Strengthening energy security through community energy planning in Churchill, Manitoba.

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Abstract

Imagine that it costs you $100 to fill your car's gas tank, and no one outside your isolated community is working to improve things. This scenario is a reality for many northern remote communities like Churchill, Manitoba, where traditional energy security definitions and centralized systems have left them with unaffordable, unsustainable power. This thesis begins the process of community energy planning in Churchill by creating a community energy profile, and vision statements to guide a future energy plan. It also examines, from a Northern perspective, energy security definitions, and their effectiveness in remote communities. Twenty-three semi-structured snowball interviews and a workshop (n=12) identified community priorities for an energy vision statement and future energy plan. The energy profile was constructed in Microsoft Excel with data from utility companies and government and visualized using ArcGIS 10.7.1. Interview and workshop data were analysed using Nvivo12 to identify common themes. Being a remote community, Churchill has limited diversity in its energy sources. 75% of Churchill's energy consumption is fossil fuels, including 5.4 million litres of jet fuel. Consequently, residents consume 35% more fossil fuel than the average Canadian. A significant portion of this can be attributed to the community's remoteness, but also the high rates of tourism with a reliance on air travel. Such high rates of fossil fuel consumption are viewed negatively in the community. All workshop participants and twenty-one interviewees mention a strong desire for Churchill to utilize more renewable energy sources. Increasing renewable energy is a seen as crucial to reducing greenhouse gases and improving sustainability in the community. Opportunities to increase the efficiency of the energy system through upgrades to building conditions, improved

technology, and energy efficiency programs are also identified and viewed favourably by participants. Energy generation occurs largely outside of the control of the community. Manitoba unique monopolistic electricity market, and government ownership of a significant portion of housing in the community results in most decisions being made outside of the community with little opportunity for input. Fourteen interview participants and all workshop participants identified increased agency as crucial to the future of the energy system. Draft vison statements for Churchill’s future community energy plan, and a reconceptualized definition of energy security included the identified elements of agency and efficiency. Churchill’s energy profile also provides the foundation to an energy plan as energy consumption is more precisely known and visualized. This research illustrates an example of energy planning to other northern communities, and in partnership with the CASES project provides ongoing support for the development and implementation of the plan.

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Statement outlining roles of manuscript authors

This thesis was the primary effort of Michael Kvern, who conducted all stages of planning, research and writing. Michael received strong guidance, editorial support, direction, and assistance from his supervisor Dr. Fitzpatrick. Dr. Fishback served as a second reader and valuable contact to facilitate arrangements within Churchill.

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1.0 Introduction

Energy is a vital resource but is most often taken for granted. We assume that the lights will turn on when we flick the switch, that our homes will be heated and warm, and that we are able to travel around our communities and to other ones. Energy, in some form, be it electricity, heat, or transport is essential to the functioning of daily life. Because of these presumptions, individuals and community seldom critically assess their energy systems. However, increasing discourse and global concern about sustainability and social justice are bringing new context and relevance to issues surrounding energy consumption and production (Karanasios & Parker, 2018; Kruyt, van Vuuren, de Vries, & Groenenberg, 2009; Sovacool & Mukherjee, 2011).

The notion that energy will be available to us when we need it and that we can use immediately is one of the most basic conceptualizations of energy security. In academia energy security is most often considered at a nation level, concerned with the supply of resources and infrastructure needed to generate and transport energy (Ang, Choong, & Ng, 2015; Kruyt et al., 2009). However, this fails to account for the complex holistic social and environmental concerns of a community that exist in addition to supply. Modern life in the developed world requires energy almost constantly, and the generation of the energy of energy requires natural resources (O'Brien & Hope, 2010). Recognizing the holistic nature of energy systems, and its necessity to daily life is the first step to reconceptualizing energy security.

Northern Canadian communities face unique energy challenges, including high cost and high fossil fuel usage (Karanasios & Parker, 2018; Natural Resources Canada, 2018; Royer, 2011; Van Hoesen & Letendre, 2010). Many northern and Arctic communities are not connected to the grid, and as a result experience significant reliability issues. Aging infrastructure and friction of distance result in more frequent, longer outages, impacting the physical, social and economic health (McCauley, Heffron, Pavlenko, Rehner, & Holmes, 2016; McDonald & Pearce, 2013). Energy is intertwined in all aspects of life, having reliable, affordable, sustainable sources of it is necessary for these communities to prosper.

Community energy plans (CEP) and the local management of energy are one solution to energy insecurity in the north (Canada Mortgage and Housing Corporation, 2000; St. Denis & Parker, 2009). CEPs are planning documents for energy that incorporate local values and concerns into generation of sustainable energy (McCauley et al., 2016; McDonald & Pearce, 2013; St. Denis & Parker, 2009). Alternatives to centralized energy systems and definitions can provide northern communities control over and benefit from energy.

Understanding the unique needs of northern communities allows for the redefinition of energy security in a way that is applicable at the community level. Local definitions and plans can more effectively include social and environmental considerations. This thesis explores the energy system of Churchill, Manitoba and how a more appropriate definitions of energy security can allow for a CEP to address energy security needs in the north.

1.1 Purpose and Objectives

This research examines energy security at the level of a community, and how that can inform energy security definitions. It documents the current energy system in Churchill, Manitoba and contemplated alternatives through an energy visioning process that will enable a community energy plan. CEPs allow communities to strengthen energy security through a critical evaluation of their energy system. CEPs create an opportunity to propose actions and alternatives to change the energy system and increase benefits to the community.

The objectives of this research are: 1) model the community's current energy system, including generation, transmission, and consumption; 2) explore community members' attitudes towards the current energy system, and interest in alternatives, 3) establish criteria for potential alternative energy generation or conservation; and 4) develop, in conjunction with the community, a draft vision statement to guide subsequence energy planning.

This work to collect baseline energy data and developing a vision statement is the first step in a larger process. This thesis provides Churchill the foundation to develop a CEP, apply for provincial and federal funding that plan, and execute any planned actions. This research constitutes my Honours thesis and partially fulfills my graduation requirements.

1.2 Background

1.2.1 Energy Security

Mainstream definitions of energy security focus on the provision fossil fuels at the national and international level (Cherp & Jewell, 2014; Kruyt et al., 2009; Sovacool & Mukherjee, 2011). This focus on fuel supply results in much of the energy security literature examining national level supply chains, producing national level definitions. Differences in national levels of economic development, available resources, and politics creates a variety of different definitions of energy security based on national differences (Winzer, 2012). Though concerned with individual nations, most energy security definitions focus on global provision of fossil fuels (Ang et al., 2015).

The vast majority of energy security definitions include the availability of natural resources for energy generation and infrastructure for transport, even if they do not focus on the national level (Ang et al., 2015; Kruyt et al., 2009). Other conceptualizations like the fours As (accessibility, affordability, availability, acceptability), are similar to traditional definitions as they include the same structural aspects and are concerned with physical security of resources (Cherp & Jewell, 2014; Kruyt et al., 2009). The fours As are an improvement on traditional definitions as they include some social and environmental aspects of energy. Common to all energy security definitions is the ability of an energy system to provide enough energy to meet demand at an affordable price (Ang et al., 2015; Molyneaux, Brown, Wagner, & Foster, 2016; Sovacool, 2011). To be traditionally secure, energy must be affordable, reliable, and consistent.

Contemporary energy challenges are evolving outside the scope of traditional energy security definitions (Cherp & Jewell, 2014). Consideration of sustainability and equitable access have come to the forefront of energy discussions, but are not included in the traditional discourse (Karanasios & Parker, 2018; Kruyt et al., 2009; Sovacool & Mukherjee, 2011). Definitions are beginning to change, but not in ways that fully support the non-national level (Ang et al., 2015; St. Denis & Parker, 2009; Winzer, 2012). The transition away from national level consideration of energy security is hampered by the legacy of traditional generations which created the current centralized energy grid. A desire to increase energy security will require a shift from consideration of national fuel supplies and a centralized grid to discussions of local energy security measures and distributed systems (Alanne & Saari, 2006; St. Denis & Parker, 2009).

1.2.2 Community energy plans

Energy systems are of a dual nature, consisting of the resources and infrastructure that allow for the generation and consumption of energy, but also the people who are the users and decision makers in the system. Managing energy at the local level is crucial for sustainability and requires a new definition of energy security (Canada Mortgage and Housing Corporation (CMHC), 2000). Individuals and communities must have sustainable, reliable, and affordable energy to be energy secure. Community energy plans (CEPs) allow communities to recognize both portions of this system, strengthen energy security through critical evaluation of their energy system, and define energy security in a manner that is locally relevant. (Alanne & Saari, 2006; Burke & Stephens, 2018; Keewaytinook Okimakanak & Idenpendent Electricity System Operator, 2016; St. Denis & Parker, 2009). St. Denis and Parker (2009) identify energy efficiency, energy conservation, and renewable energy sources as the primary areas CEPs can influence. The local management of energy keeps social and economic benefits within the region, while increasing local energy security and decreasing fossil fuel use (Alanne & Saari, 2006; Burke & Stephens, 2018). A community-based process of energy planning identifies ways to conserve energy, integrate renewable energy technologies, and identify the energy needs, priorities and goals of a community.

CEPs can face several barriers, including a lack of time, money, or authority to implement them (Canada Mortgage and Housing Corporation (CMHC), 2000). It is crucial that residents and government be engaged with, and committed to, the CEP process for it to be successful. Using CEPs communities can define how an energy system combines the physical, natural, social and economic components in a way that is beneficial and applicable to their unique situations.

1.2.3 Energy Systems and the North

Energy is produced in a variety of ways, but the norm is through large centralized systems, which use fossil fuels (Natural Resources Canada, 2018). These centralized systems have inherent vulnerabilities, ranging from fuel shortages, to infrastructure failures, to social unacceptability (Bouffard & Kirschen, 2008; O'Brien & Hope, 2010; Winzer, 2012). These vulnerabilities are increasing in frequency and intensity; for example, in the North American power grid major disruptions have risen from 50 a year in 2000, to over 300 in 2011 (Roege, Collier, Mancillas, McDonagh, & Linkov, 2014). Small failures, on the scale of a few transmission poles, which would be expected to create only a local outage, can instead shut off power to over 50 million people, and cost billions in damage and lost productivity (Roege et al., 2014). Such a high degree of integration inherent in centralized energy systems only compounds previously small outages, and creates massive failures (Bouffard & Kirschen, 2008).

