Briefing Note

Energy security in the Arctic: Policies and technologies for integration of renewable energy

Magnus de Witt, Hlynur Stefánsson & Ágúst Valfells

Remote Arctic communities depend 80% on diesel as the primary energy source. Besides the negative climate impact, the use of diesel has a negative impact on mid-term energy security. The mid-term energy security impact is due to the transportation of fuel to the communities. Harsh Arctic weather conditions restrict the transportation period and within a relatively short time window the annual consumed fuel needs to be shipped to the communities. Local energy sources can help to get independence from imported fuels. The use of local energy sources will increase the upstream energy security, which is affected by fuel price changes, oil exploration and oil production/delivery insecurity. Renewable energy technologies adopted to Arctic conditions exist but come with a significantly higher price than the same technologies in tempered areas. Policy can help to lower the barrier to entry and support a secure and sustainable energy supply in the Arctic.

This paper discusses the special implication of energy security for Arctic communities and how policy can help to strengthen energy security and concurrently reduce CO_2 emissions. Energy policy incorporates three different dimensions: energy security, affordability of energy and environmental soundness. The analysis described in this paper reviews the strengths and weaknesses of different available energy technologies and policies with a focus on energy security in remote Arctic areas.

Arctic energy systems

The Arctic can be defined by the Arctic Circle (66°33'), the tree line or the line of 10°C isotherm temperature in the summer (AMAP, 2010). This area faces harsh weather conditions with a long winter and short vegetation growth period. Around 4 million people inhabit the Arctic. Energy is an essential element for the survival of the population in the Arctic.

Currently diesel dominates electricity generation in the Arctic. It can be seen that more than 80% of the communities exclusively depend on diesel. The diesel fuel has to be imported. The import can happen in several ways: on sea by barges during the summer time or by truck over frozen rivers during winter times. In just a few exceptional cases or in case of emergency, fuel has to be flown in. This makes the fuel transportation a critical point for electricity generation and adds a high cost to it.

Magnus de Witt is a PhD Candidate, Hlynur Stefánsson is Associate Professor and Ágúst Valfells is Professor at Reykjavik University Department of Engineering, Iceland.

In addition to the aforementioned transportation issues of diesel, other negative issues are associated with the use of diesel. A global problem of burning diesel is the greenhouse gas emission with the well known effect on the climate. Besides greenhouse gases, black carbon is emitted, which has a special role in the Artic environment. Black carbon lowers the albedo effect locally. The albedo effect describes the reflection of solar radiation from a white surface, which protects the snow and ice from melting. The small black carbon particles absorb solar radiation and the snow and ice thaw faster.

In the harsh Arctic conditions a secure and reliable energy supply is an essential need of the population. Over the last decades diesel has proven a very reliable energy source for electricity generation. Arctic diesel is a diesel with an additive, so that it can withstand temperatures up to -44°C and diesel engines need just a few minutes for a cold start (1 – 5 min) (Neste, 2019). Furthermore, the engines can adjust the output to the demand of the electricity grid. The regulation of the voltage and frequency can be operated by the diesel generator.

With the aforementioned advantages and disadvantages of diesel it can be seen that a movement towards a transition to renewable energy resources has started among Arctic communities. Some technologies have been adapted, but it is crucial to reinforce the momentum, which has started during the past peak in oil prices. The number of communities which are utilizing renewables is growing. Furthermore, on the political side a movement towards renewables has happened as result of the climate conferences (Paris, Marrakesh etc.). Alaska announced the aim to increase the share of renewables up to 50% by 2025 (Allen, Brutkoski, Farnsworth, & Larsen, 2016). The Greenlandic aim is formulated quite vaguely: "By 2030, the goal is that the public energy supply must be, to the fullest extent possible, delivered from renewable energy sources" (Naalakkersuisut, 2018). Canada has set a different aim that does not include the amount of renewables. Canada aims rather for greenhouse gas reductions of 30% compared to the 2005 level, which was 738 Mt CO_2 equivalent (Environment and Climate Change Canada, 2018).

The article is mainly based on a literature review which provides an overview of already existing research, and some information used in this article has been collected during visits for case studies in the Arctic region. The article aims to give an introductory overview on energy security in the Arctic. The focus lies on the political viewpoint, how can the energy security be improved by using technologies which are currently available on a mature level. First an overview on available technologies will be given, followed by a description of the energy policies of the different Arctic countries.

