a; BC Hydro, 2015; Hydro One, 2012; GN, 2015b). Utilities concerns over continuous diesel dependency were related to rates affordability, and the need to build redundancy and increase supply reliability and self-sufficiency by reducing diesel consumption, while keeping electricity costs down (GNWT, 2008b; Yukon Energy, 2012b).

Pressures on utilities for community participation in renewable electricity generation during this period were driven by indigenous governments' renewable electricity generation goals to improve local systems' reliability and sustainability. Enhanced reliability relates to reduced diesel fuel price volatility, improved security of supply, and low electricity prices (GNWT, 2008b; NAN, 2012; OEB, 2008). Local electrical systems' sustainability improvements are associated with community owned and controlled renewable electricity generation that can reduce "black carbon" emissions, caused by the burning and road or air transportation of diesel (GY, 2015b; ECCC, 2016), and fuel spills and leakages responsible for the contamination of soils (HORCI, 2012; AANDC, 2008; AANDC, 2012; TBS, 2016). Additionally, new electricity generation can remove utility imposed load restrictions (based on the output of diesel generators), which limit new housing development and business connections (NAN, 2012), and contribute to revenue generation and/or reductions in local electricity expenses, thus increasing available funds for other pressing community needs, such as housing and education (OEB, 2008). Finally, niche level pressures during this period are expressed through advances in renewable electricity generation and storage technologies (Diaz-Gonzalez et al., 2012; NTPC, 2016c), microgrid planning (NREL, 2005), equipment quality and deployment practices (NRCan, 2017a; Tugliq Energy, n.d.), and customized hybrid solutions (Fay, Keith, & Schwörer, 2010a), combined with declining equipment costs (NREL, 2014). These pressures increased the attractiveness of small hydroelectricity, wind and solar projects as alternatives to diesel-generated electricity.

Finally, niche conditions were present in Yukon, NWT, BC, and Ontario, with indigenous governments expressing their interest in local electricity systems' transformation through participation in energy charrettes, workshops and conferences (YE, 2011; GNWT, 2008b; GNWT, 2009a; GNWT, 2009b; NAN, 2012), community driven RET propositions (VGFN, 2002;

Morissette, 2014), cooperation with utilities (Mast, 2014a; Mast, 2014b), and the interventions of indigenous political organizations on the future of electricity generation in remote communities' territories (OEB, 2008; NAN-HORCI, 2013). Indigenous governments in Quebec, Nunavut and Newfoundland and Labrador expressed less interest in renewable electricity generation (NG, 2016) due to mixed views on the potential of RET to displace diesel (Rohner, 2015; Murray, 2015) and their contribution to electricity price increases (McDonald & Pearce, 2013), or the existence of alternatives, such as Nunavik's focus on connecting to the provincial grid and the development of local hydroelectricity (KRG, 2012).

6.4.2.2 Governance processes

Governance structures towards the introduction of RETs in remote communities' electricity systems between 2001 and 2016 take the form of policies that supported (i) RET deployment and indigenous participation in electricity generation, (ii) research and development for RETs, and (iii) improvements to communities' adaptive capacity. *First*, support for renewable electricity generation to address future provincial electricity needs and carbon emission reduction took the form of RET deployment targets and commitments, the promotion of RETs in diesel powered communities, and the establishment of regulations supporting local electricity generation (Table 15). Provincial targets for renewable electricity generation in the interconnected grids of BC, Ontario, Quebec and NFL, were established after 2007 and focused on large-scale expansion of hydroelectricity and wind projects driven by predicted future growth of residential and industrial consumption and export potential. However, specific targets promoting RETs for diesel substitution in remote communities were developed only in the isolated micro-grids of NWT and Yukon. In NWT, policies aimed at supplying up to 20% of the average load of the 25 diesel powered communities through solar photovoltaic applications and displacing 10% of annual diesel-generated electricity (GNWT, 2012b), and in Yukon, recent policies targeted a 20% increase in renewable energy supply (Yukon Government, 2015). Regulations promoting the participation of remote indigenous communities in local electricity generation were introduced in Yukon, NWT, British Columbia and Ontario after 2011, and took the form of "behind the meter" and "net

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metering" policies for electricity self-generation, and IPP policies for stand-alone community owned RET generation projects (GNWT, 2008; GY, 2015c; WEL, 2009; HORCI, 2015).

Table 15: Targets and regulations for RET in provinces and territories between 2001 and 2016

	Targets	Targets for diesel substitution in remote communities	Regulations for indigenous participation	Sources
Yukon	-2009 Yukon Energy Strategy	-2009 Yukon Energy Strategy	-2015: IPP Policy	GY (2009); GY (2015c)
NWT	-2011-2015 Greenhouse Gas Strategy for NWT	-2012 NWT Solar Energy Strategy	-2014: Net metering policy -2015: IPP policy	GNWT (2011); GNWT (2012b); Cherniak, Dufresne, Keyte, Mallett, & Scott (2015); NTPC (2016b)
Nunavut	-2007 Ikummatiit- a territorial energy strategy			(GN, 2007)
BC	-2002 Energy Plan -2007 Energy Plan -2010 Clean Energy Act (CEA) -2002-2013: Eight power acquisition processes		-2002-2007: IPP policies established in the 2002 and 2007 Energy Plans	WEL (2009); BC Hydro (2013a) ; BC Hydro (2013c)
ON	-2013 Ontario's Long-Term Energy Plan	-2013 Ontario's Long-Term Energy Plan	-2012-2016: HORCI net metering, behind the meter policy 2012-2016: HORCI REIDEER (IPP policy)	OME (2013); HORCI (2015)
QU	-2006-2015 Québec Energy Strategy	-2006-2015 Québec Energy Strategy		GQ (2006a); GQ (2006b)
NFL	-2007 NFL Energy Plan		-2007 NFL net metering policy	GNFL(2007); GNFL(2015a); GNFL(2015b); NFL Hydro (2009)

Second, policies that supported the development of the innovation system during this period included financial support for research and development of RETs, offered though the Clean Energy Fund (2007-2014), and the ecoEnergy Innovation Initiative (EEII) (2011-2016) (NRCan, 2017b).

Third, policies that improved indigenous governments' adaptive capacity between 2001 and 2016 took the form of programs that reduced RET capital costs, provided technical support, and introduced generation incentives (Table 16). Programs addressing capital costs and technical support were launched successively by the federal government, while provincial programs providing grants and rebates for equipment and system balancing costs were established in BC, NWT and Ontario. Challenges of access to financial resources necessary for larger projects and community ownership were addressed through project financing mechanisms (see BC-Hydro's RCE program (BC Hydro, 2010) and Ontario's 2014 ALGP program (OFA, 2016)). Resource assessments, feasibility, and community energy planning studies addressing technical and capacity barriers in remote communities were introduced after 2003 as part of the ANCAP federal program and provincial programs in BC, and Ontario. These studies complemented RET capital reduction funding programs with a view to increasing the efficiency of RET project implementation. Finally, the establishment after 2011 of regulatory arrangements for "net metering' and IPP policies, described previously, and the accompanying generation incentives to compensate for vested interests' revenue losses and support economic development through revenue generation, was decisive for the deployment of projects implemented in Yukon, NWT and Ontario.

Table 16: Programs supporting RETs in remote indigenous communities between 2001 and 2016

Level	Programs	Source
Federal	**A. Programs that reduce capital costs** -2001-2003: Aboriginal and Northern Climate Change Program (ANCCP). -2003-2007: Aboriginal and Northern Community Action Program (ANCAP). -2007-2016: ecoENERGY for Aboriginal and Northern Communities Program (EANCP).	AANDC (2014a)
Yukon	**C. Programs that provide financial benefits** -2015: IPP policy for the five diesel-based communities in cooperation with ATKO Electric Yukon.	GY (2009); GY (2015)
NWT	**A. Programs that reduce capital costs** -2001-2003: RETCAP -2007- to date: CREF as part of the Alternative Energy Technologies (AET) program. **C. Programs providing financial benefits** -2015: IPP policy and net metering policy for aboriginal community projects.	GNWT (2011b); GNWT (2012b); Carpenter (2013); GNWT (2013); Cherniak et al., (2015)
Nunavut	No programs	
British Columbia	**A. Programs that reduce capital costs** -2009-2013: Remote Communities Initiative (RCI) -2005-2010: Community Action on Energy & Emissions (municipal) **B. Programs that provide technical assistance** -2009-2013: Remote Communities Initiative (RCI) -2005-2010: Community Action on Energy & Emissions (CAEE) (municipal) **C. Programs that provide financial benefits** -IPP, Standard Offer Program (SOP), Call for Power (CFP). -2005-2015: Remote Communities Electrification (RCE) program including IPP option.	BC Hydro (2010); BC Hydro (2013b)
Ontario	**A. Programs that reduce capital costs** -2011-2015: Northern Ontario Development Program (FedNor) -2010: Aboriginal Renewable Energy Fund (AREF) and *Community Energy Partnerships Program (CEPP)* -2014: Aboriginal Loan Guarantee Program (ALGP). -2014: Aboriginal Transmission Fund (ATF). -2015: Aboriginal Energy Partnerships Program (AEPP). **B. Programs that provide technical assistance** -2014: Remote Electrification Readiness Program. -2013: Aboriginal Community Energy Plan (ACEP) and the Education and Capacity Building (ECB) Program (technical support), as part of the AEPP. **C. Programs that provide financial benefits** 2012-2016: Behind the meter, net metering options for community buildings and REINDEER program (HORCI).	AEPP (2016)
NFL	**C. Programs that provide financial benefits** -2007: Net metering	GNFL (2007)

6.4.2.3 Transition experiments and patterns

During this period, regime and niche conditions, and governance processes, led to the development of 53 RET projects: 2 hydroelectric plants (in BC) and 8 solar demonstration projects (5 in NWT and 3 in British Columbia) were developed between 2000 and 2010, followed by one wind project

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and 42 solar installations between 2011 and 2016, deployed mainly in NWT and Ontario (Table 14). Three main technological strategies were implemented leading to the transformation of the electrical systems of 46 remote communities through four transition patterns (Table 17). First the connection to provincial grids led to a reconstellation pattern in six communities and the creation of new (indigenous) regimes due to infrastructural change. The connection to provincial grids represents a transformational opportunity to address local electricity generation goals and can lead to a virtuous cycle of economic development through indigenous governments' participation in transmission extensions, renewable electricity generation, and resource project related IBA and RSA that contribute to the creation of a reliable economic base to support communities' self-reliance and self-governance goals (AFN, 2011a). Extensions and interconnections with other electrical grids are examined in Yukon (Yukon Energy, 2012a; Yukon Energy, 2012b), NWT (NT Energy, 2013), British Columbia (BC Hydro, 2013c), Nunavut (Rogers, 2015), Ontario (WP, 2012; OME, 2013; OPA, 2014) and Quebec (GQ, 2006a; KRG, 2012).

Second, the use of community scale hydroelectricity allowed one indigenous community to become the owner and operator of their electrical system and enjoy significant socioeconomic benefits from the transition (Table 17). Small-scale run-of river hydroelectricity projects can displace diesel completely, offer security of supply due to the lack of intermittency, and, despite high capital costs, usually provide lower electricity costs than diesel, wind and solar applications (see Hatch (2013); NFL Hydro (2009)).

Third, the integration of wind and solar projects into communities' diesel systems led to adaptation and empowerment transition patterns. In the case of Independent Power Authorities (IPA) owned plants, seven indigenous regimes adapted to new innovative renewable solutions, while the installation of one wind and 39 community owned solar projects led to empowerment of 31 communities through participation in the electricity generation process. However, all projects involved low level renewable resource penetration that can displace up to 15% of diesel consumption, and, therefore, addressed local electricity generation goals and socioeconomic goals to a lesser extent than grid connection or small hydroelectricity generation (Fay, Keith, & Schwörer, 2010a; Baring-Gould & Dabo, 2009).

Table 17: Transition patterns in utilities owned systems between 2001 and 2016

System state I	Pattern	System state II	Number of RET projects	Number of communities	Type of project and community location	Technology
IPA operated communities						
-Regime: indigenous government	-Adaptation through niche innovations	-Regime: indigenous government	7	7	6 solar projects (ON) 1 hydroelectric (BC)	Solar, hydroelectricity
Utilities operated communities						
Regime: Utility (QEC)	-Adaptation through niche innovations	Regime: Utility	1	1	1 solar project (NU)	Solar
Regime: utility Niche- regime: indigenous government	-Adaptation of the incumbent regime through niche innovations	Regime: utility Niche- regime: indigenous government	2		Colville Lake (NWT) and Fort Simpson (NWT) solar projects	Solar
-Regime: utility -Niche-regime: indigenous government	-Empowerment of the niche regime and regime shift	-Niche regime (indigenous government) becomes the incumbent regime. -Old regime (utility) declines.	1	1	Tlingit FN (BC)	Hydroelectricity
-Regime: utility -Niche-regime: indigenous government	-Adaptation of the incumbent regime -Empowerment of the niche regime	-Utility remains the main regime. -Niche-regime performs regime functions.	42	31	1 solar project (BC) 2 other projects (BC) 1 wind project (ON) 6 solar projects (ON) 28 solar projects (NWT) 4 solar projects (YU)	Wind, solar
-Regime: utility -Niche-regime: indigenous government	-Reconstellation	-Infrastructural change. -Indigenous government participates in the new regime.		6	Fort Albany (ON) Kashechewan (ON) Attawapiskat (ON) Pelly Crossing (YU) Eddontenajon (BC) Telegraph Creek (BC)	Grid connection
Total			53	46		

6.5 Discussion

According to our MLP based framework, the transformation of the indigenous communities' electrical systems is the result of regime tensions, stresses, and pressures, niche related conditions, and governance processes. The analysis provides information on the origin of the transition (which level and which constellation) and development phases, the type of experiments and the learning processes involved, and the transition pattern (adaptation, empowerment or reconstellation). As a result, insights on the effectiveness of governance processes, as well as targets and levers that could be the object of policies for influencing transitions can be discussed.

6.5.1 The effectiveness of governance processes

According to our MLP modified framework (Figure 2), the effectiveness of governance processes can be assessed in terms of communities' engagement leading to RET experiments, learning processes, adaptation of expectations, and a "fast phase" of RET deployment (Grin, Rotmans, & Schot, 2010). The 1980-2000 governance processes consisted of federal policies in the form of capital support and tax write offs that supported utility owned hydroelectricity and wind projects. The initial three wind demonstration projects developed between 1986 and 1988, were followed by a second "fast" round of eight projects deployed between 1994 and 1998, leading to a total wind capacity of 705 kW by 1998 (Figure 3). However, mechanical failures, high capital and operation / maintenance costs stimulated utility learning on the low financial performance of these projects, and, eventually, ended early experimentation with small wind turbines in remote electrical systems. By 2006 only two of these systems remained operational (Weis & Ilinca, 2008).

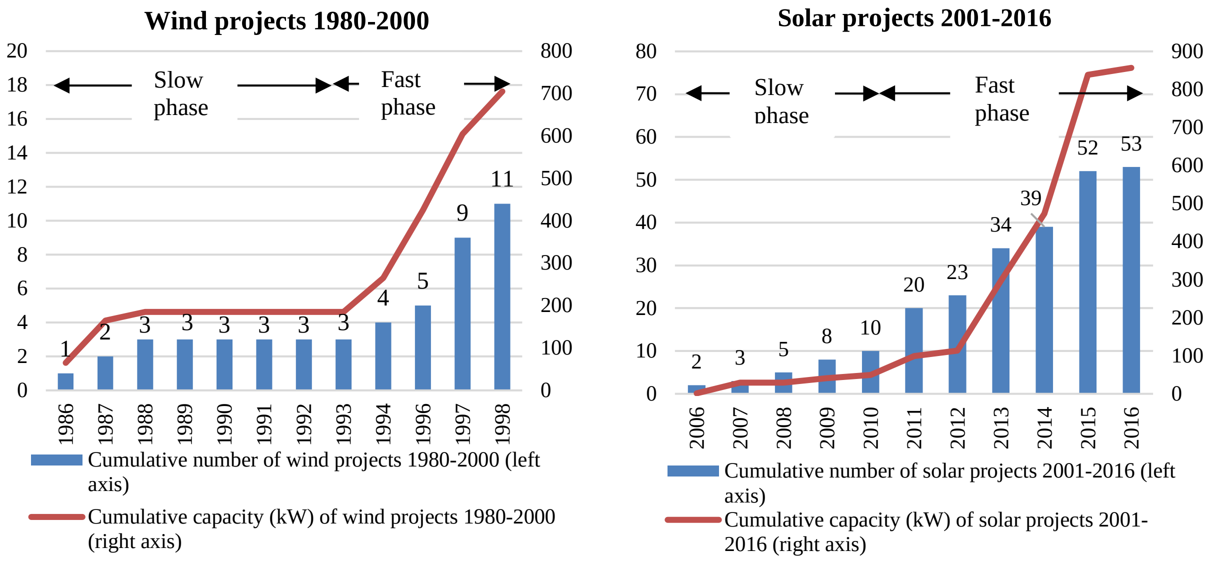
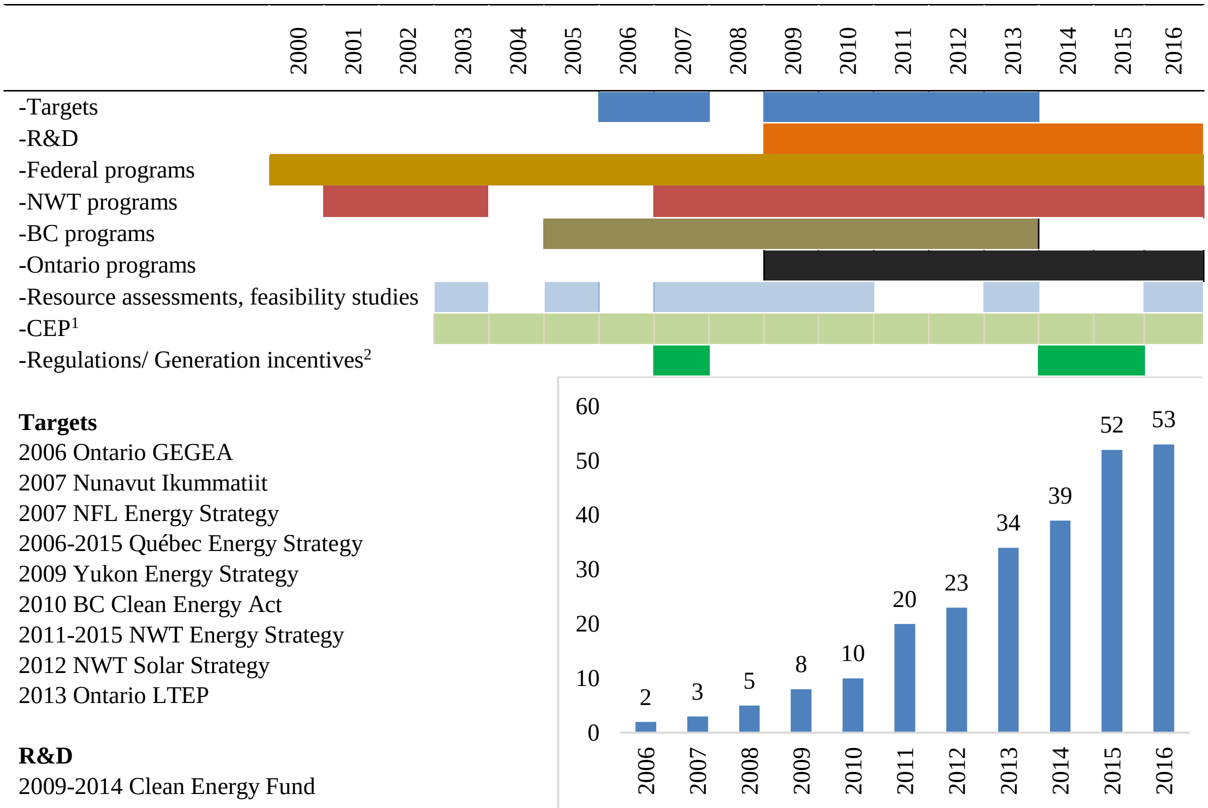


Figure 3: Cumulative number and capacity of wind and solar projects in remote indigenous communities (1980-2016)

The 2001-2016 governance processes were shaped by macro-level tensions, utilities' internal stresses, and pressures from local governments aiming to participate in electricity generation and contributed to the transformation of remote community electricity systems from "utility driven" to "community driven". Within this environment, provincial regulatory arrangements and fiscal support through federal and provincial policies and programs adjusted to community learning, new networks formation, and the adaptation of communities' visions and expectations, and were able to engage communities in one or more projects of increasing capacity and drive RET development through two phases and four development stages.



Targets
2006 Ontario GEGEA
2007 Nunavut Ikummatiit
2007 NFL Energy Strategy
2006-2015 Québec Energy Strategy
2009 Yukon Energy Strategy
2010 BC Clean Energy Act
2011-2015 NWT Energy Strategy
2012 NWT Solar Strategy
2013 Ontario LTEP

R&D
2009-2014 Clean Energy Fund
2011-2016 EcoEnergy Innovation Initiative

Federal programs
2000-2002 ANCCP
2003-2007 ANCAP
2008-2011 EANCP 1
2012-2016 EANCP 2

Provincial programs
NWT
2001-2003 RETCAP
2007-2016 CREF
British Columbia
2005-2010 CAEE
2009-2013 RCI
Ontario
2010-2014 AREF
2014-2016 ALG and ATF
2011-2014 FEDNOR
2015-2016 AEPP

Feasibility studies
NWT-ARI (2003)
Krohn (2005
Maissan (2006a)
Pinard (2007)
Weis and Ilinka (2008)
NFL Hydro (2009)
Weis and Ilinka (2010)
Arriaga, Cañizares, & Kazerani (2013)
Das & Canizares (2016)

CEP programs
2003-2008 ANCAP
2009-2013 CAEE, RCI
2013-2016 ACEP

Regulations/ Generation incentives
2007 NFL Net metering
2014 NWT Net metering
2015 NWT IPP[3] policy
2015 Ontario REINDEER
2015 Yukon IPP policy

[1] CEP: Community energy planning programs
[2] Regulatory arrangements for indigenous electricity generation and generation incentives in NFL, NWT and Ontario
[3] Independent Power Producers (IPP)

Figure 4: Governance structures and cumulative number of RET projects between 2001 and 2016

The initial phase between 2001 and 2010 (Figure 3), was characterized by the establishment of provincial targets on renewable electricity generation, and federal and provincial programs financing numerous resource monitoring, feasibility and optimization studies for wind applications (see Figure 4) developed by utilities, academia, and the Aurora Research Institute (ARI) for communities in NWT, Yukon, Nunavut, Ontario, Quebec, and NFL. During this period eight solar projects with a total capacity of 50 kW were installed on community buildings (5 in NWT and 3 in British Columbia). Early RET studies improved learning regarding resource availability, design options, technical and financial viability, and created the first networks and a community of interest on the feasibility of wind and solar applications in remote communities (BP, 2016).

The 2001-2010 "slow" phase was followed by a "fast" development phase through three successive stages of solar installations of increasing capacity (Figure 3). The local government and utility shift towards solar projects can be explained through the low performance of wind projects (1980-2000), numerous studies indicating limited wind resources, decreasing prices of solar panels, higher solar resource predictability, low maintenance and ease of siting photovoltaic projects. This shift was supported by federal programs and provincial regulatory and fiscal arrangements (Figure 4). First, in 2011-12 there were 13 small-scale (less than 5 kW) solar projects with a total capacity of 55.6 kW, funded mainly through the EANCP 1 program (8 in NWT, 4 in Yukon and 1 in British Columbia). These projects were deployed on the roof of community buildings offsetting electricity consumption and contributed to the "deepening" of learning on the potential of solar photovoltaic experiments in remote communities. Second, during the 2013-14 period, improved learning on the technical feasibility and the potential of solar applications to contribute to community well-being drove the articulation of more concrete expectations and the establishment of "net metering" arrangements that allowed for the installation of solar projects on community electricity intensive buildings for self-generation. Supported with capital funding through the EANCP 2 and provincial programs in NWT and Ontario, 15 solar projects with a total capacity of 350 kW (9 in NWT, 5 in Ontario, and 1 in Nunavut), including two projects higher than 100 kW, were installed on community water treatment plants, schools and arenas. Finally, during the 2015-16 period, further learning on the potential of such projects in offsetting the electricity expenses of communities, and financial support from EANCP 2 and provincial programs and incentives (net metering and power

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purchase agreements (PPA)), gave rise to 14 solar projects larger than 15 kW (average capacity) with a total capacity of 369 kW (7 in NWT and 7 in Ontario). Most of the projects were installed on various community buildings adding up to the creation of a national “technological trajectory” and the creation of articulated rules in the form of technical specifications and financial support (Geels & Raven, 2006, p. 378), thus contributing to the “broadening” and “scaling-up” of solar photovoltaic experiments (van den Bosch & Rotmans, 2008; van den Boesch & Taanman, 2006).

Furthermore, a number of communities were involved in successive RET projects. In NWT, 19 out of the 25 indigenous communities installed solar capacity, of which three communities (Whati, Paulatuk and Gameti) were involved in two successive projects, and two communities (Inuvik and Fort Simpson) deployed four solar projects or more. In Ontario, 11 (five communities serviced by HORCI and six IPA operated communities) out of the 25 remote indigenous communities installed solar projects, while two communities (Deer Lake FN and Kasabonika Lake FN) were involved in more than one RET application. Further learning and scaling-up (embedding) of RET projects in communities’ electrical systems is expected through three higher penetration community owned projects planned for Yukon (Tobin, 2016; Ronson, 2014; Morissette, Watson Lake Hydro Project Feasibility Study, 2014), and one in Ontario (MNDM, 2015). Successive projects of increasing capacity indicate the potential for a virtuous cycle (Grin, Rotmans, & Schot, 2010), as local governments experience socioeconomic and environmental benefits from RET implementation, improve their adaptive capacity (resources and coordination skills) and move from demonstration to higher penetration community scale and community owned projects that could, eventually, lead to a regime shift and community ownership of local electrical systems.

Moreover, policies and programs during this period contributed to the building of social networks through further participation of agencies (see Cherniak et al., 2015 for the role of the Arctic Energy Alliance (AEA) on the Lutselk’e FN project), and the involvement of the private sector, academia, NGOs, and indigenous communities in R&D activities (NRCan, 2016b; ME, 2016), feasibility studies, microgrid planning, testing, and training (ME, 2016; UW, 2014), and the deployment and installation of RETs projects (NCC, 2016).

6.5.2 *Levers for influencing the transition*

According to the MLP-based framework, the effectiveness of governance processes depends on the transition context (regime and niche related conditions, selection pressures and availability of resources) in each province/territory. According to Smith, et al. (2005) “the art of governing the transitions becomes the art of recognizing which context prevails and the drivers that offer the best leverage for guiding change in the desirable direction” (p.1498). Accordingly, governance levers for community empowerment through RETs and the transition of community systems towards more sustainable ones, take the form of (a) the existence of indigenous leadership articulating an interest on sociotechnical change, and (b) the creation of pressures on existing and target regimes for diesel displacement and local electricity systems transformation, and, at the same time, the support of innovative technological alternatives at the niche-level, so that a “modulation” of developments can take place and the “take-off” phase is reached, and (c) adjustment of policy instruments to challenges influenced by landscape developments and regime level concerns (Elzen, Geels, Hofman, & Green, 2004).

First, the existence or creation of action-oriented indigenous leadership with a clear focus on community electricity generation goals is considered as one of the main institutional factors that positively influence the successful “steering” of the transformation of local electrical systems throughout the transition phases (INAC, 2004; INAC, 2005; Henderson, 2013; Wesley-Esquimaux & Calliou, 2010). Indigenous communities, utilities and state governments should extend programs that improve local capacity and provide training to local energy professionals (APC, 2017).

Furthermore, pressures on existing and target regimes for transformation of electricity systems take the form of regulatory and fiscal policies. Regulatory policies should include long-term government commitment to diesel displacement, such as emission reduction standards, carbon pricing, and RET deployment targets in the form of percentages of electric generation from renewable resources. Examples are NWTs solar strategy (GNWT, 2012b), or Alaska’s commitment to the generation of 50% of its electricity from renewable and alternative resources by 2025 (Ardani, Hillman, & Busche, 2013). Fiscal policies supporting RET deployment should include various instruments, such as capital cost reductions, technical assistance, and generation

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incentives, tailored to address each community's non-technical and technical barriers and electricity generation goals. Incentives should also be tuned to stimulate niche-level technical innovations.

In addition, the following challenges need to be taken into consideration when designing regulatory and fiscal arrangements for the transformation of communities' electrical systems. *First*, the effectiveness of policy programs varies; for example, while rebates and grants reduce capital costs for RET projects, increase RET implementation rates, and possibly lead to revenue generation and even employment, such measures also need to recognise vested interests, such as transportation and distribution companies, that communities have developed to benefit from the delivery and storage of diesel (Weis, 2014).

Second, access to funding should be facilitated by reducing complexity and promoting consolidation of some programs. Support through multiple programs administered by multiple provincial authorities and NGOs (Inglis, 2012, p. 2) has been criticized as increasing community technical, financial and managerial needs and creating barriers to community participation (Bailie, et al., 2009).

Third, there is a need for the coordination of multiple provincial and federal policies and programs with RET related policies. Policies supporting (a) long term mining and electricity generation projects, (b) remote communities infrastructure (public works, equipment, accommodation, hardware availability, diesel upgrades, new community facilities), entrepreneurship and economic development, and (c) research and development of alternative technologies (e.g. small wind turbine designs and installation procedures for northern environments, and low cost storage technologies), could be coordinated with RET deployment policies to increase the outcome of the projects for communities, governments, and industrial partners involved. For example, the high deployment costs of RETs in remote communities caused by on reserve infrastructural deficiencies could be reduced by integrating clean energy and energy efficiency projects into the Indigenous and Northern Affairs Canada (INAC) administered Infrastructure and Capacity Program and its sub-programs, which support renewable energy projects, community infrastructure, electrification, and community buildings (INAC, 2016).

Fourth, the ownership of higher renewable penetration electricity generation projects is subject to power structures defined through regulatory arrangements and resource interdependencies between federal, provincial and local governments. Local governments' renewable electricity generation could be constrained by utilities due to integration, balancing and grid stability considerations, at least during the early stages of the transition (Fay, Keith, & Schwörer, 2010a). Additionally, in the context of the low population isolated grids of Yukon, NWT, and Nunavut, government intervention regarding the extent of RETs deployment can be justified, since community owned RETs may lead to lower utilities revenues and electricity price increases, which, in turn, may drive communities to stand alone generation and out of the provincial electricity system, which can increase the electricity costs of remaining communities (GNWT, 2008b). Furthermore, since communities' internal resources (financial and capabilities) are unable to produce large-scale RET projects, governments and utilities have the power to deploy resources in a way that will limit participation of local governments, thereby reproducing the current regime structure (Smith et al., 2005).

Fifth, the extent of local government electricity generation ownership is also subject to community benefits considerations. The operation of local governments as IPPs and the sales of community owned renewable electricity under a negotiated PPA might represent the option that maximizes local governments' revenues, and residential consumers' wellbeing, since local electricity generation and subsidization of residential rates remains the obligation of federal and provincial governments. In comparison, a regime shift could also cause changes in subsidies structures (e.g. the elimination of Ontario's Rural or Remote Rate Protection (RRRP) subsidy), which would increase the cost of electricity for residential consumers.

Finally, assuming that power, politics and political negotiation are part of the governance process (Smith et al., 2005; Meadowcroft, 2009), the governance of electrical systems' transition may be influenced by actors' competing and/or complementing interests. Accordingly, although broadly accepted goals such as emissions reductions, elimination of diesel dependency, or renewable energy access for improved community sustainability may represent the main transition motivation promoted by all stakeholders involved, the pattern of transition, and the extent of community empowerment through higher levels of community-owned renewable electricity generation

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supported by financial incentives, could depend on local circumstances and negotiations influenced by hidden economic, social or political factors related to future exploitation of northern natural resources.

6.6 Conclusion

The use of the MLP for analyzing the transformation of remote communities' electrical systems during the 1980-2016 period provides understanding of the origins and dynamics of the transitions (where, when, and how), as well as the resulting transition patterns. First, it uses tensions, stresses and pressures surrounding utilities to explain the shift from a "utility perspective of sustainability" through utilities owned wind projects developed between 1980 and 2000, to a "community perspective of sustainability" through local government owned solar projects between 2001 and 2016. Second, it explains the non-linear deployment of RETs between 2001 and 2016 mainly in NWT and Ontario, and the move from an initial slow phase of community experimenting with different technologies and demonstration scale projects to a fast phase of increasingly larger scale solar applications and recent diesel-solar-storage hybrid projects. The increase is explained through positive interactions resulting from successive rounds of local governments, utilities, and state governments learning through RET experimentation, adaptation of key actors' perspectives, and the negotiation of supportive regulatory and fiscal arrangements in the form of financing capital expenses, technical and managerial knowledge development and generation incentives.

Therefore, an analysis through the MLP and transitions management framework may offer a reflexive governance approach for the establishment of new institutions and the empowerment of indigenous communities. It points to learning as the preferred mechanism to initiate positive interactions and proposes supportive policies for experimentation that allow each community to achieve its electricity generation goals at its own pace, based on its capacity, visions and expectations, rather than solutions being imposed on them. Learning through experimentation, leads to empowerment of local governments through ownership of higher penetration renewable projects and the identification of the appropriate cooperation mode with utilities that maximizes community sustainability. Accordingly, further research through case studies and interviews with community members could identify indigenous perspectives on community electricity generation and preferred governance structures and mechanisms, thereby enabling RETs to contribute to local sustainability goals.

Through the MLP approach it also becomes evident that in the future, remote indigenous communities will not accept the role of passive recipients of new technological innovations that address sustainability concerns expressed by non-indigenous interests, but actively participate to transform technological solutions through experimentation based on local sustainability agendas, as they pursue their goals of economic development and self-governance.

Chapter 7: Explaining the diffusion of renewable electricity technologies in Canadian remote indigenous communities through the technological innovation system approach

This chapter applies the Technological Innovation System (TIS) approach to explain the diffusion of renewable energy technologies (RETs) in remote indigenous communities in Northwest Territories (NWT) and Ontario. These communities need reliable and clean electricity to address social, environmental and economic development issues. The study examines the diffusion of RETs during the 2000-2016 period, identifies the systemic and transformational failures responsible for the functional performance of the TISs, and generates insights about factors that have the potential to sustain the development of RET projects. Although there is evidence that the accumulation of TIS functions determines the rate of diffusion of renewable technologies, policy intervention to improve local learning and networking could lead to accelerated diffusion of RETs to the benefit of the communities and other stakeholders.

7.1 Introduction

There is increasing interest in the role of renewable energy technologies (RETs) within community sustainability transitions, ranging from energy efficiency measures to energy efficient housing development and local electricity generation (Walker & Devine-Wright, 2008; Seyfang & Smith, 2007; Forest & Wiek, 2015). Overall, 144 Canadian remote[14] indigenous communities, with an approximate population of 100,000, depend upon diesel generators to meet their electricity needs (AANDC, 2012; AANDC and NRCan, 2011). The transformation of these local electrical systems through the introduction of RETs therefore has the potential to reduce environmental impacts in the form of carbon emissions, fuel spills and leakages, increase electricity supply and reliability, as well as improve socioeconomic conditions through new housing and business connections and reductions of community electrification costs (AANDC, 2012).

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[14] According to AANDC and NRCan (2011), remote or off-grid communities are permanent or long term (five years or more) settlements with at least ten dwellings that are not connected to the north American electricity grid or the piped natural gas network.

However, despite the multiple potential benefits of RETs in off-grid communities (OECD, 2012), the diffusion of such projects remains low. Research in 133 remote indigenous communities indicates 71 RET projects in Yukon, Northwest Territories (NWT), Ontario, British Columbia, Ontario, Quebec and Newfoundland and Labrador between 1980 and 2016 with a total of 31.5 MW or 13% of the total electricity generation capacity. However, if hydroelectricity is excluded, 63 of these projects were small-scale wind and solar applications with a total capacity of 1.6 MW, or less than 1% of the total electricity generation capacity. 53 of these projects were developed after 2006 and the majority were installed in the NWT (29 projects) and Ontario (13 projects) (Karanasios & Parker, 2016a-g).

Prior research on the introduction of RETs in RETs in remote indigenous communities' electrical systems concentrates on the identification of technical factors that influence a project's financial viability, such as the choice over the extent of the renewable energy resource component (low, medium or high penetration RET integration), economies of scale, developers' expertise, availability of distribution infrastructure, smart grid considerations, lower cost storage technology, reliable, robust equipment, and packaged systems using plug-and-play control technologies (see for example, Baring-Gould & Corbus, 2007; Weis & Ilinca, 2008; Weis & Ilinca, 2010; Fay, Keith, & Schwörer, 2010a; Fay & Udovyk, 2013; Arriaga, Cañizares, & Kazerani, 2013; Tan, Meegahapola, & Muttaqi, 2014; Arriaga, Cañizares, & Kazerani, 2016).

In addition to quantitative studies a limited number of qualitative contributions provide insights on structural, institutional and sociocultural factors for the successful deployment of RET projects in Canadian remote indigenous communities (INAC, 2004; 2005; 2007; Rezaei & Dowlatabadi, 2015). Furthermore, the dynamics of the transition of remote indigenous communities' electrical systems to more sustainable ones have been explained using the Multi-Level Perspective (MLP) framework (Geels, 2005; Geels & Schot, 2007) and the interaction of co-evolving factors, such as destabilizing mechanisms at the landscape level, stabilizing mechanisms and governance structures at the regime level, and the adoption of innovative technologies at the niche level (Karanasios & Parker, 2008). However, the MLP is unable to elaborate in detail, first, how the implemented governance structures that influenced the transition process came about, and, second, the roles and strategies of participating actors, the interactions between actors and institutions, and the role of resource distribution in the development of networks and actors' capacity (Markard & Truffer, 2008; Smith, Stirling & Berghout, 2005).

This level of detail could be provided through the technological innovation system (TIS) approach and the use of functions and functional interactions (Hekkert et al., 2007). The TIS approach defines innovation systems as "a dynamic network of agents interacting in a specific economic/ industrial area under a particular institutional infrastructure and involved in the generation, diffusion and utilization of technology (Carlsson and Stankiewicz, 1991, p. 111)" (cited in Markard & Truffer, 2008). Actors, institutions and interactions (relationships) between them are introduced as the unit of analysis (Hekkert et al., 2007; Bergek et al., 2008). Actors include private consumers, firms, governmental agencies, universities, non-governmental organizations (NGOs) and a multitude of other organizations participating in any given technological innovation. Institutions are considered the laws and regulations, technical, formal and informal rules and norms, visions, and expectations that shape the interactions among actors (Markard & Truffer, 2008). Finally, interactions (or relationships) are means of transferring codified and tacit knowledge at the individual or organizational level; as such, interactions are developed and exchanged between the elements of the system through cooperative relationships or the establishment of networks between different actors, between actors and institutions, and among institutions (Markard & Truffer, 2008). Wieczorek and Hekkert (2012) add infrastructure, in the form of physical (artifacts, machines, roads, buildings), financial (financial programs, subsidies, grants), and knowledge (expertise, know how, strategic information), as important structural components, the existence and performance of which may directly influence the uptake of a certain TIS.