Canada is an energy rich nation, but this wealth of energy is not equally distributed, with remote and northern communities often less energy secure and using more fossil fuels (Karanasios & Parker, 2018; McDonald & Pearce, 2013; Van Hoesen & Letendre, 2010). Northern Canada, areas north of the southern limit of the discontinuous permafrost zone, experience severe energy insecurity and inequity as compared to southern Canada, resulting in the inability of these communities to be self-reliant, and sustainable (McCauley et al., 2016; Northern Scientific Training Program, 2018). This unequal distribution of energy is due to the remote nature of many northern communities.

In northern communities the friction of distance makes provision of any good or service costlier and more difficult and energy is no exception. In the provinces, electricity prices range from 8 - 15¢/kwh, whereas Nunavut and the Northwest Territories are both above 30 ¢/kwh and Yukon is slightly above 15¢/kwh (National Energy Board of Canada, 2016). The dispersed and small population of the territorial north make it very expensive for traditional, centralized energy to be provided these northern communities. Northern communities also use disproportionately high amounts of fossil, emitting greenhouse gases while sitting on the forefront of climate change (Karanasios & Parker, 2018; Mcdonald & Pearce, 2012; McDonald & Pearce, 2013; St. Denis & Parker, 2009) The high cost, emissions, and lack of energy generation related benefits in northern communities make them ideal candidates for the development of CEPs and the reconceptualization of energy security.

1.2.4 Churchill Community Overview

Churchill is small Manitoban community located on Hudson Bay in the western arctic nearly 1,500km from Winnipeg. As of the 2016 census approximately 900 people live in

Churchill (Statistics Canada, 2017). Tourism is the primary economic driver, with approximately 6,000 to 15,000 tourists visiting Churchill annually. (Dawson, Stewart, Lemelin, & Scott, 2010; Groulx, Lemieux, Dawson, Stewart, & Yudina, 2016; Huddart & Stott, 2020). The Port of Churchill, healthcare, government, and the service industry are the remaining key employers (Statistics Canada, 2017).

Energy in Churchill is provided from sources a significant distance from the community. A 400km long transmission line managed by the provincial energy utility Manitoba Hydro delivers hydroelectricity to the community. Rail and sea linkages provide a variety fossil fuels including jet fuel, propane, gasoline, and diesel to meet the remainder of the Churchill's energy needs.

Reliability of energy is low in the community, and costs for gasoline for transport are very high (Lucas, Robb, Sewell, Velo, & Villebrun-Normand, 2018). Being a subarctic coastal community Churchill also faces unique and increased threats from climate change (Burke & Stephens, 2018; Karanasios & Parker, 2018). Disruption of permafrost posses a substantial threat to the current hydroelectric transmission line, which is Churchill sole sources of electrical energy. In 2017 train service was disrupted for months following flooding and drastically increased prices for all goods and services in the community (Canadian Press, 2018). Even when rail and the transmission line are intact prices for fuel are quite high, with gasoline costing $2.25 per litre in July 2019.

The community has expressed desire to explore alternative and renewable energy sources, both through previous research and the 2011 Churchill Sustainability Planning Framework (Distasio, Dudley, & Moradzadeh, 2011; Lucas et al., 2018). In the framework, energy planning and visioning are explicitly mentioned as priority areas

(Distasio et al., 2011). Further, it recommends a process that to review the current energy system and then begin planning for conservation and generation, the process this research proposes. With Churchill's current energy challenges, an increasing vulnerability to climate change, and desire for energy planning it is a community ideally suited to develop a CEP. A CEP would assist the community in achieving energy security, and sustainability (McCauley et al 2016; St. Denis & Parker, 2009; Lucas et al., 2018). It would achieve this by providing a planning framework and document which the town could use to transition to renewable energy generation, increase energy efficiency, become energy secure, and generate economic benefits that would stay in the community. A CEP could also enable the Town to apply for various funding programs from different levels of government such as Efficiency Manitoba or Natural Resources Canada. These funds could enable the production of the plan itself, and any actions it identifies such as conservation efforts or establishment of a distributed energy system

1.3 Methods

This research uses Churchill's energy system as a case study for examining energy security in northern and remote energy systems. Berg (2007) defines case study as a "method involving systematically gathering enough information about a particular person, social setting, event or group to permit the researcher to effectively understand how the subject operates or functions" (p. 283). Case study research aims to describe and understand the research subject, and then to use that understanding to advance knowledge of that subject for insight in its own right, or generalization of the knowledge to theory (Berg, 2007; Merriam, 1988). Case study research uses multiple data collection methods to obtain a range of perspectives and insights into the case (Taylor, 2016). Case studies are best suited to situations where it is difficult to separate the phenomena or variable from its context, such as analyses of communities, policies, programs, business or education settings (Berg, 2007; Merriam, 1988). The crucial aspect of a case study approach is its focus in holistic and broad collection of data to describe the research subject in rich detail (Merriam, 1988).

This research is an intrinsic case study because the research primarily seeks to understand the case – Churchill's energy system – for its own sake. Through a period of immersion in the community for data collection, the energy system of Churchill was systematically studied. Quantitative data from local utilities was collected to understand the energy consumption, and semi-structured interviews and a community focus group were conducted to formalize community priorities.

1.3.1 Literature Review

A literature review examines energy security and provides context for Churchill and the Canadian north. Sources reviewed included literature on energy security, community energy planning, and the artic and subarctic. Non-scholarly case studies, community energy plans, sustainability plans, and community energy profiles in northern and non-northern communities were reviewed. These included the communities of Churchill, Resolute, Rankin Inlet, Iqaluit, Yellowknife Guelph, and Burlington, Churchill, Guelph, and Canmore. Documents and reports from government and nongovernmental agencies were also reviewed. These included Keewaytinook Okimakanak Chiefs Council, Natural Resources Canada, Statistics Canada, the National Energy Board, Manitoba Hydro, the

United States Department of Energy, the Community Energy Association, and the Canadian Urban Institute.

1.3.2 Data Collection

Collection of data took place during the summer of 2019, with 4 weeks spent in Churchill to collect energy consumption data, interview residents, and facilitate a community workshop. Data on Churchill's consumption of electricity, propane, gasoline, diesel, and jet fuel was gathered from utility providers and government records. An electricity profile for Churchill for 2008 to 2018 was provided by Manitoba Hydro, which included residential electricity consumption by housing type. Propane consumption for the community was provided in an aggregate format from an interview participant that works in the utility sector. Additional, more detailed data on annual consumption from 2015 to 2018 for properties owned by the Town of Churchill was compiled by the researcher using accounts payable records. Manitoba Housing provide residential consumption data that corroborated the data. Annual gasoline and diesel consumption figures were provided in an aggregate format for the community from a key informant with the Port of Churchill and Churchill Marine Tank Farm. The annual consumption of jet fuel was also provided by a key informant, one involved in the aviation fueling sector. Additional data on electricity, gasoline, diesel and propane consumption was compiled by the research using records from the Town of Churchill. Transport Canada provided a very detailed breakdown of energy consumption at the Churchill Airport for 2015 to 2018. Local infrastructure and building data were supplied by the Town of Churchill and the Province of Manitoba. This energy profile data was gathered in a numeric form and compiled into

Microsoft Excel for analysis. All residential or potentially identifying information was aggregated to the land use zone or community level to protect confidentiality.

Several types of ancillary data were used complete the energy profile. This included: demographics of the community as collected from the 2016 Canadian Census; shapefiles of property assessment parcels; land-use designation polygons; and zoning polygons were provided by the Community and Regional Planning Branch of Manitoba Municipal Relations. Vector line data on energy transmission infrastructure, road networks, and railways was obtained from the Government of Canada's Open Data portal. A partial set of building footprints polygons was provided by the Town of Churchill, the remaining building footprints were digitized as KML files in Google Earth by the researcher using on-screen digitization and then converted into shapefiles for analysis using ArcMap 10.7.1.

Semi-structured interviews are a common method of interviewing participants that uses an interview guide of standard list of questions or themes, but allows participants to depart from theme and the interviewer to modify the guide if needed (Berg, 2007). Prompts, follow-up questions, and new questions may also be added by the researcher as topics emerge in the interview. The strength of a semi-structured interview is its flexibility, and location between the extremes of structured and unstructured interviews (Berg, 2007; Bryman, Teevan, & Bell, 2009). The interviewer maintains control of the interview but has enough freedom for the interviewee to introduce new topics.

Twenty semi-structured interviews were conducted with residents of Churchill and three with energy industry experts. Embedding with the community for an extended period of time allowed the researcher to connect with many long-term residents, and obtain representation from several sectors including government, tourism, and the utility industry (see Figures 1 and 2). Participants were recruited over email, phone, social media and in person. The researcher canvassed local business, restaurants, and public spaces to solicit interviews. The researcher also participated in some community events such as National Indigenous Day celebrations, and bingo at the Legion to raise the researcher's profile in the community. The only participation criteria that they were either residents of Churchill or a relevant energy expert.

The interview guide, attached in Appendix A, was informed by priorities identified by Lucas et al. (2018) and an extensive review of energy security and energy planning literature. Interviews explored energy usage, strengths and limitations of the system, and priorities for energy moving forward. Interviews were recorded on a digital audio recorder and then transcribed into text using EasyTranscript and Microsoft Word. Written notes were also taken during interviews as a secondary data source. Participants were identified by number on both the audio recording and transcript. Audio files were deleted after transcription, and all files were destroyed in 2020.

A community workshop was facilitated in August 2019 to present preliminary results to the community and to facilitate a community visioning session. The visioning workshop collectively established energy priorities and concepts that will be included in the vision statement of a future community energy plan. Berg (2007) would classify this workshop as a focus group, as part of the visioning session involved the participants interpreting previously collected qualitative results. Participants were presented with Churchill's preliminary energy profile and attitudes on the energy system as identified through the interviews. Participants were split into two groups to discuss the challenges and opportunities in Churchill energy system where their comments where recorded. Following a brief presentation on what a vision statement is, along with some examples, participants were asked what they would include in their direction for Churchill's energy. Participants wrote their ideas and response onto cue cards and could write as many responses as they saw fit. Cards were arranged them by theme, and ranked by participants with a red or blue sticker (Wates, 2014). Red stickers indicated a theme they agreed with or liked, and blue was an theme that they were less interested in. The discussion notes and cue card responses were transcribed into Microsoft Word.

