DEPENDENCE ON ELECTRICITY AMONG
THE INHABITANTS OF THE RURAL WESTERN ARCTIC

ABSTRACT. This paper reviews the electricity dependence of inhabitants in the western Arctic and provides an overview of past developments of electricity supply and how the current relation between the inhabitants and electricity is structured. In the Arctic, electricity takes on a special role due to its importance for security in addition to a matter of entertainment and productivity as seen in more temperate areas (Allen et al. 2016). This paper discusses the importance of electricity in the North, including the questions of what would happen to Arctic communities in the absence of an electricity supply. A hypothetical case of a blackout is presented. Furthermore, the burden of high electricity costs in the Arctic is discussed. The results of this research may contribute new knowledge for further research on the potential energy transition in the Arctic. Furthermore, the results emphasize the importance of energy and its supply security in the Arctic, which provides support for a focal point on energy security for energy transition policies.

KEYWORDS: energy, renewable energy, affordability, mixed economy, value of lost load

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INTRODUCTION

The history of electricity generation in the Arctic dates back more than 100 years. One of the first hydro power plants in Alaska was built in the 1890s (AEL&P 2019). In many places in the Arctic the development of electricity infrastructure has taken place along with economic development. In the first days of the electrification of the Arctic the main economic drivers were trapping and mining. The Arctic Gold Rush, in particular, caused many people to move into the Arctic. It was followed by mining for other minerals and resources such as coal, diamonds, lead, zinc, etc., as well as recent on and off-shore oil projects (Kirk, Miller 2018; Gazeev et al. 2018; Alaska Department of Natural Resources 2019; Larsen, Huskey 2020).

Remoteness, lack of accessibility, and isolation are common characteristics of communities in the Far North, including Alaska, Yukon, Northwest Territories, Nunavut, Greenland, Svalbard, North-Western Russia, Ural, Siberia and the Russian Far East (Kaufman 2016). These communities have no connection to a regional or larger continental electricity grid. In the case of Finland and Sweden, however, such communities are fewer or non-existent. Over the past decades, remote communities have developed a strong reliance on diesel as a source of electricity generation (Chade et al. 2015; Boute 2016). This reliance has put the communities on a path of dependency, and the infrastructure has adapted to the needs of diesel (MCDonald, Pearce 2013). Breaking out of the path of dependency requires a significant effort (Sterman 2000). In the case of electricity supply, an economic and technological effort would be needed to shift the electricity generation setup. In the following, the relationship between Arctic inhabitants and electricity will be discussed. The focus is on two major issues. Firstly, the strong need for electricity by Arctic communities is analyzed. In the Arctic, electricity is not just a matter of productivity and entertainment, it is also essential for health and security due to the region’s remoteness and harsh environmental conditions (Allen et al. 2016). Secondly, the cost burden of electricity is considered, as high electricity costs create a considerable challenge in areas with existing high unemployment and poverty (Coates, Poelzer 2014; Koivurova et al. 2008). Under these conditions high cost of electricity can lead to increased social and economic problems. This study will discuss the question of the potential benefits in terms of reduced social costs of breaking the path of electricity dependency.

METHODOLOGY

The basis of the analysis of the value of lost load (VoLL) comes from the literature, which describes the situation in North America and Europe (Bliem 2005; Schröder, Kuckshinrichs 2015; Anderson et al. 2018). In North America and Europe, the main difference in VoLL is related to the difference in economic productivity. Some studies have shown high values for VoLL of up to 250 US$/kWh (in the US and New Zealand) (Schröder, Kuckshinrichs 2015). In other places the values can be much lower, depending on the economic power and type of economy. In the present research two scenarios are presented, firstly a blackout during the summer, and secondly a blackout during the winter. The winter scenario is unique in the Arctic due to the harsh and very cold climatic conditions during the winter (Government of Canada 2011).

In this study, dealing with the burden of electricity costs in Arctic areas, we use the database from our previous study on energy consumption and production patterns in the Arctic (de Witt et al. 2020). Some additional data has been gathered to carry out the present study. From the previous study the electricity consumption in the communities under discussion was known, but for the current research it was necessary to extend the data collection with data on the income structure in those communities. This information was publicly available from the national statistical offices and the national census. Several analyses on the burden of electricity cost in the Arctic were conducted using data collected for this study.

RESULTS

Economies of communities in the Arctic differ from those of the Western Hemisphere. Today subsistence continues to make an important contribution to social and economic life in northern...
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Local economies are a combination of market based and non-market based traditional economies (Poppel, Kruse 2009; Harder, Wenzel 2012; BrunSilver et al. 2016; Larsen, Huskey 2020). Since the middle of the last century modern technology, such as snow machines, rifles and the housing situation with home appliance, has changed the economy (Harder, Wenzel 2012; Wenzel 2013). To acquire such technologies money was needed and both types of economies have merged to form a mixed economy. It can be observed that the catch is shared among the members of the community, and hunting is a community effort (Harder, Wenzel 2012; BrunSilver et al. 2016). The informal part of the economy is often neglected in income databases for the region, and therefore we attempt to estimate the value of the informal economy in this study.