The performance of a TIS depends on the way that actors engage and interact with each other at multiple levels thereby influencing the quality of three main functions, the generation, diffusion, and use of the innovation investigated (Negro, Hekkert, & Smits, 2007; Jacobsson & Bergek, 2004). These functions, in turn, depend on the quality and interactions generated by a set of "sub-functions", defined as F1 (entrepreneurial activities), F2 (knowledge development), F3 (knowledge diffusion), F4 (guidance of the search), F5 (market formation), F6 (mobilization of resources), and F7 (creation of legitimacy/support from advocacy coalitions) (Hekkert et al., 2007; Bergek et al., 2008), It is during the formative period of the TIS that the interactions between sub-functions may create virtuous cycles (or motors of innovation) or processes of cumulative causation leading to the uptake of the TIS; the successful fulfillment of a function possibly leads to the fulfillment of other functions leading to the reinforcement of the process and a virtuous cycle. The sub-functions in turn are influenced by the existence and quality of the structural elements, so it is the constant interplay between the system elements, coordination mechanisms and the development of interrelations that defines the dynamic character of the TIS that may or may not lead to the uptake of certain innovative products within a specific environment (Hekkert et al., 2007; Bergek et al., 2008; Wieczorek and Hekkert, 2012).

Empirically, operationalization of the functional patterns is achieved through a set of indicators or diagnostic questions, which can be both qualitative and quantitative describing the content of the function (Bergek et al., 2008); for example entrepreneurial activities (F1) can be measured through the number of new firms established or new projects undertaken, and the function guidance of the search (F4) can be measured through the targets developed by governments or press releases that set expectations and future policy goals (Markard & Truffer, 2008). Mapping of TIS functions through activities (their operationalization) over a time period can additionally create an evolutionary pattern of the innovation under examination (Negro et al., 2007).

Accordingly, the uptake of a TIS can be examined through an analysis of both the functional and structural components that form the TIS. A combined functional-structural analysis will explain the diffusion of the innovation through the presence, or lack of, or weakness of functions, which, in turn, may be the result of systemic problems of the TIS examined. The systemic problems (or systemic failures or weaknesses) were categorized as actors' problems (presence and capabilities), institutional (presence and capacity), interaction (presence and quality), and infrastructure (presence and quality) problems (Woolthuis, Lankhuizen, & Gilsing, 2005; Negro, Alkemade, & Hekkert, 2012; Wieczorek & Hekkert, 2012). Therefore, policy related issues result from the proposition that both the structure and functions of a TIS are influenced by the existence and quality of different actors and their capabilities, institutions, and infrastructure, as well as the existence and quality of the interactions (Bergek et al., 2008; Jacobsson & Bergek, 2006; Smith, Stirling, & Berkhout, 2005). Both structure and function can be influenced by "inducement" and "blocking" mechanisms, which are responsible for the shaping of the TIS dynamics. Targeted policies may affect the mechanisms that induce the transformation process creating the "virtuous cycles" of successful activities, resulting in the moving of key processes and the diffusion of the specific technological innovation, and the transition from one sociotechnical regime to the desired next one (Bergek et al., 2008; Elzen & Wieczorek, 2005; Markard & Truffer, 2008).

The TIS approach has been criticized for its (internal) focus on innovations' functional performance and a lack of integrating external factors (Markard & Truffer, 2008; Weber & Rohracher, 2012), concepts of power (Avelino & Rotmans, 2009) and political intervention (Meadowcroft, 2009). Accordingly, systemic problems within a TIS were extended to include directionality (lack of shared vision), policy coordination (lack of horizontal and vertical policy coordination), demand articulation (absence of public demand) and reflexivity (involving actors in processes of self-governance) failures (Weber & Rohracher, 2012). Furthermore, recent TIS studies on the diffusion of RET innovations argue for exploring the link between deployment and local contexts, institutional conditions, and learning (Coenen, Benneworth, & Truffer, 2012; Dewald & Truffer, 2012; Binz, Truffer, & Coenen, 2014; Blum, Bening, & Schmidt, 2015), which could only be partially captured through a comparative structural analysis of regional or national TISs (Markard, Hekkert, & Jacobsson, 2015).

In terms of empirical studies, the TIS approach has been used to examine the development, generation and deployment of innovations as either a single process in developed countries (Hillman, Suurs, Hekkert, & Sanden, 2008; Suurs & Hekkert, 2009; Suurs et al., 2010), or as an innovation aimed at replacing existing products in developing countries (Jacobsson & Bergek, 2006). Furthermore, the approach has been used to examine both the deployment of infrastructural level energy innovations, such as combined heat and power (Jacobsson, 2008) and district heating (Hawkey, 2012), as well as the deployment of less technologically demanding RET applications in both developed (Palm, 2015) and developing country contexts characterized by remoteness (VanAlphen, Hekkert, & VanSark, 2008) and energy access challenges (Tigabu et al., 2015; Kebede & Mitsufuji, 2014). Accordingly, the purpose of this study is to apply the TIS approach to explain the diffusion of RET projects, primarily in the form of solar applications, in the specific political, cultural and institutional context of Canadian indigenous remote communities (see for example, RCAP, 1996; BCAFN, 2011; Angell & Parkins, 2011) in Northwest Territories (NWT) and Ontario between 2000 and 2016, and generate insights about factors that have the potential to sustain their development.

This paper is structured as follows: section 7.2 presents the methodological approach, followed by the results and discussion in sections 7.3 and 7.4 respectively. Section 7.5 offers concluding remarks.

7.2 Materials and methods

To explain the diffusion of RETs in Canadian remote indigenous communities and identify factors influencing their deployment, the performance of the NWT and Ontario TIS are assessed through a combined functional and structural analysis. The steps proposed by Bergek et al., (2008) and Wieczorek & Hekkert (2012) are followed (Table 18).

Table 18: Research process

Step	Description	Supporting framework	Methods	Results
Step 1	• Definition and structure of the TISs under consideration. • Identification of blocking mechanisms that influence the functional performance of the TISs.	Table 19 (based on Wieczorek & Hekkert, 2012).	Systematic review of academic and policy documents and key informant interviews in a remote indigenous community.	Section 7.3.1 and section 7.3.2.
Step 2	• Identification and analysis of systemic problems responsible for the blocking mechanisms.	Table 19 (based on Wieczorek & Hekkert, 2012).	Multiple literature reviews of academic and non-academic, policy, utilities' and communities' related literature.	Section 7.3.3.
Step 3	• Analysis and comparison of the NWT and Ontario TISs functional performance through event mapping.	Table 20 (based on Bergek et al., 2008).	Multiple literature reviews of academic and non-academic, policy, utilities and communities' literature.	Section 7.3.4.

First, the TIS under investigation is defined and the structure, functional pattern, and the main blocking mechanisms and underlying systemic problems that hinder the fulfilment of the functions in both TIS are identified using the framework presented in Table 19. In a second step, the systemic problems responsible for the poor functional performance of both the NWT and Ontario TIS are "precisely identified" and analyzed (Wieczorek & Hekkert, 2012, p. 85).

Table 19: Framework for the analysis of the TIS in remote indigenous communities

Functions	Evaluation of functions based on diagnostic questions	Identification of the reasons affecting function performance	Identification of systemic (actors, institutions, networks, infrastructure), and transformational (directionality, demand articulation, policy coordination and reflexivity) failures responsible for the blocking/inducement mechanisms
Fn With n=1, …, 7	………..	Blocking /inducement mechanisms) affecting Fn	Actors: Presence? Capabilities? Institutions: Presence? Capacity/quality? Interactions: Presence? Intensity/quality? Infrastructure: Presence? Capacity/quality? Presence and quality (effectiveness) of directionality measures? Presence and quality (effectiveness) of demand articulation measures? Presence and quality (effectiveness) of policy coordination measures? Presence and quality (effectiveness) of reflexivity measures?

Adapted from Wieczorek and Hekkert (2012) and Weber and Rohracher (2012). See also Labrinopoulou, Renwick, Klerkx, Hermans, & Roep (2014).

In a third step, the functional performances of the NWT and Ontario TIS during the 2000-2016 period are analyzed and compared in order to, first, explain the diffusion of the TISs, and, second, generate insights concerning the main factors that influence the deployment. Functional performance during the period investigated is assessed through mapping actors' activities (events) that changed institutions, influenced interactions and modified infrastructure, and, therefore, addressed systemic problems and contributed to TIS function changes and fulfillment. Events are then allocated to functions based on operationalization indicators (Suurs et al., 2010) described in Table 20. Findings follow in the form of a narrative that explains the historic development of both TISs through changes in the structure and functions' interactions. Events that contribute positively to function fulfillment are marked with a positive (+) sign, and events that influence functions in a negative way are marked with a negative (-) sign (section 7.3).

Table 20: Functions and operationalization indicators for the NWT and Ontario TIS

System function	Operationalization indicators
F1. Entrepreneurial activities	Development of remote community owned RET projects.
F2. Knowledge development	Conducting renewable resource surveys, monitoring studies, feasibility studies. Community energy plans. Small-scale RET experiments. Participation in research projects.
F3. Knowledge diffusion	Training of community members. Promoting energy-related education, developing energy campaigns, organizing and participating in conferences, exhibitions, workshops, charrettes, seminars, meetings.
F4. Guidance of the search	Establishing targets for RETs. Design of policies and regulations that favor RET solutions. Design of policies and regulations that favor RET solutions in remote indigenous communities. Establishing expectations from RETs projects on indigenous lands. Providing direction and expressing interest in RETs options. Publication of results from studies involving RETs in remote communities.
F5. Market formation	Regulatory arrangements that allow local governments and their organizations to participate in the electricity generation process as Independent Power Producers (IPP). Power purchase agreements (PPAs). Net metering agreements.
F6. Resource mobilization	Providing financial incentives (for project capital, technical training, electricity generation). Providing loans. Providing loan guarantees. Financing research projects. Mobilizing cooperation with the private sector.
F7. Support from advocacy coalitions/ legitimization	Advocating for indigenous RETs projects in remote communities. Statements of indigenous leadership on the cultural fit of RETs projects. Community visions and expectations favoring RETs deployment.

Data on the blocking mechanisms were collected through interviews with members of a remote indigenous community and a systematic review of academic and policy documents. The semi-structured interviews with ten key informants, members of a remote northern Ontario community actively pursuing RETs projects, were conducted in October 2014. Interviews were undertaken following the Tri-Council policy requirements and received ethics clearance from the Office of Research Ethics at the University of Waterloo. Participants were proposed by the Band Council, were over 18 years old and consented in writing and orally to be interviewed. Secondary data were collected through a search in Scopus and Web of Science databases of the keywords: “renewable” AND “electricity” AND “barriers” AND “indigenous” AND “Canada”, which returned 113 and 12 documents respectively. After eliminating studies irrelevant to Canadian context, seven documents were related to Canadian remote indigenous communities, of which only one document discussed barriers to RETs implementation. We then extended the search to internet and policy documents and identified 13 documents, presented in section 7.3.2., which described barriers to RET deployment into Canadian remote indigenous communities.

Data for the event analysis were collected through multiple literature reviews of academic and non-academic, policy, utilities and communities' literature. Event analysis included only events that signaled a change of state and communicated public importance (Agbemabiese, Nkomo, & Sokona, 2012). A list of the events and their allocation to functions is presented in Tables 1 and 2 in Appendix D.

7.3 Results

7.3.1 TIS structure

The NWT and Ontario TISs (see also Karanasios & Parker, 2016b; 2016e) are defined through a niche component (a new technology or sociotechnical practice) and its supporting system (Markard & Truffer, 2008). The niche consists of a sociotechnical practice, defined as the deployment of existing RETs in remote communities by indigenous governments with the purpose of undertaking (partially or in full) the electricity generation functions currently performed by Crown corporations (state utilities), with the aim to improve community sustainability, environmental and socioeconomic conditions. This deployment encompasses both the domestication and societal embedding of new technologies, as well as measures involved in selecting, designing, purchasing, commissioning, and installing (Becker, Kunze, & Vancea, 2017; Neij, Heiskanen, & Strupeit, 2017) solar and wind turbine applications in remote indigenous community diesel systems, to create hybrid solutions that provide acceptable power quality and supply. The supporting system includes a network of actors and institutions that jointly interact and contribute to the RET deployment. In addition, the TIS is concerned with the associated administrative procedures (such as planning and permitting), institutional and organizational changes, and regulatory and fiscal arrangements that allow for indigenous ownership of the RET application and participation in the electricity generation process.

The deployment of RETs in NWT and Ontario can be represented as two different TISs, with different and shared participating actors and their networks, and subject to shared and non-shared institutions. Key stakeholders in electricity generation include local indigenous governments and residential consumers, the federal and provincial/territorial governments, utilities operating mostly at "arm's length" from provincial/territorial governments, governmental agencies, academic and research institutes, non-governmental organizations, and the private sector. Indigenous people are subject to specific governance structures (the Indian Act; Land Claims and Self Government processes) (Coates, 2008), lack market economies (Alcantara, 2003), have historically experienced high unemployment and low educational attendance levels (Southcott & Walker, 2009; Wilson & Macdonald, 2010; Loppie & Wien, 2009), and most importantly, have specific cultural values and worldviews on economic development, environmental governance and resource exploitation (RCAP, 1996; IAND, 1997; AAWG, 2010).

In addition, community electrical systems are the joint responsibility of both federal and provincial governments, with the federal government responsible for capital upgrades of the electricity generation equipment, and the provincial government responsible for maintenance and operations (OEB, 2008). Furthermore, high electricity generation costs are subsidized by both federal and provincial governments, through cross subsidies, and direct and indirect funding. Communities also exhibit similar challenges, such as housing shortages, environmental concerns, economic development needs (AAWG, 2001; AAWG, 2010; OAG, 2003), competing and shifting Band Council interests and priorities, and fluctuations in federal and state funding (INAC, 2012). Entrepreneurial ventures within remote communities are the sole responsibility of indigenous governments and Local Development Corporations (LDCs) that aim at activities that fulfill three main goals, namely, economic development (in the form of revenue generation and employment), cultural preservation (in the form of minimal impact of ventures on lands and waters, ecological wellbeing, traditions and culture), and, self-governance (expressed through the use of local resources, participation in management, and ownership of assets supporting self-sufficiency and self-reliance) (Cornell & Kalt, 2003; OAG, 2003; Anderson, Dana, & Dana , 2006; Senate Committee, 2007; Slocombe, 2008; Mc Tiernan, 1991).

7.3.2 TIS functions performance

The successful deployment of RETs in Ontario and NWT indigenous communities will depend on a well-functioning TIS, influenced by the specific institutional setting and indigenous cultural, socioeconomic and self-governance considerations. The fulfillment of the TIS functions is influenced by the existence of blocking mechanisms. Table 21 presents the blocking mechanisms identified through a review of academic and policy literature (Ostrom, 1981; Ah-You & Leng, 1999 ; Parcher, 2004 ; INAC, 2004 ; INAC, 2005a ; Weis, 2006 ; INAC, 2007 ; Weis & Cobb, 2008 ; Weis, Ilinca, & Pinard, 2008 ; McDonald & Pearce, 2012 ; Inglis, 2012 ; McDonald & Pearce, 2013 ; AFN, 2011b), and informants' interviews and their influence on the different TIS functions. The performance of the functions is discussed next.

7.3.2.1 Entrepreneurial activity (F1)

The communal character of indigenous communities, limitations under the Indian Act, and cultural perceptions on entrepreneurship point to LDCs as the appropriate business development entity for RET experimentation within indigenous communities (Peredo & Chrisman, 2006). Community owned RET projects could provide electricity directly to community members, or power community buildings under net metering agreements, or generate renewable electricity from stand-alone projects, which can be sold to non-indigenous utilities that operate the local systems. Community entrepreneurial activities are hindered by the lack of community financial resources and technical expertise, infrastructural deficiencies and electricity generation regulations, as well as community interests favoring the continuation of diesel electricity generation.

7.3.2.2 Knowledge development (F2)

Knowledge development of RET applications at the community level takes the form of understanding potential community socioeconomic and environmental impacts and benefits, identifying availability of local renewable resources and potential generation sites, developing technical solutions and implementation techniques, as well as improving human capacity in terms of technical and managerial skills. The knowledge development function is blocked by existing regulatory processes associated with electricity generation and a lack of a governmental focus on addressing indigenous governance concerns through RET development. Furthermore, knowledge development and community knowledge development capabilities are blocked by limited linkages with other actors (e.g. academia and industry) and lack of community capacity to participate in renewable resources surveys and monitoring studies, feasibility studies, community energy plans, and small-scale RET experiments.

Table 21: Key blocking mechanisms and their influence on the NWT and Ontario TIS functions

System functions	Blocking mechanisms
F1. Entrepreneurial activity	-Lack of capital/access to capital (S1, S3, S4, S5, S6, S7, S8, S10, S11, S13, S14) -Vested interests (S8) -Lack of capacity (community expertise) (S2, S3, S5, S6, S8, S10, S11, S12, S13, S14) -Infrastructural deficiencies (S2, S10, S13)
F2. Knowledge development	-Existing regulatory processes associated with electricity generation (S2, S5, S8, S12, S13, S14) -Lack of legal/regulatory framework on RETs deployment (S1, S3, S6, S11, S12) -Lack of capacity (community expertise and energy education) (S2, S3, S5, S6, S8, S10, S11, S12, S13, S14) -Lack of networks (S1, S3, S10, S14)
F3. Knowledge diffusion	-Lack of capacity (community expertise and energy education) (S2, S3, S5, S6, S8, S10, S11, S12, S13, S14) -Lack of networks (S1, S3, S10, S14)
F4. Guidance of the search	-Existing regulatory processes associated with electricity generation (S2, S5, S8, S12, S13, S14) -Vested interests (S8) -Lack of capacity (community expertise and energy education) (S2, S3, S5, S6, S8, S10, S11, S12, S13, S14) -Lack of networks (S1, S3, S10, S14)
F5. Market formation	-Existing regulatory processes associated with electricity generation (S2, S5, S8, S12, S13, S14) -Vested interests (S8) -Subsidies (S1, S2)
F6. Mobilization of resources	-Electricity planning considerations (S2, S5, S8, S12, S13, S14) -Bureaucratic procedures (S14) -Lack of capacity (community expertise and energy education) (S2, S3, S5, S6, S8, S10, S11, S12, S13, S14)
F7. Support from advocacy coalitions/ legitimization	-Vested interests (S8) -High capital (investment) costs and reliability concerns (S3, S6, S10, S11, S13, S14)

Source: Ostrom, 1981 [S1]; Ah-You & Leng, 1999 [S2]; Parcher, 2004 [S3]; INAC, 2004 [S4]; INAC, 2005a [S5]; Weis, 2006 [S6]; INAC, 2007 [S7]; Weis & Cobb, 2008 [S8]; Weis, Ilinca, & Pinard, 2008 [S9] McDonald & Pearce, 2012 [S10]; Inglis, 2012 [S11]; McDonald & Pearce, 2013 [S12]; AFN, 2011b [S13], and key informants' interviews [S14].

7.3.2.3 Knowledge diffusion (F3)

Knowledge diffusion involves the dissemination of information within and across multiple communities on the cultural appropriateness, adaptation to local needs, potential benefits, and implementation difficulties of RETs. Favorite methods for the diffusion of knowledge of information exchange and learning facilitation in indigenous communities include the establishment of a network that facilitates community participation in meetings, conferences, workshops, charrettes, training of community members and promoting energy-related education.

The knowledge diffusion function can be blocked by limited linkages and inadequate networks between indigenous remote communities and specialists that can facilitate learning from established projects.

7.3.2.4 Guidance of the search (F4)

The guidance of research function represents the selection process that evaluates innovative solutions and facilitates their adoption, while taking into consideration community priorities and concerns based on local sustainability and governance perspectives. Indigenous perspectives on RETs deployment include pursuing and articulating specific targets, policies, and regulatory and fiscal reforms and incentives to improve remote indigenous communities' electrical systems. Guidance of the search can be blocked by the existing electricity generation regulatory framework, consisting of planning principles, regulations, electricity rates and subsidies, and lack of provincial targets and policies for the development of RETs. Furthermore, the function's performance is influenced by community vested interests and risk averse attitudes, lack of technical, managerial and financial capacity, as well as the lack of networks that could modify current community and governmental preferences through multiple interactions.

7.3.2.5 Market formation (F5)

Since the deployment of RETs in remote communities has to compete with established diesel generation, a market for renewable electricity should be instigated (Bergek et al., 2008). The market formation function for new renewable electricity generation is blocked, first, by reliability and safety regulations due to technical constraints associated with the penetration level of renewables in isolated diesel systems (Baring-Gould & Corbus, 2007; Tan, Meegahapola, & Muttaqi, 2014). Second, the isolated nature of local diesel electricity markets supported by multiple subsidies necessitates the availability of financial resources for the establishment of new schemes that would support indigenous ownership of RET projects and compensate for vested interests in diesel, while maintaining residential electricity prices at the present level. Regulatory and fiscal arrangements that allow local governments and LDCs to participate in the electricity generation process take the form of Independent Power Producers (IPP) policies and generation incentives in the form of Power Purchase Agreements (PPAs) and net metering agreements.

7.3.2.6 Mobilization of resources (F6)

The high cost of RETs and lack of community resources necessitates financial, material and capacity support for their deployment (IEA, 2011). Furthermore, mobilization of resources for new renewable electricity generation in the area of remote indigenous communities is influenced by uncertainty over future electricity demand growth. This results from community and industrial development, and a preference of both NWT and Ontario governments towards large-scale, cost minimizing electricity generation options, such as hydroelectricity, in association with grid extensions to supply future mining projects (NT Energy, 2013; OME, 2013).

7.3.2.7 Support from advocacy coalitions/ legitimization (F7)

The implementation of RET projects would have to overcome the resistance of established interests in diesel-generated electricity (Weis, 2014) and community consumers' concerns over reliability and increased costs (GNWT, 2009b; McDonald & Pearce, 2013). Furthermore, inclusion of indigenous perspectives on the anticipated contribution of RETs in the governance of community electrical systems, and design of policies that provide sustainable environmental and socioeconomic benefits would allow for higher acceptance of RETs by indigenous people.

The underlying systemic and transformational problems responsible for the blocking mechanisms that influence the performance of functions in both TIS are analyzed in the next sections.

7.3.3 Systemic problems influencing the NWT and Ontario TIS performance

7.3.3.1 Hard institutional problems

Two main sets of formal institutions influence the guidance of the search, knowledge development, resource mobilizations and market formation functions. *First*, the regulatory framework for the introduction of RETs, consisting of utilities' planning principles, technical, operational, and safety regulations, and existing rates and subsidies structures, is different in each province. The planning principles focus on energy security, affordability and reliability, reduction of environmental impacts and cost minimization (GNWT, 2008b), combined with business strategies aimed at electricity generation flexibility (NT Energy, 2013; GNWT, 2010). Technical, operational, and safety regulations relate to electricity services quality, since high RET penetration levels within local and isolated provincial grids are subject to balance and reliability considerations (Baring-Gould & Corbus, 2007; Baring-Gould & Dabo, 2009). Furthermore, high electricity generation costs lead to differentiated electricity rates for residential and commercial/governmental consumers funded by provincial and federal subsidies[15] making cost comparisons between diesel powered electricity and RET options difficult, and further reducing the motivation for RET deployment.

Second, formal institutions related to property rights, governance under the Indian Act, and indigenous views on development are responsible for limited entrepreneurial activities. Lack of property rights limits the possibility for non-indigenous and indigenous private entrepreneurial activities within reserve lands (Alcantara, 2003), and hinders access to banking loans, since traditional land is not accepted as collateral for financing purposes (Senate Committee, 2007; OAG, 2003). In addition, all economic activities within reserves, including energy development, are subject to indigenous governments' environmental licensing and regulation authority, which promotes projects under careful interpretation of treaty and indigenous rights and community socioeconomic benefits (Public Policy Forum, 2006; IISD, 2013).

7.3.3.2 Soft institutional problems

The existence of soft (informal) institutions associated with social norms, values and culture (Woolthuis, et al. 2005) within indigenous communities influence multiple TIS functions, including guidance of the search, knowledge development and market formation. First, communities have established vested interests in diesel generation through LDCs that cooperate with utilities, acquire rents, and provide employment through diesel storage and distribution (Weis,

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[15] The height of direct electricity subsidies for residential customers in remote communities, ranged between $ 3.5 million in 2015-2016 in Yukon (GY, 2015a), to $34 million in 2015 in British Columbia (BC Hydro, 2015b), and approximately $ 34 million in 2013 for Rural or Remote Rate Protection (RRRP) contributions in Ontario (Hydro One, 2012; Hydro One, 2008). Finally, total energy-related direct governmental subsidies in Nunavut were approximately $ 30 million for 2012-013 (GN, 2015a).

2014). These community interests benefit from diesel dependency and influence market formation, legitimization and social acceptance of the TIS, thus limiting guidance for the search for alternative entrepreneurial activities. Second, risk averse attitudes of indigenous governments may influence guidance of the search away from risky RET applications (such as wind and solar, due to the inherent intermittency of these resources). Third, a community focus on economic development guides indigenous governments' decisions towards grid electrification, since grid electricity is considered a low risk, reliable, and affordable alternative able to support productive community activities (Five Nations Energy Inc., 2006; NT Energy, 2013).

7.3.3.3 Interaction problems

Interaction problems are caused by the lack of information exchange and/or the quality/intensity of information exchange between actors, and primarily impact the following functions: guidance of the search, knowledge development and diffusion and legitimization of the TIS (Wieczorek & Hekkert, 2012). Although local governments maintain direct or indirect relationships with the federal and provincial governments, utilities and private firms, and with other communities through tribal, provincial, and national political affiliations and interprovincial networks such as the Assembly of First Nations (AFN), it is apparent that the quality/intensity of interactions and communication between indigenous people and other actors involved in the TIS are affected by various issues.

First, type and extent of interactions with provincial governments are influenced by cultural/political differences based on indigenous views on resource driven development, with community members divided between those favoring economic development, and those preferring traditional Indigenist approaches (Atleo, 2008; Atleo, 2013). Many projects are opposed due to potential impacts on the community's way of life and traditional activities (Coates & Crowley, 2013). Second, issues of trust, past relationships, grievances, and land claim disputes, which in turn are affected by indigenous choice of negotiation tactics, compatibility of goals, group cohesion and government perception of the indigenous group, shape the interaction between indigenous people, governments, and private actors (Booth & Halseth, 2011; Alcantara, 2013). Third, interactions favoring RET deployment may be deterred due to local governments' established focus on (lock-in to) diesel technologies due to the stability of significant revenues provided by diesel vested interests (Weis, 2014). Fourth, interactions may also be blocked due to the lack of intermediaries, such as mediating organizations and educational institutions that may act as “bridges” helping to surpass issues of trust between indigenous communities and governments, utilities, and the private sector. Interactions with communities that have already implemented RET projects are important, since the sharing of experiences and practices assists in the development of internal capacity to maximize benefits from the projects and legitimizes RETs (St.Denis & Parker, 2009; Krupa, 2012a).

7.3.3.4 Capability and infrastructural problems

Knowledge infrastructure within the TIS takes the form of specialized knowledge and expertise generated by universities, research institutes and industry, while financial infrastructure consists of supporting incentives, grants and subsidies (Wieczorek & Hekkert, 2012). At the community level, capability problems take the form of low administrative, managerial and technical capacity (Weis, Ilinca, & Pinard, 2008; Fay & Udovyk, 2013; McDonald & Pearce, 2012). Lack of local expertise combined with risk avoidance attitudes influence RET related guidance of the search, knowledge development and diffusion, and entrepreneurial experimentation. Furthermore, lack of physical infrastructure hinders RET implementation on reserves and erodes legitimization. Limited access during winter through a network of ice roads, year-round access by airplanes and/or barges, high accommodation, communication, and energy costs, and lack of specialized equipment (such as cranes) increase the investment cost of any project in remote communities, and necessitate the mobilization of state financial resources (INAC, 2004; INAC, 2007; Weis, 2014).

7.3.3.5 Transformational failures

Transformational failures (Weber & Rohracher, 2012) are responsible for the underperformance of the guidance of the search and knowledge development, and, in turn, the other TIS functions. Prior to 2000, indigenous participation in renewable electricity generation was minimal and RET project development and ownership were driven by cost considerations of utilities and provincial governments, pointing, therefore, to a lack of shared vision regarding the direction of the electrical system transformation process and a *directionality failure*. In addition, early governmental support through national energy efficiency policies revolved around tax write-off incentives and financial assistance for R&D activities and implementation studies (Gingras & Dalp, 1993), instead of targeting the transformation of community electrical systems through engagement and support of indigenous self-governance aspirations in the form of community participation in the decision making and planning process, indicating, therefore, both a *policy coordination* and a *reflexivity failure*. Furthermore, limited joint learning processes between governments, utilities, and communities, as well as communities' human capacity issues (INAC, 2005a; Wesley-Esquimaux & Calliou, 2010), hindered learning processes on the potential environmental and socioeconomic benefits of the introduction of RETs, thus contributing to both *reflexivity and demand articulation failure*s.

7.3.4 Performance of the NWT and Ontario TIS between 2000 and 2016

7.3.4.1 The NWT TIS performance

7.3.4.1.1 NWT policy intervention to address systemic problems

In the NWT, policy intervention during the 2001-2016 period to support RET deployment was introduced through public workshops and energy charrettes that captured stakeholders' differing perspectives on the future of NWT's energy system and led to multiple reviews of energy and electricity related targets and policies. This interactive approach allowed for reflexivity, directionality and indigenous demand articulation issues to be addressed. During the same period, energy policy coordination issues were ameliorated through the establishment of the Ministerial Energy Coordinating Committee (MECC) that periodically monitored policy coherence at the horizontal level (between sectoral policies) (GNWT, 2008a; GNWT, 2011a).

In addition, hard and soft institutional problems influencing multiple functions of the TIS were addressed through federal and territorial programs that were sequentially introduced. Initial programs emphasized capital cost reduction in RET projects, followed by programs focusing on capabilities improvements and network formation through RET related studies, and technical and educational assistance. Finally, during the 2013-2016 period, regulatory and financial arrangements were introduced to support community owned electricity generation. Network failures were mitigated through the participation, to varied extents, of utilities, universities, research institutes, the private sector and supporting organizations in the development of RET studies and projects. NTPC, ARI, NGOs like Pembina, and non-governmental agencies like Arctic Energy Alliance (AEA), engaged in renewable resource monitoring and feasibility studies, policy recommendations, advisory services, and equipment deployment, and contributed to the direction of the search, knowledge development and diffusion, mobilization of resources, and legitimization of the TIS (ARI, 2016; AEA, 2016; Weis & Cobb, 2008; Campbell & Pape, 1999; CBC, 2017c).

7.3.4.1.2 NWT TIS functional pattern (2001-2016)

The functional build-up of the NWT TIS was initiated with the release of the first NWT Energy Strategy in 2001 (+F4). In the same year the provincial RETCAP (2001-2003) and the federal "Aboriginal and Northern Climate Change Program" (ANCCP) (2001-2003) were launched (+F4) providing capital support for RET projects (+F6). These early actions were followed by the "Aboriginal and Northern Community Action Program" (ANCAP) (2003-2007), engaging indigenous communities to take action to reduce GHG emissions, through community energy planning, community capacity building and wind studies in the Arctic, and promoting collaboration between local, federal and territorial government, utility, education institutes, and renewable energy companies (+F6) (INAC, 2005b; AANDC, 2014d; INAC, 2007). As a result, feasibility studies for the installation of wind turbines were conducted between 2003 and 2006 for most of the remote indigenous communities (+F2). However, results indicated that wind turbines were financially viable for a limited number of communities (-F4) (Weis & Ilinca, 2010). In 2006 a demonstration solar application was installed in the community of Jean Marie (+F1).

The NWT government's commitment to the use of sustainable energy sources was further established during the 2007-2011 period. In 2007 the 2007 Energy Plan and the 2007-2011 Greenhouse Gas Strategy were released, both targeting the development of renewable applications and reductions in territorial emissions (+F4). In the same year, the first conference on wind turbine systems for the electrification of diesel-powered communities was organized bringing together communities, utilities, governments and private actors (+F3) (NTPC, 2007). At the same time the federal government launched the first phase of the ecoENERGY for Aboriginal and Northern Communities Program (EANCP) (2007-2011) funding RET project costs, and renewable resource monitoring and feasibility studies (AANDC, 2014a; AANDC, 2014d), while the territorial government established CREF, as part of the Alternative Energy Technologies (AET) program for financially supporting RET project costs (+F6)(Carpenter, 2013). Furthermore, the government-initiated dialogue with communities through the review of existing regulations, rates and subsidies for electricity (+F4) and focused on the coordination of all activities targeting energy reduction through the establishment of a coordinating committee and the use of AEA as a one stop agency for the delivery of programs to the communities (+F4). AEA conducted a significant number of energy planning projects during 2008-2015 and, following the latest technology developments, the Aurora Research Institute (ARI) initiated a new round of optimization studies on the feasibility of wind and solar applications (+F2, F3) (ARI, 2016) (see also Weis & Ilinca, 2008; Weis & Ilinca, 2010). Continuous dialogue between stakeholders led to reviews of the electricity process in 2008, 2009 and 2010 (GNWT, 2008b; GNWT, 2009a; GNWT, 2009b; GNWT, 2010), revealing community interest in participation in RET projects, and leading to a revised Energy Strategy and Greenhouse Gas Strategy in 2011 (+F4) (GNWT, 2011a; GNWT, 2011b). By the end of the 2007-2011 period ten small-scale solar projects had been installed in remote communities, bringing the total number of solar installations to eleven (+F1) (Table 22).

Table 22: RET projects in NWT and Ontario

Time period	Time interval	NWT		Ontario	
		Installed projects	Average project capacity	Installed projects	Average project capacity
2001-2006	6 years	1	1.3 kW		
2007-2011	5 years	10	4.1 kW		
2012-2013	2 years	10	16.6 kW	3	19.3 kW
2014-2016	2 years	8	31.9 KW	10	30.0 kW
Total		29		13	

During the subsequent 2012-2016 period a new round of guidance of the search, knowledge development and mobilization of financial resources activities led to an increase in the number and the average capacity of community RET projects. By 2012, multiple theoretical and empirical contributions on remote microgrids technology had been developed globally (Bhattacharyya, 2012). In Canada, several new optimization studies on the feasibility of RETs in indigenous remote communities added to knowledge development (+F2) (Bhattarai, 2013; Iqbal, n.d. (b); NFL Hydro, 2009; Arriaga, Cañizares, & Kazerani, 2013). Furthermore, in 2012 the NWT government announced its 2012 Solar Energy Strategy and organized the 2012 Energy Charrette to engage communities in the electricity planning process (+F4). The second phase of EANCP (2011-2016) was launched in 2011 emphasizing RET deployment in remote indigenous communities in addition to the continuous financial support from CREF (+F6) and in 2013 the government announced its 2013 Energy Plan, which included its commitment to a reflexive and collaborative policy development (+F4) (GNWT, 2013). Ten higher scale solar projects (16 kW average capacity) were installed in 2012 and 2013 (+F1).

The subsequent 2014-2016 period is characterized by the second Energy Charrette in 2014, where the impacts of previous targets and programs were discussed, and further deployment of small-scale renewable projects was emphasized (+F2, +F4) (RMA, 2014). Specialized workshops and conferences were organized in Ontario (2013) and NWT[16] (2015) supporting knowledge diffusion and interactions between multiple actors, including indigenous governments (+F3). In addition, regulatory arrangements were introduced in 2014-2015 in the form of net metering and Independent Power Producers (IPPs) policies that allowed for indigenous communities to participate in the electricity generation process creating a market for indigenous owned RET projects (+F5) (NTPC, 2016b; Cherniak, et al., 2015). Eight higher scale (32 kW average capacity) projects were developed in 2014 and 2015, resulting in a total of 18 solar projects between 2012 and 2016.

Over the 2001-2016 period in which the NWT TIS evolved, a total of 29 solar projects with a total capacity of 464 kW were developed in 19 of the 25 diesel powered remote indigenous communities. Fourteen communities developed one solar project, three communities installed two solar systems, one community installed three solar plants and one community installed six projects (Karanasios and Parker, 2016b).

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[16] 2009 Wind-Diesel Workshop, June 1-2, 2009 -Ottawa, ON, 1st Renewables in Remote Microgrids Conference, June 25-26, 2013, Toronto, ON, 2nd Renewables in Remote Microgrids Conference, September 15-17, 2015, Yellowknife, NWT.

7.3.4.2 The Ontario TIS performance

7.3.4.2.1 Ontario policy intervention to address systemic problems

In Ontario, policy intervention during the 2001-2016 period in favor of RET deployment included support for both off-grid RET projects and communities' connection to the provincial grid (OME, 2013). Reflexivity, directionality and indigenous demand articulation issues influencing the guidance of the search towards RET deployment were addressed by the Nishnawbe Aski Nation (NAN), Tribal Councils, and community leaderships expressing an interest for sustainable options to address community electricity needs (OEB, 2008; NAN-HORCI, 2013; NAN, 2014b). Furthermore, in a similar process to NWT, systemic problems were addressed through sequentially introduced federal and provincial financial support for projects' capital costs, community training, and community owned electricity generation. Network problems were improved through the participation of numerous actors, including governmental agencies (IESO, HORCI), NGOs, universities (UW, 2014), and the private sector that cooperated with indigenous communities in R&D activities related to microgrid planning, testing, and training (ME, 2016). Technical, educational, and training support for a number of projects was provided by Shibogama Technical Services (STS, 2016), an indigenous company supporting the members of the Shibogama Tribal Council, while project deployment and installation of solar projects were performed by indigenous owned enterprises (NCC, 2016). These indigenous driven RET ventures improved local knowledge, generated local employment, contributed to the legitimization of the TIS, and pointed to the importance of trusted intermediaries for successful project deployment (Schot & Geels, 2008; Smith & Raven, 2012).