1.3.3 Data Analysis

Energy profile

Electricity, propane, gasoline, diesel, and jet fuel consumption data for 2018 were entered in a Microsoft Excel spreadsheet. All fuel types were converted into petajoules (PJ) so the proportion of total energy consumption could be easily tabulated and compared. Electricity and propane consumption for key town buildings including the Town Complex, the Public Works building, the fire hall, the sewage treatment plant, water pumping station, lift station, lake pump house, CR30 (water intake station) and L5 (solid waste transfer station) were provided through town records and noted separately while being included in aggregate totals. Electricity consumption data as provided was broken down into business and residential categories. This provided an already established figure of electricity consumption for single family homes, town homes, and apartment units.

All spatial analysis took place in ArcMap 10.7.1. (ESRI, 2017). Using the building footprint polygons, the shapefiles were imported into a feature class with unique id, zoning category, electricity consumption and area attributes. Using the calculate area function, square footage for the polygons was determined. Once area was determined buildings with known electricity consumption had their 2018 PJs entered the attribute table. The total PJ consumed by known buildings in 2018 was then subtracted from total 2018 PJ to produce the “2018 remaining PJ” sum. The same process was repeated for square footage, subtracting known buildings from the town’s total square footage. The remaining PJ figure was then divided by the remaining square footage figures to produce an average PJ per square foot figure. This figure was entered into the attribute table and then multiplied by each buildings square footage to produce an estimated electricity consumption by square foot map.

A similar process was used to produce an energy usage by zone map. Using ‘select by attribute’ for the Zoning shapefile, all of a single zoning category was selected and then ‘merged’ into a single polygon. These categories were Residential; Commercial, Limited Development; Industrial; and Public and Recreation. Specific 2018 electricity consumption data for Residential and Commercial uses was provided in the electricity data from Manitoba Hydro and was inserted directly into the attribute table. The only significant building in the Public and Recreation zone was the Town Complex so this value was inserted directly into the attribute table. Consumption for the key buildings in the Limited Development zone was provide from the Town of Churchill so the total consumption was summed and inserted directly into the attribute table. Transport Canada provided specific consumption figures for the airport, in the Industrial zone. Subtracting these values from the total 2018 kilowatt hours left the remaining electricity consumption in the Industrial zone, which was added to the airport consumption and directly inserted into the attribute table. Once all zones had an estimated electricity consumption these values were visualized.

Qualitative Data

Interview notes and recordings were transcribed and imported into Nvivo12 to asses them for common themes (QSR International, 2018). Participant discussion notes and vision statement element cue cards were initially analyzed manually, recording the groupings and themes identified by participants and quantifying the number of red and blue dotes on each card, respectively. These data were then also entered into Nivo12 and examined for common themes. The coding structure was based upon the theoretical framework and structure of the interview guide. Multiple rounds of coding were done as new information was added from additional interviews and the visioning workshop (Taylor, 2016). These interview and workshop data were triangulated with each other, and several other sources to ensure validity. The triangulation included internal sources such as interview notes, participant observation, daily summaries and field summaries. It also included external sources including energy consumption data; documents and reports on Churchill's energy system; and energy security literature.

1.3.4 Validity

Reliability refers to consistent accuracy over time (Bryman et al., 2009). The reliability of the study is high, as the investigation was extremely through and extensive, acquiring representation from a broad spectrum of experts and community members. The credibility and trustworthiness of this research is also high, given the unbiased semi-structured nature of the interviews and the incorporation of all divergent opinions into the findings.

Internal validity asses the degree of certainty in the causality of research observations (Bryman et al., 2009, p. 22). Triangulation between field source – both quantitative and qualitative – and literature review ensures the validity of the findings. Triangulation is the use of multiple methods and sources of information to increase internal validity (Berg, 2007; Bryman et al., 2009). Findings between the sources and methods are compared to corroborate them. The researcher confirmed key themes and pieces of information with multiple informants and other data sources, noting discrepancies or diverging opinions.

Interview and workshop data were triangulated with internal sources such as field notes, and external sources to ensure validity. It also included external sources including energy consumption data; documents and reports on Churchill's energy system; and energy security literature.

Data collection methods of both qualitative and quantitative data followed established methodological and ethical practices. A review and collection of documents from government and utilities provided the energy consumption data. Semi-structured interviews and a visioning workshop provided insight on community desires and attitudes towards the energy system. Analysis was preformed in Excel, ArcMap, and Nvivo 12 to develop a community energy profile and understanding of community member attitudes towards the energy system and desire for alternatives. Multiple rounds of coding were done as new information was added from additional interviews and the visioning workshop (Cope & Kurtz, 2016).

1.4 Organization of Thesis

This thesis presents research done throughout 2019 to assess the energy system of Churchill. It follows a manuscript format, where the thesis focuses on a scholarly output primarily created by the student. The first chapter introduces the research, background literature, theoretical framework, and methods.

The second chapter is the scholarly manuscript for submission to *Energy Policy* which focuses on how the results can inform energy security definitions. The thesis manuscript presents the findings of the research, including the energy profile and the key themes identified in the interview and workshop data. These findings are discussed in the context the four As (availability, accessibility, acceptability, and affordability), a common energy security definition. Drawing upon key findings, gaps in the four As related to the unique needs of northern communities are addressed through adding the elements of agency and efficiency to produce a new conceptualization: A5E1. In the manuscript, the findings present the unique energy security needs of northern communities and a more accurate definition is proposed.

The third chapter present a discussion on the results of the thesis and a conclusion. It includes research done as part of the thesis not included in the manuscript. Specifically, community energy maps of Churchill, draft vision statements for a future energy plan, and discussion on the thesis's contribution to knowledge.

2.0 Manuscript: Adapting the four As of energy security to suit northern and remote communities

Highlights

- Renewable energy generation is a key priority for the future of northern energy.
- Northern communities desire local decision making in their energy systems.
- Efficiency is important to energy acceptability and affordability in the north.

Abstract

This research examines the applicability of energy security definitions to remote northern communities, and how local context can improve them. Energy security definitions primarily take into account the supply of fossil fuels, however the commonly used definition of the four As considers the social and environmental aspects of energy. Churchill, Canada, is used as a case study to understand the applicability of the four As to the unique situation of northern communities. Data on energy consumption was collected from utility providers and organized into a community energy profile. Semi-structured interviews (n=23) and a community workshop (n=12) identified challenges, opportunities, and a vision for the local energy system. 75% of Churchill's energy consumption is fossil fuel, including 5.4 million litres of jet fuel in 2018. Participants express a desire for increased acceptability in their energy system through increased usage of renewables, and an increase in energy efficiency. The community is totally reliant on external sources of energy and there is no local agency or decision-making.

Adapting the four As to include agency and efficiency (A5E1) defines energy security in northern communities more completely. Re-framing energy security as A5E1, follows the subjective nature of energy security, and better defines it for the circumstances in Churchill and northern communities globally.

Keywords

Energy security; Churchill, Manitoba; Northern Canada; Efficiency: Agency

2.1 Introduction

Increasingly, global concern about sustainability and social justice are bringing new context and relevance to issues surrounding energy security (Karanasios & Parker, 2018; Kruyt et al., 2009; Sovacool, 2011). Mounting pressures related to climate change and equity are contributing to this increase of interest in energy security. This is especially true in northern Canada, where energy systems tend be less secure (Karanasios & Parker, 2018; Mcdonald & Pearce, 2012; Rezaei & Dowlatabadi, 2016).

Traditional definitions of energy security are geopolitical and focus on the supply of oil and natural gas, largely because energy production is dependent on natural resources and modern sociopolitical structures (Cherp & Jewell, 2014; Kruyt et al., 2009; Sovacool & Mukherjee, 2011). These definitions largely leave out social and environmental considerations of energy systems (Ang et al., 2015; Chester, 2010; Kruyt et al., 2009). The present geopolitical nature of energy security also fails to conceptualize energy security as it applies to individuals and communities. Energy security is becoming increasingly relevant at the local level as there may be an increased need to develop localized power sources in support of efforts to isolate communities in the face of the COVID-19 (Chura, 2020; Graff & Carley, 2020). Along with mounting concerns regarding sustainability, increased interest and redefinition of energy security is introducing more holistic definitions (Ang et al., 2015; Chester, 2010; Karanasios & Parker, 2018; Sovacool, 2011).

One foundational definition often cited in *Energy Policy* is the "four As of energy security" (availability, accessibility, affordability and acceptability) which were created in the context of ensuring sufficient supplies of fossil fuels to nation-states (APERC, 2007). The four As allow for assessment of a given energy systems security. This article explores the unique aspects of energy security in northern and remote communities, utilizing Churchill, Manitoba, Canada as a case study. It works to understand to what degree energy security definitions like the fours As apply to remote northern communities. Ensuring energy security definitions are appropriate for remote communities removed from the mainstream is an important step in the reconceptualization and definition of energy security.

2.2 Background

Energy security is concerned with the systems and sources that provide electrical, heat, and transportation energy to people on a large-scale basis. Among the numerous definitions and conceptualizations of energy security, there is a dominant focus on securing the supply of energy sources (Ang et al., 2015; Chester, 2010; Kruyt et al., 2009). Nearly all definitions include availability of natural resources for energy generation, and infrastructure for transport of energy (Ang et al., 2015). These considerations are structural forces concerned with fuel supply and the security of infrastructure against attack or disruption. Similarly, the reduction of risk to national fuel supply chains is found to be the guiding notion behind energy security definitions (Winzer, 2012). These definitions focus on security of energy and fuel supply but fail to consider demand side energy security, how it is used by people. Rather it conceptualizes demand simply as energy's end use and not as something necessary for individuals and communities.

However, conceptualizations of energy security are beginning to expand beyond the availability of an energy source. As fossil fuel use declines in favour of renewable resources, the definition of energy security is evolving (Ang et al., 2015; Jewell et al., 2016). In emerging definitions, price, environmental sustainability, governance, and efficiency are becoming considered components of energy security (Ang et al., 2015). The complex and multidimensional nature of energy security as identified by Chester (2010) can be beneficial in this changing environment. As conditions in which energy security are conceptualized change, definitions and conceptualizations can also change, leading to expanding views of energy security.

One common definition of energy security that encompasses many of these structural considerations is the four As: Availability, accessibility, acceptability, and affordability (APERC, 2007). Each "A" addresses a specific aspect of energy security (APERC, 2007; Kruyt et al., 2009):

- Availability refers to the physical presence of the energy source within the environment;

- geopolitical factors, technology, and workforce are accessibility;
- environmental and social concerns make up acceptability; and,
- affordability refers to the cost of production and generation of energy.