Technologies to harness renewable sources for electricity generation

Several renewable energy sources can be found in the Arctic. The following section focuses on sources which are widely separated over the Arctic and where the technology has reached maturity already. The renewable energy sources identified are; wind, solar, hydro, geothermal and current / tidal power. A closer look shows that geothermal power is primarily distributed around the ring of fire – Russian and Alaskan costal area at the Pacific – and on Iceland. Current and tidal power is not mature yet and in Arctic regions as there can be a risk of ice and icebergs expected.

Hydropower

Hydropower is currently the energy source with the highest generation of electricity after diesel; the share accounts for 40% of electricity generation in the Arctic. The number of hydropower plants is relatively small, just a few relatively large hydro plants can be found in remote Arctic communities, mostly in larger communities. That is because the investment cost of hydropower plants is high and the cost per kilowatt increases with reduction of the power plant size (Tester et al, 2012). On the other hand, hydropower plants have a long lifetime from 50 to 100 years and a low operation cost (Tester et al, 2012). The energy output of such a dispatchable energy source is simple to regulate and the voltage and frequency is stable, which gives the electricity grid stability (Tester et al, 2012). Depending on the type of Hydropower plant the environmental impact can be severe, in particular if a large storage lake is needed (Kumar et al, 2012). In cases where a bypass to a river is enough, the impact is less severe (Kumar et al, 2012). In any case a powerhouse is needed, wich results in land use.

Wind power

Wind power has good availability in the Arctic, with high potentials in coastal areas (Lombardi et al, 2016; Alaska Energy Authority, 2016). The general technology of wind turbines have to be adapted to the harsh Arctic conditions. Materials need to withstand temperatures below -40°C, which leads to significant changes in material properties (Lacroix & Manwell, 2000). Icing on the blades lead to significant problems which have to be addressed, for example with the use of black blades which are heated by solar radiation or heated blades (Holdmann, 205; Lacroix & Manwell, 2000). The cold climate has a positive effect since it was observed by the US Department of Energy that wind turbines in cold regions have a 20% increase in maximum power output at around -37°C (Muhando, Keith, & Holdmann, 2010). As in most construction related projects in the Arctic the cost is higher than in temperate areas. For a wind turbine it would be 2 - 3 times more expensive (Baring-Gould & Corbus, 2007). The generation cost of electricity is reduced to operation and maintenance after the payback period: no costs for fuel are needed (Tester et al, 2012). The feasible lifetime of a wind turbine is around 20 years (Wiser & Yang, 2012). From a technical point of view, it can be even longer if the operation and maintenance costs are at an acceptable level. The environmental impact of wind turbines is related to the land use and the possible interference with wildlife, in particular bird migration (Tester et al, 2012) (Wiser & Yang, 2012).

Solar PV

Several photovoltaic solar systems are installed in the Arctic, mainly small scale for residential use or small businesses up to a 30 kW peak. The production of electricity is seasonal, according to the availability of sunlight. During the spring time it has been observed that the snow reflects the solar radiation and increases the electricity output of the solar cells (Boström & Godtliebsen, 2014). Furthermore, the low temperatures increase the efficiency as well (Boström & Godtliebsen, 2014). The solar cells have a lifetime of around 25 years (Tester et al, 2012). The environmental impact of installing solar panels is very low. In most cases they are mounted on buildings, so that no land is used. In the case of solar farms, the land use has to be accounted for.

Current policies for renewable energy in the Arctic

The following section discusses the different political aims for energy among the Arctic countries, which have communities without any connection to a continental electricity grid. This puts the focus on Alaska, Canada and Greenland. Furthermore, those strategies introduced to reach the aims are discussed as well.

Energy policy of Alaska

The Alaska State Legislator setup a Renewable Energy Fund (REF) in 2008 with annual contributions of 50 million USD (Alaska Energy Authority, 2018). The year 2008 was the peak year of oil prices (NASDAQ, 2018). First the fund was planned for five years, but in 2012 the fund was extended for ten more years (Alaska Energy Authority, 2018). The fund is managed by the Alaska Energy Authority, which is an independent, public corporation responsible for assisting energy projects development, operation and financing in the state of Alaska. The mission is to reduce the cost of energy and increase energy security. Other programs such as the 'Rural Power System Upgrades' programme helps rural communities with less than 2000 inhabitants to increase the efficiency of their generators (Alaska Energy Authority, 2019). Nearly 100 million USD has been leveraged since the introduction of that program in the year 2000 (Alaska Energy Authority, 2019).