7.3.4.2.2 Ontario TIS functional pattern (2001-2016)

The functional build-up of the Ontario TIS started with the governmental commitment towards renewable electricity generation expressed in 2003 and supported by both requests for proposals and the 2006 introduction of early feed-in-tariffs to attract investments in renewable electricity generation (+F4, +F6) (Rowlands, 2007; Stokes, 2013). Indigenous interest in renewable electricity generation and the connection of communities to the provincial grid to improve socioeconomic conditions was expressed in 2008 by NAN, the political organization representing Ontario's remote indigenous communities (+F4) (OEB, 2008; NAN, 2014b). In 2009 the government introduced the

Green Energy and Green Economy Act (GEGEA), which included financial incentives for indigenous communities' participation in RET projects (+F4) (Winfield, 2013). In the same year, and parallel to the federal EANCP program, both the Aboriginal Loan Guarantee program (ALG) and the Aboriginal Energy Partnerships Program (AEPP) were established by the Independent Electricity System Operator *(*IESO*)* to support indigenous participation in both on-grid and off-grid RETs through the development of community energy plans, feasibility and technical studies, resource assessments and training (+F6) (OFA, 2016; AEPP, 2016).

Furthermore, between 2010 and 2013, optimization studies examining the potential of wind applications in Ontario's remote communities were developed (+F2) (Weis & Ilinca, 2008; Weis & Ilinca, 2010) and the second phase of EANCP focusing on RETs for remote indigenous communities was introduced (+F6). Knowledge exchange between academia, government, utilities, private sector and communities was facilitated through the organization of the NAN energy conference in 2012 (NAN, 2014b), the first conference on renewable microgrids in Toronto in 2013 and the 2014 NOFNEC indigenous environmental conference (+F3). To support off-grid RET deployment, Hydro One Remote Communities Inc. (HORCI)[17], the utility serving 15 of the remote indigenous communities (HORCI, 2012), introduced a net metering and stand-alone arrangement creating a market for local electricity generation (+F5) (HORCI, 2015). In 2013 two small-scale solar projects and one wind turbine project were developed in three communities (19.3 kW average capacity), followed by ten higher capacity projects (30 kW average capacity) installed between 2014 and 2016 (+F1) (Table 22).

In total, as the Ontario TIS evolved from 2008 to 2016, 358 kW of RET were installed in 11 of the 25 diesel powered remote indigenous communities. Five projects were installed in HORCI serviced communities and six in communities operating as Independent Power Authorities (IPA). All projects were installed under net metering arrangements on electricity intensive buildings with a view to displacing full cost electricity, thereby reducing expenses of local governments.

However, during the same period a competing TIS was established, initiated with the governmental commitment of the connection of remote indigenous communities to the provincial grid and the electrification of future natural resources development in the Ring of Fire area (+F4 towards an alternative niche) (OME, 2013). Technical studies verified the feasibility and financial viability of

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[17] Hydro One Remote Communities Inc. (HORCI) is a subsidiary of Hydro One Inc.

the connection of 21 of the 25 remote communities (+F2, alternative TIS) (IESO, 2014; PWC, 2015; WP, 2013b), and led to the prioritization of the grid connection project in the 2013 update of Ontario's LTEP (+F4, alternative TIS), and, in turn, the participation of 21 remote indigenous communities in the establishment of the transmission company Wataynikaneyap Power that will connect the communities to the provincial grid and provide electricity to mining projects in the Ring of Fire area (WP, 2012).

7.4 Discussion

The relationship between the functional performance and the diffusion rates of RET projects is discussed in terms of presence and intensity of functions, and the existence of interactions between functions (Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007).

The analysis of the NWT and Ontario TISs demonstrates that the functional build-up during the investigated period shows a positive relationship to the number of RET projects developed and the transition toward more sustainable energy systems (Figure 5). In both TIS, the functional build-up is initiated with guidance of the search towards the introduction of RETs into community diesel systems followed by mobilization of financial resources, which are used to attract multiple actors, and the development of local knowledge through feasibility and resource monitoring studies. The results of these studies improved actors' learning on RET deployment, led to interactions between indigenous governments and other participants, and initiated a new round of guidance of the search, mobilization of resources, knowledge development and diffusion. Eventually, regulatory and fiscal arrangements were negotiated for the formation of local markets and installation of higher capacity solar applications on community buildings. In NWT, the larger scale Colville Lake project (CBC, 2017c), and the community owned Lutselk'e solar plant that operates as an independent power producer (IPP), contribute further to the legitimization of the TIS (CBC, 2017a; CBC, 2017b), and signal an interest among communities towards higher renewable penetration projects[18] under IPP ownership. Subsequent new governmental targets for RET deployment in remote communities

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[18] The integration of higher capacity RET projects into isolated diesel power plants, as measured through the ratio of the renewable component output (kW) over the primary community electrical load (kW) (instantaneous penetration) and the ratio of the renewable component energy output (kWh) over the community electricity generation output (kWh) (average penetration) (Baring-Gould & Corbus, 2007), are associated with increased technical complexity of control devices for maintaining acceptable power quality, higher reductions in diesel consumption, and higher, but riskier, financial returns.

(CBC, 2017c; GNWT, 2016; GNWT, 2017), and the search for new financial mechanisms (BP, 2016) indicate positive feedbacks between functions and a virtuous cycle characterizing the TIS development.

However, in Ontario, although the interaction of functions led to the functional build-up and entrepreneurial activities within a shorter time frame than in NWT, the functional performance was interrupted by a shift of community interest to a competing alternative (Geels & Raven, 2006), namely the potential connection to the provincial grid (new guidance of the search). The new alternative was embraced by communities who anticipate increased socioeconomic benefits through their participation in Wataynikaneyap Power. As a result, high capacity off-grid electrification projects are expected only for the remaining four communities that are unable to connect (OME, 2017).

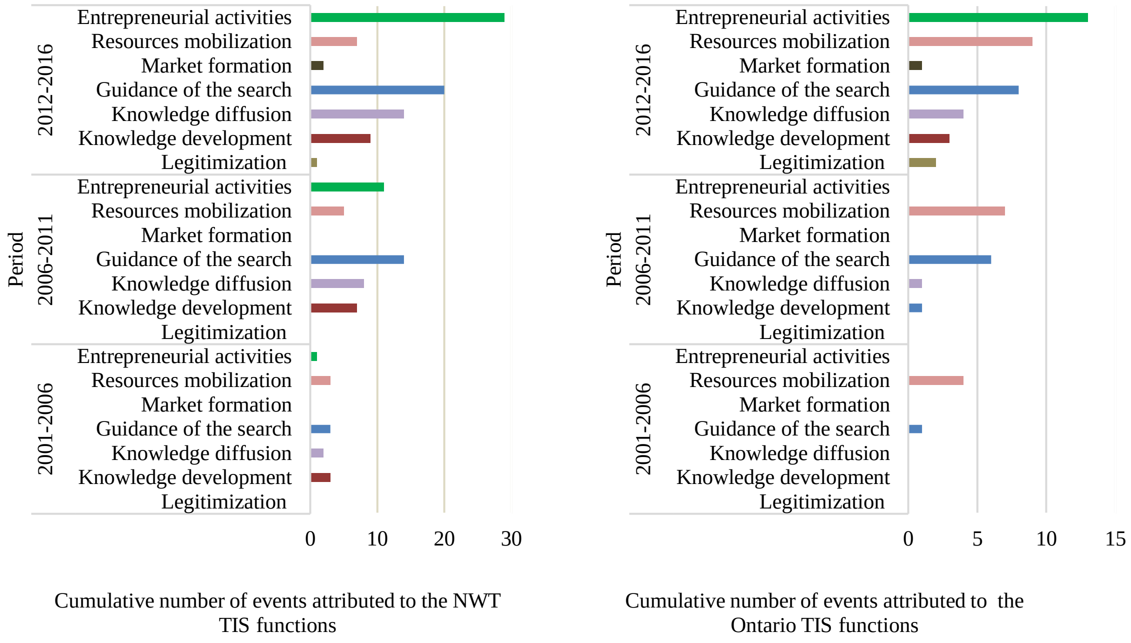

Figure 5: Accumulation of functions and RET projects developed in the NWT and Ontario TIS

Source: Data from Table 1 and Table 2 in Appendix D.

These results are consistent with the results of Tigabu et al., (2015) and Blum et al., (2015) that report a positive relationship between diffusion of RET products and projects and functional intensity in developing countries.

Results also point to three policy related implications. First, the system-building functions in both TIS, as demonstrated by their strength, are guidance of the search and knowledge development. The functional build-up is initiated with actors' shared interest towards renewable solutions and, given the availability of financial resources, the development of knowledge for the introduction of RET into community electricity systems. Knowledge development in turn engages a significant number of actors in studies and experiments that improve and diffuse knowledge on the deployment of RET. The functional pattern in both TISs consists of successive "morphogenetic rounds" of guidance of the search, mobilization of resources, knowledge development and diffusion, which, eventually, lead to new guidance of the search for ownership of higher capacity and complexity RET projects (Grin, Rotmans, & Schot, 2010, p. 96).

Second, results point to the importance of financial resources mobilization for both the initiation of the functional build-up and the improvement of the functional performance, given the high investment costs and the limited financial, technical and managerial capacity of indigenous communities. NWT has spent approximately $21 million on studying renewable energy applications for remote communities (CBC, 2016) and the federal government provided, between 2003 and 2016, $65 million through ANCAP and EANCP for knowledge development on the feasibility assessment and integration of RETs into indigenous communities (INAC, 2017).

Third, a comparison between the NWT and Ontario TIS and the rest of the provinces and territories suggests that the system building functions (guidance of the search and knowledge development) are influenced by local institutional factors. Guidance of the search is influenced by the alignment of federal and provincial governments and utilities perspectives with indigenous aspirations to participate in the electricity decision making process, as demonstrated through NWT's multiple electricity reviews, and in Ontario, through the adoption of the NAN agenda on both off-grid and on-grid participation in RETs. In addition, the performance of the knowledge development function in both TISs is influenced by the existence of local educational and research facilities (universities, research institutes and local agencies) that conducted specialized research, engaged communities in development and installation of RET projects, and contributed to "learning by searching" and "learning by doing" (Binz, Truffer, & Coenen, 2014). Finally, functions and the functional build-up in both TIS benefitted from the evolution of a localized network that was formed to promote the deployment of RETs in remote indigenous communities by addressing interaction and transformational failures. These formal networks, consisting of local actors (provincial government, utilities, communities, educational and research facilities, NGOs), but also the federal government and national scale NGOs (Pembina) as well as private firms (Bullfrog Power), were able to build trust and shared expectations, and improve local skills and knowledge through learning processes (Schot & Geels, 2008) in order to access, develop and deploy resources in a more effective way than other provinces and territories (Musiolik & Markard, 2011; Fischer & Newig, 2016).

The importance of the functional build up for the diffusion of RET projects is demonstrated by the lack of such projects in Nunavut, Quebec and Newfoundland and Labrador indigenous communities during the 2000-2016 period. In Nunavut, despite early guidance of the search towards RETs (GN, 2007) and knowledge development in the form of studies conducted between 2001 and 2009 (see for example Maissan, 2006a; 2006b), reduced availability of renewable resources (wind, solar and hydro), poor legitimization due to the failure of previous wind projects (Nunavut Power, n.d.) , as well as lack of financial resources from the government of Nunavut and Qulliq Energy Corporation (QEC), blocked RETs deployment from 2001 to 2016 (Rohner, 2015). In Quebec, although early guidance of the search for community RETs led to a number of studies financed by Hydro Quebec (Krohn, 2005), diverging and competing community priorities (grid connection and hydroelectricity generation) limited development to only one wind project over the 2001-2016 period (GQ, 2006a; Rogers, 2014; NO, 2011). Finally, no RET projects were developed in Newfoundland and Labrador between 2001 and 2016, due to lack of interest towards community RETs from provincial and indigenous governments, and limited commitment of financial resources towards feasibility studies on community wind, solar and hydroelectricity options (NFL Hydro, 2009).

7.5 Concluding remarks

The aim of this paper was, first, to explain the diffusion of RET applications in remote indigenous communities in NWT and Ontario by analyzing the performance of the technological innovation systems, and, second, to identify factors that have the potential to sustain the development of these RET projects.

The analysis shows that between 2000 and 2016 policies and programs in both jurisdictions addressed systemic and transformational failures, which allowed for the accumulation of TIS functions, which, in turn, led to the deployment of solar projects in the communities. In addition, the analysis points to the guidance of research and knowledge development as the driving forces for the build-up of the functional system. The NWT innovation system case suggests that a highly inclusive and reflexive policy design initiated by the territorial government for addressing the energy needs of the isolated territory, as well as the establishment and support of a local network, contributed to the uptake of the innovation system. In the case of Ontario, guidance of the search was driven by indigenous communities' focus on RET projects, while the functional build-up evolved over a shorter period of time than NWT, as it benefitted from both knowledge developed in NWT and the establishment of a network of actors. Furthermore, the study also shows that, given the financial constraints present in most indigenous communities, governmental support is decisive for improving actors' presence, capabilities and interactions, and the creation of market formation mechanisms necessary for the undertaking of entrepreneurial activities.

The results confirm that the TIS approach can be used to study the diffusion of technological innovations in the specific institutional setting characterizing remote indigenous communities. Recent legal decisions prioritizing indigenous perspectives, lack of a market economy, and an indigenous focus on economic development, environmental protection, and self governance signal that the determinants of RET diffusion are more complex than simple technoeconomic factors. Within the communities, locally owned RET projects are blocked by multiple institutional, capacity and infrastructural barriers that hinder their development. These systemic failures can be addressed through the functional approach proposed by the TIS.

In addition, the analysis of the functional evolution reveals that local governments and band councils engage in RET entrepreneurial ventures by (1) taking advantage of a sequence of events initiated by the provincial and territorial governments' interest in the use of renewable energy to reduce carbon emissions and electricity generation costs, and the availability of financial support for resource monitoring and feasibility studies contributing to the guidance of the search and knowledge development and diffusion, (2) learning by searching, training, and experimenting through projects installed in communities, and through engaging with numerous actors to improve knowledge on the specific applications and their potential to contribute to indigenous goals, and

(3) modifying and articulating their perspectives, based on accumulated learning, towards RETs policies and programs that are supportive of indigenous aspirations and sustainability goals.

Furthermore, results suggest that, given the “system building” nature of the functions guidance of the search and knowledge development for community entrepreneurial activities, the aim of federal, provincial/territorial and indigenous governments should be policies targeting systemic and transformational problems (capabilities and interaction failures) that block these functions. Policy intervention for network building, capability improvements and knowledge development through experimenting with RETs will support further learning and empower indigenous communities and participating actors, enable them to adjust their perspectives and articulate policy direction according to their values and beliefs, and strengthen their governance structures. Accordingly, further research should, first, investigate local learning processes (Hegger, VanVliet, & VanVliet, 2007; Neij, Heiskanen, & Strupeit, 2017) in the environment of remote indigenous communities in terms of who, how, and what is learned related to RET deployment. Second, given that knowledge development and diffusion are facilitated by local networks, further research could focus on both the role that community leadership and trusted local intermediaries play in the definition of the guidance of the search and knowledge development and diffusion, as well as their strategies for guiding the build-up of local TIS functions.

Chapter 8: Conclusion

This chapter summarizes the research findings previously outlined as well as the study's contributions. Section 8.1 reviews the purpose and objectives of the research followed by a summary of the findings in section 8.2. Subsequent sections 8.3, 8.4, and 8.5 discuss the research implications, and offer recommendations for future research and the design of RET supporting policies. Finally, section 8.6 discusses the study's contribution and section 8.7 the overall conclusion.

8.1 Purpose and objectives

The purpose of this doctoral dissertation has been to improve understanding on the factors that influence the transformation of indigenous community electrical systems to more sustainable ones. The study had three specific objectives:

1. Develop a conceptual framework to examine the transformation of remote community electrical systems;
2. Use the conceptual framework to improve understanding of the "wickedness" (the technical, contextual, and social complexity) associated with the introduction of RETs into remote indigenous community electrical systems, and explain the diffusion of RET projects within these systems to date; and
3. Examine the processes implemented to cope with the wickedness of the problem (in the form of mechanisms and actor strategies) and how these processes were modified to encompass indigenous perspectives in order to identify pathways and develop policy recommendations for their transition to more sustainable systems.

To achieve the objectives, the study examined the electrical systems of indigenous communities and the perspectives of participating stakeholders and used a modified MLP framework, at the national level, to examine the extent of transformation of these electrical systems. The TIS framework was used, at the sub-national level, to compare the functional performance of the NWT and Ontario TISs.

8.2 Findings

Findings were presented in chapters four, five, six and seven. Chapters four and five improved understanding on the contextual, technical, and social complexity associated with the introduction of RETs in remote indigenous communities. Chapter four described the structure of remote indigenous communities' electrical systems, provided an overview of the diversity of communities in terms of population, power systems size, electricity generation costs, and subsidies structures, and identified 71 RET projects deployed between 1980 and 2016. Furthermore, the chapter reviewed provincial and territorial RET targets, as well as future large-scale electricity generation alternatives and small-scale RET options that are available to address both utilities' and indigenous communities' concerns.

Chapter five shed additional light on the "wickedness" inherent within the introduction of RETs into remote communities' systems and identified four interrelated factors that influence the deployment of RETs. First, there was the institutional complexity of the electricity system, stemming from the different types of utilities, rates, subsidy structures and funding sources, technical regulations, and community vested interests. The second factor encompassed the diversity of stakeholder perspectives (government, utilities and indigenous peoples) on community electricity generation and the challenges that the introduction of RETs is expected to address. Third, an additional factor was the uncertainty over the future "long term" structure and governance of provincial and territorial electricity generation systems. Such decisions are influenced by the availability of local available resources, mainly hydroelectricity, future mining and natural resources developments, and the possibility for connection to local or interconnected grids. Fourth, community uncertainty over the financial viability of small-scale off-grid applications influenced the deployment of RETs. The performance of such projects is influenced by the size of communities' diesel systems, availability and integration level (low, medium, high) of local renewable resources, capital costs, electricity rates and subsidies structures, economies of scale, and, given the inherent risk of RET projects, community attitude towards risk.

Chapter six used an MLP based framework and explained, first, how the transition of remote Canadian indigenous community electrical systems through RETs between 1980 and 2016 unfolded, and second, how the transition was managed (what governance processes were involved). Development of RETs during this phase is explained through the interplay between numerous factors including pressures from changing legislation, indigenous sustainability concerns, technology advances, and governmental and utility pressures for renewable electricity alternatives, expressed through RET targets and supporting policies.

Finally, chapter seven used the TIS approach and analyzed the underlying factors that drove RET policy selection and identified micro-level mechanisms responsible for the deployment of RETs in NWT and Ontario between 2001 and 2016. Findings suggest that the deployment was blocked by systemic and transformational problems in both territories, in the form of regulatory and institutional problems, lack of interaction between participants, and financial and capability challenges in communities. To address the issues and increase diffusion of RET projects, governments engaged in a dialogue with participants and the design and adjustment of targets, policies, and programs. Policies shifted from capital support, to policies supporting capabilities' improvements and network formation through RET related studies and technical and educational assistance, and, finally, to regulatory and financial arrangements that were introduced to support indigenous demand for community owned electricity generation.

8.3 Implications

Both the MLP and TIS analyses indicate that indigenous communities' transition process is not made through a random interplay of factors but is the result of actors' choices selected, strategies pursued, and resources employed. The evidence captured as part of the research in the form of "temporal sequences and events and the conjunctures of event chains" (Grin et al., 2010, p. 93) suggests that the complex causal mechanisms predicted by the frameworks (described in Chapters six and seven) were present. Furthermore, there is evidence that the proposed "morphogenetic cycles" or "motors of innovation" (Grin et al., 2010, p.99; Suurs & Hekkert, 2009) positive feedback mechanisms performed as expected; the negotiation of policies (in the form of regulatory and fiscal arrangements that support indigenous aspirations of self-sufficiency), experimentation and learning, and the creation of networks led to an increase in the number and capacity of RET projects. In this sense the frameworks pass a difficult "hoop test" (high complexity of the causal mechanisms involved), which increases the confidence in the validity, and hence the importance, of the hypothesized mechanisms (Mahoney 2012; Kay & Baker, 2015). The lack of the mechanisms (despite the presence of RET targets and policies) and the limited number of RET projects in remote indigenous communities in Nunavut, Quebec, and Newfoundland and Labrador strengthens the "hoop test" further.

The findings point to the importance of visions and expectations in the transition process in the context of indigenous communities. Visions and expectations in the transitions management literature function as "a framework for formulating short-term objectives and evaluating existing policy" (Rotmans, Kemp, & VanAsselt, 2001, p. 24). Indigenous aspirations of achieving self-reliance through economic independence based on their lands, resources, and the creation of entrepreneurial ventures of minimal environmental impact with indigenous and/or non-indigenous partners functioned as an overarching vision and "shaped" the transformation of the communities' electrical systems. The collectively created vision (Farla et al., 2012) of community owned RET projects structured the transition of community electrical systems by contributing to the definition of the problem that RETs is expected to address, therefore reducing the problem's wickedness, and motivated all participating actors to seek an appropriate solution. It additionally provided the "possibility space" and indicated alternatives acceptable to indigenous communities, allowed for targets and programs to be developed and modified, specified participation of relevant actors in networks, and directed actors' activities for the allocation of financial and regulatory resources (Smith et al., 2005).

Furthermore, combining the MLP with the TIS framework for the analysis of the diffusion of RET projects in remote indigenous communities allowed for the identification of actors' choices, strategies, and resources. While the MLP-based framework revealed that indigenous governments and utilities increased their involvement and cooperation in the electricity generation process as a result of changing legislation, environmental concerns and the adoption of participatory approaches throughout the 2001-2016 period, the TIS analysis points to how participants and organizations came together. First, in terms of choices, indigenous governments articulated their desire to participate in the local electricity generation process to address socioeconomic and environmental challenges and collaborated with federal, provincial/territorial governments and utilities.

Research institutes (such as Aurora Research Institute in NWT), technical experts, and supporting NGOs (Arctic Energy Alliance and Pembina) also gradually upgraded their role to achieve common goals as the network of actors was enlarged and more projects were deployed. During the later stages, private proponents (indigenous and non-indigenous) (such as Canadian Solar and Bullfrog Power) entered the network offering research, technical advice and installation services. An important implication is that early isolated project developments (2001-2010 period) were followed by a significant increase in the number of projects as a result of actor network formation and collective, rather than isolated, action.

Second, the actors participating in the transition process used different strategies (in the form of targets and activities) and resources (in the form of human resources, finance, and networks) to achieve their goals. Governmental strategies took the form of targets, policies and programs to support the deployment of RETs, and were directed mainly to utilities (during the 1980-2000 period) and communities (during the 2001-2016 period), as well R&D programs towards industry partners. Governmental strategies directed at communities focused mainly on addressing systemic and transformational problems (discussed in Chapter seven). Furthermore, both governmental and community strategies focused on changing institutional structures, in the form of standards, regulations, and fiscal support (e.g. net metering and power purchase agreements) to allow for community participation in the electricity generation process. In addition, community strategies focused on negotiations with governments for the co-development of policies supporting indigenous aspirations and targeted knowledge and expertise acquisition and sharing by engaging with utilities, agencies, NGOs, research institutions, and experts. Finally, all participants pursued their strategies collaboratively as they all joined research program networking activities (such as conferences, meetings, charrettes) and project development initiatives.

Third, findings also indicate the importance of resources in the formulation and execution of actors' strategies. Resources took the form of organizational resources (knowledge and financial means) and institutional structures (technical knowledge, beliefs and worldviews, regulations and formal policies). Findings indicate that all main participants (governments, utilities, local governments, network actors) possessed a mix of resources, which were employed in the formulation and implementation of their strategies. Although governmental organizational and institutional resources benefitted utilities prior to 2000, the subsequent period is associated with increasing levels of resource mobilization towards indigenous communities to shift power relationships and unblock indigenous participation in the electricity generation process. Indigenous people used initially their status, knowledge and worldviews, and after 2010, the resources provided by governments, to promote their ideas and change the perspective of other participants on the role that RETs are expected to play within communities. Indigenous perspectives on RET deployment were enriched through knowledge acquired by early experimenting and newly formulated networks and led to the formulation of indigenous expectations that had “a structuring role in the innovation process” (Farla, Markard, Raven, & Coenen, 2012, p. 996), which, in turn, guided further indigenous knowledge development and negotiating strategies.

Furthermore, findings also suggest that geographical factors, in the form of institutional complementarities and institutional thickness (Coenen, Benneworth, & Truffer, 2012), also contributed to the functional performance of the innovation, and the resulting difference in the number of RET projects deployed in the two provinces. NWT’s demographic structure and isolated electrical system led to an early governmental involvement in the promotion of renewable energy, the adoption of a reflexive governance approach, the creation of multiple institutions, and the involvement of multiple organizations (state governments, utilities, communities, educational and research institutions, consultants, and non-governmental organizations) dedicated to the uptake of RET projects and the reduction of diesel-powered electricity. Ontario’s network was developed later, included state actors and corporations, local utilities, research facilities, and non-governmental organizations, as well as indigenous political organizations, and Tribal Councils’ technical organizations, and focused on both the connection of communities to the provincial grid and off-grid RET deployment. Such RET supporting networks were not developed in Nunavut and Newfoundland and Labrador, while actors from NWT and Ontario’s networks were involved, to differing extents, in projects in British Columbia, Yukon, and Quebec. Furthermore, the prospect of connecting remote communities to provincial electrical grids was responsible for limited interactions in these provinces and territories.

8.4 Directions for future research

The analysis and findings presented in this study are constrained by the choice to examine the transition of the electrical systems of 133 Canadian remote indigenous communities. The lack of readily available secondary data, the geographically extended nature of the study, and the multitude of theoretical and conceptual challenges involved in the study of energy transitions within indigenous communities necessitated an exploratory study that would allow potentially limited generalization of findings (Reiter, 2017). The findings function as the foundation to further focused research questions in two main directions: (a) research on the factors that influence the decision-making process and, given the importance of learning and experimenting, research on learning processes within the communities, and (b) research on the impacts of implemented RET projects on community sustainability and assessment of future technologies on the potential to support community transformation according to indigenous aspirations.

The first line of inquiry would involve case studies in remote indigenous communities in different provinces and territories to identify context related factors and interactions (Bergek, et al., 2015) and actors' strategies that influence the decision-making process for the adoption of RETs. The research would employ qualitative interviews with community members in both communities that have implemented RET projects and communities that have not yet developed any such projects, as well as interviews with regime and other actors, to understand sociotechnical configurations and social practices, and the replicability of specific implementation models (see Ulsrud et al., 2015). Research questions would focus on landscape, political, and regime related structural and institutional factors, the interaction of niche-regimes with current regimes and their strategies, the choice over scale of RET projects, and how context and community group characteristics influence the scaling up of projects. Such case studies would also provide useful information on the role and strategies of community leadership and trusted local intermediaries, as well as geographical factors (such as comparative institutional advantage and institutional thickness, see Coenen, Benneworth, & Truffer, 2012), and their contributions to the definition of the "guidance of the search", "knowledge development" and "knowledge diffusion" functions of the innovation system. The identified (critical) factors and interactions (of successful projects) could provide insights on the replicability of specific implementation models and the reconstruction of transition pathways to generate best practices (see Forrest & Wiek, 2014; 2015).

Within the same line of inquiry, a further important research theme, given the "system building" nature of the functions "guidance of the search" and "knowledge development" for community entrepreneurial activities, revolves around local learning processes (Hegger, VanVliet, & VanVliet, 2007; Neij, Heiskanen, & Strupeit, 2017) in terms of who, how, and what is learned related to RET deployment.

The second line of inquiry, using case studies and similar methodologies, would concentrate on the impacts of implemented RET projects within remote indigenous communities. In a first step, investigating the management of local microgrids would offer information on preferred governance structures and what constitutes a "successful" off-grid RET project. For example, an examination of the management models of the hydroelectricity projects of Kitasoo FN and Tlingit FN in British Columbia could provide insights on the different interpretations of successful community owned electricity generation. Furthermore, besides identifying "if" RET projects were successful, research would provide insights on outcomes (changes in the community wellbeing), and "if" and "how much" such projects contributed to indigenous aspirations of self-governance and self-reliance. Within the same line of inquiry further research questions that emerge are, first, which energy technologies and systems could improve community wellbeing and reduce community reliance on diesel (e.g. combined heat and power applications), and, second, what are best practices for communities that want to take control of their electrical systems and transition to more sustainable options. Future-oriented technology analysis (FTA) employing quantitative and qualitative and participatory methodologies (see for example, Stephen, et al., 2016; Moore, Durant, & Mabee, 2013; Trutnevyte, Stauffacher, & Scholz, 2012) could provide a better understanding of the complex energy (electricity, heat, transportation), food, and water systems nexus of communities and assist with policy development, since it can enable dialogue between participants with different experiences and perspectives, create visions on future community energy systems, and generate research, innovation, and policy design agendas to support the transformation of communities (Cagnin, Havas, & Saritas, 2013).

8.5 Policy recommendations

One of the objectives of the study was to develop policy recommendations for the transition of communities' electrical systems to more sustainable ones. Policy support is justified since transformation of communities' non-sustainable systems is unlikely to happen as a result of market forces alone, or the constraints of established governance regimes. Furthermore, as Schot and Geels (2008, p. 539) state, "one important reason for governments to subsidise and nurture not yet profitable innovations is the expectation that they will become important for realising particular societal and collective goals in the future". In this sense, the introduction of RETs into a remote community electrical system was conceptualized as a niche level technological innovation that will allow niche-regimes (such as indigenous governments) to apply a different approach (in terms of structure, culture and practices) to the electricity generation process, and cooperate with, or compete with, or replace utilities that provide diesel-generated electricity, and eventually reduce diesel consumption, achieve community socioeconomic and environmental goals, and improve community wellbeing.

Findings suggest that policies supporting indigenous aspirations are important for the uptake of RET projects. Indigenous governments learned by searching, training, and experimenting through projects installed in communities, and through engaging with numerous actors. As a result, they improved their knowledge on the potential benefits from RET applications and modified and articulated their perspectives, based on accumulated learning, towards the design of policies and programs that were increasingly supportive of indigenous goals of self-sufficiency and self-reliance. The adoption and implementation of such policies (in the form of IPP regulations, net metering and PPAs) in NWT and Ontario led to an increase in RETs projects during the examined period.

Accordingly, three policy recommendations result from the research. First, provincial/territorial governments should establish specific targets, policies, and programs for the reduction of diesel consumption and the introduction of RETs, as well as a comprehensive framework that considers all energy-related activities in remote indigenous communities. These measures will act as a pressure to current niche-regimes and established regimes for the transformation of diesel systems to more sustainable ones. Such policies range from targets that establish a percentage of energy generation from renewable sources, such as NWT's solar strategy (GNWT, 2012b), or Alaska's commitment to the generation of 50% of its electricity from renewable and alternative resources by 2025 (Ardani, Hillman, & Busche, 2013), to capital cost reductions, loans, technical capacity building, and generation incentives, such as net metering and local FIT tariffs. Innovative generation policies practiced in other countries include behind the meter, in front of the meter, or both, policies, combined with variable compensations for generation (therefore favouring or disfavouring battery storage) and system sizes limits (Couture, Jacobs, Rickerson, & Healey, 2015).

Second, given the complex nature of the provincial and territorial systems and the multiple interests involved in the current and future electricity system generation, policies should develop in a collaborative way and be negotiated with the indigenous people to the benefit of all participants. Negotiated agreements (such as IBAs in mining projects) are extensively used by indigenous people to communicate their perspectives and improve community socioeconomic conditions (Fidler, 2010; Sosa & Keenan, 2001; Dylan, et al., 2013). Policies should be able to accommodate indigenous aspirations for participation in both electricity infrastructure and on-grid renewable electricity generation, as well as off-grid RET projects, since both electricity generation options have the potential for providing benefits to the communities. Furthermore, given the differences in community financial and technical capacity, location and access, electricity cost, and available renewable resources, policies should be negotiated and tailored to address each community's (or group of communities) systemic and transformational problems.

Third, findings suggest that indigenous people learn, adapt, and modify their perspectives through participation in networks. Therefore, energy-related policy intervention should be effectively coordinated between different departments to reduce bureaucratic hindrances, avoid overlaps, and build a coherent policy framework directed towards communities' energy issues, which, in combination with regional loan schemes and state support for bank financing models, would attract multiple participants (Timilsina & Shah, 2016). Policies involving the participation of multiple actors in, for example, technical assessments of community renewable resources potential, new technology testing, on site feasibility studies, regulatory arrangements for IPP producers and fiscal support through net metering and PPAs, improve interactions and learning and could lead to higher community participation.

8.6 Contributions

The dissertation makes three contributions: First, it improves understanding of the nature of the problem associated with the introduction of RETs into Canadian remote indigenous communities by providing a description of the origins, dynamics, extent, and pattern of transition and the associated technical, contextual, and social complexity. Problem understanding is critical for the definitional clarity of the issues that the introduction of RETs is expected to address, given the renewed interest of the federal government in helping indigenous communities to embrace renewable energy. Furthermore, by examining the transformation of remote (off-grid) indigenous communities the study provides insights on the role of indigenous people in the Canadian energy transition.

Second, it contributes to the sustainability studies field by providing research from a context other than a developed or developing country. Both the MLP and TIS concepts are based on process theory and gain their theoretical strength from “the variety of cases, contexts, events, and patterns the theory can adapt to” (Grin, Rotmans, & Schot, 2010, p. 95). As Loorbach (2007, p.32) states “the basic hypothesis, which is to be tested and elaborated in transition research, is that the multi-level and multiphase concepts form a sound and adequate heuristic framework to describe and explain the complex dynamics of societal transformations”. Both frameworks were tested in the context of remote Canadian indigenous communities and there is evidence that the proposed complex causal mechanisms were present and performed as predicted.

Third, the study combines both the MLP and TIS and captures macro-, meso-, and micro-factors and mechanisms, that have the potential to induce the diffusion of technological innovations such as RETs. By combining these two frameworks, the individual analytical weaknesses of each framework are covered by the other, thereby benefitting the analysis of the complex multi-level and multi-stakeholder context of remote community electrical systems (Markard & Truffer, 2008). Furthermore, by comparing the NWT and Ontario TISs, the study offers evidence that regional institutional structures and networks (or the lack of them) played an important role in the diffusion of RET projects, therefore supporting Markard et al. (2015) who argue that the comparison of two regional TISs is able to offer empirical evidence of geographical factors, such as structures and institutions, that may influence the transition process.

8.7 Overall conclusion

This study used the MLP and TIS analytical tools to explain the deployment of RETs in remote indigenous community electrical systems between 1980 and 2016 with the goal of identifying pathways to increase the uptake of renewable electricity generation. The study’s findings indicate that a transition management approach was implemented to increase RET deployment. Evidence shows that the complex mechanisms proposed by the MLP and TIS frameworks were present between 1980 and 2001 and that they performed as predicted. After 2000, indigenous governments took advantage of federal and provincial and territorial governments' interest in the use of renewable energy to reduce carbon emissions and electricity generation costs and used the supporting policies to engage in RET entrepreneurial ventures. Participating in RET projects and engaging with numerous actors improved knowledge on the specific applications and their potential to contribute to indigenous goals. The number of indigenous-owned RET projects increased when indigenous people negotiated regulatory and fiscal arrangements necessary for meaningful participation (such as IPP regulations and net metering and PPAs market formation policies that contribute to indigenous self-governance and self-sufficiency aspirations). Although there is no evidence that these complex mechanisms are the only factors that have influenced the diffusion of RET projects since 2010, their presence, and the fact that they functioned as expected, combined with the lack of RET projects in provinces and territories where these mechanisms were not present, infers that they are indeed relevant and important for the deployment of RETs in remote indigenous communities.

Accordingly, a transition management approach involving the co-development of policies supportive of indigenous aspirations, experimenting and learning, and evaluation and adjustment of policies based on the acquired knowledge, may lead to an increased number of RET projects in remote indigenous communities.

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Appendices

Appendix A

Recent developments in renewable energy in remote aboriginal communities in Yukon, NWT, Nunavut, British Columbia, Ontario, Quebec, and Newfoundland and Labrador

Appendix A consists of seven papers published in *Papers in Canadian Economic Development.* The papers are:

Karanasios, K., & Parker, P. (2016a). Recent Developments in Renewable Energy in Remote Aboriginal Communities, Yukon, Canada. *Papers in Canadian Economic Development, 16*, 29-40.

Karanasios, K., & Parker, P. (2016b). Recent developments in renewable energy in remote aboriginal communities, NWT, Canada. *Papers in Canadian Economic Development, 16*, 41-53.

Karanasios, K., & Parker, P. (2016c). Recent Developments in Renewable Energy in Remote Aboriginal Communities, Nunavut, Canada. *Papers in Canadian Economic Development, 16*, 54-64.

Karanasios, K., & Parker, P. (2016d). Recent Developments in Renewable Energy in Remote Aboriginal Communities, British Columbia, Canada. *Papers in Canadian Economic Development*, *16*, 65-81.

Karanasios, K., & Parker, P. (2016e). Recent developments in renewable energy in remote aboriginal communities, Ontario, Canada. *Papers in Canadian Economic Development, 16*, 82-97.

Karanasios, K., & Parker, P. (2016f). Recent Developments in Renewable Energy in Remote Aboriginal Communities, Quebec, Canada. *Papers in Canadian Economic Development, 16*, 98-108.

Karanasios, K., & Parker, P. (2016g). Recent Developments in Renewable Energy in Remote Aboriginal Communities, Newfoundland and Labrador, Canada. *Papers in Canadian Economic Development, 16*, 109-118.

1. Recent Developments in Renewable Energy in Remote Aboriginal Communities, Yukon, Canada

Remote aboriginal communities in Canada's Yukon Territory are undergoing a transition from carbon-intensive diesel-generated electricity to low carbon, renewable sources of electricity. Hydroelectricity is the main source of power in the territorial grid, so the extension of the grid and the addition of new hydroelectricity sources offers one path to low carbon electricity future for some communities. In more remote parts of the territory, wind, solar and smaller hydroelectric generation projects are considered to reduce diesel consumption and the associated greenhouse gas emissions. Yukon's Climate Change Action Plan promotes cutting the carbon intensity of electricity. This paper reviews community electricity systems, past renewable electricity projects, as well as available renewable resources, generation alternatives, and policies, plans and proposed future projects that could help transform the supply of electricity in the remote communities. The transition to cleaner electricity systems also creates an opportunity for new investment models and development options where communities or private parties may replace public utilities as investors in new generation technologies. Government support for the transition of communities from greenhouse gas intensive diesel generation to low carbon renewable sources of electricity include the microgeneration and Independent Power Producer policies. Initial success with small renewable energy projects in the remote Yukon communities is leading to additional and larger projects being planned.

Introduction

Renewable energy (hydroelectricity) has a long tradition in the Yukon as the main source of electricity for Whitehorse and the local grid connected communities. New interest has arisen in the potential for renewable energy to displace diesel in Yukon's remote aboriginal[19] communities to achieve environmental, economic and social goals. The shifting of electricity generation from diesel to renewables is identified as an immediate step to reduce greenhouse gas emissions to help mitigate climate change (GY, 2015b). However, advocates for renewable energy in aboriginal communities argue that these projects can be part of broader changes to empower aboriginal communities and to build local capacity for community development (Henderson, 2013). Before reviewing recent climate and energy policies in the Yukon and identifying the communities with the greatest opportunities for investment in renewable energy, this paper sets the context by providing an overview of the population served in 23 remote communities, the capacity and type of current electricity generation systems, electricity price and rate structures, future demand expectations, renewable resource availability, as well as policies, plans and pilot projects to support renewables in the remote communities.