The four As define energy security as a steady supply of reasonably priced energy that is acceptable to extract and generate (APERC, 2007; Cherp & Jewell, 2014; Kruyt et al., 2009). The paradigm of the four As has been assessed and utilized by many scholars directly and indirectly to consider energy security (Cherp & Jewell, 2014; Chester, 2010; Hughes, 2009; Kruyt et al., 2009; Sovacool & Mukherjee, 2011; Winzer, 2012). The four As provide a strong starting point for energy security, as they include the social considerations of energy acceptability. However, their application to sub-national systems or northern regions is limited and applying them in a northern setting is novel. The Arctic and Subarctic are incredibly unique, heterogenous environments that face a variety of energy challenges and require a multifaceted approach to assessing energy security (Gjorv, 2017). Utilizing the four As allows for this multifaceted approach required in the North, and aids in further understanding the unique needs of remote northern communities.

2.2.1 Case setting

Churchill Manitoba, a subarctic community on the western shore of Hudson Bay, is approximately 1,500km from Winnipeg. With no road access, it relies on rail, air, and sea transportation. Churchill's population is just under 900 people; tourism and the Port of Churchill are the primary employers in this community (Statistics Canada, 2017). Tourism is foundational to it's economy with16 tour operators and 15 hotels (Churchill Chamber of Commerce, 2020; Travel Manitoba, 2020). Churchill is often referred to as a "last chance tourism" destination, marketed as a unique site for viewing disappearing natural environments and wildlife (Dawson et al., 2010; Lemelin & Whipp, 2019). An estimated 6,000 to 15,000 tourists annually visit Churchill, the majority arriving by air (Dawson et al., 2010; Groulx et al., 2016; Huddart & Stott, 2020).

A survey conducted in 2017 found energy reliability, as judged by the community, to be low (Lucas et al., 2018). Between May 2017 and October 2018, the rail line to Churchill was not functional making fuel supplies uncertain. As a consequence of the rail outage, external supplies including propane, gasoline, diesel and jet fuel increased in cos as a result of the supply chain accessibility challenges.

The energy system in Churchill is reliant on sources from outside the community. Non-electrical energy, primarily propane, gasoline, diesel, and jet fuel are delivered by rail. Similar to other northern communities, costs for transportation fuels (gasoline, diesel, jet fuel) are considered very high by community members (Lucas et al., 2018). An approximately 400km transmission line from Gillam, MB delivers hydroelectricity directly to the community. Building age and condition are deemed crucial to the energy profile by community members. Uniquely, the province of Manitoba, through Manitoba Housing, owns and operates a majority the housing stock in Churchill (Distasio et al., 2011). The community is presently in a time of energy transition as the Manitoba government seeks to electrify heating in provincially owned housing (Manitoba Sustainable Development, 2017).

Being a subarctic coastal community Churchill faces unique and increased threats from climate change, disruption of permafrost posseses a substantial threat to the current hydroelectric transmission line, which is Churchill sole source of electrical energy (Burke

& Stephens, 2018; Karanasios & Parker, 2018). The community has expressed desires to explore alternative and renewable energy sources, both through previous research and the 2011 Churchill Sustainability Planning Framework (Distasio et al., 2011; Lucas et al., 2018). In the planning framework, energy planning and visioning are explicitly mentioned as priority areas (Distasio et al., 2011). Due to Churchill's current energy challenges, its increasing vulnerability to climate change, and desire to undertake energy planning, the community is ideally suited for energy security and related research.

2.3 Methods

This research employed a case study design to capture data on Churchill's energy system in a holistic manner. Case studies use multiple data collection methods to obtain a range of perspectives into the case, and are best suited to situations where it is difficult to separate the research subject from its context, such as analyses of communities (Berg, 2007; Merriam, 1988; Taylor, 2016). A community energy consumption profile explored energy use, and semi-structured snowball key-participant interviews and a community workshop identified residents' criteria for a future energy system.

Data on Churchill's consumption of electricity, propane, gasoline, diesel, and jet fuel were gathered from utility providers. 2018 consumption was confirmed as being consistent with past years through key sources and 10-year electricity consumption records. To tabulate the energy profile, 2018 consumption data for electricity, propane, gasoline, diesel, and jet fuel were entered in a Microsoft Excel spreadsheet and converted into kilowatt-hours. Using records from the Town of Churchill, Province of Manitoba, Manitoba Hydro electricity consumption was divided by land use zone and by square footage (Webster, 2016). Electricity consumption was then visualized in a series of maps produced in ArcMap 10.6.1 (ESRI, 2017; Evenson, Margerm, & McDonough, 2013).

Semi-structured interviews were conducted, twenty with residents of Churchill and three with energy industry experts. The interview guide was informed by previous priorities identified by Lucas et al. (2018) and an extensive review of energy security, resilience, and energy planning literature. Interviews explored energy usage, strengths and limitations of the system, and priorities for energy moving forward. Participants were asked specifically to identify challenges in the present system, and their long-term vision for it. Interview notes and recordings were transcribed and imported into Nvivo12 for analysis, along with workshop discussion group notes and vision statement element cue cards. (QSR International, 2018). The coding structure was informed by a literature review of energy security and resilience, and systematic process (Cope & Kurtz, 2016).

A community workshop presented preliminary vision themes from interviews to participants (n=12). These findings were then discussed in two small groups and participants added their own ideas to identify elements they considered important for an energy plan vision statement. Participants wrote their elements on cue cards, grouped them by theme and ranked and prioritized elements using a dotocracy ranking (Wates, 2014).

2.4 Results

Figure 3 illustrates Churchill's energy consumption in 2018. The greatest source of energy was fossil fuels, including nearly nine million litres of fuel, including 5.4

million litres of jet fuel, 2 million litres of propane, 900,000 litres of gasoline, and 660,000 litres of diesel. The town also used just over 27 million kilowatt hours of hydroelectricity. If jet fuel were excluded from the community's energy profile, the primary source of energy is electricity at 50%. Figures 4 and 5 demonstrate how Churchill consumes proportionately more fossil fuels than Manitoba, and slightly less than the nation (Canada Energy Regulator, 2019). However, on a per capita basis the average Canadian consumes approximately 2.5×10^{-4} petajoules (PJ) of fossil fuels annually, whereas the average Churchillian consumes 3.35×10^{-4}PJ, nearly 35% more (Canada Energy Regulator, 2019; Statistics Canada, 2019). Electricity consumption is also greater in Churchill than at the provincial or national level, both as a proportion of total energy consumption and per capita consumption. Residents of Churchill consumed approximately 1.08×10^{-4}PJ of electricity in 2018, whereas the Canadian average is 5.45×10^{-5}PJ, an order of magnitude less than Churchill (Canada Energy Regulator, 2019; Statistics Canada, 2019).

Twelve interview participants and the workshop discussion notes directly connect acceptability with sustainability and environmental considerations. These considerations include reducing total consumption, reducing greenhouse gas emissions, and reducing the risk of spills related to storage and transportation of fuel. The environmental benefits of reducing consumption are combined with a view that increased efficiency will create a more acceptable and secure energy system. Twenty-one interview participants and all workshop participants directly mention the desire for renewable energy generation in Churchill, and all twelve workshop participants note it in their vision theme elements. There is a strong focus on renewable and carbon-neutral energy production using technologies like wind, solar or tidal. High consumption decreases acceptability of Churchill's energy system but can be mitigated through efficiency and the use of renewable energy generation.

> *"Churchill becomes a leader in alternate energy sources. 100% zero net carbon, 100% off grid." (workshop participant)*

> *"I'd say wasting energy is the biggest issue in this town" (participant 7).*

High consumption of energy, especially fossil fuels, is of high concern to community members. Thirteen participants mention infrastructure age, poor building conditions, wasteful behaviours, or the lack of incentives to retrofit creates significant unneeded energy consumption. Fewer noted the decline of provincially run energy efficiency programs for home retrofits and upgrades as a barrier to modernization and efficiency in the community (6,7,11,14,18,22,23.) To address these issues, several participants suggest educational programs in schools or in the broader community to promote the conservation behaviour (participants 5 – 8,11,12,18,19,22,23). The lack of energy efficiency is related to socially and environmentally acceptable energy sources and is strongly linked to a desire for more renewable energy and less fossil fuel usage.

The desire for a more acceptable energy system is further expressed by participants' interest in achieving a greater local agency. All workshop discussion groups and fourteen interviewees discuss how Churchill's energy system is completely dependent upon the south and lacking control over the supply and distribution of energy. Most of the decision making is done outside of the community by large government bureaucracies like Manitoba Housing or Manitoba Hydro. The supply of most energy comes from the south, without local benefit or generation options.

> *"It seems as if major companies have a monopoly on the energy source that are in communities and towns and cities. It's just a shame we can't use what's given to us naturally to help communities and populations and people" (participant 12).*

> *"I think in [10 years] maybe instead of having a provincial body making decisions on energy for an entire province maybe you bring it more down to the regional level and you have local energy co-ops for example." (participant 5).*

The lack of higher education and skilled trades in the community is also identified as a barrier to the maintenance of the current energy system, and the adoption and integration of a future, more sustainable system (participants 7,11,14,18,22-23). A local system would strive to be renewable and use resources closer to the community, relying less on the main grid (workshop participants). The presence of a utility monopoly and the lack of skilled trades result in very little local decision making, leading to a lack of social acceptability and agency.

As a remedy to the lack of agency and acceptability, eighteen interview and all workshop participants mention they desire an energy system unique to Churchill. Frustrated with the lack of control the community has over its energy system three participants envisioned a totally local, not grid connected, self-sufficient energy generation and distribution system. The notion of energy sovereignty is discussed by one interviewee and within the workshop discussion groups. Local generation of energy is seen as key to a sustainable, renewable, local energy system. Local energy generation would require both the technology and skills to repair maintain the system in the community.

> *"I would love the independence. I'm sure there's ways we could do that and not be reliant on sources from the south" (participant 13).*
>
> *"Churchill's energy is produced in Churchill, energy sovereignty" (workshop participant).*

This local energy system envisioned by the community integrates renewable technology and efficiency upgrades to reduce consumptions and emission. In situ generation would also centralize decision making in the community and reduce dependency on southern systems.

Churchillians want environmentally friendly solutions to reduce consumption but need to be aware of affordability. Nine interview participants link the lack of affordability to the community's high per capita energy consumption. Affordability of energy is one of the most prevalent concerns regarding updating and improving the community's energy system. Energy security improvements and technologies that are affordable, and that can be maintained and repaired by the community are key to successful implementation (participants 6,7,11,21,22,23).