Since the introduction of the Renewable Energy Fund (REF) in Alaska over 280 grants for projects have been assessed and over 250 million USD have been allocated to projects. The fund helped 73 projects which are now in operation. With the executed projects it is possible to save a lot of diesel. The total financial savings from displaced diesel are annually over 70 million USD. In 2018 a number of the 56 projects supported by the REF have been under progress (Alaska Energy Authority, 2019).

Another program very specific to remote communities is the Rural power System Upgrade (RPSU) programme, which has successfully completed 86 projects among small remote communities. The average increase of efficiency is around 15% but peaks sometimes even above 30% (Alaska Energy Authority, 2019). The increase in efficiency is due to a more efficient use of the diesel. For example, less diesel is used to provide the needed amount of energy – that would result in lower energy generation costs. Another example would be to recover heat from a generator and use it for heating purposes. This would not directly decrease the cost of generation, but the new product heat can be sold, which reduces the cost indirectly.

An observation shows that modern technology can be a problem in small remote communities. For example, clean and technically more complicated diesel engines according to the tier 4 standard are not very common. For such a technically complicated engine it is hard to find a skilled workforce in many remote places.

Alaska has a long experience with islanded microgrids. A lot of research and development has been done, on a scientific level e.g. at the Alaska Centre for Power and Energy or by private companies and utility companies. For this achievement, dedicated funds have been very important, from the state, region etc. Alaska is, with 25 – 30% renewables in the electricity mix, more than halfway towards its target of 50% renewables in 2025. It will be ambitious to achieve the remaining half in the next six years.

Energy policy of Canada

Canada's energy transition pathway is based on four pillars: first wasting less energy, second switching to clean power, third using more renewable fuels and fourth producing cleaner oil and gas (Smith & Coady, 2018). These parameters are in alliance with the three general parameters for energy policy: affordability, reliability and cleanness (Röpke, 2013). A problem of introducing renewables are the high upfront costs on the investment side, which makes it important to have a strategy to support renewable projects. To increase the attractiveness of such projects the 'generation energy council report' recommends the introduction of capital cost depreciation, strategic initiatives and other tax treatments (Smith & Coady, 2018). Moreover, existing funds and investment programs should be streamlined and the access to them should be extended (Smith & Coady, 2018). To support the transition, subsidies for the use of fossil fuels in an inefficient way for electricity generation will phase out in 2025 (Environment and Climate Change Canada, 2017).

The Canadian government's aim is to reduce the 2005 CO_2 by 30% until the year 2030, which would entail a maximum CO_2 emission of 500 Mt CO_2. The long-term goal is even more ambitious with a reduction of 80% compared to 2005 by the year 2050. The CO_2 emission of 2017 was 716 Mt CO_2, a reduction of 2.9% compared to the 738 MT CO_2 in 2005. In other terms it means that approximately 8% of the aimed reduction of 220 Mt CO_2 was reached after 2 years. To reach this aim Canada has introduced several programmes to support renewable projects. The 'Energy Innovation Program' has allocated 49 million USD in over three years. The program is set up to support innovations for clean energy. The 'Canadian Renewable and Conservation Expenses' program is more consumer orientated, with the target group of industry. The program allows the write-off of equipment associated with producing clean energy with 30 – 50% per year. The common depreciation rate without the program would be 4 – 20 % per year for such equipment. The 'Green Infrastructure Program' has a sub-category, which focuses on 'Clean Energy for Rural and remote Communities'. The goal is to reduce dependency on diesel and establish local and clean sources such as wind, solar, biomass and hydropower.

Canada has just done a little step towards the aimed CO_2 reduction in the first years. But it has to be considered that the supporting programs have to be first set up and introduced, and such projects take time before they show some effect. There are eleven more years to reach the aim. The funding options are relatively new, and they seem to be a mix aiming for research and development and for integration of renewables.

Energy policy of Greenland

The aim of the Greenlandic government is very vague, but the large communities are powered by hydropower. This makes the renewable portion of the total energy mix very strong with around 70% (WWF, 2017). In 2016 the first solar test side was opened and in 2018 the first wind turbine was erected in Greenland. Private consumers have been much more open to solar power. Several small-scale solar systems can be found on residential buildings.