SIMULATION OF A BLACKOUT

The value of lost load (VoLL) describes the monetary impact associated with an interruption in electricity supply (Schröder, Kuckshinrichs 2015; Anderson et al. 2018). The value of lost load (VoLL) takes into account the loss in economic production as well as losses in social life. VoLL can vary significantly in different areas. For example, the study of Anderson (2018) calculates a VoLL of 100 US$/kWh for New York south of 42nd Street after Hurricane Sandy in 2012. This high value is due to the high financial power in that particular area. Studies for other areas show much lower values, e.g. in Austria where VoLL was estimated to be approximately 10 US$/kWh (Bliem 2005). In the Arctic it can be expected that the VoLL is relatively low due to the small sizes of local and regional economies. However, a blackout during the harsh winter months could lead to a breakdown in the utility infrastructure—bursting freshwater pipes and district heating pipes. This very close relation between the inhabitants and energy will be further studied in the following simulation. To show the special Arctic situation, two scenarios have been constructed: firstly, a blackout during summer times, which can be seen as a base case that considers economic and private losses; the second scenario, more specific to the Arctic—a blackout under the harsh conditions of Arctic winter, which still considers economic and private losses, but also includes the losses from damages to the utility infrastructure.

The usual implications of a blackout are represented in Figure 1. The first implication is for the private life, which represents the inconvenience in recreational routines, such as watching TV, listening to music, browsing the internet or socializing with other people, which can be disrupted. Tagging this with a monetary value is very complicated, because everyone values their recreational activities differently. Some things, such as meeting friends, are nice to have, others are a necessity, for example housekeeping. The private part of VoLL must also include the damage to food from non-working fridges and data losses on computers due to the blackout. Some literature estimates a value of 10 US$/kWh for private losses (Bliem 2005; Schröder, Kuckshinrichs 2015). For the Arctic a similar, although perhaps slightly lower value can be assumed due to a reduced offer of activities. As already mentioned, the economic loss is very dependent on the economic activities. In the Arctic different types of communities can be seen, with different kinds of sustenance. This paper takes Kotzebue in Alaska as an example to estimate the VoLL. The VoLL is calculated as shown in formula (1).

The Gross Regional Product (GRP) per capita in Alaska was 59.420 US$ in 2018 (FRED 2019). This value does not capture the informal economy, and therefore provides a biased estimate. People in the Arctic participate in both informal and formal economies, of which only the reported part (the formal
economy) is captured in official statistics (Schmidt et al. 2015). The population of Kotzebue was 3,154 in 2017 (Alaska Energy Gateway 2019). The commercial electricity consumption of Kotzebue was 10,407 MWh in 2013 (Alaska Energy Gateway 2019). All this leads to an approximation of the VoLL of 18 US$/kWh in Kotzebue. However, since the GRP per capita used in the calculations is the average for Alaska, this value is an approximation. For a more meaningful VoLL it would be necessary to examine the economy of Kotzebue in more detail. It can be expected that the basic healthcare system continues to be provided, with the help of back-up generators in the hospital.

Subsistence has a significant social and cultural importance among Inuit communities. A closer look at the technologies used for subsistence activities shows that they are relatively independent from electricity, e.g. snow-machines, all-terrain vehicles, motorboats and rifles (Wenzel 2013), which suggests more reliance on fuel than on electricity. Therefore, the informal segment of the mixed economy is not included in the following.

During winter the harsh Arctic climate creates an additional impact on the utility infrastructure. The absence of electricity can cascade down to the fresh water supply and, if available, to the district heating system, as represented in Figure 2. The missing heating and electricity can have a negative impact on
people in the cold climate and may reduce the health safety (Allen et al. 2016). Private and health care losses may lead to a social loss, the size of which is difficult to determine since it is partly on the economical side and social side and can be also influenced directly and indirectly by the interruption in electricity delivery (Bliem 2005; Schröder; Kuckshinrichs 2015). Losses due to health care and social challenges lead to an expected higher VoLL value in winter than under normal conditions in the presented study. The literature has estimated high values for the private VoLL to approximate 40 US$/kWh in Tol’s research (Schröder; Kuckshinrichs 2015). In the winter an additional reparation cost for utility infrastructure must be added to the 18 US$/kWh. The utility reparation cost cannot be expressed in terms of dollar per kWh. Furthermore, the reparation of utilities such as water and district heating can prolong the loss in the industrial sector. Fisheries is one of the main industries in the Arctic, and water is needed for fish processing (Dybbroe 2008; AMAP 2018).