> *"My primary concern is the high costs of energy, and the cost to repair and maintain our present energy systems" (participant 21).*

The high cost of upgrading or retrofitting buildings, and the capital costs associated with sustainable or renewable energy projects present one of the largest affordability challenges (participants 1-3,5,7,9,11,13,14,16,18,19-23; workshop discussion notes).

Affordability is seen as a barrier to the implementation of renewable energy technologies like wind, solar or tidal. Cost is consistently mentioned by participants as a key barrier to improving efficiency and sustainability of the energy system.

Affordability of energy is also a barrier to the present system. Fourteen interview participants and the workshop groups directly mention high cost and poor affordability as a primarily challenge Churchill's energy system faces. Most often, concern about high cost is related to hydroelectricity and propane, but also extended to gasoline and diesel.

> *"Cost to diversify [is high] . . .and that all across the board, that's propane that's heat that's hydro. And to do any upgrades, the cost is prohibitive" (participant 17).*

In July of 2019, gasoline cost approximately CAD$2.25/L, and propane cost approximately $1/L. Participants who pay for electric heat in their homes state that in the coldest months their hydroelectricity bills are often over $300 a month. In comparison, the average cost for electric baseboard heat in Manitoba is approximately $100 a month (Manitoba Hydro, n.d.). The high costs of gasoline or diesel fuel for cars is more accepted than high costs of propane or hydroelectricity for heat within the community. Only three participants directly mention the high cost of gasoline or diesel as a barrier. The remainder focus solely on propane and hydro electricity, and only one participant mentions the cost of jet fuel. The affordability of transporting people or goods to and from the community is seen as less related to energy but to the cost of travel. The affordability of energy is one of the most prevalent concerns about the present energy system, especially cost of propane and hydroelectricity.

The availability of power generation within the community itself is minimal. Three participants note the occasional use of wood stoves for heat in trapping cabins outside of the community that are also powered by wind or solar off-grid. However, all primary sources of energy for the community come from hundreds or thousands of kilometers away, either by rail or hydroelectric transmission line. Churchill's reliance on external system is perceived by community members as a barrier to local self-sufficiency:

> *"With the tenuous nature of having a single hydro line that comes into the town you know and there is no sort of plan B like if something serious were to happen to that power supply" (participant 16).*

> *"Well what I'd like to have is I'd like it to be self-sufficient. Realistically, I would like to see us look at renewables a little stronger to supplement the grid and be able to provide that back up system if required even to a point of a limited time" (Participant 14).*

Back-up systems in the form of diesel generators exist for key community infrastructure like the hospital and water treatment plant, but reliance is primarily on tenuous connections to the grid and fossil fuel supply chains. The dependency of the community on external sources and little in situ generation capacity greatly impacts how residents perceive energy availability.

The lack of locally available energy and dependence on external systems is perceived as a barrier to self-sufficiency and disaster preparedness by eighteen interviewees. There are concerns among twelve interviewees and both workshop groups that the present energy system is unable to manage large disruptions or emergencies in its current state. Nine interview participants express anxiety that the energy supply's vulnerability to disruption of the rail or hydro line. Should a disruption occur, there are emergency short-term backups in the town complex, but these are not sustainable or resilient. These worries are exacerbated by a recent 18-month rail outage in 2017 and 2018 that impacted supply of propane, gasoline, and diesel to the community. Nine participants consider a self-sufficient energy system as key to disaster management. However, the rail outage did significantly impact residents' perceptions of energy security, especially of propane, gasoline and diesel, and are reflected in the vison statement.

Six participants envision increased accessibility of Churchill to the outside world and markets as key to improved and reimagined energy security. Innovative solutions that position Churchill as a leader in renewable energy generation and energy efficiency were sought by four workshop participants. Three interview participants note the re-activation of the port provided a strong economic spur for the community and that a new energy system should aim to do the same thing.

> *"[To increase energy security] I think economic investment and development is needed like polar bears international" (participant 6).*
>
> *"Foster new partnerships" (workshop vision theme cue card)*

Increased accessibility to external markets beyond tourism is seen to provide an economic development strategy for Churchill's future that included improved energy systems (participants 6,17,19,23). Opportunities for partnership with business, research, and other communities to share knowledge and increase opportunities for technological advancement are considered by three participants. Increasing accessibility of Churchill's energy system is seen by some participants are key to creating new, more secure, energy systems.

2.5 Discussion

The themes that emerge from the interviews and workshops generally align with the four As and work of energy security scholars (APERC, 2007; Cherp & Jewell, 2014; Kruyt et al., 2009). Energy is available and accessible to the community through rail and hydroelectric transmission line. In cases of previous rail disruptions sea lift was used to ensure accessibility and supply fuel given Churchill's remoteness. Acceptability of the energy system could be increased, as residents desire greater use of renewables sources, increased efficiency, local control and self-sufficiency through local generation. Affordability could also be increased, as many community members cited concerns about their ability to pay for the present and any future changes.

Scholars note that definitions like the four As historically fail to consider social, environmental, and community - level issues in any significant or holistic manner (Ang et al., 2015; Winzer, 2012). This aligns with two themes, agency and efficiency were very prominent in the data, and are not adequately included within the framework of the fours As. To create a more holistic and representative definition, we propose the addition of the elements of efficiency and agency to the four As, resulting in A5E1 (Agency, Acceptability, Affordability, Availability, Accessibility, and Efficiency). This conceptualize redefines energy security to incorporate the specific needs of northern communities in a holistic way that achieves sustainable, local energy management.

The four As of energy security take into consideration the availability of fuel, but not the need for improved efficiency. Increased energy consumption is typical of northern communities, impacting the affordability and acceptability of energy systems (Karanasios & Parker, 2018; McDonald & Pearce, 2013). Churchill exemplifies this with its higher than average per capita consumption of electricity and fossil fuels, using approximately 30 percent more energy than the Canadian average. This results in disproportionate emission, and a strong desire by communities for efficient and sustainable energy. Northern communities are on the forefront of climate change, they are most likely to be impacted severely with the least capacity to adapt (Karanasios & Parker, 2018; St. Denis & Parker, 2009). Efficiency is crucial for reducing emissions of greenhouse gases, and reconsidering energy security to include the element of efficiency produces energy that less emitting. High consumption also increases costs, in the north energy can be three to ten times the cost than in southern Canada (National Energy Board, 2016; Rezaei & Dowlatabadi, 2016). As a result, Churchill's energy system is less affordable, less acceptable, because of its high consumption. Considering efficiency in the energy system is an important step identified by the community in mitigate these challenges and makes the four As more robust and applicable to northern communities.

Churchill's high fossil fuel use, especially of jet fuel demonstrates the lack of sustainable options in northern communities and the need for increased efficiency. Churchill's reliance on air transport for people and goods is environmentally damaging, and unaffordable. In 2019 round trip air fare between Churchill and Winnipeg was over $CAD 1,700 per person, limiting the mobility and agency of community members. This portion of the energy profile is only mentioned by one participant, and jet fuel is not generally perceived by the community as part of its energy consumption. Tourists are a significant user of air transport and thus jet fuel. Churchill's unique and accessible wildlife makes it a globally unique destination, attracting thousands of visitors a year (Dawson et al., 2010; Groulx et al., 2016; Huddart & Stott, 2020). The majority of tourists arrive by air which explains a portion of the high jet fuel consumption. Churchill is very dependent on airfreight for its connection to the outside world, as demonstrated by its staggering jet fuel consumption, but this is not often considered as related to energy by the community. There are massive social and environmental implications of this high consumption. The reliance on external systems of shipping and transport further reduces agency and efficiency and removes local capacity from the community.

Agency is incredibly important by communities that are far removed from their energy sources. Many of the criticisms include that Churchill is reliant on shipping and external decision making. The capacity of the community to improve the present system using its current capacity is limited, and frustrating for residents. This desire is expressed within the interviews and workshops as desires for self-sufficiency, local control, education, and skills training. Churchillians feel that they lack agency in their current system through its high cost, the lack of consultation or decision-making power, and lack of in situ generation.

Manitoba is unique in that a state-owned monopoly, Manitoba Hydro, controls and delivers electricity in the province. Manitoba Hydro's offices and board are located in the provincial capital of Winnipeg, nearly 1000 km away from Churchill. As a result, local decision making about electricity is almost non-existent. Other energy sources are controlled by private utility companies, only one of which has a human presence in

Churchill. Residents feel that they are subject to the system rather than a part of it. This is compounded by the fact that a significant portion of housing in Churchill is also government owned and managed, meaning tenants cannot install their own energy efficiency upgrades or makes choices about their energy. Further, no Manitoba Housing tenants in Churchill pay for utilities, which led some residents to speculate if a lack of financial incentive leads to unnecessary consumption. There is a lack of any direct agency in Churchill's present energy system for residents.

Agency is needed in order to bring about the desired new energy system in Churchill. Government ownership of housing, energy monopolies, and private utilities reduce agency in the present system and thus Churchill's ability to take independent action for it's future. The community lacks the funds and skilled trades people to effectively transition to renewable and local energy generation. Increased agency must include Churchill having the capacity to explore the changes it needs to make to ensure energy security. Participants express the desire to simply live at the same standards as southerners: to have affordable, reliable, acceptable energy that they have a say in.

Managing energy at the local level is crucial for long-term sustainability and requires a new components of energy security (Canada Mortgage and Housing Corporation, 2000). The local management of energy keeps social and economic benefits within the region, while increasing local resilience and decreasing fossil fuel use (Alanne & Saari, 2006; Burke & Stephens, 2018). The COVID-19 pandemic highlights the crucial need for local energy security, and the unique challenges faced by remote northern communities (Chura, 2020; Graff & Carley, 2020). Local control and self-sufficiency as desired by the community are necessary for long-term sustainability, but are not completely captured by the four As. The addition of agency to the four As more completely reflects the realities of energy security in the north.

Community interest in achieving increased acceptability can be achieved through efficiency. Barriers to acceptability such as high fossil fuel use and aging infrastructure can be solved with an efficiency consideration. Energy efficiency upgrades and programs were mentioned by seven participants and would be a strong starting point at reducing consumption. Acceptability can be further increased through the usage of renewable energy generation technologies in situ, something strongly desired by nearly every participant. The barriers to acceptability can be partially mitigated through efficiency, and utilizing renewable generation as suggested by the community.