Comparison of energy policies among the Arctic countries

A comparison of the hydropower electricity generation in the different countries shows on a first look that Greenland produces more than 70% of its electricity by using renewables (WWF, 2017). In Canada it is around 66% renewables (Natural Resources Canada, 2018). USA is far behind with 25 – 30% renewables, but these numbers are on a country level (EIA, 2019). A breakdown on just remote areas draws a different picture. In Greenland all communities are remote, so nothing changes. But a look on Canadian remote communities shows that just 25% of all remote communities can supplement the diesel electricity generation with renewables. In Alaska 15% of all remote communities harvest a portion of the electricity from renewables. The lower use of renewables in remote places can be associated with the high investment cost for renewable power projects.

It can be seen that renewables are a viable option to support electricity generation and lower the carbon footprint of society. The introduction of renewables has a positive effect on electricity prices. It is among the Arctic communities that the highest electricity prices around the world can be found. For example, in Alaska prices can be 2 – 5 times higher compared to the lower 48.

Conclusion

At the current stage there is mature technology available to power entire Arctic communities by renewables like hydropower, or at least to supplement the electricity mix with renewable energy such as wind and solar. It is important to assess the local circumstances, which natural resources are available and which amount can be harnessed. Moreover, it has to be analysed if renewable energy can be harnessed in an economically viable way and cost-effective policies introduced to facilitate the transition. Alaska and Greenland have already implemented policies to support directly the use of renewable energy resources. Canada is however focusing directly on the reduction of greenhouse gas emissions, which will lead to an increase of low carbon technologies such as renewables. To reach these goal's several initiatives have been started by the governments, reaching from a country wide approach up to specific programs just for rural Arctic communities. Overall it can however be seen that the share of renewable energy in the Arctic is still very low.

Sustainable energy technologies are at a point of development where the integration in to Arctic electricity systems is feasible. The use of local energy sources can increase the energy security in communities and lower the cost of energy. For the small communities such projects are often very complicated to execute because of the high upfront investment cost. Since many sustainable systems are modular it is however possible for the communities to adjust the output in accordance to the demand, if the population growth or businesses require more energy. The policies that have already been introduced are helpful and the launched funding programmes are very important for supporting the implementation of renewable energy in the Arctic. However, more funding is needed to stimulate the transition, and smaller communities also need expert assistance for evaluating resource and technological potentials and with applying for funding.

References

Ahmed, M., Amin, U., Aftab, S., & Ahmed, Z. (2015). *Integration of renewable Energy Resources in Microgrids.* Energy and Power Engineering.

Alaska Energy Authority. (2016). *Reneable Energy Atlas of Alaska.* Anchorage: Alaska Energy Authority.

Alaska Energy Authority. (2018, 05 16). *Alaska Energy Authority*. Retrieved from Alaska Energy Authority: http://www.akenergyauthority.org/Portals/0/Programs/FactSheets/Documents/REF.pdf

Alaska Energy Authority. (2019). *2018 Report to Alaska.*

Allen, R., Brutkoski, D., Farnsworth, D., & Larsen, P. (2016). *Sustainable Energy Solutio for Rural Alaska.* RAP.

AMAP. (2010, 02 10). *Definitions of the Arctic region*. Retrieved 06 06, 2019, from https://www.amap.no/documents/doc/definitions-of-the-arctic-region/248

Baring-Gould, I., & Corbus, D. (2007). Satus of Wind-Diesel Applications in Arctic Climates. Anchorage: NREL.

Bhattarai, P. R., & Thompson, S. (2016). Optimizating an off-grid electrical systemin Brochet, Manitoba, Canada. *Renewable and Sustainable Energy Review, 53*, 709-719.

Boström, T., & Godtliebsen, F. (2014). *UiT*. Retrieved 09 03, 2018, from http://site.uit.no/canada2014/files/2014/09/CNNII_23SEP_1_8_Godtliebsen.pdf

Boute, A. (2016). Off-grid renewable energy in remote Arctic areas: An analysis of the Russian Far East. *Renewable and Sustainable Energy Reviews, 59*, 1029-1037.

Chalvatzis, K. J., & Hooper, E. (2009). Energy security vs. climate change: Theoretical framework development and experience in selected EU electricity markets. *Renewable ans Sustainable Energy Reviews*, 2703-2709.