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[19] The term aboriginal community is used in this paper. It is recognized that some communities prefer the term indigenous community while others prefer aboriginal community and that both are used in the literature.

Population

There are 23 remote communities in Yukon with a total population of approximately 37,000 people in 2014 (YBS, 2014). The majority of the population (approximately 28,000 people) is gathered in Whitehorse, with Dawson City and Watson Lake being the next largest communities with populations of 2,000 and 1,500 respectively. The First Nation population in Yukon was estimated at 7,650 people, representing approximately 21% of the total population, of which 4,130 resided in Whitehorse and the rest in rural communities (YBS, 2014). There are five remote communities that are not connected to the territorial grid with a population of approximately 2,000 people (Table 1).

Table 1: Remote Aboriginal communities, Yukon

Nr	Community name	Population 2014	Diesel plant capacity (MW)	Annual electricity demand (2012) (MWh)
1	Destruction Bay/ Burwash Landing-Kluane FN[20]	147	0.9	1,996
2	Beaver Creek- White River FN	112	1.0	1,897
3	Swift River	10	0.2	263
4	Watson Lake	1,496	5.3	15,024
5	Old Crow- Vuntut Gwitchin FN	254	1.1	2,083
	Total	**2,009**	**8.5**	**21,263**

Source: YBS (2014); YEC (2013, p. 114).

Electricity system

Electricity is supplied by the Yukon Energy Corporation (YEC), established in 1987 as a publicly owned business operating at “arm’s length” from the Yukon government. Yukon Energy Corporation directly serves about 1,700 customers, most of whom live in and around Dawson City, Mayo and Faro, and provides power to many other Yukon communities through the Yukon Electrical Company Limited (YECL), recently renamed as ATCO Electric Yukon[21] (Yukon Energy, 2015b). ATCO Electric Yukon (AEY) is a private investor-owned utility and a member of the ATCO Group of Companies with head office and service centre in Whitehorse. ATCO Electric Yukon purchases power from YEC for distribution to 17,000 customers in 19 communities from south of the Yukon border to north of the Arctic Circle (ATCO, 2015).

Yukon’s electricity system, presented in Figure 1, consists of one large hydroelectricity based grid called the Yukon Integrated System (YIS), and five isolated diesel powered communities (Watson Lake, Swift River, Destruction Bay/Burwash Landing, Beaver Creek, and Old Crow). Yukon Energy Corporation has the capacity to generate approximately 132 megawatts of power; 92 MW are provided by hydro facilities in Whitehorse, Mayo and Aishihik Lake (40 MW at Whitehorse,

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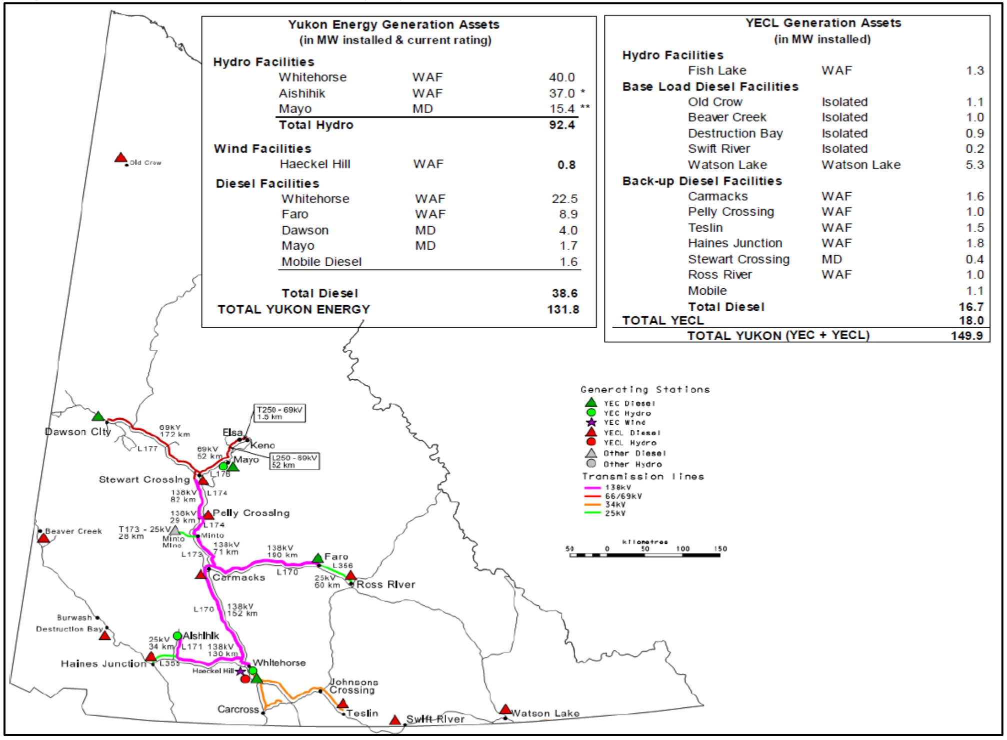
[20] Destruction Bay and Burwash Landing share the same generator in Destruction Bay.

[21] The Yukon Electrical Company Limited (YECL) or recently renamed as ATCO Electric Yukon. Figure 5 mentions YECL instead of ATCO Electric Yukon.

37 MW at Aishihik and 15 MW at Mayo), 39 MW by diesel generators (used currently only as back-up generators), and 0.8 MW by two wind turbines located on Haeckel Hill near Whitehorse (Yukon Energy, 2016). ATCO Electric Yukon owns and operates the 1.3 MW Fish Lake Hydro plant, on the outskirts of Whitehorse, and maintains 8 MW back-up diesel plants in Carmacks, Teslin, Haines Junction and Ross River in the event of a power interruption. Additionally, ATCO Electric Yukon serves five off grid communities with 8.4 MW of diesel generation (5.3 MW in Watson Lake, 2.0 MW in total for the Destruction Bay, Beaver Creek, and Swift River communities along the Alaska Highway, and 1.1 MW in Old Crow). All these communities are accessed by roads except the community of Old Crow, home of the Vuntut Gwitchin First Nation (ATCO, 2015; Yukon Energy, 2012).

Figure 1: Yukon's electricity system



Yukon Energy Generation Assets
(in MW installed & current rating)

Hydro Facilities			
	Whitehorse	WAF	40.0
	Aishihik	WAF	37.0 *
	Mayo	MD	15.4 **
	Total Hydro		**92.4**
Wind Facilities			
	Haeckel Hill	WAF	**0.8**
Diesel Facilities			
	Whitehorse	WAF	22.5
	Faro	WAF	8.9
	Dawson	MD	4.0
	Mayo	MD	1.7
	Mobile Diesel		1.6
	Total Diesel		**38.6**
TOTAL YUKON ENERGY			**131.8**

YECL Generation Assets
(in MW installed)

Hydro Facilities			
	Fish Lake	WAF	1.3
Base Load Diesel Facilities			
	Old Crow	Isolated	1.1
	Beaver Creek	Isolated	1.0
	Destruction Bay	Isolated	0.9
	Swift River	Isolated	0.2
	Watson Lake	Watson Lake	5.3
Back-up Diesel Facilities			
	Carmacks	WAF	1.6
	Pelly Crossing	WAF	1.0
	Teslin	WAF	1.5
	Haines Junction	WAF	1.8
	Stewart Crossing	MD	0.4
	Ross River	WAF	1.0
	Mobile		1.1
	Total Diesel		**16.7**
TOTAL YECL			**18.0**
	TOTAL YUKON (YEC + YECL)		**149.9**

Source: Osler (2011, p. 22)-modified.

Yukon's total electricity generation in 2013 was 424,720 MWh from hydro (94.8%), 23,215 MWh from thermal plants (5.2%) and 277 MWh from wind generation (0.1%) (YBS, 2013). Total diesel electricity generation for the five communities in 2010 was 20,000 MWh, of which approximately 70% was for Watson Lake (Yukon Energy, 2012). Since approximately 95% of Yukon's electricity was provided from renewable resources, total diesel electricity generated GHG emissions in Yukon in 2010 were 30,726 tonnes, of which approximately 13,500 tonnes were from the diesel plants in the five off-grid communities (Yukon Energy, 2012). Utility power generation in Yukon accounts for only about 3% of GHG emissions, while transportation and building heating account for over 85% of GHG emissions (Yukon Energy, December 2011, p. 51).

Electricity rates

Yukon electricity rates are considered the lowest in Northern Canada due to the legacy hydro assets of Mayo, Aishihik and Whitehorse (Yukon Energy, April 2012). For residential consumers Yukon has a single rate zone with the same rate of 12.14 c/kWh[22] for the first 1,000 kWh per month, and a high of 13.99 c/kWh for consumption over 2,500 kWh, except Old Crow which has a rate of 30.77 c/kWh (Table 2). The same rates apply for residential government rates and general services rates (both non-government and municipal) with the highest rate being 41.45 c/kWh for residential government services in the community of Old Crow (Yukon Energy, June 2011). Residential consumption is subsidized through the Interim Electrical Rebate, which provides residential customers with a maximum rebate of $26.62 per month for the first 1,000 kilowatt hours of power used (Yukon Energy, 2015a). In 2013 the average residential electricity consumption was approximately 10,200 kWh with an average consumer cost of 14.16 c/kWh, which is higher than the cost in Southern Canada, but low in comparison to the average cost in NWT and Nunavut (YBS, 2013).

Table 2: Yukon residential electricity rates 2015

Rate schedule	All communities (except Old Crow)	Old Crow Community
For the first 1,000 kWh/month	12.14 c/kWh	12.14 c/kWh
Between 1,001-2,500 kWh/month	12.82 c/kWh	12.82 c/kWh
Over 2,500 kWh/month	13.99 c/kWh	30.77 c/kWh

Source: Yukon Energy (2016).

Recent grid extensions and future load growth

Yukon’s energy development is subject to challenges associated with cyclical mining development and population growth. Yukon’s electricity system enhancements are to be designed with the following objectives: to secure ratepayers against financial risks and potential rate increases, to address sustainability issues, to reduce diesel generation and to meet its service criteria of affordability, reliability, flexibility and environmental responsibility (Yukon Energy, April 2012).

Two major extensions of Yukon’s electricity infrastructure were undertaken in the last decade to address mining development and grid access, as well as power balance requirements between the previously separate Whitehorse-Aishihik-Faro and Mayo/Dawson power grids. First, the 2008

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[22] All prices in Canadian currency (CAD).

connection of Minto copper-gold mine to the Yukon electrical grid benefitted Little Salmon Carmacks First Nation, Selkirk First Nation and Na-Cho Nyak Dun First Nation along the path of the transmission line. The benefits of the grid extension for the communities included construction related employment, elimination of expenses for diesel purchases and increased sales of surplus hydroelectricity. The reduced electricity rates increased profit margins for the Minto mine leading to higher royalties and taxes for the Yukon Government and Selkirk First Nation (CMC, 2008). Second, the Carmacks Stewart Transmission project in 2011, was built to meet new demand by current and proposed mining projects located in the proximity of remote communities. It connected the Whitehorse-Aishihik-Faro and Mayo/Dawson power grids through a new 138 kV transmission line running generally along the Klondike Highway, providing grid electricity to the remote community of Pelly Crossing and encouraging economic development along the corridor (Yukon Energy, 2012; Yukon Energy, 2006).

Yukon expects a significant power load increase in the next 40-year period. According to Yukon Energy (2012), diesel load is forecast to increase from 58 GWh in 2011 to 1,442 GWh in 2030 mainly due to the increase of off-grid mine loads from 37 GWh to 1,337 GWh, which are expected to rely on diesel or LNG supply options. Non-industrial loads are forecast to increase a moderate 2.26% over the same period. In the case of the five diesel powered communities, load growth is projected to rise from 20 GWh in 2011 to 22 GWh by 2030, and GHG emissions are expected to increase from 13,900 tonnes to 15,473 tonnes respectively.

Yukon plans to address future power load growth mainly through enhancements of current hydroelectric facilities and the development of new hydroelectric projects, while other options include Demand Side Management (DSM) and Supply Side Management (SSM) programs, solar applications, natural gas developments and potential connection to the Alaska Highway Pipeline, as well as the option of extending the current grid and connect to the BC or Alaska electrical grid (Yukon Energy, 2012; Yukon Energy, April 2012).

Availability of renewable energy sources in Yukon

According to Yukon Energy (2012), Yukon plans to address future power demand mainly through hydroelectricity “short term” enhancements and new ‘long term” project developments; total potential supply is expected to exceed 6,800 GWh/year with estimated full utilization costs (including transmission) below 15 c/kWh (in 2009). It is assumed that the Yukon Integrated System (YIS) will be able to accommodate only one wind project at Mount Sumanik of approximately 20 MW (Yukon Energy, 2012, p. 18), given the non-dispatchable character of wind and the higher costs, for which a feasibility assessment is already available (Yukon Energy, January 2009). Although solar photovoltaic applications are limited in Yukon, solar irradiance data are measured on three grid connected solar electric demonstration sites, namely a 4.0 kW installation at the Yukon government’s Main Administration Building and a 1.5 kW system at Yukon College, both in Whitehorse, and a 4.4 kW system in Yukon's Northern Lights Space and Science Centre located in the community of Watson Lake. The results indicate photovoltaic performance ranging between 825-1,069 kWh/kWp.year, which combined with installation costs of approximately $ 5/Watt and modest predictions on diesel fuel increases, could result in competitive costs for solar electricity in the community of Old Crow, which has higher electricity rates (YGESC, 2014).

Renewable energy policies and promotion

In 2009 the Yukon Government released its Climate Change Action Plan (GY, 2009b) aiming to reduce GHG emissions from the government's internal operations by setting a cap on GHG emissions in 2010, reducing GHG emissions by 20% by 2015 and becoming carbon neutral by 2020. Mechanisms to achieve these targets include the reduction of emission intensity of on-grid diesel power generation by 20% by 2020, and the reduction of energy use through demand-side management programs by 5 GWh by 2016 (GY, 2015b).

To achieve these targets, Yukon's 2009 energy strategy promoted a target of 20% increase of renewable energy supply by 2020, the development of a policy framework for geothermal applications, support for projects in off grid diesel communities, and promotion of renewable sources for heating and transportation (GY, January 2009). The development of renewable energy projects was to be facilitated through the Independent Power Producers (IPP) purchase policy, the net metering policy for small producers (now called the microgeneration policy), and incentives for demand management (GY, November 2009). The IPP policy (GY, October 2015) promotes three approaches for renewable projects: the Call for Power (CFP) program, which applies to large IPP projects to be integrated into YIS, requires a government approval, and aims at addressing future electrical needs as previously described; the Standing Offer (SOP) program promotes the development of new, small projects (up to 10,000 MWh for the YIS and 2,100 MWh for the Watson Lake grid) that will sell electricity to Yukon Energy Corporation in the YIS and to ATCO Electric Yukon in the diesel grid in Watson Lake; finally, the third approach of Unsolicited Proposal covers projects that are larger than the SOP limits, which will be assessed based on the territory's needs.

Three diesel powered aboriginal communities (Old Crow, Beaver Creek and Destruction Bay/Burwash Landing) are encouraged to work in cooperation with ATCO Electric Yukon and develop their own community owned IPP projects to acquire economic benefits, improve self-reliance and address environmental issues through the Unsolicited Proposal process, while projects up to 50 kW are eligible under the microgeneration policy. The microgeneration policy[23] includes projects offsetting electricity consumption by connecting renewables to homes or businesses under all rates classes. In the case of communities connected to Yukon Integrated System the applicable

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[23] http://www.energy.gov.yk.ca/microgeneration.html

rate is \$0.21/kWh, while the rate for diesel powered communities is \$0.30/kWh (GY, October 2013).

Renewable projects in remote communities

Yukon's remote communities of Destruction Bay/ Burwash Landing, Beaver Creek, Swift River, Watson Lake and Old Crow are not connected to the local grid. Instead, they are powered by five diesel plants[24] with a total capacity of 8.5 MW serving approximately 2,000 people in 2014. The power plants generate approximately 21,263 MWh/year, consume approximately 6 million litres/year of diesel fuel and contribute 17,000 tonnes/year in $CO_{2,eq}$ emissions[25] (Table 1).

Three of the five diesel powered communities in Yukon are considering the displacement of diesel through the development of renewable energy projects (Table 3). The community of Watson Lake has been monitoring solar resources and photovoltaic performance under the cold conditions since 2011 through a 4.4 kW solar system installed on Yukon's Northern Lights Space and Science Centre. It also examined local hydroelectricity options: a feasibility study conducted in 2014 concluded that two potential sites could provide electricity at a cost of 0.18-0.21 \$/kWh and create annual savings of \$1.3- \$2.4 million in comparison to the current diesel based electricity generation system (Morissette, 2014).

Table 3: Renewable electricity projects in remote communities, Yukon

	Community	Hydro MW	Wind kW	Solar kW	Year	Source
Existing projects						
1	Destruction Bay/ Burwash Landing	-	-	4.7	2012	Pinard (2013); Tobin (2016)
2	Beaver Creek- White River FN	-	-	-		
3	Swift River	-	-	-		
4	Watson Lake	-	-	4.4	2011	YGESC (2014)
5	Old Crow- Vuntut Gwitchin FN	-	-	3.6	2011	Cherniak et al. (2015)
				12.1	2011	See [26]
	Total			**24.8**		
Proposed projects						
1	Destruction Bay/ Burwash Landing	-	300	42		Pinard (2013); Tobin (2016)
2	Beaver Creek- White River FN		-	-		
3	Swift River		-	-		
4	Watson Lake	1.5	-	-		Morissette (2014)
5	Old Crow- Vuntut Gwitchin FN	-	-	330		Cherniak et al.(2015)
	Total	**1.5**	**300**	**372**		

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[24] Destruction Bay and Burwash Landing, home of the Kluane First Nation, are served by the same diesel generator in Destruction Bay.

[25] Assuming an average efficiency rate of 3.6 kWh/litre for the diesel engines and an average of 0.00080 tonnes $CO_{2,eq}$/kWh, for direct carbon emissions (emissions resulting from diesel and natural gas combustion only). See HORCI (2012).

[26] kza.yk.ca/wp-content/uploads/2011/08/OldCrowResearch1.pdf.

The Kluane First Nation, based in the remote communities of Burwash Landing and Destruction Bay, is directly involved in renewable energy projects. In addition to a 4.7 kW roof mounted solar project installed in 2012, they are planning the development 42 kW of solar panels on three community buildings to displace diesel under a "net metering" agreement (Tobin, 2016). Additionally, the community wants to develop a 300 kW community owned wind project at Kluane Lake (Pinard, 2013; Pinard, 2014; Tobin, 2016) to generate and sell electricity to ATCO Electric Yukon under the IPP policy and a Power Purchase Agreement (PPA) (Tobin, 2016). The project is being developed using federal and provincial capital funding, as well as financial support from Bullfrog Power (GY, 2015a; BP, 2017).

Similarly, the community of Old Crow, home of the Vuntut Gwitchin FN, wants to reduce its dependence on diesel and has installed solar panels on two of its community buildings (Vuntut Gwitchin First Nation, 2002; Ronson, 2014). Old Crow plans to develop a community owned 330 kW solar-diesel-storage hybrid energy system[27] that will displace approximately 98,000 liters of diesel annually and generate revenue for the community under a PPA agreement with ATCO Electric Yukon (Tukker, 2016).

Finally, the commercial viability of solar applications in Yukon has been confirmed by private sector projects. Northwestel, a communications company, successfully deployed four 10 kW photovoltaic arrays in 2014 for the operation of its microwave sites in remote locations, and reduced its diesel consumption by 20,000 litres [28] (Northwestel, 2015; GY, 2015b). This combination of private and public success with initial projects is leading to proposals for larger renewable energy projects in remote Yukon locations.

Conclusion

Remote aboriginal communities in the Yukon are undergoing an energy transition from GHG intensive diesel generation to low carbon renewable sources of electricity. The transition is being achieved in two ways: grid expansion and local renewable energy projects. The community of Pelly Crossing has been connected to the territorial grid which is primarily supplied by hydroelectricity. In addition to the environmental benefits of lower GHG emissions, the community gains increased opportunities for economic and social development with lower electricity prices and increased supply capacity. In the remote diesel powered communities, the Yukon Government has promoted investment in renewable energy with supportive policies including the microgeneration policy (<50kW) and Independent Power Producer policy to reduce diesel consumption and to encourage community participation and ownership of electricity generation

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[27] See also: www.arcticinspirationprize.ca/docs/2014-aip-laureates-en.pdf; http://www.yukon-news.com/news/old-crow-wants-to-build-yukons-largest-solar-plant/

[28] See also: NorthwesTel Remote Station Solar/Diesel Hybrid Feasibility study, in http://www.energy.gov.yk.ca/publications.html.

assets. Initial success with renewable energy projects in the remote Yukon communities is leading to additional and larger projects being planned.

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2. Recent Developments in Renewable Energy in Remote Aboriginal Communities, NWT, Canada

Remote aboriginal communities in Canada's Northwest Territories are starting an energy transition from high cost, carbon-intensive diesel powered electricity to greater local reliance on renewable sources of electricity. This paper reviews 25 remote communities' electricity systems, past renewable electricity projects, as well as provincial targets and policies for the introduction of renewable electricity alternatives. Besides small hydro-electricity projects and the future extension and interconnection of the two local grids, the transition to cleaner electricity systems is promoted through climate change policy emission targets and financial incentives focusing on solar photovoltaic applications (up to 20% of local generation capacity in the short term). The development of solar projects in 19 remote communities between 2009 and 2016, mainly under net metering agreements, in addition to two recent utility owned solar installations developed in cooperation with communities, and a community owned solar plant under a power purchase agreement with the local utility, represent successful deployment models that increase community benefits and improve environmental performance. Finally, the private sector has demonstrated the financial feasibility of commercial scale wind technology at the remote Diavik diamond mine, documented the diesel and carbon savings and enabled these lessons to be transferred to future developments.

Introduction

Remote aboriginal[29] communities in the Northwest Territories (NWT) and the Territorial Government are looking to change their sources of electricity from fossil fuel (diesel and natural gas) based generators to renewable energy sources. The high dependence on fossil fuels in remote communities is contrasted with hydro-electricity as the main source of electricity for the larger Snare and Taltson grids. The NWT electricity system faces significant challenges due to the small number of customers, harsh winter conditions, isolated diesel fueled plants, and limited economies of scale resulting in high electricity costs (GNWT, 2009a). The extensive use of fossil fuels for remote electricity generation increased interest in introducing renewable alternatives to reduce greenhouse gas emissions to help mitigate climate change (NT Energy, 2013). Mini-hydro, biomass cogeneration, wind and solar applications under community ownership are considered as options to reduce electricity cost structures (GNWT, 2009a). Other potential benefits include improving environmental performance by reducing emissions and increasing local self-sufficiency. The next sections of this paper provide an overview of the population served in NWT remote communities, the capacity and type of current electricity generation systems, electricity price and rate structures, future demand expectations, renewable resource availability, as well as policies, plans and pilot projects to support renewable electricity generation in the remote communities.

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[29] The term aboriginal community is used in this paper. It is recognized that some communities prefer the term indigenous community while others prefer aboriginal community and that both are used in the literature.

Table 4: Remote Aboriginal communities in NWT

	Community name	Population 2014	Diesel and natural gas plant capacity (MW)	Annual electricity demand (2012) (MWh)
1	Aklavik	691	1.280	2,890
2	Colville Lake	158	0.240	406
3	Deline	514	1.440	2,533
4	Fort Good Hope	560	1.230	2,650
5	Fort Liard	619	1.320	2,727
6	Fort McPherson	792	1.825	7,636
7	Fort Providence	815	1.480	2,942
8	Fort Simpson	1,244	3.210	7,636
9	Gameti	296	0.612	970
10	Jean Marie River FN	71	0.230	248
11	Inuvik	3,396	D:7.8, NG:7.7	28,327
12	Kakisa-Kaagee Tu FN	45[30]	0.300	358
13	Lutselk’e	299	0.820	1,460
14	Nahanni Butte- Deh Cho FN	97	0.230	397
15	Norman Wells	766	D & NG: 2.120	D:388, NG:8,402
16	Paulatuk	304	0.840	1,385
17	Sachs Harbour	128	0.795	929
18	Trout Lake-Sambaa K’e Dene	104	0.397	447
19	Tsiigehtchic	160	0.500	664
20	Tuktoyaktuk	962	2.205	3,662
21	Tulita	562	1.100	2,172
22	Ulukhaktok (previously Holman)	465	1.160	1,833
23	Wekweeti	142	0.380	610
24	Whati	497	0.975	1,570
25	Wringley- Pehdzeh Ki FN	146	0.781	642
	Total	13,788	40.97	83,884

Abreviations: D=Diesel, NG=natural gas

Source: GNWT (2015); NT Energy (2013); AANDC and NRCan (2011).

Population

NWT’s 33 remote communities had a total population of 44,088 in 2015. There were 15 communities with a population below 350, 12 communities with a population up to 1,000, and six communities with over 1,000 people. The total aboriginal population was estimated at 22,050, while there were 22,038 non-aboriginal residents. Yellowknife is the territorial capital and has a population of 20,637, of which approximately 15,000 are non-aboriginal (GNWT, 2015). There are 25 remote communities that are not connected to the two electricity grids with a combined population of approximately 14,000 people (Table 4).

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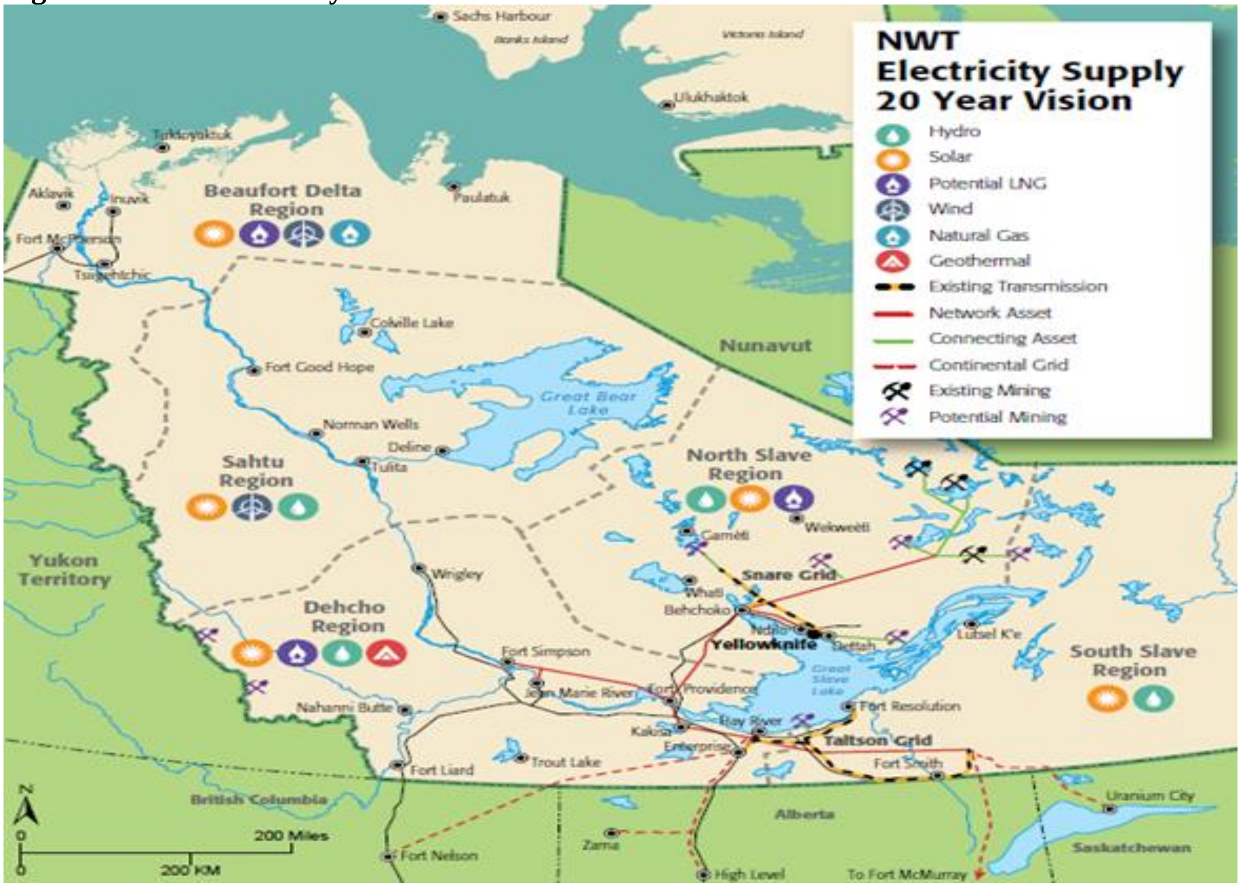
[30] Population for 2011: https://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CSD&Code1=6104005&Geo2=PR&Code2=01&Data=Count&SearchText=Kakisa&SearchType=Contains&SearchPR=61&B1=All&Custom=&TABID=1

Electricity system

Electricity in NWT is generated mainly from three sources: natural gas, hydro-electricity and diesel fuel. It is supplied by NT Hydro, a public agency established in 2007 under the Northwest Territories Hydro Corporation Act, and fully owned by the Government of the Northwest Territories (GNWT) (NTPC, October 2011). NT Hydro fully owns Northwest Territories Power Corporation (NTPC), which operates hydro-electric, diesel, natural gas, solar power generation facilities, and transmission systems to provide electricity services in the Northwest Territories. The NWT electrical system is presented in Figure 2.

Figure 2: The electrical system in Northwest Territories



Source: NT Energy (2013, p. iii).

There are two main electrical grids, the Snare grid servicing Yellowknife, Dettah, N'Dilo and Behchokö, and the Taltson grid servicing Fort Resolution, Fort Smith, Hay River and Enterprise. Electricity in the two grids is generated mainly by hydroelectric plants backed by diesel generators. The rest of the communities use diesel-generated electricity, except Norman Wells and Inuvik, where both diesel and natural gas are used. Renewable energy projects are also deployed in NWT communities, as will be discussed in the next sections (NT Energy, 2013).

The generation and distribution structure of NWT electrical system is presented in Table 5. NTPC generates and distributes electricity to 25 of the 33 communities in NWT and supplies electricity on a wholesale basis to Northland Utilities (NUL) owned by ATCO (NT Energy, 2013). NTPC activities are subject to regulation by the Northwest Territories Public Utilities Board (PUB). NTPC owns almost all the electricity generation assets in NWT and distributes power to approximately 45% of the population.

Table 5: NWT electricity service providers and generation source

Service Provider	Community	Generation source
NTPC Generation and distribution	Dettah, Fort Resolution, Fort Smith, Behchokö	Hydro-electricity (8 communities)
NUL Distribution	Hay River, Hay River Dene Reserve, Enterprise and Yellowknife	
NTPC Generation and distribution	Aklavik, Colville Lake, Deline, Fort Good Hope, Fort Liard, Fort McPherson, Fort Simpson, Jean Marie River, Lutselk’e, Nahanni Butte, Paulatuk, Gameti, Sachs Harbour, Tsiigehtchic, Tuktoyaktuk, Tulita, Ulukhaktok, Whati, Wrigley	Diesel (23 communities)
NUL Generation and distribution	Kakisa, Fort Providence, Trout Lake, Wekweètì	
NTPC	Inuvik, Norman Wells	Natural gas and diesel (2 communities)

Source: adapted from GNWT (2008, p.4); GNWT (2009, p.99).

NUL consists of Northland Utilities (Yellowknife) Ltd., which distributes hydroelectric power in Yellowknife (Hay River, Hay River Dene Reserve, Enterprise and Yellowknife), and Northland Utilities (NWT) Ltd., which generates and distributes diesel-electric power to four isolated communities in the South Slave (Kakisa, Fort Providence, Trout Lake, Wekweètì). NUL serves almost 55% of the population located in the largest NWT communities. Imperial Oil Ltd is a utility company that sells natural gas fired electricity to NTPC for distribution in Norman Wells (GNWT, 2012a; GNWT, 2009a; GNWT, 2008).

The total installed capacity of NWT power plants in 2012 was 148 MW, with hydro-electricity accounting for 54.8 MW, diesel 78.3 MW (of which 35 MW represent communities’ diesel generators and 43.3 MW industrial generators), and natural gas 14.5 MW. Total community related generation for 2010 was 309 GWh (75% or 228.66 GWh hydroelectric, 17% or 52.53 GWh diesel, and 9% or 27.81 GWh natural gas), while the total NWT electricity generation including the industrial consumers was 722 GWh (GNWT, 2012a; NT Energy, 2013). Diesel electricity generation related emissions from communities and mines were 437,000 tonnes $CO_{2,eq}$ in 2010 and 482,800 tonnes $CO_{2,eq}$ in 2011 (or 36% of total emissions of 1,220 kT $CO_{2,eq}$ in 2010 and 34% of 1,420 kT $CO_{2,eq}$ in 2011 respectively) (GNWT, 2011a; GNWT, 2013).

Table 6: NWT residential electricity rates, 2015

Community	Zone	Residential Electricity Rate (¢/kWh)		Actual cost
Colville Lake, Nahanni Butte, Sachs Harbour, Jean Marie River, Gameti, Paulatuk, Wrigley, Tsiigehtchic, Tulita, Whati, Deline, LutselK'e, Fort McPherson, Ulukhaktok, Fort Good Hope, Tuktoyaktuk, Fort Liard, Fort Simpson, Aklavik, Inuvik	NTPC Thermal	For the first 1000 kWh[31]	29.73 c/ kWh	60.83 c/kWh
		Each additional kWh	60.83 c/ kWh	
Norman Wells	NTPC Norman Wells	For the first 1000 kWh	29.73 c/ kWh	47.54c/kWh
		Each additional kWh	47.54 c/ kWh	
Fort Smith, Fort Resolution, Hay River	NTPC Taltson	For the first 1000 kWh	21 c/ kWh	31.1 c/kWh
		Each additional kWh	21 c/ kWh	
Dettah, Behchoko, Yellowknife	NTPC Snare	For the first 1000 kWh	29.73 c/ kWh	21 c/kWh
		Each additional kWh	31.1 c/ kWh	
Fort Providence, Dory Point/Kakisa, Wekweeti, Trout Lake	NUL (NWT) Thermal	47.39*		
Hay River, Hay River Reserve, Enterprise	NUL (NWT) Hydro	27.21*		
Yellowknife	NUL(YK)	23.72*		

* Indicates 2012 rates for the communities served by NUL[32].

Source: NTPC (2016); GNWT (2012a).

Electricity rates

Electricity costs in NWT are high due to the limited number of communities connected to the two local hydroelectric grids, high fixed and operating costs, and isolated diesel plants (GNWT, 2009a). Additionally, the communities' small customer base, small size diesel plants and fuel imports reduce the possibility for economies of scale and increase electricity costs and rates (GNWT, 2008). The 2010 Electricity Review changed the Territorial Power Subsidy Program (TPSP) and increased the applied subsidy from 700 kWh to 1,000 kWh per month during the winter months and 600 kWh in the summer months and equalized residential rates within these remote communities to Yellowknife's rate. The residential electricity rates in NWT's remote communities start at 29.73 c/kWh for the first 1,000 kWh, with additional charges for excess use depending on the electricity generation cost in each community (Table 6).

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[31] For the winter months (September to March). In the summer months (April to August) the rates apply for the first 600 kWh and above 600 kWh respectively.

[32] See GNWT (2012a).

Future power requirements and plans

NWT's electricity system has been the focus of numerous reviews aimed at addressing the primary northern related issues of reliability, affordability, environmental impacts, economic development and job creation, aboriginal involvement and energy self-sufficiency (GNWT, 2008; GNWT, 2009a; GNWT, 2009b; NT Energy, 2013). Public consultation initiated between 2008 and 2010 resulted in nineteen actions that changed the structure of the electrical system described in the 2010 Electricity Review (GNWT, 2010); three of the main changes were the reduction of the number of rate schedules from 33 to seven (described previously), the advancement of conservation measures, and the promotion of alternative (natural gas) and renewable energy generation options.

Electrical demand growth in NWT is driven by residential, commercial and industrial load increases (NT 2103). Residential electricity demand has increased due to population growth and increases in per capita household appliance use with approximately one-half (0.5) percent growth per year between 2007 and 2013. Future industrial load increases may result from oil exploration projects in the Sahtu region and mining activities in the North and South Slave regions, which currently host two of the four mines in operation in NWT, the Diavik and Ekati mines, while the Snap Lake mine was recently shut down[33] (NT Energy, 2013). Both the Snare and Taltson grids can meet future demand in the case of future mine operation in the area[34]. In the case of diesel communities, the existing diesel plants are adequately sized to meet future community demands.

Resource options to address electricity generation issues and future load growth include diesel, liquefied natural gas (LNG), solar, wind, biomass, hydro-electricity, expansion of the transmission system to connect the remote communities and mines to the grid[35], and finally, the interconnection of the NWT transmission system with one or more of the Saskatchewan, Alberta or British Columbia provincial grids (NT Energy, 2013). A review of the costs and benefits of available options indicates that medium sized (10 MW scale) hydro-electric projects, such as the La Martre Falls, Snare Site 7, and the Taltson Expansion, together with the expansion and interconnection of the two local grids, represent the biggest options for the NWT electrical system to maximize provincial economic development by providing access to low cost hydro resources to support future industrial loads and the potential for exports in the case of potential interconnection(s) to the continental grids (NT Energy, 2013).

Availability of renewable energy sources in NWT

As mentioned, the available resources to offset diesel generation in NWT remote communities include solar, wind, and small hydro. NWT's potential hydro-electric resources are estimated at 11,000 MW, of which only 55 MW are developed (Snare and Taltson), and 69 MW (La Martre and Taltson expansion) are proposed for future development (GNWT, 2011a). Solar resources in NWT are considered good due to long hours of sunlight during the spring and summer months,

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[33] See http://www.cbc.ca/news/canada/north/snap-lake-shutdown-layoffs-1.3353295

[34] The proposed Tamerlane and Avalon mining projects (NT Energy, 2013).

[35] In this case the interconnected grid will be based on the Taltson and Snare grids.

providing electrical generation between 800 and 1,200 kWh/kW (GNWT, 2012b). Although wind resources are available in northern NWT communities, wind speeds are considered low, ranging from 5.4 m/s in Yellowknife to 6.5 m/s in Sachs Harbour and 6.7 m/s in Ulukhaktok (GNWT, 2011a). Extensive wind studies in NWT communities have been conducted by the Aurora Institute (ARI, 2016), but the majority of the communities lack sites with wind potential of over 6-7 m/s, which is considered necessary for a financially viable project in the difficult conditions of the NWT arctic environment (Pinard, 2007).