The four As focus on macro-scale accessibility and availability of energy delivered by centralized national energy systems and the security of fossil fuel supplies and infrastructure (Kruyt et al., 2009). Churchill does not fit well within the centralized grid given its isolation and tenuous connection to it. The loss of Churchill's rail in 2017 and 2018 is a pertinent demonstration of how centralized energy systems are tenuously connected to northern communities and how their disruption can jeopardize the accessibility and availability of energy. The external provision of energy, while impacted by tenuous availability and accessibility, is a matter of agency. Redressing Churchill's need for local generation and reliable energy can be achieved through increased agency and a local energy system as opposed to centralized grid.

Modern energy systems and definitions of energy security have failed to adequately provide energy systems to the North that are sustainable. Communities in the Canadian North like Churchill experience unique energy challenges; a lack of reliable and affordable energy, a disproportionate use of fossil fuels, and often bear the burdens of large-scale energy production. Southern paradigms do not apply well to northern communities and need to be personalized to the unique conditions of the North. Assessing energy security in Churchill can be done more robustly by including the elements of agency and efficiency into the four As. Utilizing A5E1 includes the strengths of the four As definition, and adds essential elements to strengthen energy security as identified by community members in Churchill. A5E1 more effectively captures the needs of the community and provides a more accurate reflection of Churchill's energy system and how it is perceived by the community.

2.6 Conclusion and Policy Implications

One key observation in energy security literature has been the contextual and changing nature of energy security (Ang et al., 2015; Chester, 2010; Sovacool, 2011; Winzer, 2012). Past definitions of energy security are now being phased out because they were only fuel and supply oriented and are no longer applicable to holistic energy systems. Future definitions of energy security that consider long-term sustainability with carbon free renewable sources will be just as important in shaping future energy systems as past definitions have been for past systems. Under traditional definitions of energy security northern communities were considered secure as they had a source of fuel, but a more nuanced, holistic approach reveals the gaps left by traditional definitions.

Ultimately, considerations of energy security are imprecise and subjective. Many energy security concerns within Churchill are multi-faceted, and do not fit neatly into one category. There is substantial overlap in the needs and desires of the community among numerous elements and conceptualizations of energy security.

That being said, the four As of energy security do not completely address the unique needs of northern and remote communities, but can be built off of. Through modelling Churchill's energy system and understanding criteria for alternatives as presented by community members, an alternative framing of energy security for the north is contemplated. A5E1 (Agency, acceptability, affordability, availability, accessibility and efficiency) incorporates the elements of efficient and agency into the existing four As of energy security definition to better reflect the requirements for energy security in northern Canada. Re-framing energy security as A5E1, is in line with the subjective nature of energy security and better defines it for the circumstances in Churchill.

Declaration of competing interest

Dr. Fishback is community member and resident of the study site, Churchill, Manitoba, Canada. The other authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Michael Kvern: Conceptualization, Methodology, Formal Analysis, Investigation, Data Curation, Writing – Original Draft Preparation, Writing – Reviewing and Editing, Visualization, Funding acquisition. **Patricia Fitzpatrick:** Conceptualization, Methodology, Resources, Writing – Reviewing and Editing, Supervision, Project administration, Funding acquisition. **LeeAnn Fishback:** Resources, Writing – Reviewing and Editing, Supervision.

3.0 Discussion and Conclusion

3.1 Community Energy Profile and Maps

Modelling Churchill's energy system is a key goal of this research, which is achieved through the energy profile and associated maps. The energy profile illustrates Churchill's high energy consumption, especially of fossil fuels. More importantly, it provides baseline data to community decision-makers on where and how their energy is used.

Energy mapping provides a baseline of present community usage, and also be used to model various future scenario (Evenson et al., 2013; Webster, 2016). Energy maps tend to focus most often on building energy use, which primarily consume electricity and natural gas for heat. Transportation energy use is more difficult to map, as it is inherently mobile, and consumption is not linked to a specific location. But is very important to include as transportation is a significant contributor to GHG emissions. In some CEPs, separate transportation maps are made to illustrate transport demand, along with aggregate figures on community transportation energy consumption (Evenson et al., 2013).

Community energy mapping can provide a variety of benefits at and beyond the community level. Within a community, mapping allows identification of hot spot areas where conservation efforts can be most effective (Evenson et al., 2013; Reul & Michaels, 2012). More broadly, mapping leads to a better understanding of energy consumption and where GHG emission can be reduced (Webster, Korteling, Gilmour, Margerm, & Beaton, 2011). Mapping exercises done with community members can directly mobilize knowledge within the community, and set a local vision for energy (Evenson et al., 2013). Results of mapping, can allow researchers and policy makers access to data on communities, and opportunities to explore research questions(Reul & Michaels, 2012). Community energy maps serve a variety of purposes, but it is important that they operate in tandem with CEP or other planning processes so their results can be integrated into beneficial policy that achieves progressive in the community.

During this thesis energy maps of Churchill was produced, which focus on the community's electrical consumption. Transportation energy is not mapped due to the common challenges noted above. Propane consumption data is at community level with no spatial association. Electricity is the sole energy source with the appropriate link to location to enable mapping. It is mapped at the land use zone level to protect confidentially.

Map 1 illustrates how consumption of electricity varies across land use zones. The Public and Recreation zone consumes the most electricity, because one of the largest buildings, the Town Complex is within this zone. The Town Complex is a unique structure that houses most of Churchill's amenities including the school, daycare, hospital, town administration office, hockey rink, curling rink, pool, gymnasium, theatre, and community hall. Further making this building unique, it is heated by electric boilers whereas as most residential and industrial heat in Churchill is propane. The Town Complex's large size, numerous functions, and electric heat all account for the Public and Recreation zone's electricity consumption.

The Limited Development zone's higher usage is a factor of it housing most of the town's utility services. The landfill, water treatment plants, sewage plant, and several pumping stations all of which are powered by electricity are in this zone. Residential usage is a significant component of community energy, and it is important to note that electricity data does not distinguish between uses, such as heating, which is a key use in Churchill. Commercial and industrial zones consume the least electricity per square foot. In part due the size of these zones, but also the nature of their use. Industrial activities in Churchill consist mainly of the port, which uses high amount of diesel and propane not captured in this map. This is the same for the commercial zone, which includes many propane heated buildings, and tourism operators which use high amounts of diesel and gasoline.

3.2 Vision Statements

Resulting from the analysis of interview and workshop data are the key themes expressed by participants, as discussed in the manuscript above. These themes provide important insight into how the community views its present energy system, and where it wants to go in the future. To that end, several draft vision statements emerged from the data analysis:

- Through the use of renewable generation technology located in the community, Churchill aims to be a leader in northern sustainability and example of the feasibility of generating energy in Churchill for Churchill.

- Generation of energy in Churchill and for Churchill using renewable technologies that allow for self-sufficiency in an affordable and practical manner.

- Using renewables, Churchill aims to generate its own energy within the community, focusing on becoming carbon neutral and creating a system that can be operated and repaired by local who possess the necessary skill and knowledge to do so

Theses vision statements reflect community priorities and serve as working guidance for a community energy plan. The vision statements are now in the ownership of the community and will inform the next steps of Churchill's energy planning.

3.3 Contributions to Knowledge

Northern communities experience uniquely high rates of energy insecurity. Prices are often higher, service is less reliable, and generation is more fossil fuel based (McDonald & Pearce, 2013; National Energy Board (NEB), 2016). Churchill is an energy insecure community, with low fuel diversity, high costs, and a severe susceptibility to climate change. This research provides Churchill with baseline energy data and a cohesive vision to guide subsequence energy planning and the potential creation of a CEP. A CEP provides understanding of community energy usage, and identifies opportunities for conservation and alternative energy generation (Keewaytinook Okimakanak & Idenpendent Electricity System Operator, 2016). For Churchill, a CEP would enable the community to understand its energy system and take actions to increase resilience of its system either through conservation or generation of energy.

Previous University of Winnipeg research found that the town desires to establish a community energy plan and explore alternative energy (Lucas et al., 2018). This aligns with goals set out in Churchill's Sustainability Plan, and discussions between Dr. Fitzpatrick and the Town of Churchill (Distasio et al., 2011). This research provides the data needed to identify a vision for a CEP and potential energy options (conservation or generation within the community), which allows Churchill to become more energy secure, resilient, and sustainable. Through this project, the Town of Churchill is able to explore a CEP and create the more sustainable energy system they desire.

While this research was limited to a singular case study, it is supported by a broader network of research through the Community Appropriate Sustainable Energy Security (CASES) partnership. The CASES partnership is a joint venture between industry, government, and northern and Indigenous communities to "reimagine energy security by co-creating and brokering the knowledge, understanding, and capacity to design, implement and manage renewable energy systems that support and enhance social and economic values" ("CASES - Renewable Energy Homepage" n.d.). The partnership seeks to frame energy security for the unique and specific needs of northern and Indigenous communities and jointly establish local energy systems that improve community benefit. With an established energy profile and community vision, the foundation now exists for future planning and implementation of a renewable energy system in Churchill through the CASES partnership. The findings from this case study will be shared and applied to other northern communities in Canada and internationally.

Because of Manitoba's monopolistic energy market, CEPs are rare in Manitoba. This research would serve as a model for other communities, especially remote or subarctic ones, to develop local, sustainable strategies. Mapping of energy systems to model consumption is a underutilized method in Canada, with few examples but many practical applications. The integration of resilience and energy security on the micro-level of a single community is scarce within academia, this research would provide knowledge to fill that gap. This research also directly contributes to environmental stewardship by promoting a planning process for a reliable, affordable and sustainable energy system in Churchill that would reduce greenhouse gas emissions.

3.4 Conclusion

Using Churchill, Manitoba as a case study this research examines how energy security function at the level of a community. Traditionally, energy security is not considered at the level of individuals or communities. Further, definitions do not fully account for the unique needs of remote northern communities. This research begins the process of providing tangible energy security solutions to Churchill, while reconceptualizing academic considerations of energy security.

This thesis is the beginning of a CEP for Churchill that will allow the community to work toward a more sustainable and desirable future. An energy consumption profile and draft vision statements enable the creation of a CEP. Data from twenty-three interviews and community workshop provide insight into what the community envisions for its future energy system, and the barriers and strengths of the present system.