**BURDEN OF ELECTRICITY COST FOR THE INHABITANTS OF THE WESTERN ARCTIC**

High rates of unemployment and poverty present significant challenges in many parts of the Arctic, and even more so in many indigenous communities (Koivurova et al. 2008; Coates, Poelzer 2014). The following shows the impact of electricity costs on the life in northern communities. As shown in Figure 3, the cost burden in rural Alaska is significant, with up to 45% of the net income spent on electricity. Therefore, it is assumed that the average consumption per household is 572 kWh per month in 2018, with the average household accommodating 2.74 people (US Census 2000; EIA 2018).

<table>
<thead>
<tr>
<th></th>
<th>Non-Indigenous</th>
<th>Indigenous</th>
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<tbody>
<tr>
<td>Population</td>
<td>16</td>
<td>2.768</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>6.329</td>
</tr>
<tr>
<td>el. Price (US¢/kWh)</td>
<td>20</td>
<td>116</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>181</td>
</tr>
<tr>
<td>Income per capita US$</td>
<td>8.761</td>
<td>31.747</td>
</tr>
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<td></td>
<td>5.469</td>
<td>28.941</td>
</tr>
</tbody>
</table>

Table 1 shows the main properties of the comparison, with 164 samples collected in Alaska, of which 143 communities were recognized as indigenous ones, and the remaining 21 not recognized as indigenous communities, and therefore categorized as non-indigenous ones. A more detailed look at the situation shows different patterns for communities, which are recognized by the state as indigenous entities and are eligible by the state to receive services from the US Bureau of Indian Affairs (US Bureau of Indian Affairs 2019). In terms of community size and electricity prices it can be seen that the range for indigenous communities is larger, but, as seen in Figure 4, the average values of indigenous and non-indigenous communities are close together. In terms of monetary income per capita, for the average non-indigenous communities it is considerably higher, i.e. 13.138 US$ on average in indigenous communities compared to 19.086 US$ in non-indigenous ones. The studies of Wenzel (2013) and BurnSilver (2016) show that the catch per capita is 120-360 kg per annum for several villages in the Alaskan and Canadian Arctic. This would add approximately 1.200 - 3.600 US$ per year to the per capita income in natural goods, with a price of 10 US$ per kg of harvested goods accordingly (Wenzel 2013). This would increase the income of indigenous people in the Arctic. For the non-indigenous villages, the cost of electricity is 11% of their income ad maximum. For the indigenous communities the maximum is at 30%, which is nearly three times as high as for non-indigenous communities.
The different lifestyles of indigenous and non-indigenous communities may, however, affect the electricity consumption. Among indigenous communities, where subsistence is customary and makes up an important part of material wellbeing of households, the demand for electricity may be lower. We therefore attempt to account for this effect as well and the collected data on electricity sales for residential purpose. Figure 5 shows that the burden of electricity costs for indigenous communities is much lower than in the previous, more generalized, analysis, but it is still high. The big difference between the previous graphs (Figure 3) leads to the conclusion that electricity consumption in the connected part of Alaska must be higher, to lift the average electricity bill per household up to 572 kWh per month.

The previous steps have analyzed the burden of electricity in remote Alaska within the context of the formal economy. At the next step the informal economy is introduced to account more accurately for the burden of electricity costs in the case of a mixed economy setting (see Figure 6). Therefore, two scenarios have been established: a low subsistence scenario, which adds 1.200 US$ to the income per capita in indigenous communities; and a case of high subsistence, which adds 3.600 US$ to the indigenous income per capita. The origin of the values is explained earlier in this section.

Results for the Canadian Arctic can be expected to be similar to the US Arctic, since the lifestyle is similar and both regions have high rates of poverty and unemployment. The main difference in this sense is that in the Canadian Arctic the cost of electricity is slightly lower that in the US Arctic.

A look at Greenland shows a completely different picture. The highest percentage of net income spent on electricity is seven percent. As shown in Figure 7, the difference between towns and settlements is not big (in Greenland the distinction between town and settlement is defined by a population of 1.000 inhabitants). In January 2018, the Greenlandic government launched a new policy of uniform prices for electricity and water (Government of Greenland 2018). Since then, all communities in Greenland pay the same price for electricity, which has resulted in huge savings for remote places. For example, the government predictions show cost savings of 51% for water and electricity for a family (two parents and two children) in Sarfannguit (Naalakkersuisut 2018).
Figure 4 Comparison of net income, spent in rural Alaska on electricity by indigenous and non-indigenous communities, with the Alaska average electricity consumption. The data set is the same as in Figure 3, but the communities have been grouped into indigenous and non-indigenous ones according to (US Bureau of Indian Affairs 2019).