Renewable energy policy and promotion

The installation of solar photovoltaic projects in NWT was initiated in the 1980s and some continue to operate thirty years later (Carpenter, 2013). The 2011 "Greenhouse Gas Strategy for the NWT 2011-2015" (GNWT, 2011b) identified solar energy as a potential source to reduce communities' GHG emissions. The "2012 NWT Solar Energy Strategy" (GNWT, 2012b) established steps and actions to increase solar project implementation to supply up to 20% of the average load of the 25 diesel powered communities, and targeted a 10% displacement of annual diesel-generated electricity. As a result, there are more than 200 solar installations in NWT communities and 25 grid connected solar photovoltaic systems, while it is estimated that the planned 1.8 MW of solar PV installations to be deployed over the next five years will displace 570,000 litres of diesel per year and reduce emissions by 1,660 tonnes $CO_{2,eq}$ per year[36] (GNWT, 2012b). Finally, the NWT's "2013 Energy Action Plan" focused on developing local renewable energy resources, such as biomass, solar and wind, to create sustainable communities, the interconnection of NWT local grids and linkages to mineral development, as well as hydro-electric developments and transmission projects in the communities of Whati, Kakisa and Fort Providence (GNWT, 2013; NT Energy, 2013).

The promotion of solar projects is supported by incentives in the form of rebates and financial support. The first incentive program for solar photovoltaic applications in the NWT was the RETCAP (2001-2003) with the primary goal to displace diesel and reduce noise from generators. The program provided a 50% rebate on panels and balance of system costs, and during its two-year period led to the installation of 36 solar systems in off grid homes, houseboats and remote lodges, with a total of 204 kW in 16 communities, namely in Hay River, Yellowknife, Jean Marie River, Inuvik, Sachs Harbor, Wekweeti, Nahanni Butte, Behchoko, Paulatuk, Fort Smith, Norman Wells, Gameti, Whati, Edzo, Fort Good Hope and Fort Simpson (Carpenter, 2013). More recently, the Alternative Energy Technologies (AET) program, administered by the Arctic Energy Alliance (AEA)[37], provides funding for communities, businesses and residents for the installation of renewable energy technologies, including solar, hot water heating systems, wind turbines, and solar photovoltaic panels, to reduce fuel consumption and lower the cost of their operations. The program is split into the Residential Renewable Energy Fund (RREF), the Business Renewable

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[36] This equals to $2.8X10^{-3}$ tonnes $CO_{2,eq}$/ litre diesel or 0.0008 tonnes $CO_{2,eq}$/kWh with an average diesel engine efficiency of 3.6 kWh/litre diesel.

[37] See http://aea.nt.ca/programs/alternative-energy-technologies-program

Energy Fund (BREF) and the Community Renewable Energy Fund (CREF). The CREF assists with the installation of larger, community systems of renewable energy or the conversion of an existing conventional energy system to a system using an alternative energy technology. It provides up to one-half of the cost of a community-based alternative energy project, up to a maximum of $50,000 annually. Eligible community entities include aboriginal communities and governments, GNWT departments, boards and agencies, and non-profit organizations (GNWT, 2013).

Renewable energy projects in remote communities

NWT's 25 remote communities are powered by isolated diesel generators (and natural gas plants in two communities) with a total capacity of 41 MW. The power plants generate approximately 84,000 MWh/year, consume approximately 23,330,000 litres/year of diesel fuel and contribute 67,000 tonnes/year $CO_{2,eq}$ emissions[38] (Table 1).

There is one 50 kW wind turbine, developed in 1998, and 29 solar photovoltaic installations in 19 remote communities with a total renewable capacity of 524.3 kW (Table 7). Of these projects, 17 have less than 10 kW capacity, 10 are larger than 10 kW but less than 20 kW capacity, and three have a capacity larger than 20 KW. Most solar projects are deployed on community buildings reducing diesel consumption and expenses for the local governments.

Five additional solar projects with a total capacity of 41 kW are planned for the communities of Aklavik, Fort Simpson, Jean Marie River, Norman Wells and Whati. The solar panels are to be deployed on community buildings under a net metering agreement[39], and they will reduce diesel consumption and community electricity expenses[40].

Diavik mine also introduced renewables to reduce its combustion of diesel to generate electricity. The $31 million investment in four wind turbines (9 MW) resulted in savings of $5 million in reduced diesel purchases (4 million litres) in its first year of operation thereby reducing the expected payback period from 8 to 6 years (Varga, 2014). After the success of Diavik's 9 MW wind hybrid system (DDC, 2014; CANWEA, 2014), a 1.8 MW wind project is considered for Storm Hills outside of Inuvik, which could meet approximately 18% of Inuvik's annual electricity demand (Matangi, 2014). Finally, pilot projects are being developed for biomass in Dettah and geothermal technologies in Fort Liard (GNWT, 2013).

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[38] Assuming an average efficiency rate of 3.6 kWh/litre for the diesel engines and an average of 0.00080 ton $CO_{2,eq}$ for direct carbon emissions (emissions resulting from diesel and natural gas combustion only). See HORCI (2012).

[39] "Net metering" allows residential and commercial customers who generate their own electricity from renewable electricity technologies to feed excess electricity generated back into the grid. See, for example, http://www.ntpc.com/docs/default-source/default-document-library/ntpc-net-metering-13-08-14.pdf?sfvrsn=2.

[40] http://aea.nt.ca/blog/2016/02/request-for-proposals-community-government-building-solar-projects

Table 7: Renewable energy projects in remote communities. Northwest Territories

	Community	Hydro (MW)	Wind (kW)	Solar (kW)	Year	Source
Existing projects						
1	Aklavik			15	2015	
2	Colville Lake			135.5	2014	Pembina (n.d. (a)); see also[41]
3	Deline			-		
4	Fort Good Hope			5	2013	
5	Fort Liard			10.5	2014	
6	Fort McPherson			-		
7	Fort Providence			15	2013	
8	Fort Simpson			104	2013	See also[42]
				5	2013	
				5	2013	
9	Gameti			5	2012	
				17	2015	
10	Jean Marie River FN			1.3	2006	
					2016	
11	Inuvik			5	2009	Dignard, Martel, & Ross (1998)
				7	2009	
				1	2011	
				3.5	2011	
				10	2013	
				1.7	2013	
12	Kakisa-Kaagee Tu FN			-		
13	Lutsel'Ke			35	2015	AEA (2016); CBC (2016b)
14	Nahanni Butte- Deh Cho FN			4.8	2011	
15	Norman Wells			4.8	2011	
16	Paulatuk			5	2011	
				1.7	2011	
17	Sachs Harbour		50	4.3	1998	Pinard & Weis (2003); Carpenter (2013)
					2010	
18	Trout Lake-Sambaa K'e Dene			-		
19	Tsiigehtchic			18	2015	
20	Tuktoyaktuk			-		
21	Tulita			10	2013	
22	Ulukhaktok			-		
23	Wekweeti			4.2	2010	Carpenter (2013)
24	Whati			5	2012	
				16	2015	
25	Wringley- Pehdzeh Ki FN			19	2015	
	Total		**50**	**474.3**		
Proposed projects						
1	Aklavik			10	2016	
2	Fort Simpson			10	2016	
3	Jean-Marie River			6	2016	For all proposed projects see[43]
4	Norman Wells			10	2016	
5	Whati			5	2016	
	Total	**-**	**-**	**41**		

Source: For all existing projects see Carpenter (2013); Cherniak, Dufresne, Keyte, Mallett, & Scott (September 2015); GNWT (2012b); Prieur (2015).

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[41] https://www.ntpc.com/smart-energy/how-to-save-energy/colville-lake-solar-project

[42] http://www.skyfireenergy.com/solar-commercial/grid-tied-electric-systems/104kw-diesel-offset-solar-photovoltaic-system-fort-simpson-northwest-territories/

[43] http://aea.nt.ca/blog/2016/02/request-for-proposals-community-government-building-solar-projects

Conclusion

The 25 remote aboriginal communities in NWT are undergoing an energy transition through the introduction of mainly solar photovoltaic installations into the diesel powered electrical systems, new small hydro-electricity projects, and the future extension and interconnection of the two local grids. The Government of NWT has established provincial targets and supported investment in photovoltaic systems with financial incentives to reduce diesel consumption and encourage community participation in electricity generation. As a result, 28 solar photovoltaic projects were deployed in 19 remote communities between 2009 and 2016. Most of the projects were developed under net metering agreements that reduced community electricity expenses while displacing diesel. The success of two community scale projects developed by NTPC in cooperation with communities, as well as Lutselk'e's community owned and operated solar installation under a PPA agreement, provide successful models for future deployment of renewable electricity in remote communities with increased community benefits, reduced costs and improved environmental performance.

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3. Recent Developments in Renewable Energy in Remote Aboriginal Communities, Nunavut, Canada

Remote aboriginal communities in Nunavut are entirely dependent on diesel powered electricity. This paper reviews the electricity systems in 25 remote communities, past renewable electricity projects and available renewable resources. Despite past efforts to introduce renewable energy into these communities, alternative energy generation is limited to a few district heating installations, and wind and solar demonstration projects. The high cost of deployment of renewable technologies in Nunavut's isolated locations and limited government financial resources hinder communities' participation in renewable electricity generation. However, growing demand and the necessity for diesel plant replacements or upgrades in 17 of the 25 communities, combined with recent decreases in the cost of solar and battery storage technologies, provide an opportunity for communities with high wind resources to integrate wind and solar projects into their electricity systems and to reduce dependence on fossil fuels.

Introduction

Each of Nunavut's 25 communities is remote and isolated with no road or electricity grid connecting them. They are entirely dependent on diesel-generated electricity with diesel delivered in the summer and stored in tanks for use throughout the year. The result is a high cost, carbon-intensive system. Efforts have been made to introduce renewable energy in the past (Ah-You & Leng, 1999), but renewable electricity generation is limited to a few wind and solar demonstration projects (Senate Canada, 2014a). System efficiency has been improved with district heating systems in ten communities that use residual or waste heat from the diesel plants (Senate Canada, 2014a). Although there are hydroelectricity resources capable of reducing Nunavut's diesel consumption, the necessity of upgrading the outdated diesel generators and the Government of Nunavut's limited financial resources restrict the deployment of renewable electricity projects (Senate Canada, 2014a). However, the need for change is recognised and new interest has arisen in the potential for renewable resources to displace diesel through the integration of wind, solar and battery storage in the local systems as old diesel plants are upgraded (Das & Canizares, 2016). The next sections provide an overview of the population served in Nunavut's remote aboriginal[44] communities, the capacity and type of current electricity generation systems, electricity price and rate structures, future demand expectations, renewable resource availability, as well as policies, plans and pilot projects to support renewable electricity generation in the remote communities.

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[44] The term aboriginal community is used in this paper. It is recognized that some communities prefer the term indigenous community while others prefer aboriginal community and that both are used in the literature.

Population

Nunavut has 25 communities[45] with a 2014 population of approximately 36,500 (Table 8), of which approximately one third (or 11,389 people) is under the age of 15. Nunavut's population increased at an average annual growth rate of 2.3% from 2006 to 2014. The capital Iqaluit has a population of 7,542 and the communities of Arviat and Rankin Inlet follow with populations of 2,611 and 2,820 respectively (NBS, 2014).

Table 8: Remote aboriginal communities, Nunavut

	Community name	**Population 2014**	**Diesel plant capacity (MW)[46]**	**Annual electricity demand (2013) in MWh**
1	Arctic Bay (Ikpiarjuk)	875	1.07	3,008
2	Arviat	2,611	2.24	8,028
3	Baker Lake (Qamanittuaq)	2,164	2.24	8,938
4	Cambridge Bay (Ikaluktutiak)	1,684	3.11	9,144
5	Cape Dorset (Kinngait)	1,508	1.80	6,110
6	Chesterfield Inlet (Igluligaarjuk)	387	0.81	2,002
7	Clyde River (Kangiqtugaapik)	1,039	1.35	3,681
8	Coral Harbour (Sallit)	961	1.31	3,367
9	Gjoa Haven (Uqsuqtuuq)	1,370	1.65	5,009
10	Grise Fiord (Aujuittut)	163	0.465	1,250
11	Hall Beach (Sanirajak)	895	1.345	3,257
12	Igloolik	2,007	1.74	6,183
13	Iqaluit	7,542	15.10	56,888
14	Kimmirut	481	0.93	2,.062
15	Kugaaruk (formerly Pelle Bay)	953	0.835	2,653
16	Kugluktuk (Qurluqtuq)	1,591	2.22	5,576
17	Pangnirtung (Pangniqtuuq)	1,613	2.22	6,477
18	Pond Inlet (Mittimatalik)	1,673	2.25	5,993
19	Qikiqtarjuaq (formerly Broughton Island)	526	1.305	2,531
20	Rankin Inlet (Kangiqiniq)	2,820	3.55	17,396
21	Repulse Bay (Naujaat)	1,068	0.99	3,584
22	Resolute (Qausiuttuq)	247	2.05	4,778
23	Sanikiluaq	924	1.2	3,483
24	Taloyoak (Talujuaq)	998	1.5	3,418
25	Whale Cove (Tikirarjuaq)	456	0.75	1,753
	Total	**36,556**	**54.03**	**174,507**

Source: AANDC (2012b); NBS (2014); QEC (2013).

Electricity system

Electricity generation in Nunavut was the responsibility of Northern Canada Power Commission (NCPC) from 1949-1988, followed by Northwest Territories Power Corporation (NTPC) until

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[45] AANDC (AANDC, 2012) mentions 26 communities and includes the community of Bathurst Inlet (Kingoak), which currently has zero population, see https://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CSD&Code1=6208065&Geo2=PR&Code2=01&Data=Count&SearchText=Bathurst%20Inlet&SearchType=Begins&SearchPR=01&B1=All&GeoLevel=PR&GeoCode=6208065&TABID=1

[46] https://en.wikipedia.org/wiki/List_of_generating_stations_in_Nunavut and the Nunavut power archives, such as http://web.archive.org/web/20040829121348/http://www.nunavutpower.com/communities/chester.html in the case of Chesterfield inlet for example. See also AANDC and NRCan (2011).

2001 (NTPC, 2016). Following the creation of the new territory, new arrangements were made with power generation being provided by Qulliq Energy Corporation (QEC), a corporation owned by the Government of Nunavut (QEC, 2015a). QEC generates, transmits and distributes electricity through 26 stand-alone diesel plants in 25 communities (there are two diesel plants in Iqaluit) and approximately 275 km of distribution lines, with a total installed capacity of 54 MW, serving approximately 14,400 electrical customers (Figure 3) (GN, 2015a).

Diesel-generated electricity in Nunavut was 176,850 MWh in 2013[47] and was projected to increase by 2.3% to 187,610 kWh in 2014/2015. Electricity generation in 2013 was fueled by approximately 48 million liters of diesel resulting in an average efficiency of 3.69 kWh/liter, at an average cost of 0.91 $/lit (QEC, 2013). Diesel fuel is shipped in bulk during the summer and stored in fuel tank facilities in each community (QEC, 2014; GN, 2015a). Electricity related greenhouse gas emissions for 2013 were estimated at approximately 116,000 tonnes CO_{2eq}, while total emissions (electricity, heating and transportation) were 473,813 tonnes of CO_{2eq} , an increase of 14,941 tonnes since 2009 (GN, 2015a).

Figure 3: Electricity system in Nunavut: communities with diesel generators

Source: QEC (2013).

Electricity rates

The cost of electricity in Nunavut depends on the community and the rate class, which in turn is based on the distinction between residential, government and commercial customers. Residential

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[47] QEC 2014/2015 General Rate Application, Vol 1, p.45/372.

rates in 2014 ranged from 62.23 c/kWh in Rankin Inlet to as high as 114.16 c/kWh in Kugaaruk or 144.80 c/kWh for government accounts in Whale Cove (QEC, 2015b) (Table 2). Residential and small commercial consumption are subsidized through the Nunavut Electricity Subsidy Program. For small commercial enterprises subsidization applies to the first 1,000 kWh of monthly consumption, while residential customers are subsidized for the first 1,000 kWh during the October to March period and the first 700 kWh during the April to September period; in this case all consumers pay the same rate, which is 50 percent of Iqaluit's base rate, or 30.15 c/kWh (GN, 2015b; CBC, 2014). Excess consumption is billed at the electricity rate of each community presented in Table 9.

Table 9: Qulliq Energy Corporation (QEC) electricity rate schedule, May 2014

	Community	**Domestic**		**Commercial**	
		Non-government c/kWh	**Government**	**Non-government c/kWh**	**Government**
1	Arctic Bay (Ikpiarjuk)	87.87	87.87	78.97	78.97
2	Arviat	79.14	79.14	74.03	74.03
3	Baker Lake (Qamanittuaq)	70.31	70.31	66.09	66.09
4	Cambridge Bay (Ikaluktutiak)	76.06	76.06	66.07	66.07
5	Cape Dorset (Kinngait)	68.59	71.87	64.47	71.87
6	Chesterfield Inlet (Igluligaarjuk)	97.54	97.54	91.14	91.14
7	Clyde River (Kangiqtugaapik)	78.19	78.67	69.66	69.66
8	Coral Harbour (Sallit)	94.66	94.66	87.11	87.11
9	Gjoa Haven (Uqsuqtuuq)	89.45	92.28	85.96	85.96
10	Grise Fiord (Aujuittut)	92.09	110.79	105.92	105.92
11	Hall Beach (Sanirajak)	89.03	92.32	85.91	85.91
12	Igloolik	63.23	63.23	58.35	58.35
13	Iqaluit	60.29	60.29	50.68	52.04
14	Kimmirut	103.74	103.51	87.70	88.13
15	Kugaaruk (formerly Pelle Bay)	114.16	114.16	101.77	101.77
16	Kugluktuk (Qurluqtuq)	93.32	98.68	87.19	87.19
17	Pangnirtung (Pangniqtuuq)	65.74	70.13	58.66	64.26
18	Pond Inlet (Mittimatalik)	89.95	97.29	82.88	82.88
19	Qikiqtarjuaq (formerly Broughton Island)	77.92	88.71	74.06	88.71
20	Rankin Inlet (Kangiqiniq)	62.23	62.23	55.04	60.64
21	Repulse Bay (Naujaat)	85.06	85.06	75.30	75.30
22	Resolute (Qausiuttuq)	101.35	103.15	96.81	96.81
23	Sanikiluaq	82.25	82.25	79.01	79.01
24	Taloyoak (Talujuaq)	98.36	106.46	96.78	96.78
25	Whale Cove (Tikirarjuaq)	90.42	144.80	111.18	122.71

Source: QEC (2015b).

Future power requirements and plans

Electricity load growth is forecasted for all Nunavut communities due to new housing, territorial and federal government driven major projects, and exploration activities in the mining sector (QEC, 2015a). Load growth for Iqaluit is forecasted to average 3-4% annually. Rapid growth is expected in Cambridge Bay due to the creation of the Canadian High Arctic Research Station (CHARS) campus, which will be responsible for a 75% increase in the community's electricity demand. Although QEC aims to participate in mining driven generation projects, its main objective remains the affordable and reliable supply of electricity to residential and commercial customers (QEC, 2015a).

The need for an energy strategy in Nunavut was first examined in the Ikuma report (GN, 2001) and outlined in Ikummatiit (GN, 2007). Nunavut's goal was (a) to reduce diesel consumption that reached approximately 172 million liters in 2006, of which 40% was accounted for by transportation, 37% for heat and hot water and 23% for electricity generation, and (b) to develop alternative forms of energy such as hydroelectricity, wind power and solar power, complemented with energy efficiency measures. In the case of electricity generation, the strategic plan included the development of studies for renewable energy generation and the creation of an Independent Power Purchase Policy to encourage the private sector to undertake renewable energy projects and then sell surpluses to QEC (GN, 2007).

Recent reports and discussions focus on the urgent need for replacement and updates of QEC diesel plants, since 17 out of 25 facilities have reached the end of their designed service life[48] (Senate Canada, 2014b; Bell, 2015). There is also a need for infrastructure investments in hydroelectricity projects to power Nunavut's potential mining operations and to reduce diesel consumption (Senate Canada, 2014a; Windeyer, 2015).

Hydroelectricity investment studies have focused on a project outside of Iqaluit, which could address increasing loads and infrastructure upgrades issues, as well as replacing 15 million liters of diesel fuel (GN, 2015a; Senate Canada, 2014b). The project has been postponed due to its high projected cost ($250 to 500 million) and the limited ability of Nunavut government to add additional debt (Rohner, 2015). Other renewable options include run-of-the-river facilities at locations near Iqaluit, at Akulikutaq, Tungatalik and Qairulituq (GN, 2007; NWT, 2011; Northern Vision, 2014). Finally, although past wind projects in Kugluktuk, Cambridge Bay and Rankin Inlet exhibited high costs and limited performance[49] (Weis, Ilinca, & Pinard, 2008; George, 2012), a wind-hydrogen-diesel project has been examined for Cape Dorset (Northern Premiers Forum, 2014; Senate Canada, 2014b).

Another option is the proposed connection of the five Nunavut communities (Arviat, Whale Cove, Rankin Inlet, Chesterfield Inlet and Baker Lake) in the Kivalliq region to Manitoba's electrical grid (Senate Canada, 2014b). A recent study estimated the cost of the 1,000 km transmission line at approximately 900 million with potential savings of $40 million a year from the replacement of diesel with clean hydroelectric power, and additional benefits of future load growth coverage (from 38 GWh to 185 GWh by 2035), lower electricity costs (from an average of 75 c/kWh to 13 c/kWh), reduced emissions, and the foundation for fibre-optic infrastructure (Rogers, 2015) .

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[48] http://www.nunatsiaqonline.ca/stories/article/65674senate_study_nunavuts_power_generation_system_unsustainable/

[49] http://www.nunatsiaqonline.ca/stories/article/65674wind_power_for_nunavut_dont_hold_your_breath_qec_boss_says/

Availability of renewable energy sources in Nunavut

Alternatives to diesel fueled electricity examined for Nunavut include locally discovered resources of oil and gas, renewable resources, grid connection, and small nuclear power plants (Senate Canada, 2014b). Solar potential in Nunavut is estimated to range from 567 - 691 kWh/kWp in Iqaluit (Poissant, Thevenard, & Turcotte, 2004) to 1,158 kWh/kWp in Chesterfield Inlet (GN, 2015a), while average wind speeds in the area of communities range from 5 m/s in Coral Harbour to 7.7 m/s in Whale Cove. Wind resources with average wind speeds higher than 7 m/s are present in the communities of Arviat, Chesterfield Inlet, Clyde River, and Whale Cove (Weis & Ilinca, 2008; Weis & Ilinca, 2010). A recent study indicates that significant savings in diesel consumption and operation and maintenance costs could be achieved through the introduction of wind and solar applications into local diesel systems for the communities of Sanikiluaq, Iqaluit, Rankin Inlet, Arviat, and Baker Lake (Das & Canizares, 2016).

Renewable energy policies and promotion

Although renewable energy projects are technically viable in Nunavut, there is a lack of territorial programs supporting such high capital cost alternatives due to limited financing (McDonald & Pearce, 2012). At the federal level the program ecoENERGY for Aboriginal and Northern Communities Program (EANCP), established with the objective to support renewable energy projects for greenhouse gas emissions reductions, attracted five applications during the 2007-2011 period and six applications during the 2011-2014 period from Nunavut, in comparison to seven and twelve applications respectively from Northwest Territories (AANDC, 2014b). Recent federal budget commitments of $10.7 million over two years for developing renewable projects in northern aboriginal communities could assist Nunavut’s communities to examine RETs applications for diesel displacement (DFC, 2016; CBC News, 2016).

The 25 remote communities of Nunavut are powered by diesel generators with a total capacity of 54 MW, generated approximately 174,000 MWh in 2013 (Table 10), and consumed 48,000,000 litres of diesel, resulting in the emissions of approximately 116,000 tonnes CO_{2eq} (QEC, 2014; GN, 2015a). Starting in the 1987 a number of renewable energy technologies in the form of solar photovoltaics, solar water heating, and wind turbines have been installed (Table 3). Projects included a 3.2 kW solar photovoltaic system on the Arctic College in Iqaluit in 1995 (INAC, 2004; Poissant, Thevenard, & Turcotte, 2004), solar photovoltaics in 1998 and a 66 kW wind turbine in 2000 in Rankin Inlet (INAC, 2004; Dignard, Martel, & Ross, 1998), a 80 kW wind turbine in Cambridge Bay in 1994, and two 80 kW turbines in Kugluktuk installed in 1996 (QEC, 2002; INAC, 2004). The three wind projects encountered equipment malfunctions and maintenance issues so were decommissioned (GN, 2016).

Table 10: Renewable electricity projects in remote communities, Nunavut

	Community	Hydro MW	Wind kW	Solar kW	Year	Source
Existing projects						
1	Arctic Bay (Ikpiarjuk)					
2	Arviat					
3	Baker Lake (Qamanittuaq)					
4	Cambridge Bay (Ikaluktutiak)		100 80		1987 1994	Ah-You & Leng (1999); Weis & Ilinca (2008)
5	Cape Dorset (Kinngait)					
6	Chesterfield Inlet (Igluligaarjuk)					
7	Clyde River (Kangiqtugaapik)					
8	Coral Harbour (Sallit)					
9	Gjoa Haven (Uqsuqtuuq)					
10	Grise Fiord (Aujuittut)					
11	Hall Beach (Sanirajak)					
12	Igloolik		20		1988	Ah-You & Leng (1999); Weis & Ilinca (2008)
13	Iqaluit			3.2	1995	Poissant, Thevenard, & Turcotte (2004); INAC (2004)
14	Kimmirut					
15	Kugaaruk (formerly Pelle Bay)			4	2014	See[50]
16	Kugluktuk (Qurluqtuq)		160		1996	Ah-You & Leng (1999); Pinard & Weis (2003)
17	Pangnirtung (Pangniqtuuq)					
18	Pond Inlet (Mittimatalik)					
19	Qikiqtarjuaq (formerly Broughton Island)					
20	Rankin Inlet (Kangiqiniq)		50		1998	Ah-You & Leng (1999); Weis & Ilinca (2008)
21	Repulse Bay (Naujaat)					
22	Resolute (Qausiuttuq)					
23	Sanikiluaq					
24	Taloyoak (Talujuaq)					
25	Whale Cove (Tikirarjuaq)					
	Total		**410**	**7.2**		
Proposed projects						
1	Arviat			10		See[51]
2	Iqaluit			2.86		Murray (2015)
	Total			**12.86**		

Source: Nunavut Power (n.d.); Ah-You & Leng (1999).

Future renewable electricity applications include a 4 kW photovoltaic system to be installed on the local hockey arena in Kugaaruk to reduce the electricity consumption of community’s freezer during the summer months (Rogers, 2014), a 2.86 kW solar system to be installed in Qulliq Energy Corporation's Iqaluit plant (Murray, 2015), and a 10 kW solar photovoltaic system to be installed on the Arviat recreation center (Table 3) (GN, 2015a).

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[50] http://www.nunavutenergy.ca/en/Nunavuts_Energy_System; http://www.nnsl.com/frames/newspapers/2014-08/aug11_14ae.html

[51] http://www.nunavutenergy.ca/en/Nunavuts_Energy_System

Conclusion

Remote communities in Nunavut are entirely dependent on diesel fuel for electricity, heating and transportation. The Government of Nunavut, Qulliq Energy Corporation and the communities are interested in renewable energy to reduce diesel dependence and to increase local self-reliance. However, the high cost of deployment of renewable technologies in Nunavut's isolated locations and limited government financial resources restrict communities' investment in renewable electricity generation. Local interest in renewables is supported by external groups. For example, the environmental group, World Wildlife Fund – Canada (WWF), is promoting a shift to renewables in Nunavut and supported the pre-feasibility study by Das and Canizares (2016) that found renewables to be financially feasible in selected communities (WWF, 2016). Given, recent decreases in the cost of solar technology and battery storage applications combined with the necessity for diesel plant replacements or upgrades in 17 of the 25 communities, an opportunity has arisen to consider the potential for renewables to be integrated into the electricity systems of Nunavut's remote communities, to build local capacity and to reduce the communities' dependence on fossil fuels.

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4. Recent Developments in Renewable Energy in Remote Aboriginal Communities, British Columbia, Canada

Hydroelectricity has a long tradition in British Columbia, provides approximately 95% of the province's electricity supply, and powers the electrical systems of several remote aboriginal communities. However, diesel generators remain in 23 remote aboriginal communities and a transition from fossil fuels to renewables is desired. This transition has been promoted through a series of Energy Plans from 2002 and the 2010 Clean Energy Act. One of the goals of the Act is to encourage economic development of First Nation and rural areas through the development of clean and renewable energy projects. The stage of development of these clean energy projects varies among communities and insights can be gained by reviewing progress to date. This paper reviews current community electricity systems, past renewable electricity projects, as well as available renewable resources, generation alternatives, and supportive targets and policies in British Columbia. The results show that two communities recently connected to the newly constructed Northwestern transmission line, and that 15 out of the 23 remote aboriginal communities participate, or plan to participate, in renewable electricity generation to reduce diesel dependence and greenhouse gas emissions, and to increase self-sufficiency.

Introduction

Renewable energy (hydroelectricity) has a long tradition in British Columbia and provides approximately 95% of the province's electricity supply. However, the electricity system in 23 remote aboriginal[52] communities was typically based on diesel generators. A transition from fossil fuels to renewables in these communities has been promoted through a series of Energy Plans from 2002 and the 2010 Clean Energy Act. One of the goals of the Act is to encourage economic development of First Nation and rural areas through the development of clean and renewable energy projects (BC Hydro, 2013f). The stage of development of these clean energy projects varies among communities and insights can be gained by reviewing progress to date. Some of the larger communities, serviced by BC Hydro, are powered by hydro-electricity projects owned by communities or Independent Power Producers (IPP). In some cases, communities have completely displaced diesel while achieving socio-economic benefits by having the community own run-of-river hydroelectric plants. The remaining diesel powered communities that independently operate their own systems are participating in hydroelectricity, solar or biomass proposals to reduce greenhouse gas emissions and increase local self-sufficiency. Before reviewing these renewable energy projects, the next sections of this paper will provide an overview of the population served in British Columbia's remote aboriginal communities, the capacity and type of current electricity generation systems, electricity price and rate structures, future demand expectations, renewable

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[52] The term aboriginal community is used in this paper. It is recognized that some communities prefer the term indigenous community while others prefer aboriginal community and that both are used in the literature.

resource availability, as well as policies, plans and future projects to support renewable electricity generation in remote aboriginal communities.

Population

According to AANDC and NRCan (2011) in 2011 there were 86 remote communities in British Columbia (BC) with a total population of approximately 24,000 people, of which 25 were aboriginal communities with a population of approximately 8,000, and 61 were non-aboriginal communities with a population of 16,000 (AANDC and NRCan, 2011). Recent grid connections reduced the number of remote communities to 70 (Inglis, 2012). Of the 23 remote First Nation communities presented in Table 11 and Figure 4 only 12 communities have a population over 100, two communities have a population between 50 and 99 and seven communities have a population lower than 50.

Table 11: British Columbia's non-integrated area serviced and independent aboriginal communities

Nr	Community Name	First Nation name	Population 2011[53]	Diesel plant capacity kW	Annual energy demand (2011) MWh[54]	Service	
1	Anahim Lake	Ulkatcho FN	355	2,650	4,990	NIA served by BC Hydro- Zone II	Communities with a population larger than 100 people
2	Atlin	Taku River Tlingit FN	322	2,650[55]	4,400		
3	Bella Bella	Heiltsuk FN	1095	8,750	10,147		
4	Bella Coola	Nuxalk Nation FN	850	7,630	17,147		
5	Fort Ware	Kwadacha FN	250	755	n/a		
6	Hartley Bay	Gitga't FN	155[56]	1,000	1,344		
7	Refuge Cove	Hesquiaht FN	80	150	438		
8	Kitasoo	Kitasoo FN	315	250	n/a		
9	Lower Post (Liard River)	Liard FN	102	995	n/a		
10	Masset (Old Masset)	Haida Nation	607	11,524	24,275		
11	Nemiah Valley (Chilco Lake and Lohbiee)	Xeni Gwet'in FN	148	305	1,279		
12	Skidegate Landing	Haida Nation	781	No data	No data		
13	Finlay River	Tsay Keh Dene FN	105	500	No data		
14	Elhlateese	Uchucklesaht FN	19	125	255		
15	Sim Creek- Dead Point	Da'nawda'xw FN	20[57]	No data	No data	Independent	Communities with a population less than 100 people
16	Chenahkint	Ehattesaht	70	50	No data		
17	Good Hope Lake	Dease River	32	1,230	613		
18	Hopetown	Gwawaenuk Tribe-/Kwa-wa-aineuk	14	40	No data		
19	Sundayman's Meadow	Kluskus- Lhoosk'uz Dene FN	32[58]	20	260		
20	Gwayasdums	Kwicksutaineuk-ah-kwaw-ah-mish-Haxwa'mis FN	50	225	No data		
21	Katit	Oweekeno-Wuikinuxv FN	65	1,050	1,168		
22	Hope Island	Tlatlasikwala	29	70	No data		
23	Quaee	Tsawataineuk - Dzawada'enuxw FN	90	900	1,208		
	Total		**5,586**	**40,869**	**67,524**		

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[53] http://pse5-esd5.aadnc-aandc.gc.ca/fnp/Main/Search/FNPopulation.aspx?BAND_NUMBER=540&lang=eng

[54] According to AANDC and NRCan (2011), unless otherwise noticed.

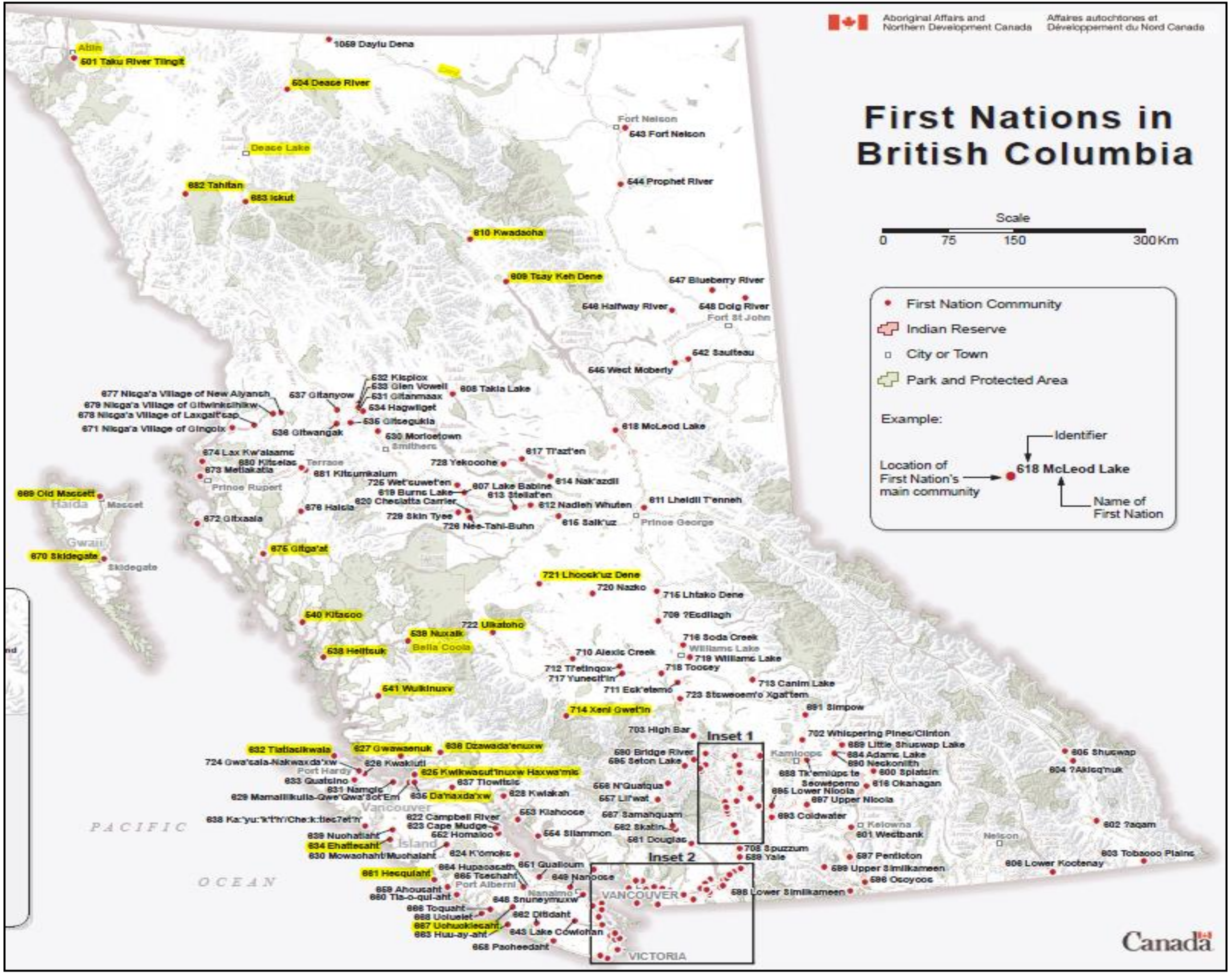
[55] The Atlin community is currently powered by hydroelectricity.

[56] Census population in 2006.

[57] Registered population in December 2015.

[58] AANDC and NRCan (2011) based on the 2006 census.

Figure 4: Map of remote aboriginal community locations, British Columbia



Source: AANDC and NRCan (2011); AANDC (2016)[59].

Electricity system

British Columbia's electrical system is part of the North American western interconnected electricity system, with BC Hydro providing power to 1.9 million customers, or approximately 95 percent of the population, through 31 hydroelectric plants and three thermal plants, with a total capacity of 12,000 MW (BC Hydro, 2013a; BC Hydro, 2014). Renewable electricity from BC Hydro's hydroelectric plants and from Independent Power Producers' (IPPs) owned hydroelectric generation projects meet approximately 95% of the electricity demand, with the remaining electricity generated using natural gas and other renewables (BC Hydro, 2014; OPC, 2010). British Columbia's transmission and generation system is presented in Figure 5.