A critical analysis of energy security definitions and their relevance to northern energy system takes place in the manuscript. Applying the findings from Churchill, especially interview and workshop themes, illustrates that contemporary energy security definitions do not entirely capture how energy security is lived and perceived by northern residents. The foundational definitions of the fours As of energy security reflect the majority of energy security needs in the north, but have two main gaps. Participants identify that agency and efficiency are crucial yet absent in their energy system. To better define energy security, we propose that agency and efficiency be combined with the four

As to create A5E1. This conceptualization better reflects the unique realities of northern energy systems and their end users.

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5.0 Figures and Maps

Figure 1: Length of time interviewees have resided in Churchill

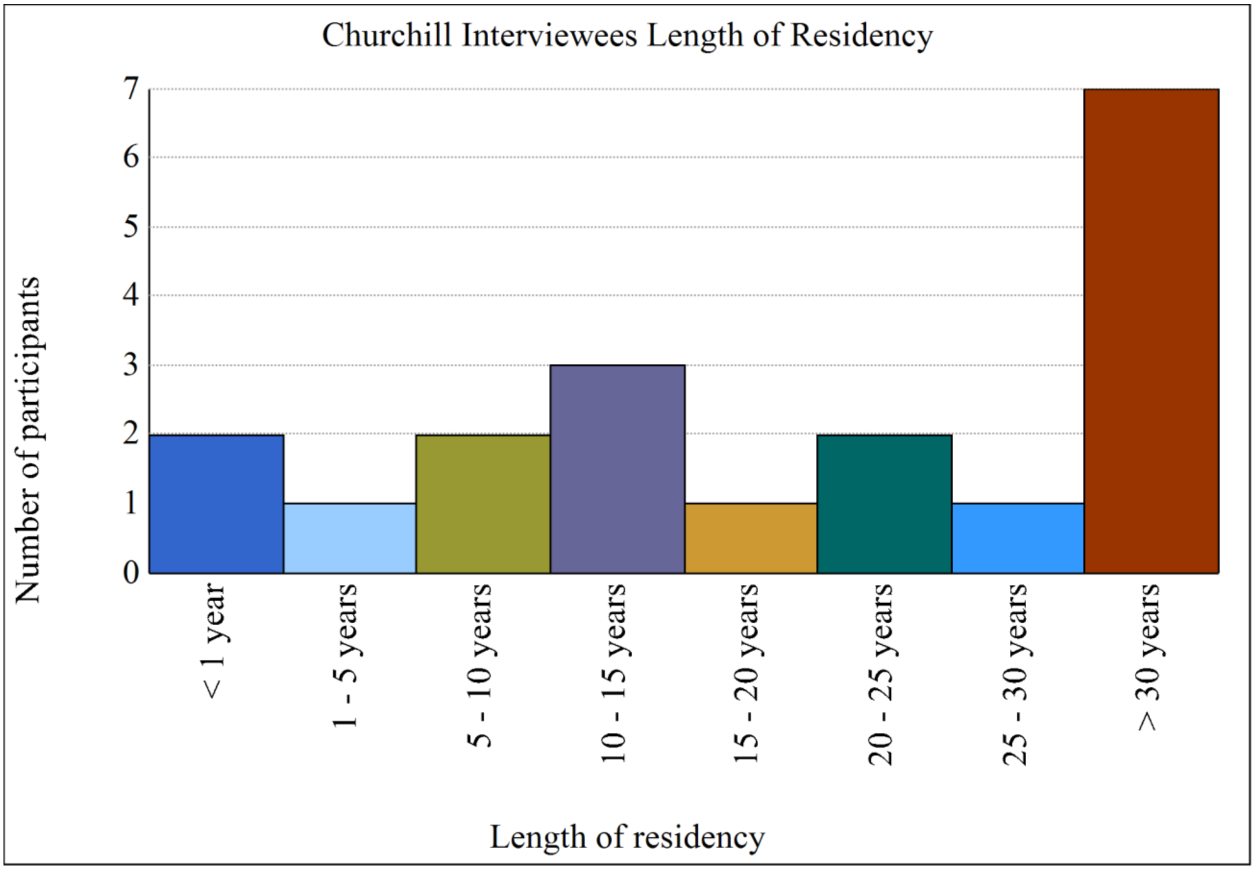


Figure 2: Occupations of interviewees

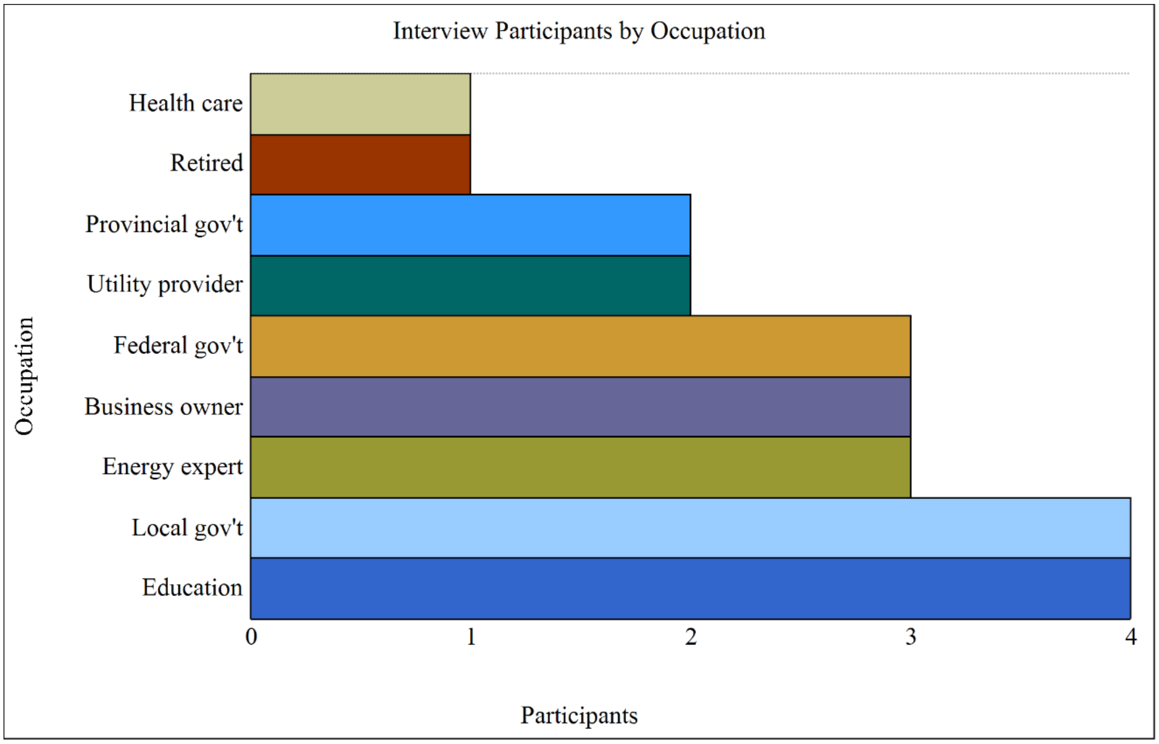


Figure 3: Proportions of Churchill total 2018 energy consumption (Consumption did not differ significantly from earlier years, even with the 18 month rail outage in 2017).