Figure 5 shows the net income spent on electricity in relation to the local electricity consumption. While in Figure 3 and 4 the average consumption of Alaska was the base, Figure 5 took the residential electricity sold and divided it by the population of the community.
Figure 6 shows the net income including subsistence spent on electricity in relation to the local electricity consumption (low subsistence scenario net income + 1.200 US$ for indigenous communities, high subsistence scenario net income + 3.600 US$ for indigenous communities).

Figure 7 shows the net income spent on electricity in Greenland, distinguished between towns (more than 1.000 inhabitants) and settlements (less than 1.000 inhabitants).
DISCUSSION

The results of the analysis of the electricity prices in remote Arctic communities suggest that high electricity prices have an impact on the residential market and present a burden for the local economy. High electricity prices may result in lower economic capacity, which will lead to lower income. This vicious cycle presents a big challenge for Arctic communities. A solution to break the vicious cycle could be renewable energy. For several communities, where renewable energy sources have been introduced, lower electricity prices have been achieved over a mid-term time horizon in some Alaskan communities. In Greenlandic communities an electricity price difference was visible before the unified electricity price was introduced in 2018 (Meiners 2019; Thor 2018). Given the availability of renewable energy resources, renewable energy has been shown to have the potential for providing affordable electricity, as well as jobs (Bhattarai, Thompson 2016). The main renewable energy technologies found in the Arctic are hydro power, wind power and photovoltaic (Muhando et al. 2010; Suslov 2012; Boute 2016). Even if renewable energy production does not create many new local jobs, a lower long-term price for electricity may help to improve the local economy. Lower electricity prices, available through the use of renewable energy in remote Arctic communities, can contribute to achieving the UN sustainable development goal 7, ‘affordable and clean energy’ (UN Sustainable Development 2019). Moreover, the introduction of renewable energy can contribute to the UN sustainable development goal 1, ‘no poverty’ (UN Sustainable Development 2019).

As shown in the previous sections, it is important to take social aspects into account for the design of an energy transition strategy.

The summer and winter cases of the VoLL show that the inhabitants of the Arctic have a critical need for a secure electricity supply, especially during the cold winter. On the other hand, high electricity prices create a considerable cost burden in the Arctic. The size of the cost burden underscores the importance of having in place a transition process towards local renewable energy with lower electricity prices. A previous study has pinpointed that the needed technology is available and proven under the harsh Arctic conditions, and that renewables can help to reduce the cost burden of electricity and improve energy security (de Witt et al. 2019).

CONCLUSION

This paper emphasizes the social importance of going further in the direction of a sustainable energy transition in the remote Arctic. Electricity plays a crucial role in the Arctic for the survival and general wellbeing of population. Therefore, it is important to ensure a reliable and constant electricity supply at an affordable price. In some parts of the Arctic initiatives have been launched to overcome this problem, but there is still a huge discrepancy between small and large communities in many regions, as well as indigenous and non-indigenous communities. It is important to lower the overall level of the percentage spent on electricity and close the income gaps between communities of different sizes and between indigenous and non-indigenous cost burdens. In the accomplishment of these tasks renewables can play a key role. However, in areas with a weak economy, such a transition has to be carried out in a sensitive and inclusive way. It is therefore important to find optimal solutions to the transition from fossil fuel towards renewable energy sources. Hence, further studies are needed on the transition process.

ACKNOWLEDGMENTS

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ЗАВИСИМОСТЬ ОТ ЭЛЕКТРОЭНЕРГИИ ЖИТЕЛЕЙ СЕЛЬСКОЙ ЗАПАДНОЙ АРКТИКИ

АННОТАЦИЯ. Рассматривается зависимость жителей Западной Арктики от электричества, дается обзор прошлых разработок в области электроснабжения и современной ситуации, как в настоящее время структурирована связь между жителями и электричеством. В Арктике электричество играет особую роль в связи с его важностью для безопасности в дополнение к развлечениям и производительности. Обсуждается важность электричества на Севере, включая вопросы о том, что будет происходить с арктическими сообществами при отсутствии электроснабжения. Представлен гипотетический случай отключения электроэнергии. Рассматривается вопрос высоких затрат на электроэнергию в Арктике. Результаты исследований могут способствовать получению новых знаний о потенциальном переходе на энергоснабжение в Арктике. Выводы подчеркивают важность энергообеспечения Арктики и безопасности его поставок.

КЛЮЧЕВЫЕ СЛОВА: энергия, возобновляемая энергия, доступность, смешанная экономика, стоимость потерянной нагрузки

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