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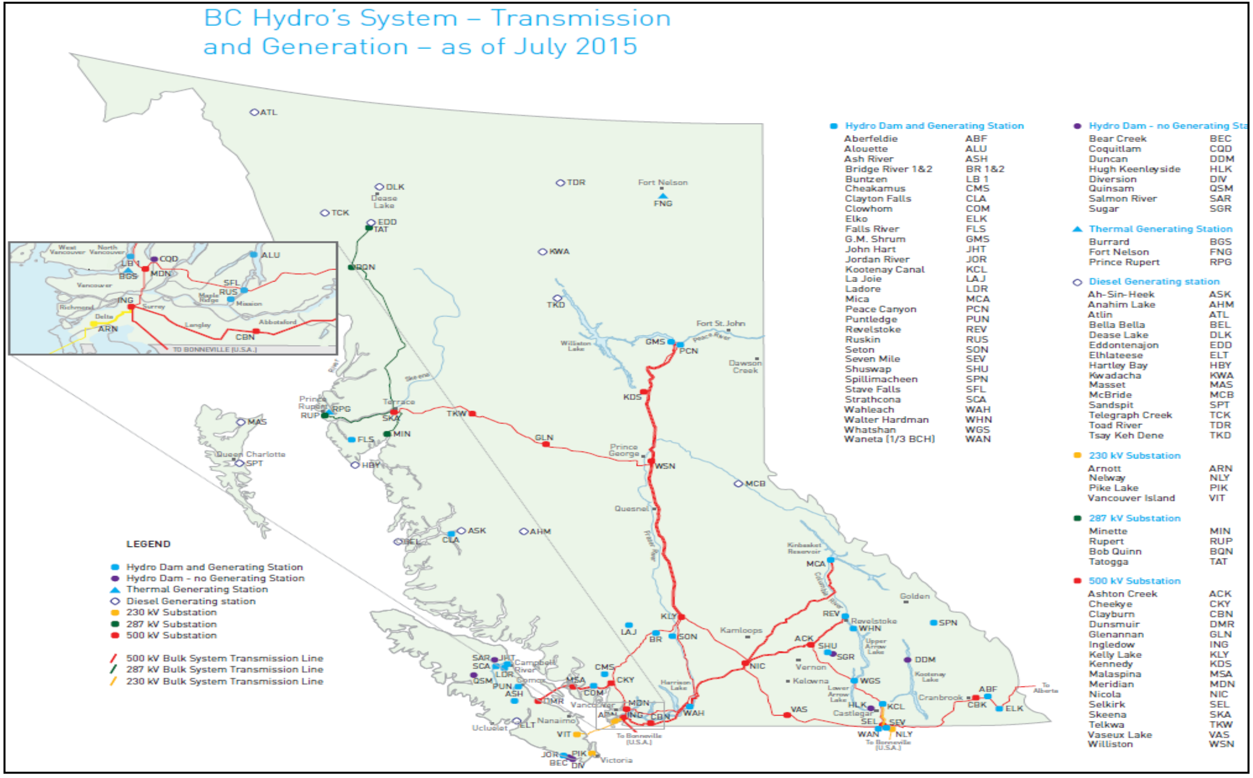
[59] See https://www.aadnc-aandc.gc.ca/eng/1100100021015/1100100021021

Figure 5: BC Hydro's generation and transmission system, July 2015.

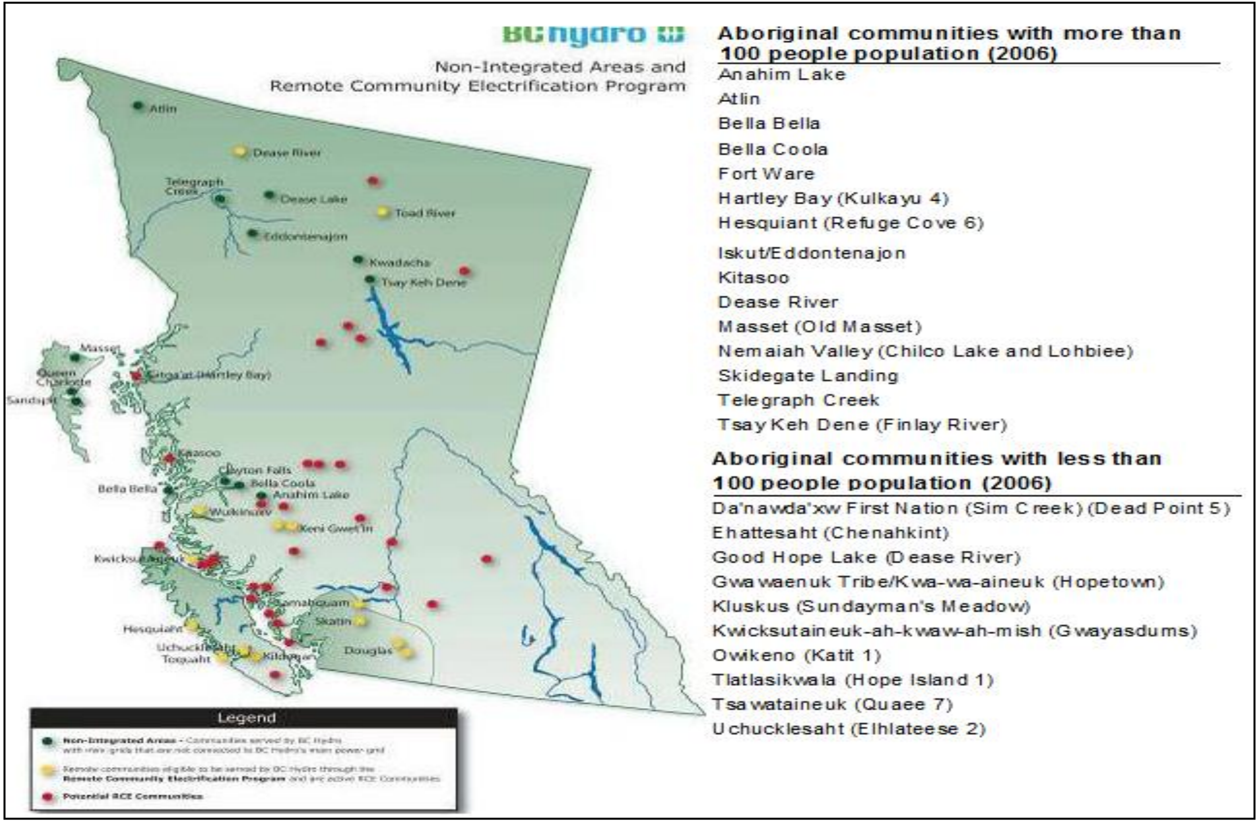


Source: *https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/accountability-reports/financial-reports/annual-reports/bch-system-map-Jul-2015.pdf*.

In 2012 British Columbia used 57,000 GWh of electricity, of which 10,900 GWh were produced by IPPs. Approximately 25% of the IPPs contribution was hydro generation, and this is forecast to increase over the next 20 years to approximately 25% of the total supply (BC Hydro, 2014; BC Hydro, 2012b; BCBC, 2013). Due to its hydroelectricity generation assets, the total emissions for electricity generation were 631,000 tonnes $CO_{2,eq}$ in 2012 and 730,000 tonnes $CO_{2,eq}$ in 2013, leading to average emission intensities of 18.5 tonnes $CO_{2,eq}$/ GWh (or 18 gr $CO_{2,eq}$/ kWh) (BC Hydro, 2014; BC Hydro, 2015c).

Most of British Columbia's communities are connected to the main grid within the integrated electrification area. The communities that are not connected to the main grid are either within BC Hydro's non-integrated area or outside it. Within the non-integrated area, BC Hydro either owns the electricity generation assets or buys electricity from IPPs and resells the electricity to the communities at similar rates to those in the integrated areas. Remote communities outside the non-integrated area may receive services from BC Hydro through the Remote Community Electrification (RCE) Program, or they may choose to operate their own electricity systems (BC Hydro, 2015a; ISIS, 2011). The remote aboriginal communities in the non-integrated area, the communities that are part of the RCE program, as well as the communities that could participate in the RCE program in the future are presented in Figure 6.

Figure 6: Remote aboriginal communities by type of BC Hydro program



Aboriginal communities with more than 100 people population (2006)

Anahim Lake
Atlin
Bella Bella
Bella Coola
Fort Ware
Hartley Bay (Kulkayu 4)
Hesquiant (Refuge Cove 6)
Iskut/Eddontenajon
Kitasoo
Dease River
Masset (Old Masset)
Nemaiah Valley (Chilco Lake and Lohbiee)
Skidegate Landing
Telegraph Creek
Tsay Keh Dene (Finlay River)

Aboriginal communities with less than 100 people population (2006)

Da'nawda'xw First Nation (Sim Creek) (Dead Point 5)
Ehattesaht (Chenahkint)
Good Hope Lake (Dease River)
Gwawaenuk Tribe/Kwa-wa-aineuk (Hopetown)
Kluskus (Sundayman's Meadow)
Kwicksutaineuk-ah-kwaw-ah-mish (Gwayasdums)
Owikeno (Katit 1)
Tlatlasikwala (Hope Island 1)
Tsawataineuk (Quaee 7)
Uchucklesaht (Elhlateese 2)

Source: Modified from BC Hydro (2010, p.4); AANDC and NRCan (2011).

Within the non-integrated area there are four local grids that are served by hydroelectricity and diesel generators, namely the Bella Bella and Bella Coola local grids in mainland BC, and the Masset and Sandspit local grids in Haida Gwaii. The Bella Coola grid provides electricity to approximately 2,000 people. It is powered by diesel generators established in 1955 in the Ah-Sin-Heek station and hydroelectricity through the Clayton Falls[60] run-of-river facility built in 1962 and updated to 2 MW in 1991 (BC Hydro, 2016a). The Bella Bella communities of Waglisla (home of the Heiltsuk First Nation) and Shearwater receive their electricity from the Central Coast Power Corporation (CCPC). The IPP provides electricity - to the Bella Bella non-integrated area that is generated mainly by the Ocean Falls hydroelectricity plant, while the diesel plants in Shearwater provide approximately 1% of the communities' annual electricity demand (BC Hydro , 2007). In

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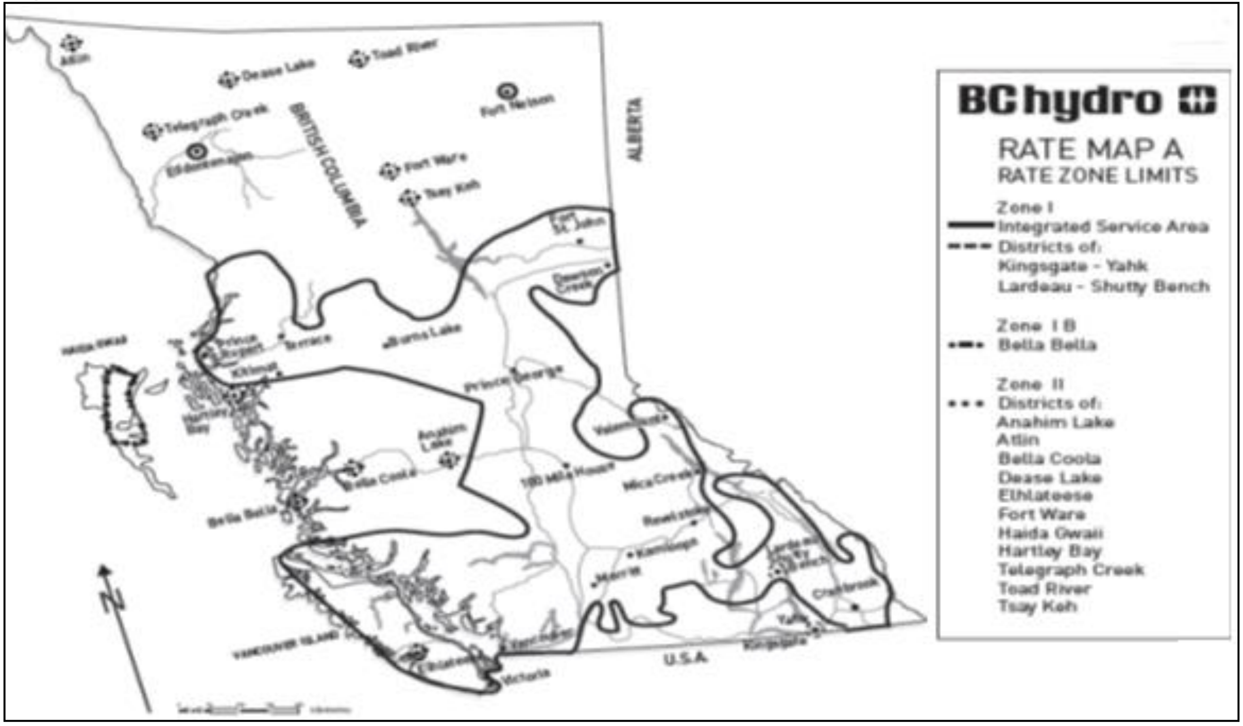
[60] https://www.bchydro.com/community/recreation_areas/clayton_falls_recreation_site.html

Haida Gwaii, BC Hydro provides electricity through the northern grid that serves Old Masset, Masset and Port Clements using a diesel generating facility in Masset. The southern grid serves Skidegate, Queen Charlotte City, Tlell and Sandspit and receives power from the private 6 MW hydroelectric plant in Queen Charlotte with a backup BC Hydro diesel generation station available in Sandspit (BC Hydro, 2012a).

Figure 7: British Columbia's electricity rate system zones



Source: BC Hydro (2015b, p. 50).

Electricity rates

Electricity rates in British Columbia are set through a public hearing process and, despite recent increases (9% in 2014 and 6% in 2015), are some of the lowest electricity rates in Canada (OPC, 2010, p. 32), as a result of the large hydroelectric facilities on the Peace and Columbia rivers (OPC, 2010; BC Hydro, 2015d). As the original BC electrical system (consisting of diesel generators and hydroelectric plants) transformed to the integrated BC system with Zone I rates, the communities outside the system formed the non-integrated areas with the Zone II rate system, which include the districts of Anahim Lake, Atlin, Bella Coola, Dease Lake, Elhlateese, Fort Ware, Haida Gwaii, Hartley Bay, Telegraph Creek, Toad River and Tsay Keh (Figure 7), while a number of smaller aboriginal communities are served by IPPs or community energy systems (see Table 11).

In BC Hydro's non-integrated area serviced remote communities under Zone II rates, residential customers pay similar rates to residential customers under Zone I (9.55 c/kWh in comparison to 7.97 c/kWh) for the first 1,500 kWh/month, while for consumption beyond 1,500 kWh/month a higher rate is charged to discourage electric space heating from diesel-generated electricity (Table 12) (BC Hydro, 2015b). Small general service customers and general service customers in Zone II also pay similar rates to Zone I. According to BC Hydro (2015b) very few residential customers under Zone II exceed the 1,500 kWh /month threshold, therefore electricity costs are comparable between Zone I and Zone II residential customers[61].

Table 12: Residential rates for Zone I and Zone II communities

2016 Rates	Residential Zone I RIB Rate (RS 1101)	Residential Zone II Rate (RS 1101)
Base Charge/day (cents)	17.64	18.82
Consumption threshold (kWh/month)	675	1500
Rate for consumption below threshold (c/kWh)	7.97	9.55
Rate for consumption above threshold (c/kWh)	11.97	16.41

Source: BC Hydro (2015b p. 22).

Since the total cost for the generation of electricity in the non-integrated area zones is higher than the revenue generated, the non-integrated area customers are subsidized by the ratepayers of Zone I. In 2014 under-recovered costs in Zone II equalled approximately $31.5 million and are forecasted to increase to approximately $34 million in 2015 and $35 million in 2016 (BC Hydro, 2015b).

Future power requirements and plans

BC hydro forecasts an electricity demand growth of 23,000 GWh, or more than 40% of the current (2012) 57,000 GWh, over the next 20 years, due to increasing population, residential demand, economic activity and mining and liquefied natural gas developments (BC Hydro, 2013a). BC Hydro's Integrated Resource Plan under the Clean Energy Act of 2010[62], addressed future demand through a combination of conservation measures, supply from major projects (such as the Site C on the Peace River), and supply from smaller renewable (biomass, run-of-river hydro and wind) projects. These projects are to be developed in cooperation with Independent Power Producers (IPP), who currently operate 81 clean and renewable power generation plants that are funded through Electricity Purchase Agreements providing about 20% of the BC Hydro's electricity (BC Hydro, 2013a; BC Hydro, 2013b).

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[61] https://www.bchydro.com/accounts-billing/rates-energy-use/electricity-rates/residential-rates.html
https://www.bchydro.com/about/planning_regulatory/2015-rate-design/resources.html#2015rda

[62] http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/00_10022_01#section3

Electricity demand in BC Hydro's non-integrated area's thirteen remote communities represented approximately 0.2% of BC Hydro's total, or 103 GWh in 2012. Demand grew at an average of 0.4% per year over the last four years and is forecast to increase by 2%, 1.2% and 0.7% annually over the next 5, 11 and 21 years due to anticipated growth in residential and commercial consumers (BC Hydro, 2012b). There are no available data on forecast future electricity demand for the ten smaller independent aboriginal communities. In 2014 the communities of Eddontenajon and Telegraph Creek were connected to the provincial grid by the newly constructed Northwestern Transmission line (BC Hydro, 2016b; RWB, 2011).

Availability of renewable energy sources in British Columbia

The identified potential of BC's renewable resources allows for successful demand coverage, as well as the achievement of provincial objectives of self-sufficiency, support for clean energy and economic development, and reduced greenhouse gas emissions (BC Hydro, 2014). The 2013 Resource Options Report assessed demand-side management options and resource options for generation and transmission for the next 20-30 years and identified solutions consistent with the 2010 Clean Energy Act (BC Hydro, 2013b). Options included biomass, wind, geothermal, run-of river, combined cycle gas turbine and cogeneration, as well as limited capacity from wave, tidal, and solar resources (BC Hydro, 2013c).

A complete list of available renewable energy options for the province is provided in BC Hydro (2013e) and OPC (2009). Supply options include 4,271 MW of onshore wind, 3,819 MW of offshore wind, 1,189 MW of run-of-river, and 1,100 MW from Site C, with costs ranging from 8 c/kWh to 1.17 $/kWh (BC Hydro, 2013c). Evaluation of the available renewable energy options included, besides impacts on provincial GDP, revenues, and employment from construction and operations (BC Hydro, 2013e), future potential electricity purchase agreements for IPPs, which are tied to specific impact benefit agreements signed with First Nation communities, therefore supporting aboriginal economic development (BC Hydro, 2013d). For example, bioenergy electricity purchase agreements have broad economic benefits for forestry and transportation besides construction and operation of facilities (BC Hydro, 2013d, p. 17).

Renewable energy policies and promotion

During the 2002-2012 period, British Columbia emphasized a shift towards clean energy through the introduction of the 2002 Energy Plan, the 2007 Energy Plan, and the 2010 Clean Energy Act. First, the 2002 Energy Plan introduced the private sector and IPPs for development of new electricity generation, with BC Hydro undertaking "improvements of existing plants" and the development of Site C (GBC, 2002, p. 9; BC Hydro, 2013f). Second, the 2007 Energy Plan proposed a policy framework promoting energy self-sufficiency, 90% renewable energy electricity generation and the creation of a market for renewable energy through a Standing Offer Program (OPC, 2010; BC Hydro, 2013f; GBC, 2007). Alternative energy policies were established through the Innovative Clean Energy Fund for the promotion of renewable energy technologies, the creation of a provincial bioenergy strategy, and the support of renewable fuels and hydrogen and fuel cell technologies[63]. Finally, the 2010 Clean Energy Act (CEA)[64] introduced British Columbia's 16 energy objectives, including the goals of generating 93% of electricity from "*clean or renewable resources and to build the infrastructure necessary to transmit that electricity*"[65], reducing GHG emissions in communities, introducing conservation measures, and encouraging economic development of First Nation and rural areas through the development of clean and renewable energy projects (BC Hydro, 2013f). Since the Energy Plan 2002 there have been eight power acquisition processes and a number of bilateral agreements for the creation of a renewable energy market, presented in Table 13, resulting in 87 electricity purchase agreements, of which 41 are in operation representing 5,300 GWh/year and 46 projects representing an additional 7,100 GWh/year are in the development stage (BC Hydro, 2013f) (BC Hydro, 2010).

The 2010 CEA also gave the ability to BC Hydro to implement feed-in-tariffs for specific renewable energy technologies[66] and provided for the creation of the First Nations Clean Energy Business Fund (FNCEBF). The FNCEBF promotes aboriginal community participation in the clean energy sector within their asserted traditional territories and treaty areas. The fund provides (a) revenue sharing agreements with First Nations where there are provincial water and/or land rentals from renewable energy projects undertaken in their territory, (b) capacity funding for the implementation of project feasibility studies and financial analysis of potential projects, community energy planning or engaging with project proponents, and (c) funding for financially viable renewable energy projects through an electricity purchase agreement.

Table 13: BC Hydro power acquisition processes since 2002

Acquisition process	**Launch date**
Green Power Generation Call	October 2002
F2006 Open Call for Power	December 2005
Standing Offer program (SOP)	April 2008
Bioenergy Phase 1 Call, Request For Proposals	February 2008
Clean Power Call	June 2008
Integrated Power Offer	Mid-2009
Community-Based Biomass Power Call Request for Expressions of Interest	April 2010
Bioenergy Phase 2 Call Request For Proposals	May 2010
Bilateral Agreements (e.g. Forest Kerr, Waneta Expansion)	Various

Source: BC Hydro (2013f, p. 4).

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[63] http://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/innovative-clean-energy-solutions/innovative-clean-energy-ice-fund

[64] http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/00_10022_01#section3

[65] http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/00_10022_01#section3

[66] http://www.pembina.org/reports/pembina-assessment-of-the-clean-energy-act-final.pdf

The development of clean and renewable energy projects by British Columbia's remote and grid connected aboriginal communities is supported by regional, provincial and federal programs, as well as programs for non-governmental organizations and programs specifically tailored to assist First Nation communities[67].

At the federal level, the Aboriginal and Northern Climate Change Program (ANCCP), the Aboriginal and Northern Community Action Program (ANCAP), the ecoENERGY for Aboriginal and Northern Communities Program (EANCP) and the Climate Change Adaptation Program (CCAP) covered both remote and on-grid aboriginal communities and provided funding for project's initial costs, community energy planning and capacity building (AANDC, 2014d). Aboriginal Affairs and Northern Development Canada (AANDC) and Aboriginal Business Canada (ABC) delivered the Aboriginal Business & Entrepreneurship Development (ABED) program that aimed to support both individuals and community related projects[68].

At the regional level, the Remote Community Implementation (RCI) program, which ran until March 2013, provided funding related to renewable energy[69] for both aboriginal and non-aboriginal remote communities. Finally, at the utility level, the Remote Community Electrification Program[70], established by BC Hydro in 2005, supported the electrification of the independent remote communities by BC Hydro. The program prioritized the inclusion of renewables in the communities' electricity mix and provided different financing options for community participation (BC Hydro, 2015a; BC Hydro, 2010)[71].

Renewable electricity generation in remote communities

The 23 remote aboriginal communities in British Columbia are powered by local diesel generators and hydroelectricity. There are approximately 41 MW of installed diesel capacity, which generated approximately 67,500 MWh in 2011, consumed 18,750,000 liters/year of diesel fuel, and contributed 54,000 tonnes $CO_{2,eq}$/year in $CO_{2,eq}$ emissions[72] (Table 1).

Hydroelectricity generation in remote aboriginal communities has a total capacity of 29.2 MW (Table 4) and nine of the 23 remote aboriginal communities are involved in renewable electricity generation. The electrical systems of Atlin, Bella Bella, Bella Coola, Kitasoo and Skidegate

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[67] See "Support Program Guide for First Nation & Civic Community Energy Efficiency & Clean Energy Projects, updated May 2015" in http://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/electricity-alternative-energy/community_energy_funding_and_support_guide_-_update.pdf.

[68] https://www.aadnc-aandc.gc.ca/eng/1100100032796/1100100032800

[69] http://www.fraserbasin.bc.ca/ccaq_rci.html.

[70] https://www.bchydro.com/energy-in-bc/our_system/remote_community_electrification.html

[71] The threshold for a community's consideration under BC Hydro's Remote Community Electrification (RCE) program is a community with at least ten residences (Inglis, 2012).

[72] Assuming an average efficiency rate of 3.6 kWh/litre for the diesel engines and an average of 0.00080 tonnes $CO_{2,eq}$/kWh, for direct carbon emissions (emissions resulting from diesel and natural gas combustion only). See HORCI (2012).

Landing are powered by a total of 26 MW of hydroelectric plants backed up by diesel generators. The remote communities of Atlin and Kitasoo completely displaced diesel through community owned small run-off-river plants and increased economic benefits through employment during construction and operations, subcontracting opportunities, and revenue generation to be used for further community business investment (Kirby, 2009). The Taku River Tlingit FN's Pine Creek (Atlin) project exports excess electricity (Morrin, 2016; Kirby, 2009), while the Kitasoo FN hydro plant powers the community owned seafood production facility that employs most of the community members (Sisco & Stewart, 2009). A solar-diesel minigrid was developed in Nemiah Valley in 2007 that displaces 26,000 liters of diesel annually (or 25% of the electricity generated) (Pelland, Turcotte, Colgate, & Swingler, 2012). The installation of a smart grid in Hartley Bay in 2008 led to the reconfiguration of the diesel engine dispatch strategies and displaces 77,000 litres of diesel fuel annually (NRCan, 2016). Finally, a hybrid hydro-hydrogen-storage system was installed in Bella Coola in 2010 to store excess energy generated, reduce diesel consumption by 200,000 litres, and cut down emissions by 600 tonnes $CO_{2,eq}$ annually (Fuel Cells Bulletin, 2010).

Future projects include a 3.4 MW extension of the Atlin project (Morin, 2015), and hydroelectricity plants for five communities (Masset, Lower Post, Hesquiant, Oweekeno, and Elhlateese). A 28 kW solar plant is planned for Kitasoo, while a wood based biomass powered plant is considered for the community of Anahim Lake (see Table 14).

Table 14: Renewable electricity projects in remote communities, British Columbia

	Community	Other	Hydro MW	Wind kW	Solar kW	Year	Source
Existing projects							
1	Anahim Lake						
2	Atlin		2.1			2009	Kirby (2009)
3	Bella Bella		15			1980	OPC (2009); BC Hydro(2007)
4	Bella Coola	Hydrogen	2			1992	Fuel Cells Bulletin (2010)
5	Fort Ware						See[73]
6	Hartley Bay	DRS				2008	NRCan (2016)
7	Refuge Cove						
8	Kitasoo		1.1			2006	GEA (2016)
9	Lower Post (Liard River)						
10	Masset (Old Masset)						
11	Nemiah Valley				28	2007	Pelland, et al.(2012)
12	Skidegate Landing		6			1992	Ah-You & Leng (1999)
13	Finlay River				Solar	2011	See[74]
14	Elhlateese						
15	Sim Creek- Dead Point						
16	Chenahkint						
17	Good Hope Lake		3			1997	Ah-You & Leng (1999)
18	Hopetown						
19	Sundayman's Meadow						
20	Gwayasdums						
21	Katit						
22	Hope Island						
23	Quaee						
	Total		**29.2**		**28**		
Proposed projects							
1	Atlin		3.4				Morin (2015)
2	Elhlateese		1				See[75]
3	Kitasoo				28	See	See[76]
4	Masset (Old Masset)						See[77]
5	Katit (Oweekeno)						See[78]
6	Annahim Lake						See[79]
7	Refuge Cove (Hesquiaht FN)						See[80]
8	Lower Post (Liard River)						See[81]
	Total		**4.4**		**28**		

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[73] https://www.ceaa-acee.gc.ca/050/documents_staticpost/63919/85328/Vol5_Appendix-Kwadacha.pdf

[74] Solar powered airfield.

[75] https://www.bchydro.com/content/dam/hydro/medialib/internet/documents/community/aboriginal/Elhlateese_bch_service.pdf.

[76] http://nationtalk.ca/story/bullfrog-power-and-b-c-s-kitasooxaixais-first-nation-partner-on-school-solar-project

[77] http://www.canadianenergylawblog.com/2013/03/12/bc-hydro-launches-the-haida-gwaii-request-for-expressions-of-interest-rfeoi/

[78] https://www.aadnc-aandc.gc.ca/eng/1334855478224/1334856305920

[79] http://www.bchydro.com/content/dam/hydro/medialib/internet/documents/planning_regulatory/acquiring_power/2010q3/20100706_cbb_sch_7.pdf

[80] http://www.firstpowercanada.ca/files/HesquiahtBrochure.pdf

[81] http://www.kaskadenacouncil.com/kaska-nations/dease-river-first-nation/44-kaska-dena/213-dease-river-development-corporation

Remote communities may also connect to the provincial grid and end their remote classification as they gain access to much larger supply systems. The cooperation of aboriginal communities, hydroelectricity developers and BC Hydro led to the development of the Northwest Transmission line in 2014, which provided electricity for eleven potential mining projects from newly constructed hydroelectricity projects in the area, connected the remote communities of Eddontenajon and Telegraph Creek, and led to the generation of socioeconomic benefits for the Tahltan First Nation (RWB, 2011; BC Hydro, 2016b). According to the Tahltan Central Council, the impact benefit agreement signed with Alta Gas with respect to the Forrest Kerr Hydroelectric Project[82] includes contracting, training and employment opportunities during construction and operation of the project, and financial benefits of $1.8 billion over the projected life of the project (RWB, 2011, p. 3).

Conclusion

Remote aboriginal communities in British Columbia are undergoing an energy transition from diesel generation to low-carbon renewable sources of electricity. The transition is being achieved through grid expansion and local hydroelectricity, solar and biomass projects. The remote communities of Eddontenajon and Telegraph Creek were recently connected to the provincial grid and benefit from large hydroelectricity generation within their territories. Nine remote communities are involved in large and small hydro projects within the non-integrated areas and generate and sell electricity to BC Hydro. One community plans to expand its hydroelectric plant and five remote communities are considering new community owned hydroelectricity generation. Two more communities are planning a solar photovoltaic project and a biomass based power plant, increasing the number of communities that will be using renewable resources for electricity generation to 15 out of the 23 remote aboriginal communities. The communities' transition from diesel-generated electricity to renewable resources is promoted through provincial targets and programs, and financially supported by IPP policies and electricity purchase agreements, in cooperation with BC Hydro, so that both communities within the non-integrated areas and independent communities can own renewable electricity assets, reduce their dependence on diesel and increase community revenues.

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[82] The Forest Kerr Project received a 60-year electricity purchase agreement from BC Hydro, see http://www.farris.com/images/uploads/BAN__ALH_-_2010_-_Tahtlan_Nation_Sign_Precedent.pdf.

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5. Recent Developments in Renewable Energy in Remote Aboriginal Communities, Ontario, Canada

Northern Ontario's 25 remote aboriginal communities are looking to introduce renewable electricity sources into their diesel-powered systems. This paper reviews community electrical systems, past renewable electricity projects, as well as available renewable resources, generation alternatives, and supportive targets and policies for community owned renewable electricity generation in Northern Ontario. Communities are transforming their electrical systems by introducing renewable electricity into their electrical systems and participating directly in the proposed transmission line that would connect 21 of the 25 communities to the provincial grid. Renewable projects are financially supported by federal and provincial programs and take the form of small-scale applications under "behind the meter" agreements, or community scale projects under power purchase agreements with HORCI, the utility that services 15 remote communities. Under the long-term option of the interconnection to the provincial grid, communities are expected to be supplied with low carbon, reliable and affordable electricity, and to be able to participate in the development of larger scale community owned renewable electricity generation assets. The model of increased aboriginal community decision making authority is used to increase their socioeconomic benefits and self-sufficiency and may serve as a valuable model for other community assets and service delivery in the future.

Introduction

Ontario's 25 remote aboriginal[83] communities are highly dependent on diesel for electricity generation and are looking to introduce renewable electricity sources into their electrical systems. Diesel-generated electricity is responsible for direct (combustion) and indirect (e.g. transport, including delivery by airplane in some cases) greenhouse gas emissions, fuel spills and fuel tank leakages during transportation and storage, as well as limitations to economic development due to imposed load restrictions (GY, November 2009). Although some of Ontario's early utility owned renewable electricity projects experienced performance issues (Weis & Ilinca, 2008), there is renewed interest in hydroelectricity, wind, solar and biomass cogeneration applications to address emission, cost, reliability and self-sufficiency issues. Community ownership or partnership is encouraged to build local capacity and to increase local socio-economic benefits. The next sections of this paper provide an overview of Ontario's remote aboriginal communities, the capacity and type of current electricity generation systems, electricity price and rate structures, future demand expectations, renewable resource availability, as well as policies, plans, and existing and future projects to support renewable electricity generation in the remote communities.

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[83] The term aboriginal community is used in this paper. It is recognized that some communities prefer the term indigenous community while others prefer aboriginal community and that both are used in the literature.

Population

There are 37 remote communities in Ontario, of which 25 are aboriginal communities with a population of approximately 15,000[84]. The communities are isolated and accessed only by winter roads and air, while the community of Fort Severn is additionally accessed by barge[85, 86] (OPA, 2014). There are only two communities with a population over 1,200 and 11 communities have a population between 300 and 800 (Table 1). Most of the communities are members of the Nishnawbe Aski Nation (NAN), a political territorial organization representing 49 northern Ontario First Nation communities with an estimated total membership (on and off reserve) of around 45,000 (NAN, 2014). The communities are also grouped by Tribal Council (Windigo First Nations Council, Wabun Tribal Council, Shibogama First Nations Council, Mushkegowuk Council, Matawa First Nations, Keewaytinook Okimakanak, and Independent First Nations Alliance) based on certain regional, ethnic or linguistic characteristics (NAN, 2014).

Electricity system

Northern Ontario's remote communities are serviced by Hydro One Remote Communities Inc. (HORCI), and Independent Power Authorities (IPAs) (Table 15 and Figure 7). HORCI, a Hydro One subsidiary company, distributes electricity to 21 remote communities in Northern Ontario, of which 15 are aboriginal communities (Hydro One, 2013; Service Ontario, 2013). HORCI services 3,332 customers and generates electricity from 18 generation stations using 55 generators, two hydroelectric stations (in Deer Lake and Sultan), and four wind demonstration projects (two in Kasabonika Lake FN, one in Fort Severn and one in Big Trout Lake) (Hydro One, 2012; COGUA, 2013; HORCI, 2012).

IPAs, established in the 1970s, are community owned and operated utilities servicing 11 northern Ontario remote aboriginal communities (Hydro One, 2012; OEB, 2008). IPAs currently operate 10 stations and 34 generators[87], and service 1,462 customers (1,287 residential, 52 general service and 113 governmental customers) (OEB, 2008). IPA communities' members mention certain benefits from running their own power systems, namely local control (which directly affects rate settings according to community needs), support for members facing poverty issues, opportunities for local job creation, and a source of community pride (NAN, 2014a; OEB, 2008).

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[84] 2011 National Household Survey. Released November 13, 2013.http://www12.statcan.gc.ca/nhs-enm/2011/ref/no13reserves/table-tableau.cfm?Lang=E&CSD_UID=3560085 (accessed January 31, 2014).

[85] http://www.mndm.gov.on.ca/en/northern-development/transportation-support/northern-ontario-winter-roads

[86] http://www.hydroone.com/OurCommitment/RemoteCommunities/Pages/home.aspx

[87] The communities of Keewaywin and Koocheching are served by the diesel plant in Keewaywin.

Table 15: Remote aboriginal communities, Ontario

Nr	Community name	Other name	Population 2011[88]	Diesel plant capacity kW[89]	Annual energy demand (2011) MWh[90]	Member-ship	Utility
1	Bearskin Lake FN		400	825	2,826	NAN	HORCI
2	Deer Lake FN		722	825	5,018		
3	Fort Severn FN		477	550	2,420		
4	Kasabonika Lake FN		890	825	4,114		
5	Kingfisher Lake FN		415	825	2,370		
6	Marten Falls	Ogoki Post	234	610	1,438		
7	Neskantaga FN	Lansdowne	240	705	1,795		
8	North Caribou Lake FN	Weagamow, Round Lake	810	825	4,480		
9	Sachigo Lake FN		420	550	2,847		
10	Sandy Lake FN		1,954	3,250	11,290		
11	Wapekeka FN	Angling Lake	371	550	2,535		
12	Webequie FN		670	825	2,737		
13	Whitesand FN	Armstrong	262	1,400	4,104	Other First Nation	
14	Kiashke Zaaging Anishinaabek FN	Gull Bay, Gull River	218	550	1,282		
15	Kitchenuhmaykoosib Inninuwug FN	Big Trout Lake	971	2,600	6,059		
16	Kee-Way-Win FN	Niska	337	350	2,364	NAN	IPAs
17	North Spirit Lake FN		275	420	2,085		
18	Wawakapewin FN	Long Dog	22	55	n/a		
19	Pikangikum FN		2,280	1,250	5,033		
20	Poplar Hill FN		495	600	2,189		
21	Muskrat Dam Lake FN		267	650	2,116		
22	Nibinamik FN	Summer Beaver	335	705	1,996		
23	Weenusk FN	Peawanuck, Winisk	234	400	2,249		
24	Wunnumin Lake FN		516	1,115	2,213		
25	Eabametoong FN	Fort Hope, Ebanetoong	1,085	1,565	3,400		
	Total		**14,900**	**22,825**	**78,960**		

Source: AANDC and NRCan (2011); (HORCI, 2012); OEB (2008).

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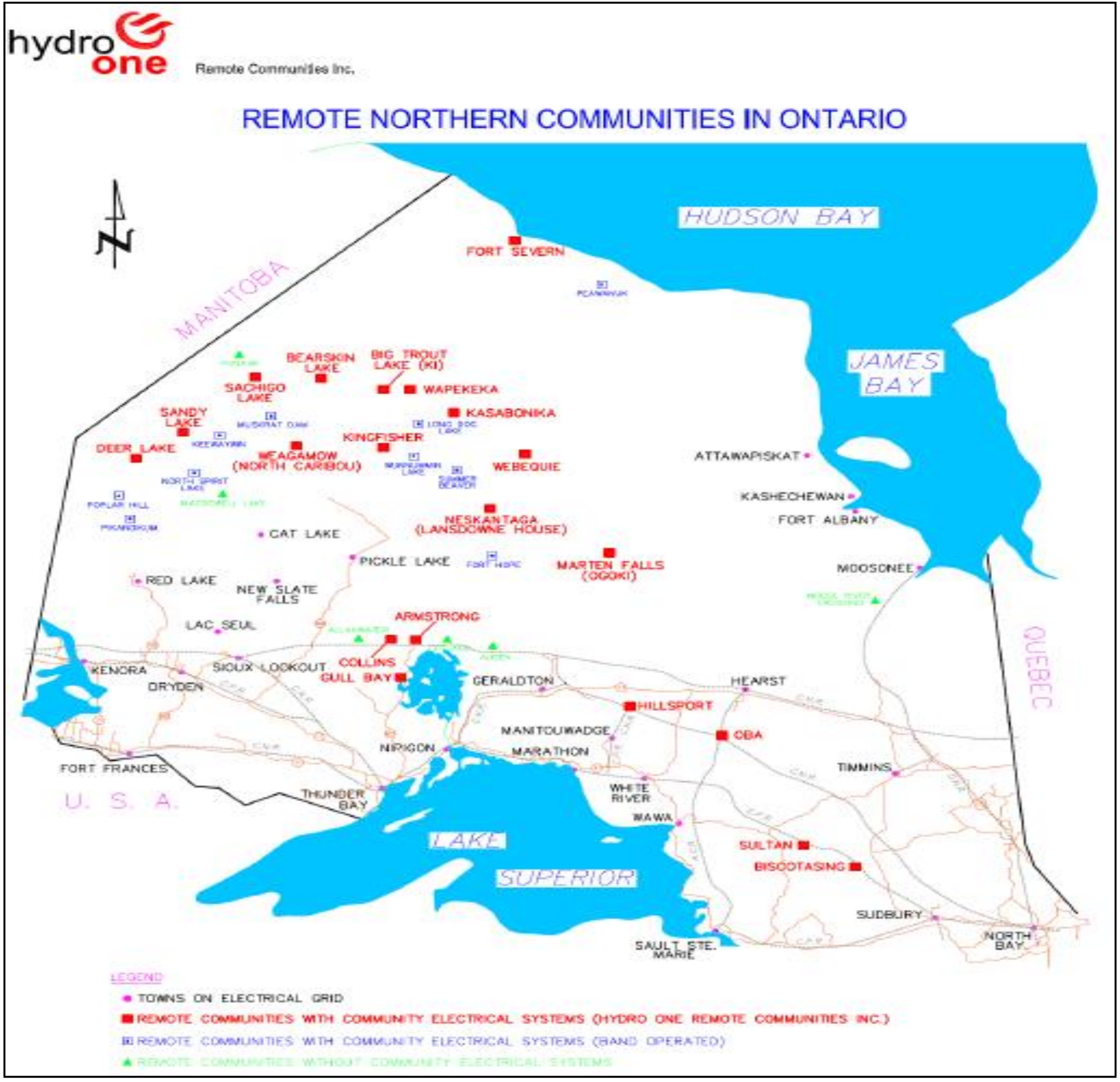
[88] See also: http://pse5-esd5.aadnc-aandc.gc.ca/fnp/Main/Search/FNPopulation.aspx?BAND_NUMBER=540&lang=eng.