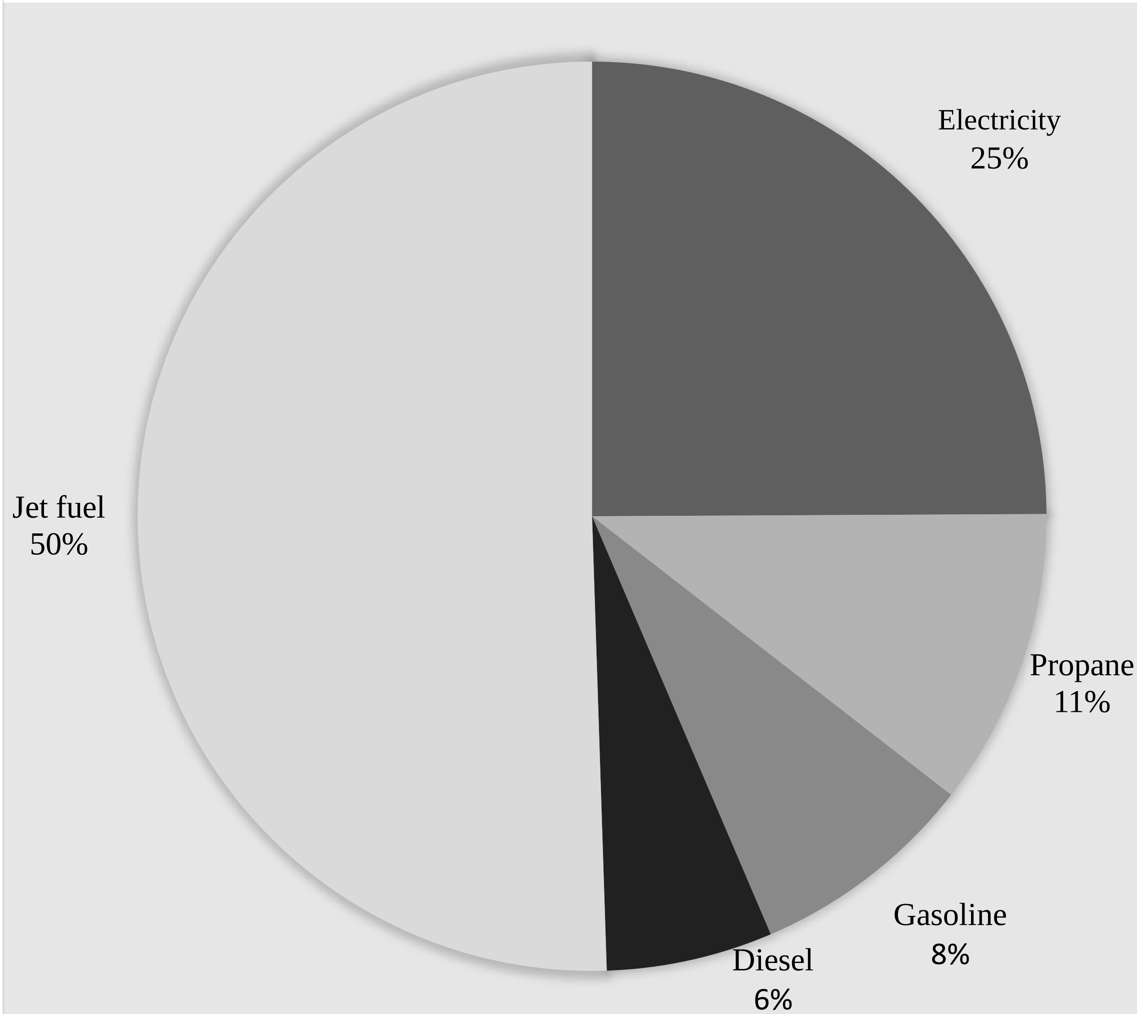
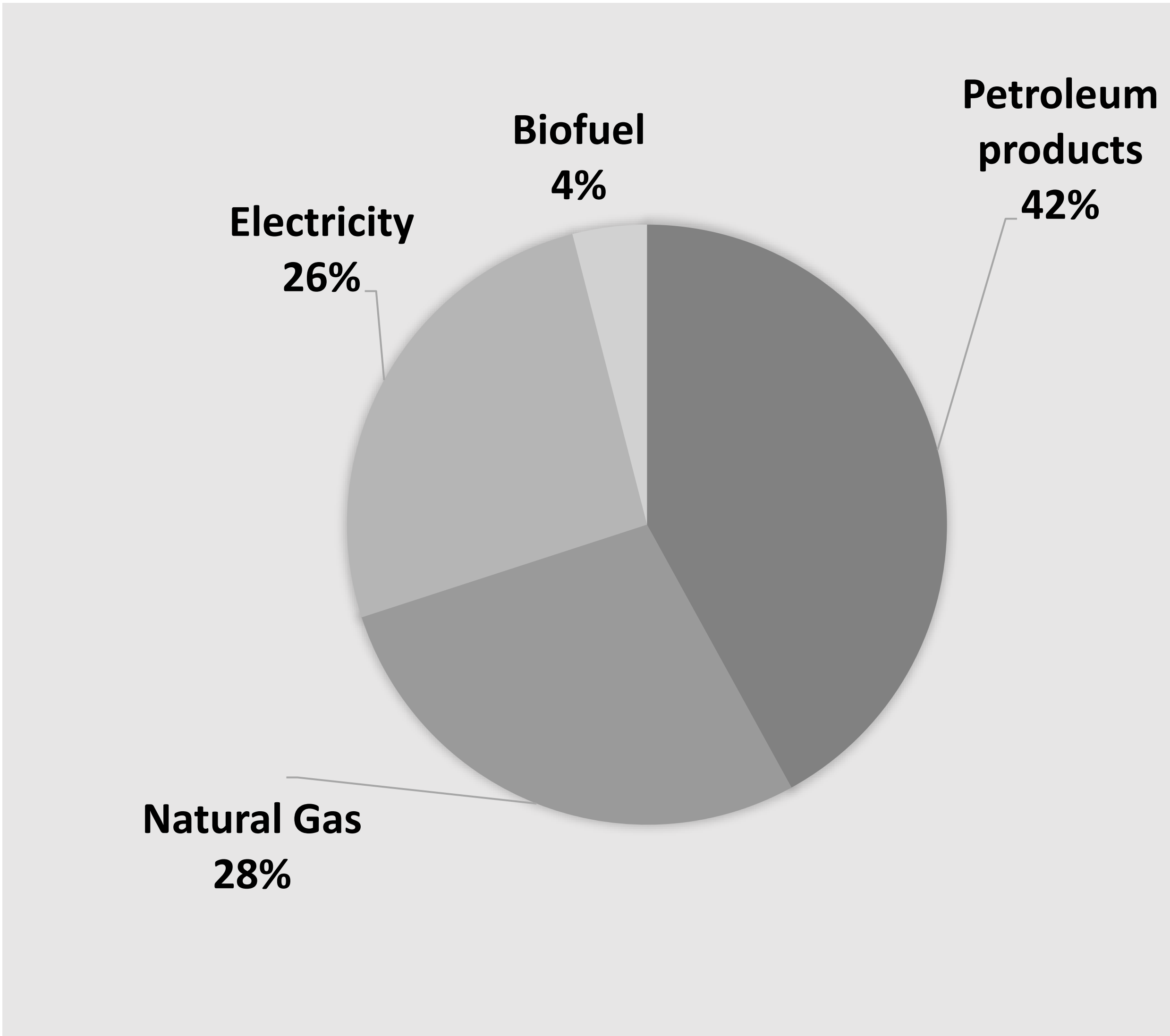
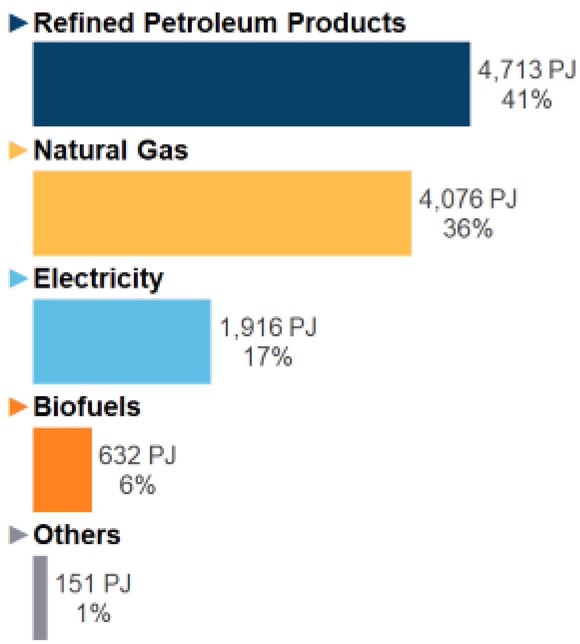


Figure 4: Manitoba 2018 energy consumption by fuel.



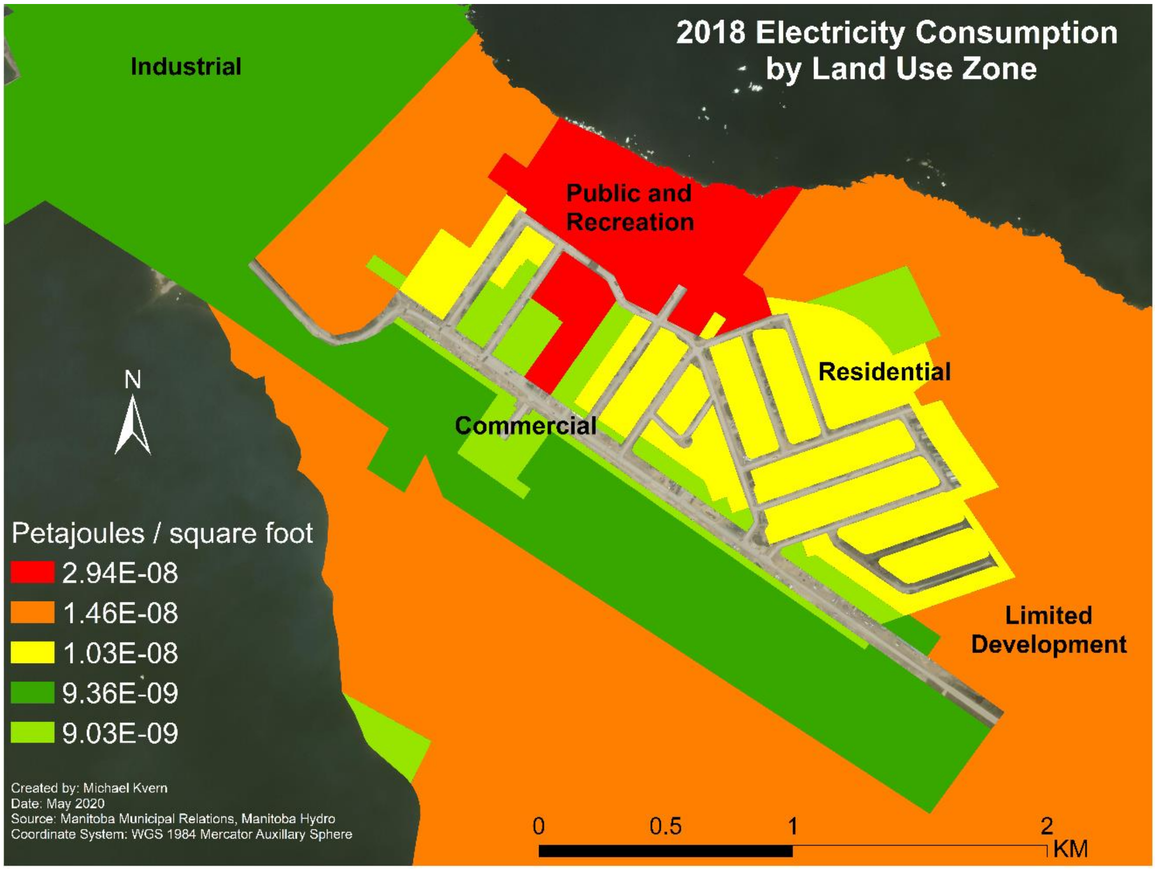
Source: Canada Energy Regulator, 2019

Figure 5: Canadian end-use energy demand 2017.



Source: Canada Energy Regulator, 2019

Map 1: Churchill 2018 Electricity Consumption by Land Use Zone



6.0 Appendices

6.1 Appendix A: Research questions

1) What do you do?

2) Do you know where your power comes from?
   Prompts: Electricity? Heating? Fuel?

3) What are important elements to consider about energy?
   Prompts: Generation? Conservation? Transportation? heating? For electricity? Passive?

4) Which of these elements would be most important in an energy plan for Churchill?
   Prompt with responses to #2, or Prompts: Generation? Conservation? For transportation? For heating? For electricity?

5) What challenges do you think Churchill faces, with respect to energy?
   Prompts: Individual aspects? Community aspects? electrification? MB Housing?

5(a) If appropriate, probe the reason for these challenges

6) What can be done with the energy system in Churchill to make it better at withstanding change and uncertainty?
   Prompt: individual changes; community changes; government supports;

7) What sort of changes would you like to see to Churchill energy system?

   Prompt: Do you think Churchill should invest in renewable energy generation?

   Prompt: How much effort should be put into conservation of existing energy?

8) What changes, with respect to energy, would you prioritize for the community?
   Prompt: Do you have ideas as to how to implement these changes ?

9) Are they things you want to do at an individual or household level? <if business, say business level>
   Prompt: Rebates etc. What could be done to support these changes? Passive solutions?

10) In 10 years, what do you want Churchill's energy system to look like?

11) Does that change if I say 25 years?

6.2 Appendix B: Workshop discussion questions

1) In your opinion, what are the main issues or challenges surrounding energy in Churchill?
2) What opportunities do you know of to help address energy challenges?