EIA. (2018, 5). *Alaskas Net Electricity Generation by Sources May 2018*. Retrieved 08 22, 2018, from https://www.eia.gov/state/?sid=AK#tabs-4

EIA. (2019, 02). *Alaska State Profile and Energy Estimates*. Retrieved 05 10, 2019, from https://www.eia.gov/state/?sid=AK#tabs-4

Environment and Climate Change Canada. (2017). *Achieving a Sustainable Future.* Gatineau: Environment and Climate Change Canada.

Environment and Climate Change Canada. (2018). *Canadian Environmental Sustainability Indicators - Progress towards Canada's greenhouse gas emissions reduction target.* Gatineau: Environment and Climate Change Canada.

Environment and Climate Change Canada. (2018). *National Inventory Report 1990-2016 Greenhouse gas sources and sinks in Canada.* Gatineau: Environment and Climate Change Canada.

Government of Canada. (2011). Status of Remote/Off-Grid Communities in Canada.

Hague, P. (2006). *A Practical Guide to Market Research.* Stockport: Grosvenor House Publishing Ltd.

Holdmann, G. (2015). Alaska - the microgrid frontier. *The Circle - renewable energy in the Arctic*, pp. 6 - 9.

Hu, J., Zhang, T., Du, S., & Zhao, Y. (2015). An Overview on Analysis and Control of micro-Grid System. *International Journal of Control and Automatisation, 8*(6), 65 - 76.

Kumar, A., Schei, T., Ahenkorah, A., Rodriguez, R. C., Devernay, J.-M., Freitas, M., . . . Liu, Z. (2012). Hydropower. In O. Edenhofer, R. P. Madruga, & Y. Sokona (Eds.), *renewable Energy Sources and Climate Change Mitigation* (pp. 437-496). Cambridge: Cambridge University Press.

Lacroix, A., & Manwell, J. F. (2000). *Wind Energy: Cold Weather Issues.* Amherst: University of Massachusetts.

Lombardi, P., Sokolnikova, T., Suslov, K., Voropai, N., & Styczynski, Z. A. (2016). Isolated Power Systems in Russia. A chance for renewable energies? *Renewable Energy, 90*.

Muhando, B., Keith, K., & Holdmann, G. (2010). *Power Electronics Review - Evaluation of the Ability of Inverters to Stabilize High-Penetration Wind-Diesel Systems in Diesel-Off Mode Using Simulated Components in a Test Bed Facility.* Fairbanks: Alaska Center for Energy and Power.

Murphy, J., Holdmann, G., & Witmer, D. (2009). *Energy Storage for Alaskan Communities Technology Summary.* The Alaska Center for Energy and Power.

Naalakkersuisut. (2018). *Cheap, Modern and Green Energy and Water for Everyone.* Nuuk.

NASDAQ. (2018). *Crude Oil - WTI (NYMEX) Price.* Retrieved 08 20, 2018, from https://www.nasdaq.com/markets/crude-oil.aspx?timeframe=10y

Natural Resources Canada. (2018, 09 12). *Natural Resources Canada.* Retrieved 05 09, 2019, from https://www.nrcan.gc.ca/energy/facts/electricity/20068

Pedrasa, M. A., & Spooner, T. (2018, 01). *Researchgate.* Retrieved 02 01, 2018, from https://www.researchgate.net/publication/225183496_A_Survey_of_Techniques_Used_to_Control_Microgrid_Generation_and_Storage_during_Island_Operation

Röpke, L. (2013). The development of renewable energies and supply security: A trade-off analysis. *Energy Policy*, 1011-1021.

Schaede, H., Schneider, M., Vandermeer, J., Mueller-Stoffels, M., & Rinderknecht, S. (2015). *Development of Kinetic Energy Storage Systems for Island Grids.*

Smith, M., & Coady, L. (2018). *Canada's Energy Transition - Getting to our Energy Future, Together.*

Spiller, A. (2010). *Marketing Basics - Ein Online-Lehrbuch* (1 ed.). Göttingen: Georg August Universität Göttingn.

Tester, J. W., Drake, E. M., Driscoll, M. J., Golay, M. W., & Peters, W. A. (2012). *Sustainable Energy - Choosing Among Options* (2 ed.). Cambridge: MIT Press.

Wiser, R., & Yang, Z. (2012). Wind Energy. In O. Edenhofer, R. P. Madruga, & Y. Sokona (Eds.), *Renewable Energy Sources and Climate Change Mitigation* (pp. 535-608). New York: Cambridge University Press.

WWF. (2017). *Renewable ebergy across the Arctic: Greenland Report.*