[89] According to AANDC and NRCan (2011) and OEB (2008).

[90] According to AANDC and NRCan (2011), unless otherwise noticed.

Figure 7: Remote communities of Northern Ontario and their electricity providers



Source: HORCI (2012, p.7).

Electricity rates

Electricity rates in HORCI's communities are differentiated between the Standard-A and the non-Standard-A rate. Residential and commercial customers pay the Non-Standard-A subsidized rates, which are equivalent to customers who are connected to the main Ontario grid. Federal, provincial and community buildings pay the Standard-A rate, which equals the cost of electricity generation in the remote communities (0.92 $/kWh in 2013), and is applicable to all accounts paid directly or indirectly out of federal and/or provincial government funding. Electricity costs in IPAs are estimated to be approximately 2% higher than HORCI electricity costs, due to the lack of economies of scale in fuel purchasing and equipment maintenance (OPA, 2010; OEB, 2008).

HORCI's residential customers' rates are subsidized mainly by AANDC and Ontario's Rural or Remote Rate Protection (RRRP) funding mechanism. IPAs receive subsidies from AANDC to support residential consumers but rates are significantly higher for general service and governmental accounts (see Table 16), due to the lack of the RRRP subsidy, since IPAs are not licensed by the Ontario Energy Board (OEB, 2008).

Table 16: Electricity rates in Ontario's remote communities

Rates type	HORCI electricity rates for 2013	IPAs electricity rates
Non-Standard-A	Energy charge first 1000 kWh…......0.08 $/kWh Energy charge next 1500 kWh…......0.11 $/kWh Energy charge all additional kWh ....0.17 $/kWh	Residential…. 0.18 $/kWh -0.25 $/kWh Business……. 0.18 $/kWh-0.90 $/kWh Government…0.90 $/kWh-1.90 $/kWh
Non-Standard-A General Service	Energy charge first 1000 kWh…......0.08 $/kWh Energy charge next 1500 kWh…......0.11 $/kWh Energy charge all additional kWh ...0.17 $/kWh	
Standard-A Residential	Energy charge first 250 kWh…0.56-0.84 $/kWh Energy charge all additional….0.64-0.92 $/kWh	
Standard-A General service	|Energy charge………………...0.64-0.92 $/kWh	

Source: Hydro One (2012, p.748); OEB(2008).

Future power requirements and plans

Electricity generation in the HORCI operated communities increased at an average 2% annually from approximately 24,500,000 kWh in 1990 to approximately 59,000,000 kWh in 2011, due to population, dwelling and community building increases (HORCI, 2012). Similarly, electricity generation for the IPA communities increased an average of 2% annually between 2004 and 2011 (OEB, 2008). Future electricity load is forecast to increase due to community population growth and new resource development projects within Nishnawbe Aski Nation territory connected with the discovery of significant deposits of nickel and copper in the Ring of Fire area (Burkhardt, Rosenbluth, & Boan, n.d.; NRCan, September 2012). Under these resource development projections, OPA (2010) and OPA (2014) anticipate a load increase from 18 MW to 85 MW and generation needs from 84,000 MWh to 394,000 MWh between 2013 and 2053 (Table 17).

Table 17: Forecast peak demand for Ontario's 25 remote aboriginal communities

Description	Forecast Peak Load for the 25 remote communities				
	2013	2023	2033	2043	2053
Peak Load (MW)	18	27	38	57	85
Energy consumption (MWh)	84,000	122,000	179,500	266,000	394,000

Source: OPA (2010, p.23).

Additionally, Ontario's 25-year economic plan for Northern Ontario (Ministry of Infrastructure, 2011) identifies renewable energy generation as an emerging priority economic sector. Ontario's Long-Term Energy Plan targets 20,000 MW of renewable energy generation by 2025, or approximately half of the provincial installed capacity, with 10,700 MW being wind, solar and bioenergy, and 9,300 MW being hydroelectric power (OME, 2013). Provincial targets for electricity generation also call for increased participation by aboriginal communities in clean electricity generation based on local resources, to address pressing socioeconomic and environmental issues (OME, 2013; AECOM, 2012).

Availability of renewable energy sources in northern Ontario

A total of 1,500 MW of potential hydroelectricity capacity has been identified for Northern Ontario (SNC Lavalin, 2006), of which approximately 270 MW are in the proximity of 20 of the 25 remote aboriginal communities (NAN, 2014b; Hatch, 2013). Aboriginal communities have also examined the creation of a transmission line in cooperation with industrial proponents to connect communities and future mining projects with the provincial grid, and access 155 MW of hydroelectricity potential that are within 30 km from the proposed Wataynikaneyap transmission line (OWA, 2014b; WP, 2012). These resources can produce renewable electricity at a lower cost than the current diesel plants (Table 4)[91] (OWA, 2014b; Hatch, 2013; WP, 2012). Wind resources of 6-7 m/s are available at Deer Lake FN, Fort Severn FN and Weenusk FN, while the rest of communities have wind speeds of about 4 m/s (at 50 m height), which is considered low for the development of wind projects, under current capital and electricity generation costs (Weis & Ilinca, 2010; Maissan, 2006a; Weis & Ilinca, 2008; ARI, 2003). Finally, solar resources in northern Ontario's remote communities are considered sufficient, with average direct solar radiation in the range of 2.81-3.81 kWh/m^2.day (Table 18).

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[91] The Levelized Unit Electricity Cost (LUEC) presented does not include transmission costs.

Table 18: Available renewable energy resources in Ontario's remote aboriginal communities

Renewable resource	**Wind**		**Solar**	**Hydroelectricity [3]**				
Community name	**Average wind speed (m/sec) [1]**	**Average wind speed (m/sec) [2]**	**Monthly Aver. Normal Radiation (kWh/m^2. day) [2]**	**Size MW**	**Energy GWh/y**	**Capacity factor**	**Capital cost $million**	**LUEC[92] $/kWh**
Bearskin Lake FN	6	4.07	3.62	5.6	24.4	0.5	36	0.086
Deer Lake FN	5.5	6.11	2.81	5.4	23.8	0.5	32	0.08
Fort Severn FN	7	5.20	3.51	-	-	-	-	-
Kasabonika Lake FN	5	4.0	3.79	6.9	30.4	0.5	50	0.091
Kingfisher Lake FN	5	4.1	3.57	2.4	13.9	0.44	16	0.108
Marten Falls	-	4.15	3.68	4.3	19	0.5	24	0.078
Neskantaga FN	-	4.17	3.70	23	114	0.56	123	0.059
North Caribou Lake FN	5.5	4.12	3.61	-	-	-	-	-
Sachigo Lake FN	5.5	4.05	3.63	5.3	23.4	0.5	36	0.089
Sandy Lake FN	5	4.03	3.59	15.5	76.1	0.56	86	0.062
Wapekeka FN	6.5	4.10	3.61	6	26.3	0.5	54	0.109
Webequie FN	5.5	4.21	3.62	23	114	0.56	142	0.066
Whitesand FN (Armstrong)	-	4.23	3.60	-	-	-	-	-
Kiashke Zaaging Anishinaabek FN	6	4.42	3.81	2.2	9.5	0.5	11.5	0.083
Kitchenuhmaykoosib Inninuwug FN	6.5	4.10	3.61	5.5	24.1	0.5	36	0.089
Kee-Way-Win FN	5.5	4.05	3.59	24.1	119	0.56	140	0.063
North Spirit Lake FN	5.5	4.07	3.60	2.6	9.9	0.44	16	0.104
Wawakapewin FN	5	4.10	3.58	4.3	18.9	0.5	37	0.109
Pikangikum FN	-	4.03	3.61	8.2	36.1	0.5	44	0.071
Poplar Hill FN	-	4.00	3.67	11.8	57.8	0.56	65	0.064
Muskrat Dam Lake FN	-	4.07	3.59	38	185	0.56	196	0.056
Nibinamik FN	-	4.16	3.64	17	85.3	0.56	96	0.062
Weenusk FN	7	6.97	3.33	4.1	18	0.5	22.6	0.078
Wunnumin FN	5.5	4.14	3.64	13.5	66.5	0.56	83	0.068
Eabametoong FN	-	4.20	3.67	26	129	0.56	141	0.059

Source: [1] Weis & Ilinca (2010), [2] NASA surface meteorology and solar energy-available Tables[93]; [3] Hatch, (2013).

Renewable electricity policies and promotion

Support for renewable energy projects in Ontario was strengthened with Ontario's Green Energy and Green Economy Act (GEGEA) in 2009. The Act provided financial support for renewable energy projects and access to transmission and distribution for proponents (OME, 2012). The Act was criticized for its high incentives and their subsequent consequences on the global adjustment portion of electricity bill increases and, therefore, its effects on the provincial economy; positive effects of job generation were offset by losses due to the closing of conventional electricity facilities (Auditor General, 2011; Angevine, Murillo, & Pencheva, 2012; Winfield, 2013). Although renewables were blamed for the increases in electricity rates, the larger share of the extra costs in the global adjustment portion of electricity bills were the result of long term contracts with nuclear and gas plants (IESO, 2016). For example, between October 2011 and September 2012 the

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[92] LUEC= Levelized Unit Electricity Cost

[93] https://eosweb.larc.nasa.gov/cgi-bin/sse/grid.cgi?email=skip@larc.nasa.gov

contribution of nuclear and natural gas contracts to the global adjustment were 42% and 26% respectively versus a contribution of 17% by renewable contracts, including hydroelectric generation (Navigant Cons., 2014).

Within the Green Energy Act, aboriginal participation in on-grid renewable energy projects is possible through the Feed-In-Tariff (FIT) and microFIT programs or through the generation procurement for projects of 500 kW or more, which includes the Hydroelectric Standard Offer Program (HESOP), the Large Renewable Procurement (LRP), and the Combined Heat and Power Standard Offer Program (CHPSOP 2.0) (IESO, 2015). Aboriginal participation is encouraged by providing priority points (when an aboriginal community has greater than a 15% economic interest in the project), while financial assistance is provided through reduced security payments ($ 5/kW regardless of the renewable fuel type), and price adders for addressing increased development costs. Access to capital is facilitated through the Aboriginal Loan Guarantee Program (ALGP), administered by the Ontario Financing Authority (OFA), for transmission projects and wind, solar and hydroelectric generation projects (OFA, 2016). Ontario's Aboriginal Energy Partnerships Program (AEPP), which includes the Aboriginal Renewable Energy Fund (AREF), the Aboriginal Community Energy Plan (ACEP) and the Education and Capacity Building (ECB) Program, address both the financial barrier of high renewable energy initial capital costs and technical support for renewable project development (AEPP, 2016). Implementation of these programs led to aboriginal participation in approximately 240 projects with over 1,000 MW of clean electricity capacity connected to the main grid (OME, 2013).

Besides provincial support, remote communities in Ontario and other provinces and territories benefitted from federal programs that supported capital expenses for renewable electricity generation. Programs launched by the federal government between 2001 and 2016 included the Aboriginal and Northern Climate Change Program (ANCCP), the Aboriginal and Northern Community Action Program (ANCAP), the ecoENERGY for Aboriginal and Northern Communities Program (EANCP) and the Climate Change Adaptation Program (CCAP), and covered both remote and non-remote aboriginal communities. Additionally, the ANCAP provided funding for community energy planning and capacity building (AANDC, 2014a; AANDC, 2014b; AANDC, 2014d). Finally, at the community level, HORCI supported diesel displacement and emissions reductions through technological upgrades, fuel switching, demand side management, "behind the meter"[94] and "net metering"[95] arrangements, and the Renewable Energy INovation DiEsel Emission Reduction (REINDEER) program, which provided a local FIT tariff for the connection of renewable electricity projects in HORCI serviced communities (HORCI, 2012).

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[94] "On-site, behind the meter": electricity generation connected to consumer's side of the meter that provides power to offset electricity purchased form the utility. Since behind the meter electricity generation offsets retail kWh purchased, the benefit received is superior to a negotiated Power Purchase Agreement. See (Kildegaard & Myers-Kuykindall, 2006).

[95] "Net metering" allows customers that generate their own electricity from renewable electricity technologies to feed excess electricity generated back into Hydro One's distribution system for a credit towards your electricity costs. See: http://www.hydroone.com/Generators/Pages/NetMetering.aspx.

Renewable electricity generation in remote communities

The 25 remote aboriginal communities in Northern Ontario are powered by diesel generators and a limited number of renewable electricity projects. There are approximately 23 MW of installed diesel capacity, which generated approximately 79,000 MWh/year in 2011, consumed 22,000,000 liters/year of diesel fuel, and contributed 67,000 tonnes $CO_{2,eq}$/year in $CO_{2,eq}$ emissions[96] (Table 15).

Remote communities in Northern Ontario investigate both participation in renewable electricity generation and direct connection to the provincial grid as means to reduce their dependence on diesel and to improve their socioeconomic conditions using renewable resources. In the case of connection to the provincial grid, and based on the experience from the development of Five Nations Energy Inc.[97], communities anticipate increased electricity reliability, reduced environmental impacts and risks, and socioeconomic benefits, such as new residential sub-divisions, new schools and recreational facilities, and electrically heated homes (Five Nations Energy Inc., 2006). The 21 remote communities participating in the development of the Wataynikaneyap transmission line, expect similar benefits to be associated with the electrification of resource developments in the Ring of Fire area through aboriginally owned renewable electricity generation and transmission (OME, 2013; WP, 2013c; WP, 2012). The ownership model proposed for the transmission line involves using some of the revenue generated by the transmission line to purchase an increasing equity share in the project from the private partner until it becomes 100% First Nation owned (WP, 2017; NOB, 2016; WP, 2016).

> *"Our people's vision is to own, control and benefit from major infrastructure development in our homelands. Through this partnership, we are changing the landscape of how First Nations can do business into the future. Together we have reached a major milestone towards getting our communities off diesel generation, and improving the socio-economic situation for everyone's benefit."* Margaret Kenequanash, Chair of Wataynikaneyap Power (Ontario Newsroom 2015).

Remote aboriginal communities are also gaining direct experience with small renewable electricity projects. Four of the first wind demonstration projects were installed in the communities of Kasabonika Lake FN, Fort Severn FN, Weenusk FN and Big Trout Lake (Kitchenuhmaykoosib Inninuwug FN) in 1997, and one of the first hybrid hydroelectricity-diesel systems was installed in Deer Lake in 1998 by Hydro One (Ah-You & Leng, 1999). These projects are owned by HORCI and reduce diesel consumption and greenhouse gas emissions in the communities (HORCI, 2012). Deer Lake's 490 kW hydroelectricity plant achieves the highest emissions reductions displacing

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[96] Assuming an average efficiency rate of 3.6 kWh/litre for the diesel engines and an average of 0.00080 tonnes $CO_{2,eq}$/kWh, for direct carbon emissions (emissions resulting from diesel and natural gas combustion only). See HORCI (2012).

[97] Five Nations Energy Inc. is the first aboriginal transmission line established in 2001 that connected three northern Ontario remote communities. The communities of Fort Albany and Kashechewan were connected in 2001 and Attawapiskat in 2003 (Five Nations Energy Inc., 2006).

approximately 36% of community’s fuel consumption (HORCI, 2012) and the community examined further upgrades in cooperation with HORCI to improve performance and community benefits. Between 2013 and 2016 there have been 12 community owned solar photovoltaic projects with a total of 338 kW installed in energy intensive community facilities (such as the water and wastewater plant, schools and arenas) in 11 remote communities (Table 19). The projects were developed under a “behind the meter” agreement, and reduce facilities’ electricity consumption and, thus, electricity expenses paid from band council and government budgets, therefore allowing funds to be focused on other pressing community needs.

Eight more solar photovoltaic installations on community facilities are planned for Kingfisher Lake FN, Keewaywin FN, North Spirit FN, Wapekeka FN, Wunnumin Lake FN, Eabametoong FN, Sachigo Lake FN, and Webequie FN (Table 5). Furthermore, community scale solar installations under Power Purchase Agreements (PPA) with HORCI are being examined for Kasabonika Lake FN and Fort Severn (MNDM, 2015). Finally, the community of Whitesand FN in planning the generation of electricity and thermal power for community needs through a combined heat and power plant (CHP) plant (Neegan Burnside, 2013), increasing the number of Ontario’s remote communities involved in renewable electricity generation to seventeen.

Table 19: Renewable electricity projects in remote communities, Ontario

	Community	Hydro MW	Wind kW	Solar kW	Year	Source
Existing projects						
1	Bearskin Lake FN					
2	Deer Lake FN	0.49			1998	Ah-You & Leng (1999)
				152	2014	WN (2014); HORCI (2014)
				10	2014	
3	Fort Severn FN		n.d.		1980	Ah-You & Leng (1999)
				20	2015	See[98]
4	Kasabonika Lake FN		30		1997	Ah-You & Leng (1999)
			30		2013	
				10	2015	
5	Kingfisher FN			10	2013	See[99]
6	Marten Falls FN					
7	Neskantaga FN					
8	North Caribou Lake FN			18	2016	See[100]
9	Sachigo Lake FN					
10	Sandy Lake FN					
11	Wapekeka FN					
12	Webequie FN					
13	Whitesand FN					Neegan Burnside (2013)
14	Kiashe Zaaging Anishinabek FN					
15	Kitchenuhmaykoosib Inninuwug		50		1997	Ah-You & Leng (1999)
16	Keewaywin FN			20	2015	See[101]. See also[102]
17	North Spirit Lake FN			20	2015	See[103]
18	Wawakapewin FN			18	2013	Enermodal (2013)
19	Pikangikum FN					
20	Poplar Hill FN,			20	2015	See [104]
21	Muskrat Dam Lake FN			20	2015	
22	Nibinamik FN					
23	Weenusk FN		n.d.		1997	Ah-You & Leng (1999)
				20	2015	See[105]
24	Wunnumin Lake FN					
25	Eabametoong FN					
	Total	**0.49**	**110**	**338**		
Proposed projects						
1	Fort Severn FN			300		MNDM (2015)
2	Kasabonika Lake FN			250		
3	Kingfisher FN			n.d.		See[106] n.d.=no data
4	Wapekeka FN			n.d.		
5	Wunnumin Lake FN			n.d.		
6	Weenusk			n.d.		
7	Keewaywin			n.d.		
8	Eabametoong FN			n.d.		
9	Sachigo Lake FN			n.d.		
10	Webequie FN			n.d.		
	Total			**550**		

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[98] http://www.daigroup.ca/keewaywin.html

[99] http://www.shibogama.on.ca/?q=node/103

[100] https://www.youtube.com/watch?v=Ypz3Ucb5yas

[101] http://www.bullfrogpower.com/wp-content/uploads/2015/09/Day1-Part1-CanadianSolar_09-16-2015.pdf.;

[102] http://www.daigroup.ca/keewaywin.html

[103] http://www.bullfrogpower.com/wp-content/uploads/2015/09/Day1-Part1-CanadianSolar_09-16-2015.pdf.

[104] http://www.daigroup.ca/diesel-offset-solar-projects.html

[105] http://www.daigroup.ca/diesel-offset-solar-projects.html

[106] EANCP: https://www.aadnc-aandc.gc.ca/eng/1334855478224/1334856305920#sect1

Conclusion

Remote aboriginal communities in Ontario are transforming their electrical systems by introducing renewable electricity projects and participating in plans for the Wataynikaneyap transmission line that would connect most communities to the provincial grid. While early renewable electricity projects were developed by the local utility (HORCI), recent projects in 11 remote communities were owned by the communities and concentrated on solar photovoltaic applications connected to energy intensive community facilities. These projects operate under "behind the meter" agreements in cooperation with HORCI, displace diesel fuel, reduce greenhouse gas emissions, and reduce local electricity expenses. Projects were financially supported by federal and provincial programs and eight further solar plants based on this successful deployment model are proposed. These renewable energy projects provide some immediate benefits, but to date the scale is small. Deeper transitions from diesel to renewables are being studied. One long term option that is being planned is the creation of a transmission line that will connect 21 of the 25 remote communities to the provincial grid, supply communities with clean, reliable and affordable electricity, and provide the opportunity for the development of larger scale community owned renewable electricity generation assets. The model of community ownership of assets has been demonstrated with some of the small renewable energy generation projects and is being proposed for the transmission line with multiple First Nations collaborating as partners and co-owners. The model of increased aboriginal community decision making authority is used to increase their socioeconomic benefits and self-sufficiency and may serve as a valuable model for other community assets and service delivery in the future.

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6. Recent Developments in Renewable Energy in Remote Aboriginal Communities, Quebec, Canada

Northern Quebec's 14 remote aboriginal communities are dispersed through the land of Nunavik and are entirely reliant on diesel for their electricity needs. This paper reviews Nunavik communities' electrical systems, past renewable electricity projects, as well as available renewable resources for electricity generation. One renewable project was installed in Kuujjuaq in 1986, but despite the availability of wind and hydroelectricity resources, there were no subsequent renewable electricity installations in Nunavik. However, the need for alternatives to diesel powered electricity is recognized and communities are examining two options: the potential connection to the provincial grid to access reliable and clean electricity and the integration of renewable applications into local community diesel systems. The success of the Mesgi'g Ugju's'n wind farm partnership with Mi'gmaq communities in Gaspe, and the Raglan Mine community scale wind turbine, combined with falling storage prices and technological advancements in controller design, could provide an opportunity for the development of high penetration wind projects in locations with high wind regimes, including some of Nunavik's aboriginal communities.

Introduction

There are 44 remote communities in Quebec served by autonomous electricity grids based on hydroelectric and thermal power plants. Northern Quebec's 14 remote aboriginal[107] communities are dispersed through the land of Nunavik and are entirely reliant on diesel for their electricity needs (AANDC, 2012). Although one of the first wind-diesel projects in Canada was installed in Kuujjuaq in 1986 (Ah-You & Leng, 1999; Hydro Quebec, 2016a) to reduce both the need for diesel and greenhouse gas emissions, and despite the availability of wind and hydroelectricity resources in the proximity of communities, there were no subsequent renewable electricity installations in Nunavik. However, the need for alternatives to diesel powered electricity is recognized and communities are examining the potential connection to the provincial grid to access reliable and clean electricity to improve their socioeconomic conditions. The next sections provide an overview of the population served in Nunavik's 14 remote aboriginal communities, the capacity and type of current electricity generation systems, electricity price and rate structures, future demand expectations, renewable resource availability, as well as Quebec's policies, and Nunavik's plans to support community participation in renewable electricity generation.

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[107] The term aboriginal community is used in this paper. It is recognized that some communities prefer the term indigenous community while others prefer aboriginal community and that both are used in the literature.

Population

According to AANDC and NRCan (2011), in 2011 there were 44 remote communities in Quebec with a total population of approximately 35,000, of which 25 are non-aboriginal communities with a population of approximately 20,000, and 19 are aboriginal communities with a population of approximately 15,000. The community of Whapmagoostui FN is serviced by the diesel plant in Kuujjuaraapik and the community of Obedjiwan is part of the diesel grid of Haute Maurice. The community of La Romaine (home of the Innu Montagnais de Unamen Shipu) is part of the Basse-Côte-Nord grid and powered by a 5.7 MW diesel generator. There are no data available for the communities of Rapid Lake and Grand Lac Victoria. The remaining 14 communities are the Inuit communities in Nunavik (Akulivik, Aupaluk, Inukjuak, Ivujivik, Kangiqsualujjuaq, Kangiqsujuaq, Kangirsuk, Kuujjuaq, Kuujjuaraapik, Puvirnituq, Quaqtaq, Salluit, Tasiujaq, Umiujaq) with a population of approximately 12,090 people in 2011 (CRC-CAC, 2015; RRSSSN, 2011) (Table 20).

Table 20: Remote aboriginal communities, Nunavik

	Community Name	**Population 2011**[108]	**Diesel plant capacity in 2000 kW**[109]	**Annual electricity demand in 2000 MWh**[110]
1	Akulivik	615	850	2,016
2	Aupaluk	195	550	1,020
3	Inukjuak	1597	2,990	5,744
4	Ivujivik	370	1,050	1,264
5	Kangiqsualujjuaq	874	1,760	3,394
6	Kangiqsujuaq	696	1,520	2,342
7	Kangirsuk	549	1,050	2,349
8	Kuujjuaq	2375	3,935	11,973
9	Kuujjuaraapik	657	3,405	7,976
10	Puvirnituq	1692	2,870	6,077
11	Quaqtaq	376	1,045	1,448
12	Salluit	1347	2,000	4,419
13	Tasiujaq	303	850	1,493
14	Umiujaq	444	1,050	1,643
	Total	**12,090**	**24,325**	**53,158**

Source: AANDC (2012b); CRC-CAC (2015); Hydro Quebec (2002).

Electricity system

Hydro Quebec has an installed capacity of 36,912 MW from 87 generating stations and over 99% of its supply is hydroelectricity (Hydro Quebec, 2015). Hydro Quebec is the main distributor of electricity for the five autonomous grids in Quebec, namely the Îles-de-la-Madeleine, Haute-Mauricie, Schefferville, Basse-Côte-Nord (including Anticosti Island), and Nunavik, which serve

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[108] http://pse5-esd5.aadnc-aandc.gc.ca/fnp/Main/Search/FNPopulation.aspx?BAND_NUMBER=540&lang=eng

[109] Hydro Quebec (2002, p.11). The 2011 AANDC and NRCan (2011) study features the same generators capacity.

[110] Hydro Quebec (2002, p.11)

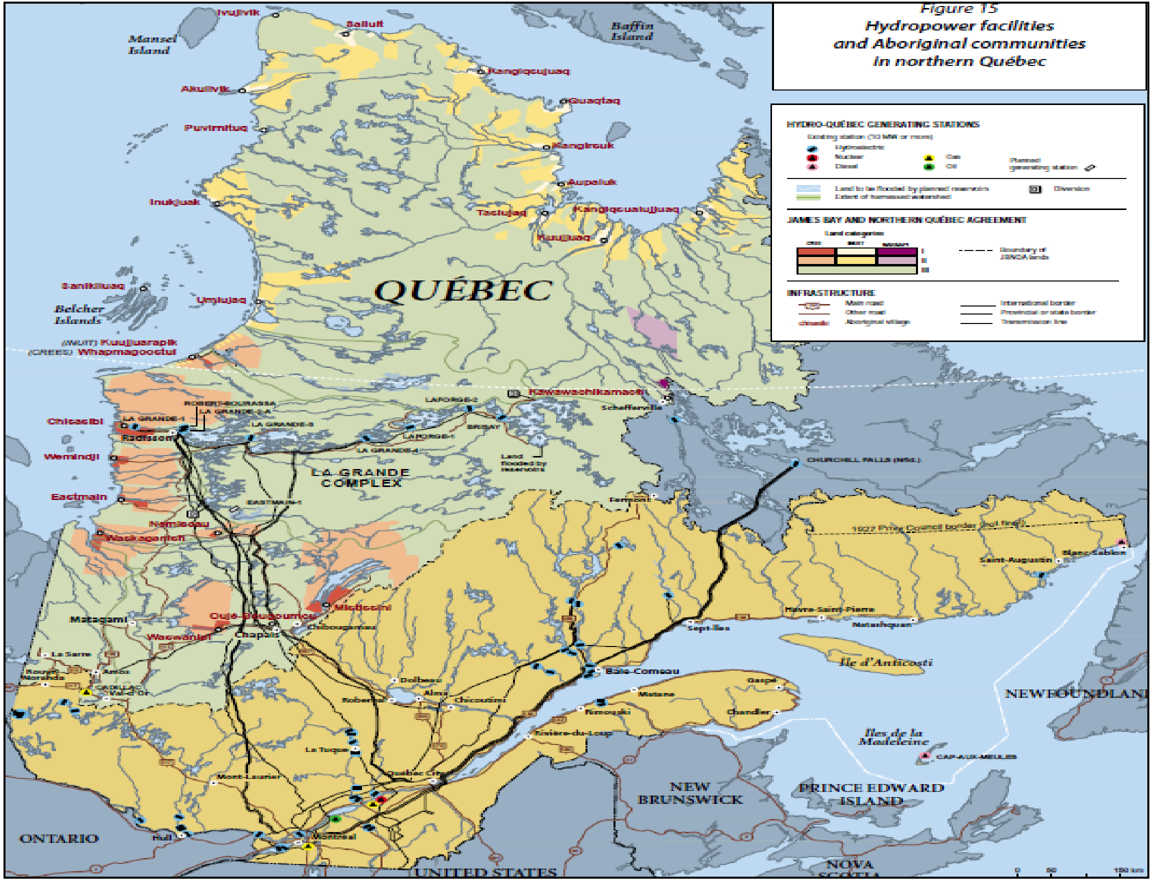
in total approximately 35,000 residents (Table 21 and Figure 8). Total power requirements for the isolated grids in 2012 were 93 MW, supplying 412 GWh to approximately 17,600 customers (Hydro Quebec, 2013). In 2015 there were 23 plants in off grid systems with a total capacity of 131 MW (Hydro Quebec, 2015).

Table 21: Quebec's autonomous electrical grids

	Autonomous electrical grids in Quebec	Power plant type
1	Îles-de-la-Madeleine	Light/heavy diesel
2	Haute-Mauricie	Diesel plants
3	Schefferville	Menihek hydroelectric station in Labrador and diesel plants
4	Basse-Côte-Nord (including Anticosti Island)	Lac-Robertson hydroelectric station and diesel back-up
5	Nunavik	Isolated diesel power plants

Source: Hydro Quebec (2013).

Figure 8: Hydro Quebec's electricity system and Nunavik's remote communities



Source: Hayeur (2001, p. 69).

The largest of Quebec's autonomous grids is the Îles-de-la-Madeleine grid, serving approximately 43% of all autonomous grid customers using two thermal power stations, one on Île-d'Entrée using light diesel, and one at Cap-aux-Meules using heavy fuel oil. In 2012 the power requirements were 42.1 MW and electricity consumption was 187 GWh, while the 2012 annual emissions exceeded 125,000 tonnes $CO_{2,\ eq}$ annually (Hydro Quebec, 2013). The small grid of Haute-Mauricie comprises of the communities of Opiticiwan and Clova, each supplied by a diesel-fired thermal power station, which generate a total of 10.8 GWh. The Schefferville grid is powered by the Menihek hydroelectricity plant in Labrador, and serves the communities of Schefferville, Matimékush-Lac-John and Kawawachikamach, which consume approximately 43.4 GWh. The Basse-Côte-Nord grid is powered by the Lac-Robertson hydroelectric generating station with an installed capacity of 33.7 MW that provides approximately 80% of the grid, and two thermal power stations, 2.8 and 5.7 MW, installed in the Port-Menier and La Romaine communities respectively. The grid serves communities from La Romaine to Blanc-Sablon and the community of Port-Menier on Anticosti Island and its power requirements were 86.4 GWh in 2012 (Hydro Quebec, 2013). Nunavik's isolated diesel communities are described in the next sections.

Electricity rates

Electricity rates in Quebec are currently the lowest in Canada, due to Quebec's vast hydroelectricity resources (Hydro Quebec, 2015). Although the cost of electricity generation in Nunavik's communities is significant and ranges between 65 c/kWh and 132.4 c/kWh (see Table 22) (GQ, 2014; Cherniak, Dufresne, Keyte, Mallett, & Scott, 2015), electricity rates in remote communities are heavily subsidized to as low as 5.71 c/kWh for the first 900 kWh/month and 37.62 c/kWh for any additional kWh (Hydro Quebec, 2016b).

Table 22: Electricity cost in Nunavik's remote aboriginal communities

	Community Name	**Total electricity cost, 2013 (c/kWh)**
1	Akulivik	109.7
2	Aupaluk	119.4
3	Inukjuak	77.7
4	Ivujivik	132.4
5	Kangiqsualujjuaq	78.8
6	Kangiqsujuaq	85.2
7	Kangirsuk	78.9
8	Kuujjuaq	86
9	Kuujjuaraapik	70.4
10	Puvirnituq	66.2
11	Quaqtaq	95.4
12	Salluit	65
13	Tasiujaq	90.6
14	Umiujaq	95.9

Source: GQ (2014, p. 16).

Future power requirements and resources availability in Nunavik communities

Electricity generation in the Nunavik communities increased at an average 3.6% annually from 53,158 MWh in 2000 (Hydro Quebec, 2002) to approximately 82,400 MWh in 2012 (Hydro Quebec, 2013) and 85,500 MWh in 2013 (GQ, 2014). Hydro Quebec estimates future electricity demand increase for the fourteen Nunavik communities between 2% and 4% annually for the period 2005 to 2024, due to anticipated population, dwellings, and community building increases (Hydro Quebec, 2003). Local governments estimate that by 2025 the annual peak demand will reach 110 MW (NRBHSS, 2014; NRBHSS, 2013).

The need to address future community load increases, provision of clean electricity, and economic development is examined in "Plan Nunavik" (KRG, 2012). The plan proposes the interconnection to Hydro Quebec's provincial electricity grid as the main alternative for communities to reduce their dependence on diesel for both electricity and heating, and to improve their socioeconomic conditions through low cost, locally sourced, clean hydroelectricity. The transmission line to connect all 14 communities and the Raglan Mine is estimated to cost between $900 to $1,600 million with a construction period of 6 to 14 years (KRG, 2012; George, 2011). Communities plan to use local resources for community owned, hydroelectricity generation and transmission facilities that will cover regional demand including the extensions of the Raglan and Nunavik Nickel mining sites, and attract future mining exploration projects in the area (GQ, 2006; KRG, 2012; NRBHSS, 2014). Aboriginal governments identify Nunavik's hydroelectricity resources as able to support from 6,300 to 7,200 MW of renewable electricity generation, and the existence of significant tidal power potential in the Ungava Bay. However, there is a lack of studies on the economic, technical and environmental potential of these resources (MC-KRG-GQ, n.d.; George, 2011).

Renewable energy policies and promotion in Nunavik communities

Quebec's 2006-2012 Action Plan included an energy strategy focused on the provision of low cost electricity to support industrial development and electricity exports through the addition of 4,500 MW of hydroelectricity and the development of 4,000 MW of wind potential by 2015 (GQ, 2008). Communities (including aboriginal communities) are encouraged to participate in privately owned generating stations under 50 MW to promote social and economic development (GQ, 2006b; GQ, 2015). To support the creation of aboriginal renewable generation assets and to help meet community socioeconomic needs, Hydro Quebec made available 250 MW of renewable electricity procurement and prioritized aboriginal consultation and the development of energy projects in cooperation with communities (GQ, 2016). The largest of these grids connected projects is the 150 MW Mesgi'g Ugju's'n (MU) Wind Farm, a 50-50 partnership between the three Mi'gmaq communities of Gesgapegiag, Gespeg and Listuguj and the independent renewable power producer, Innergex (MU, 2016a). The benefits to the Mi'gmaq communities include equal membership on the board of directors, direct employment (110 out of the 300 construction workers and four of the eight operational workers were from the communities), an indexed social development fund of $75,000/year and estimated profits of $200 million over the 20-year contract period (MU, 2016b).

Table 23: Renewable energy projects in remote Nunavik communities

	Community	Hydro MW	Wind kW	Solar kW	Year	Source
Existing projects						
1	Akulivik					
2	Aupaluk					
3	Inukjuak					
4	Ivujivik					
5	Kangiqsualujjuaq					
6	Kangiqsujuaq					
7	Kangirsuk					
8	Kuujjuaq		65		1986	INAC(2004); Ah-You & Leng (1999). See also[111].
9	Kuujjuaraapik					
10	Puvirnituq					
11	Quaqtaq					
12	Salluit					
13	Tasiujaq					
14	Umiujaq					
	Total		**65**			

The 14 northern communities of Nunavik are powered by isolated diesel generators with a total capacity of 24.325 MW, generated approximately 82,400 MWh/year in 2012, consumed approximately 23,000,000 litres/year of diesel fuel, and contributed 65,000 tonnes/year CO$_{2,eq}$

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[111] http://www.hydroquebec.com/learning/eolienne/historique-eolien-hydro-quebec.html

emissions[112] (Table 20) (KRG, 2012; Hydro Quebec, 2013). Although renewable electricity projects for Canadian remote communities were initiated in Quebec, starting with the first 230 kW wind turbine installed in Îles-de-la-Madeleine in 1976 (Adamek & Tudor, 2009), there has been only one 65 kW wind turbine installed in the Nunavik community of Kuujjuaq in 1986[113] (Table 23).

The potential for wind-diesel projects in Nunavik's communities was examined by the Institut de Recherche d' Hydro-Québec (IREQ) (Krohn, 2005) and through the installation of wind measurement equipment in Inukjuak, Whapmagoostui, Akulivik, and Kangiqsualujjuaq by Hydro Quebec (Hydro Quebec, 2003; Hydro Quebec, 2007). Studies indicate wind resources higher than 7 m/s for all 14 Nunavik communities (Weis & Ilinca, 2008; Weis & Ilinca, 2010; Krohn, 2005). Simulation studies, performed for all communities, indicated that wind-diesel projects, under certain assumptions, could be economically viable for the communities of Inukjuak, Kuujjuaraapik, Kangiqsualujjuaq, Kangirsuk, Kangiqsujuaq, Umiujaq, and Akulivik, with the greatest potential identified in the community of Inukjuak (Hydro Quebec, 2007). An 8 MW hydroelectricity project was also examined for Inukjuak (George, 2011; Atagotaluuk, 2016).

Despite the considerable number of wind studies for the 14 Nunavik communities conducted between 2003 and 2008 (see Maissan, 2006a; Krohn, 2005) and past announcement for governmental support for the development of wind-diesel projects in the autonomous grids (including Nunavik) to reduce the use of costly and greenhouse gas emissions intensive diesel generation (GQ, 2006) there has been no renewable electricity applications installed in Nunavik's aboriginal communities. High deployment costs, communities' vested interests in diesel generation, equipment availability, and resistance to change from Hydro Quebec are the main reasons identified as barriers to wind deployment in Quebec's remote communities (Weis, 2014; GQ, 2014). Recent Hydro Quebec announcements state that wind and hydroelectricity projects are not financially viable under current economic conditions (Rogers, 2014).

However, the installation of a wind-hydrogen-smart grid system at Nunavik's Glencore's Raglan Mine in 2016 signals the potential of community scale wind applications in remote locations. The project used an Arctic grade wind turbine, hydrogen storage technologies, an advanced controller, and low environmental impact foundations at a Canadian Arctic mine location, and displaced 3.4 million liters of diesel and 10,200 tons of greenhouse gases within its first 18 months of operation, or 2.2 million liters of diesel per year (Tugliq Energy, n.d.; NRCan, 2017). The project's successful deployment demonstrates the potential for wind power to displace diesel consumption in remote communities (NRCan, 2017).

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[112] Assuming an average efficiency rate of 3.6 kWh/litre for the diesel engines and an average of 0.00080 ton $CO_{2,eq}$ for direct carbon emissions (emissions resulting from diesel and natural gas combustion only). See HORCI (2012).

[113] The Kuujjuaq wind turbine is currently not operational and used for educational purposes at the Cégep de la Gaspésie et des Îles. See footnote 4.

Conclusion

Remote communities in Nunavik are entirely dependent on diesel fuel for electricity, heating and transportation. Communities are examining the introduction of wind power into communities' local diesel generation operations and potential connections to the provincial grid as alternatives to reduce diesel dependency and to improve socioeconomic conditions. The success of the Mesgi'g Ugju's'n wind farm partnership with Mi'gmaq communities in Gaspe may provide valuable lessons for projects in the north. However, despite available wind resources and Hydro Quebec's experience in wind-diesel hybrid systems, wind deployment is currently considered not financially viable for the Nunavik communities. Recent successful deployment of a community scale wind turbine in Raglan Mine, combined with falling storage prices and technological advancements in controller design, could enhance the feasibility of high penetration wind projects in locations with high wind regimes, including some of Nunavik's aboriginal communities. An alternative pathway to clean, reliable electricity is the connection to the provincial grid that could also provide multiple benefits to the communities through local hydroelectricity or wind generation and transmission to existing and future mining development in Nunavik.

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7. Recent Developments in Renewable Energy in Remote Aboriginal Communities, Newfoundland and Labrador, Canada

An energy transition is being proposed for Labrador's remote aboriginal communities that are currently serviced by diesel fueled electricity generators. The Nunatsiavut Regional Government (NRG) is concerned about electricity price increases, power outages and shortages that affect economic development in communities. The high cost of connecting the communities to the Labrador or Newfoundland interconnected grids restricts access to clean and affordable hydroelectricity provided by large projects in southwestern Labrador. Instead, the NRG proposed local renewable sources of electricity as the means to improve community wellbeing. This paper reviews the electrical systems, past renewable electricity projects, as well as available renewable resources for electricity generation in Labrador's isolated communities. A transition from diesel-generated electricity to less carbon intensive generation is promoted through utility scale run-of-river projects in five of the 16 communities and wind and solar pilot projects to be developed by the Nunatsiavut Regional Government. A net metering policy encourages community participation in small-scale wind and solar applications to reduce their greenhouse gas emissions, high electricity expenses and increase development capacity.

Introduction

The remote aboriginal[114] communities in Labrador are serviced by diesel fueled electricity generator systems operated by Newfoundland and Labrador Hydro, with the exception of one community that independently runs its diesel electric system. Despite the substantial operating costs of these diesel systems, the cost of connecting the communities to the Labrador or Newfoundland interconnected grids is prohibitively high, therefore limiting access to the renewable electricity provided by large hydroelectric projects in southwestern Labrador (GNFL, 2007). Recently, the Government of Newfoundland and Labrador, in cooperation with Newfoundland and Labrador Hydro and Nunatsiavut's Regional Government, have begun to examine the potential of integrating hydroelectricity, wind and solar into communities' systems to reduce diesel consumption and greenhouse gas emissions (GNFL, 2015a). The next sections provide an overview of the population served in Labrador's 16 remote aboriginal communities, the capacity and type of current electricity generation systems, electricity price and rate structures, future demand expectations, renewable resource availability, as well as provincial plans to support communities' participation in renewable electricity generation.

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[114] The term aboriginal community is used in this paper. It is recognized that some communities prefer the term indigenous community while others prefer aboriginal community and that both are used in the literature.

Figure 9: The 16 remote aboriginal communities in Newfoundland and Labrador

Source: Nalcor Energy (2014, p.64), modified.

Population

There are 28 remote communities in Newfoundland and Labrador with a total population of 9,500 in 2011. Eleven remote communities are non-aboriginal communities, while 16 out of the 17 communities in Labrador are aboriginal communities with a population of approximately 5,700 (AANDC and NRCan, 2011; Statistics Canada, 2012) (Figure 9).

Fifteen of the aboriginal remote communities are serviced by Newfoundland and Labrador Hydro (NLH) and one community, the Natuashish-Mushuau Innu First Nation, runs its own electricity system as an Independent Power Authority (IPA). Four communities (Mud Lake, Norman Bay, Paradise River, and Williams Harbour) have a population below 100. The challenges faced by these small communities are illustrated by Williams Harbour where the residents voted to be relocated to other areas[115], while Black Tickle[116] is experiencing a steep decline in community services (Table 24). Eight communities have a population between 100 and 500, two communities have

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[115] http://www.cbc.ca/news/canada/newfoundland-labrador/williams-harbour-votes-96-in-favour-of-relocation-only-1-no-vote-1.3213147

[116] http://www.cbc.ca/news/canada/newfoundland-labrador/why-black-tickle-s-residents-are-so-leery-about-moving-1.3207617

approximately 550 people, and two communities, the Natuashish-Mushuau Innu First Nation and Nain, have population of approximately 1,000.

Table 24: Remote Aboriginal communities, Newfoundland and Labrador

Nr	Community name	Population 2011	Diesel plant capacity (2011)[117] kW	Annual electricity demand (2011) MWh[118]	Serviced by
1	Black Tickle	138[119]	765	1,080	NLH Hydro
2	Cartwright	516	1,485	3,933	
3	Charlottetown	308	620	1,496	
4	Hopedale	556	1,840	2,673	
5	Makkovik	361	1,300	2,422	
6	Mary’s Harbour	383	1,300	3,110	
7	Mud Lake	60 Ɨ	180	221	
8	Natuashish-Mushuau Innu FN	931	695	No data	IPA
9	Nain	1188	2,920	5,142	NLH Hydro
10	Norman Bay	45[120]	No data	No data	
11	Paradise River	14[121]	145	186	
12	Port Hope Simpson	441	1,390	2,186	
13	Postville	206	735	1,293	
14	Rigolet	306	870	2,064	
15	St. Lewis	207	695	1,923	
16	Williams Harbour	59 Ɨ	325	419	
	TOTAL	**5,719**	**15,625**	**28,148**	

Ɨ Population according to AANDC and NRCan (2011).

Source: Statistics Canada (2012); NLH (2016).

Electricity system

Electricity generation and distribution in Newfoundland and Labrador is provided through Newfoundland Power and Newfoundland and Labrador Hydro (NLH), a subsidiary of the Crown Corporation Nalcor Energy since 2007 (GNFL, 2016). NLH was established as Newfoundland Power Commission (NPC) in 1954 with the goal to extend electrification within the province to rural areas. NPC provided electricity, built transmission lines, and installed diesel plants between 1958 and 1964, and in 1975 was incorporated into Newfoundland and Labrador Hydro (NLH) (Baker , 1990). Currently, NLH provides electricity to approximately 290,000 customers through hydroelectric, residual oil-fired, wind, biomass and diesel generation plants. Customers are

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[117] According to AANDC and NRCan (2011), unless otherwise noticed.

[118] According to AANDC and NRCan (2011), unless otherwise noticed.

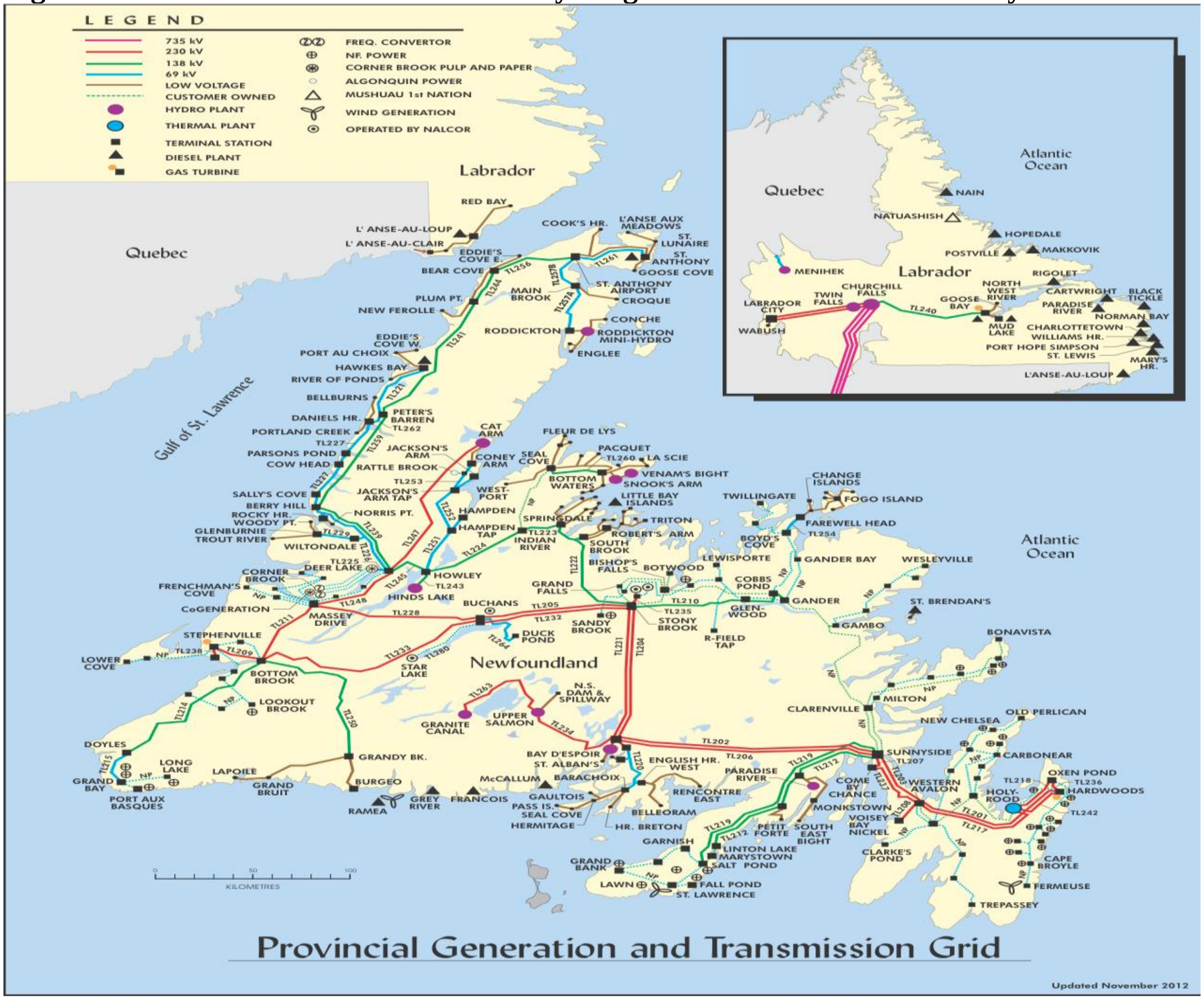
[119] http://www.cbc.ca/news/canada/newfoundland-labrador/why-black-tickle-s-residents-are-so-leery-about-moving-1.3207617

[120] http://www.southernlabrador.ca/home/norman_bay.htm

[121] http://www.southernlabrador.ca/home/paradise_river.htm

connected to the Island Interconnected System (IIS), the Labrador Interconnected System (LIS), and the various isolated diesel systems (PA-Hatch , 2015). NLH operates 25 thermal plants province-wide, with a total capacity of 35.8 MW (PA-Hatch , 2015, p. 39; NLH, 2016). 16 diesel plants are in Labrador's remote communities and serve approximately 3,300 customers, consuming approximately 15 million litres of diesel annually (NLH, 2009; Nalcor Energy, 2014b) (Figure 10).

Figure 10: Newfoundland and Labrador Hydro generation and transmission system



Source: PA-Hatch (2015, p.33).

Electricity rates

Each of the five electricity systems in Newfoundland and Labrador (Island Interconnected, Labrador Interconnected, Island Isolated, Labrador Isolated, and the L'Anse de Loup system) has different electricity rates based on the different costs of electricity generation. Residential customers on the isolated diesel systems receive the same rates as the customers in the interconnected systems. The 2015 electricity rates in diesel serviced areas for residential consumers were 10.573 c/kWh for the first block of kWh per month and 11.933 c/kWh for the second block (see Table 25). All kWh in excess of 1,000 kWh monthly were charged with 16.261 c/kWh. However, the application of the Northern Strategic Plan (NSP) subsidy in residential consumers decreases the rates to as low as 3.38 c/kWh for the first block of electricity consumption (Cherniak, Dufresne, Keyte, Mallett, & Scott, 2015). The general service rates were 16.82 c/kWh and rates for governmental residential and governmental general service accounts were 83.567 c/kWh and 75.468 c/kWh respectively (NLH, 2015).

Table 25: Residential rates for Newfoundland and Labrador communities in diesel serviced areas

	Rates c/kWh	**Electricity consumption blocks, in kWh**											
		Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
First Block	10.573	1000	1000	900	900	800	800	700	700	700	800	900	1000
Second Block	11.933	0	0	100	100	200	200	300	300	300	200	100	0

Source: NLH (2015, p. 47).

The cost for electricity generation in the isolated diesel powered communities is considerably higher, and approximately 75% of the cost is subsidized through the contributions of other ratepayers in the interconnected systems (GNFL, 2007; PA-Hatch , 2015). The provincial government provides additional subsidies (approximately $ 1.6 million for 2012) through the Northern Strategic Plan (NSP), established in 2007, for reducing electricity costs for residential customers in Labrador’s and Labrador Straits’ coastal aboriginal and non-aboriginal communities (NFL-AA, n.d.; Nalcor Energy, 2012).

Future power requirements and plans

Electricity demand in the Island Interconnected system is projected to increase at an annual rate of 0.9% for the 2015 to 2032 period with the system peak increasing by approximately 0.8% annually for the same period (PA-Hatch , 2015). The annual electricity demand for the Labrador Interconnected system has decreased since 2009 due to reduced demand from mining and energy industries but is expected to recover to its previous levels by 2022. With the anticipated connection of the Labrador and Island grids, the new interconnected system is expected to have modest annual energy and peak growth requirements from 2017 to 2022 (PA-Hatch , 2015). Finally, electricity requirements in the isolated diesel systems have increased since 2007 at an annual rate of 3.4%, due to new connections and an increase in residential consumption (PA-Hatch , 2015).

The future requirements of Newfoundland and Labrador's electricity system are related to increased exploration and development of mining and energy resources, and development of clean renewable electricity for domestic use and exports (Nalcor Energy, 2014a). Government plans also include targets for greenhouse emission reductions through the introduction of renewables, and the promotion of energy efficiency through the Residential Energy Efficiency Program (REEP), promoted by Newfoundland and Labrador Housing Corporation (NFL, 2011; GNFL, 2015a). One primary goal is the elimination of approximately 1.3 million tonnes of carbon emissions from the Holyrood thermal plant through the building of the Lower Churchill project and the development of the Labrador-Island Transmission link. Government targets in relation to Labrador's remote aboriginal communities include the participation of aboriginal groups in natural resources projects, cooperation in areas where wind developments are subject to aboriginal treaties or land claims, and collaboration with aboriginal governments for the displacement of diesel fuel in community electricity systems (NE, 2014; GNFL, 2015a).

Availability of renewable energy sources in NFL's remote communities

Renewable supply options for Newfoundland and Labrador's future electricity demand include the development of the provinces hydroelectricity and wind resources. The Lower Churchill project, consisting of the 825 MW Muskrat Falls and the 2,250 MW Gull Island site developed downstream of the 5,428 MW Churchill Falls project, and the 1,100 km Labrador-Island link transmission are the main providers of clean, affordable hydroelectricity for the coverage of provinces' residential, industrial and interprovincial trade needs (GNFL, 2015a). Additionally, Nalcor is examining the potential for the integration of large-scale wind projects, and currently has two Power Purchase Agreements for two 27 MW wind projects on Newfoundland to reduce demand (and greenhouse gas emissions) from the Holyrood thermal plant (GNFL, 2015a).

Renewable energy policies and promotion in NFL remote communities

The 16 aboriginal communities in Labrador are powered by diesel generators operated by NLH, except for the community of Natuashish-Mushuau Innu First Nation, which runs its own diesel powered electricity system. There are approximately 16 MW of installed diesel capacity, which generated approximately 28,000 MWh in 2011, consumed approximately 7,800,000 litres/year of diesel fuel, and contributed 22,400 tonnes $CO_{2,eq}$/year in carbon emissions[122] (Table 1). Only the community of Mary's Harbour was involved in renewable electricity generation through a 175 kW hydroelectric project developed in 1987 (Table 26), but which has been inactive for the last seven years (Roberts, 2016).

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[122] Based on the assumption of an average efficiency of 3.6 kWh/lit diesel and emissions of 2.88 kg CO_2/lit diesel.

Table 26: Renewable electricity projects, Newfoundland and Labrador

	Community	Hydro MW	Wind kW	Solar kW	Year	Source
Existing projects						
1	Black Tickle					
2	Cartwright					
3	Charlottetown					
4	Hopedale					
5	Makkovik					
6	Mary's Harbour	0.175			1987	Ah-You & Leng (1999)
7	Mud Lake					
8	Natuashish-Mushuau Innu FN					
9	Nain					
10	Norman Bay					
11	Paradise River					
12	Port Hope Simpson					
13	Postville					
14	Rigolet					
15	St. Lewis					
16	Williams Harbour					
	Total	**0.175**				

The main priority of the Government of Newfoundland and Labrador remains the development of large-scale hydroelectricity and wind projects in cooperation with Nalcor Energy (GNFL, 2015a).

Support for small-scale wind, solar power and micro-hydro as alternative technologies able to contribute to the province's electricity supply was initiated with the "2007 Energy Plan" and a "net metering" policy to support small renewable generation developers (GNFL, 2007). Government support was provided for the introduction of renewable electricity into remote community systems by financing the development of the Ramea wind-diesel project (GNFL, 2015a). The Ramea[123] project was initiated as a medium penetration system with the connection of three 65 kW wind turbines to the community's grid in 2004 (Oprisan, 2007). To increase system efficiency three 100 kW wind turbines and a hydrogen energy storage system were added in 2010. The project has produced approximately 615,000 kWh of renewable electricity since 2010 and is used as a model for wind-hydrogen-diesel applications in the environment of Canadian remote communities (GNFL, 2015a).

Additionally, since 2008 the provincial government has invested more than $3.5 million for the installation of equipment and data analysis of communities' wind and hydroelectric potential (GNFL, 2015a). The potential for integration of solar, wind and small-scale hydroelectric facilities into communities' diesel systems was assessed through an NFL Hydro study of Labrador's larger communities (with annual load of more than 200 kW and generation in excess of 3,000 MWh) conducted in 2009 (NLH, 2009). According to the study, the communities of Hopedale, Makkovik,

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[123] Ramea is a non-aboriginal remote community located in Newfoundland.

Charlottetown, Port Hope Simpson, and Mary’s Harbour have sites for hydroelectricity generation that could lead to electricity costs lower than the current diesel generation cost, and interconnection points to connect hydroelectric facilities capable of powering two or three of the communities (NLH, 2009). The potential for wind power applications is limited for Cartwright, Charlottetown, Mary's Harbour, and Port Hope Simpson, while savings between 30-43% in diesel consumption can be realized for the communities of Hopedale, Makkovik, and Nain due to strong wind resources. The study also identifies a low solar potential for all communities due to limited insolation during the summer months. Additional support for small-scale renewable deployment is examined through a “net metering” policy that will assist residential and general service customers to offset their own electricity usage through individual renewable generation systems that will not exceed a maximum limit of 100 kW, while additional limits on total generation apply in the isolated diesel systems (GNFL, 2015b).

Finally, the Nunatsiavut Regional Government (NRG), expressing its concerns over electricity price increases and power outages and shortages that affect economic development in communities (Cherniak, Dufresne, Keyte, Mallett, & Scott, 2015), developed an energy strategy and plan to address energy security issues in remote aboriginal communities and improve the communities’ socioeconomic conditions (NG, 2016). The plan identified the installation of pilot projects, such as efficient heating stoves and district heating systems, the installation of new diesel generators that reduce diesel consumption and community expenses, the installation of a demonstration solar photovoltaic project on the Illusuak Cultural Centre in Nain, the installation of a small-scale wind-diesel system in Hopedale, and feasibility studies for small hydro projects in Makkovik, Nain and Hopedale. The Nunatsiavut Regional Government aims to develop and implement these projects through the financial support of the Government of Newfoundland and Labrador, as well as industry contributions (NG, 2016).

Conclusion

The 16 remote aboriginal communities in Labrador rely on diesel fueled generators for their electricity needs while the high cost of connection to the main grid limits community access to a reliable and clean hydroelectricity supply from the Labrador Interconnected grid. The transition from diesel-generated electricity to renewable resources is promoted through utility scale   run-of-river projects in five of the 16 communities supported by the Government of Newfoundland and Labrador and Newfoundland and Labrador Hydro, and wind and solar pilot projects to be developed by the Nunatsiavut Regional Government with government and industry financial support. The “net metering” policy could encourage the successful deployment of small-scale wind and solar applications by local governments as the cost of the technology decreases and positive experience is gained in other northern jurisdictions. This could enable communities to reduce high electricity costs, service interruptions and greenhouse gas emissions while improving socio-economic conditions as desired by the Nunatsiavut Regional Government.

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Appendix B

List of interview questions

1. I would like you to tell me about how the community and its electricity system have developed over time.
    a. Has the community, or Band Council, provided input into the investment decisions made regarding electricity supply and use? Has this changed over time?
    b. More broadly, has electricity and its changing uses affected the quality of life and personal well-being in the community?

2. Does the community want to provide more input into decisions regarding electricity?
    a. (If yes) What motivations, reasons or factors are important for consideration in these decisions?

3. Are there barriers that affect the ability of the community to influence the decision process regarding the electricity system?
    a. (If yes) What are the barriers? How can the barriers be removed?

4. Does the community have concerns regarding diesel-generated electricity?

5. Could you tell me about the renewable energy projects that have been undertaken in the community?

6. How important is it to introduce renewable energy to the local electricity system?
    a. How important are the following reasons to promote renewable energy:
        i. reduction of diesel consumption
        ii. reduced emissions
        iii. increase harmony with nature
        iv. reduce risk of future diesel price rises
        v. increase energy security with local supplies
    b. How should renewable energy system assets be owned, operated and financed?

7. Could renewable energy resources play an economic development role (generating income, employment and increasing self-sufficiency) for the community?
    a. What are the best economic development opportunities while the community relies on its local micro-grid for electricity?
    b. What are the best economic development opportunities if the community is connected to the provincial grid for electricity?

Appendix C

Renewable electricity projects in Canadian remote indigenous communities

Table 1: Renewable electricity projects in remote Canadian indigenous communities

Nr	Period/	Province/ Territory	Year	Name	Type of RETs	Capacity
1	1st period: 1974-1986	BC	1980	Bella Bella- Heiltsuk FN	Hydro	15 MW
2		Quebec	1986	Kuujjuaq	Wind	65 kW
3	2nd period: 1987-2000	Nunavut	1987	Cambridge Bay	Wind	100 kW
4		NFL	1988	Mary's Harbour	Hydro	175 kW
5		Nunavut	1988	Igloolik	Wind	20 kW
6		BC	1992	Bella Coola- Nuxalk Nation FN	Hydro	2 MW
7		BC	1992	Skidegate Landing-Haida Nation	Hydro	6 MW
8		Nunavut	1994	Cambridge Bay	Wind	80 kW
9		Nunavut	1995	Iqaluit	PV	3.2 kW
10		Nunavut	1996	Kugluktuk	Wind	160 kW
11		BC	1997	Good Hope Lake-Dease River	Hydro	3 MW
12		ON	1997	Kasabonika Lake FN	Wind	30 kW
13		ON	1997	Kitchenuhmaykoosib Inninuwug FN	Wind	50 kW
14		ON	1997	Weenusk FN	Wind	n.d.
15		ON	1997	Fort Severn	Wind	n.d.
16		ON	1998	Deer Lake FN	Hydro	490 kW
17		Nunavut	1998	Rankin Inlet	Wind	50 kW
18		NWT	1998	Sachs Harbour	Wind	50 kW
19	3rd period: 2001-2008	BC	2006	Kitasoo- Kitasoo FN	Hydro	1.1 MW
20		NWT	2006	Jean Marie River FN	PV	1.3 kW
21		BC	2007	Nemiah Valley- Xeni Gwet'in FN	PV	28.0 kW
22		BC	2008	Bella Coola- Nuxalk Nation FN	Storage	
23		BC	2008	Hartley Bay	DRS	
24	4th period: 2009-2016	BC	2009	Atlin-Taku River-Tlingit FN	Hydro	2.1 MW
25		NWT	2009	Inuvik	PV	5 kW
26		NWT	2009	Inuvik	PV	7 kW
27		NWT	2010	Sachs Harbour	PV	4.3 kW
28		NWT	2010	Wekweeti	PV	4.2 kW
29		BC	2011	Tsay Keh Dene FN	PV	n.d.
30		NWT	2011	Nahanni Butte- Deh Cho FN	PV	4.8 kW
31		NWT	2011	Norman Wells	PV	4.8 kW
32		NWT	2011	Paulatuk	PV	1.7 kW
33		NWT	2011	Paulatuk	PV	5 kW
34		Yukon	2011	Watson Lake	PV	4.4 kW
35		Yukon	2011	Old Crow- Vuntut Gwitchin FN	PV	3.6 kW
36		Yukon	2011	Old Crow- Vuntut Gwitchin FN	PV	12.1 kW
37		NWT	2011	Inuvik	PV	1.0 kW
38		NWT	2011	Inuvik	PV	3.5 kW
39		Yukon	2012	Destruction Bay/ Burwash Landing-Kluane FN	PV	4.7 kW
40		NWT	2012	Gameti	PV	5 kW
41		NWT	2012	Whati	PV	5 kW
42		NWT	2013	Fort Good Hope	PV	5 kW
43		NWT	2013	Fort Providence	PV	15 kW
44		NWT	2013	Fort Simpson	PV	5 KW
45		NWT	2013	Fort Simpson	PV	104 kW
46		NWT	2013	Fort Simpson	PV	5 KW
47		NWT	2013	Inuvik	PV	10 kW

48		NWT	2013	Inuvik	PV	1.7 kW
49		NWT	2013	Tulita	PV	10 kW
50		ON	2013	Kingfisher FN	PV	10 kW
51		ON	2013	Wawakapewin FN	PV	18 kW
52		ON	2013	Kasabonika Lake FN	Wind	30 kW
53		NWT	2014	Fort Liard	PV	10.5 kW
54		Nunavut	2014	Kugaaruk	PV	4 kW
55		ON	2014	Deer Lake FN	PV	152 kW
56		ON	2014	Deer Lake FN	PV	10 kW
57		ON	2014	Kasabonika Lake FN	PV	10 kW
58		NWT	2015	Aklavik	PV	15 kW
59		NWT	2015	Colville Lake	PV	135.5 kW
60		NWT	2015	Gameti	PV	17 kW
61		NWT	2015	Lutsel’Ke	PV	35 kW
62		NWT	2015	Tsiigehtchic	PV	18 kW
63		NWT	2015	Whati	PV	16 kW
64		NWT	2015	Wringley- Pehdzeh Ki FN	PV	19 kW
65		ON	2015	Fort Severn	PV	20 kW
66		ON	2015	Keewaywin	PV	10 kW
67		ON	2015	North Spirit Lake	PV	20 kW
68		ON	2015	Poplar Hill FN	PV	20 kW
69		ON	2015	Muskrat Dam Lake FN	PV	20 kW
70		ON	2015	Weenusk	PV	20 kW
71		ON	2016	North Karibou Lake FN	PV	18 kW

Appendix D

Main events and events' allocation to functions for the NWT and Ontario TIS

Table 1: Main events and events' allocation to functions for the NWT TIS

Year	Event	Function
1998	GNWT Official Statement on Climate (GNWT, 2008a)	Guidance of the search
1998	Establishment of Arctic Energy Alliance (AEA)	Guidance of the search Knowledge development
2001	Aboriginal and Northern Climate Change Program (ANCCP) (2001-2003) (AANDC 2014b; AANDC 2016)	Resources mobilization
2001	RETCAP (2001-2003): provincial program providing providing 50% rebates for equipment and system balance costs	Resources mobilization
2001	A Greenhouse Gas Strategy for the Northwest Territories (GNWT, 2011b)	Guidance of the search
2003	Aboriginal and Northern Community Action Program (ANCAP) (2003-2007) (AANDC 2014b; AANDC 2016)	Resources mobilization
2003	Feasibility studies for wind projects for Sachs Harbour, Tuktoyaktuk, Holman, and Paulatuk (ARI 2003)	Knowledge development Guidance of the search
2003	Feasibility studies for wing projects for Sachs Harbour, Ulukhaktok, Paulatuk, Tuktoyaktuk, Yellowknife, Inuvik (Pinard 2007)	Knowledge development Guidance of the search Knowledge diffusion
2006	Feasibility studies for wind projects for 31 communities in NWT (Maissan 2006a; 2006b)	Knowledge development Guidance of the search Knowledge diffusion
2006	Jean Marie FN solar photovoltaic demonstration project	Entrepreneurial activities
2007-2011	ecoENERGY for Aboriginal and Northern Communities Program (EANCP) (Phase 1: 2007-2011) (AANDC 2014a; INAC 2017)	Resources mobilization
2007-2016	CREF (2007-todate) as part of the Alternative Energy Technologies (AET) program providing funding for RETs projects costs (Carpenter 2013)	Resources mobilization
2007	-Energy for the future- An Energy Plan for the Northwest Territories -A Greenhouse Gas Strategy for the Northwest Territories 2007-2011 (GNWT 2007; GNWT 2011b)	Guidance of the search
2007	Remote Community Wind Energy Conference Tuktoyaktuk (NTPC 2007)	Knowledge diffusion
2007-2016	CREF (2007-todate) as part of the Alternative Energy Technologies (AET) program providing funding for RETs projects costs.	Mobilization of resources
2008	-2008: Energy priorities framework- Ministerial Energy Coordinating Committee (MECC) -2008: Review of Electricity Regulation, Rates and Subsidy Programs in the Northwest Territories (GNWT 2008a; GNWT 2008b)	Guidance of the search
2008-2015	Feasibility studies for wind and solar projects for Colville Lake, Deline, Jean Marie River, Trout Lake, and Fort Providence in NWT (Pinard and Maissan 2008, ARI 2016)	Knowledge development Guidance of the search Knowledge diffusion
2008	Optimization studies for wind projects for 12 communities in NWT (Weis and Ilinca 2008)	Knowledge development Guidance of the search Knowledge diffusion
2008-2015	Community energy profiles: community energy planning activities by AEA (AEA 2016)	Knowledge development Guidance of the search Knowledge diffusion
2009	-Electricity review. A discussion with northerners about electricity	Guidance of the search

	-Creating a brighter future: a review of electricity regulation, rates and subsidy programs in the northwest territories (GNWT, 2009a; GNWT, 2009b)	
2009	Inuvik: development of two small-scale solar photovoltaic projects	Entrepreneurial activities
2010	Efficient, Affordable and Equitable: Creating a Brighter Future for the Northwest Territories' Electricity System. Response to the 2008 and 2009 NTPC review (GNWT 2010)	Guidance of the search
2010	Optimization studies for wind projects for 12 communities in NWT (Weis & Ilinca, 2010)	Knowledge development
2010	Development of solar projects in Sachs Harbour and Wekweètì	Entrepreneurial activities
2011	-NWT energy report. Report of Ministerial Energy Coordinating Committee (MECC) -2011: A Greenhouse Gas Strategy for the Northwest Territories 2011-2015 (GNWT, 2011a; GNWT, 2011b)	Guidance of the search
2011	AEA: Publishing the "Best energy practices for remote facilities" guide (AEA 2011)	Knowledge development Guidance of the search Knowledge diffusion
2011	Development of solar projects in Nahanni Butte, Norman Wells, Paulatuk (two projects) and Inuvik (two projects)	Entrepreneurial activities
2011	AANDC and NRCAN publication: Status of remote communities (AANDC and NRCan 2011)	Guidance of the search Knowledge diffusion
2012-2016	ecoENERGY for Aboriginal and Northern Communities Program (EANCP) (Phase 2: 2012-2016) 2011) (AANDC 2014a)	Mobilization of resources
2012-2015	Community energy profiles: community energy planning activities by AEA (AEA 2016)	Knowledge development Guidance of the search Knowledge diffusion
2012	Development of solar projects in in Gameti and Whati	Entrepreneurial activities
2012	Northwest Territories Solar Energy Strategy 2012-2017 (GNWT, 2012a)	Guidance of the search
2012	NWT Energy Charette (GNWT, 2012)	Knowledge diffusion Guidance of the search
2013	Development of solar projects in Fort Good Hope, Fort Providence, Fort Simpson (three projects), Inuvik (two projects), and Tulita	Entrepreneurial activities
2013	The NWT Energy Action Plan (GNWT 2013)	Guidance of the search
2014	Development of a solar project in Fort Liard	Entrepreneurial activities
2014	NWT Energy Charette (GNWT 2014)	Knowledge diffusion Guidance of the search
2014	NTPC net metering (NTPC, 2016)	Market formation
2015	IPP policy and net metering policy for aboriginal community projects (NTPC, 2016)	Market formation
2015	2nd Renewables in Remote Microgrids conference (BP, 2016)	Knowledge diffusion
2015	GNWT response to the 2014 NWT energy charrette report (GNWT 2015)	Knowledge diffusion
2015	Development of solar projects in Aklavik, Colville Lake, Gameti, Lutselk'e, Tsiigehtchic, Whati, and Wringley- Pehdzeh Ki FN	Entrepreneurial activities
2016	NWT-Energy strategy discussion (GNWT 2016)	Guidance of the search
2016	CBC announcements for RET indigenous projects (CBC 2016a; 2016b; 2016c; 2016d)	Legitimization

Table 2: Main events and events' allocation to functions for the Ontario TIS

2001	Aboriginal and Northern Climate Change Program (ANCCP) (2001-2003) (AANDC 2014b; AANDC 2016)	Mobilization of resources
2003	Aboriginal and Northern Community Action Program (ANCAP) (2003-2007 (AANDC 2014b; AANDC 2016)	Mobilization of resources

2003	Governmental commitments for renewable electricity generation	Guidance of the search,
2004-2005	Call for proposal and request for proposals for renewable electricity generation (Rowlands 2007)	Mobilization of resources
2006	RESOP, Feed-in-tariffs and Net metering policies for renewable electricity introduced (Rowlands 2007)	Mobilization of resources
2007-2011	ecoENERGY for Aboriginal and Northern Communities Program (EANCP) (Phase 1: 2007-2011) (AANDC 2014a; INAC 2017)	Mobilization of resources
2008	OEB (talks about the communities' goals and the NAN) (OEB 2008)	Guidance of the search
2009	GEGEA Act (Stokes 2013)	Guidance of the search
2009	Aboriginal Loan Guarantee Program (ALG) (OFA 2016)	Mobilization of resources
2009	Aboriginal Energy Partnerships Program (AEPP) (AEPP 2016)	Mobilization of resources
2010	2010 Ontario's LTEP (OME, 2013)	Guidance of the search
2010	OPA: Draft technical report for the connection of remote communities (OPA 2010)	Guidance of the search
2010	Optimization studies for wind projects for 16 communities in Ontario (Weis and Ilinca 2008; 2010)	Knowledge development
2011	AANDC and NRCAN publication: Status of remote communities (AANDC and NRCan 2011)	Guidance of the search Knowledge diffusion
2012-2016	ecoENERGY for Aboriginal and Northern Communities Program (EANCP) (Phase 2: 2012-2016). (AANDC 2014b; AANDC 2016)	Mobilization of resources
2012	NAN Energy conference (NAN 2012)	Knowledge diffusion
2013	Optimization study for Kasabonika Lake First Nation (Arriaga, Cañizares and Kazerani 2013)	Knowledge development
2013	REINDEER program (a HORCI communities' diesel displacement incentive) (HORCI, 2015)	Market formation
2013	2013 Ontario's LTEP (OME, 2013)	Guidance of the search
2013	1st Remote Microgrids Conference in Toronto	Knowledge diffusion
2013	Development of two solar projects in Kingfisher FN and Wawakapewin FN and one wind turbine project in Kasabonika Lake FN	Entrepreneurial activities
2014	2014 Northern Ontario First Nations Environmental Conference (NOFNEC)	Knowledge diffusion
2014	IESO programs launched: Aboriginal Transmission Fund (ATF), Remote Electrification Readiness Program, Education and Capacity Building (ECB) Program (IESO 2015)	Mobilization of resources
2014	Development of two solar projects in Deer Lake FN, and one solar project in Kasabonika Lake FN	Entrepreneurial activities
2014	Indigenous press on the development of a solar project in Deer Lake (WN, 2014)	Legitimization
2014	NCC press announcements on indigenous projects (NCC 2016)	Legitimization
2014	IESO: Draft technical report for the connection of remote communities (IESO, 2014)	Guidance of the search
2015	Development of solar projects in Fort Severn FN, Keewaywin FN, North Spirit Lake FN, Poplar Hill FN, Muskrat Dam FN, and Weenusk FN.	Entrepreneurial activities
2016	Development of a solar project in North Karibou Lake FN	Entrepreneurial activities
2016	Optimization study for Kasabonika Lake First Nation (Arriaga, Cañizares and Kazerani 2016)	Knowledge development