Feasibility Assessment of Microgrid Wind Energy Systems: Implementation of TASED in the Arctic Regions of Yamal and Murmansk

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ABSTRACT

Due to its extreme climate and low population density, the Russian Arctic region remains largely infrastructurally undeveloped. Many settlements in the Arctic area are not connected to the Unified Energy System of Russia (UES) and employ various carbon-intensive sources for local electricity generation. Currently, the Russian government has drafted a strategic development plan for the region, specifically utilizing the region's vast supply of oil and natural gas reserves for electricity generation. The Arctic ecosystem is fragile, and constructing new oil, gas, or diesel power stations may not be sustainable for the region. Additionally, the utilization of fossil fuels would exclude the current technological advancements in electricity systems. This paper offers an improved and more sustainable approach to developing electricity generation in remote localities. Given unique regional ecological and sustainability concerns, Territories of Advanced Social and Economic Development (TASED) should be created in the Arctic regions of Yamal and Murmansk in order to integrate wind electricity generation on a small scale in these regions' most remote population centers. Not only would this protect the region's ecosystem from the negative effects of new fossil fuel power stations, but it would also present new opportunities for equitable development of the region's economy.

1. Introduction

The development of the Arctic is a key proposition set forth by the Russian Government. As it is outlined in the law "Basic Principles of Russian Federation State Policy in the Arctic to 2035," Russian authorities see the region as a place to employ the country's defense systems, oversee the shortest northern sea route from Europe to Asia, and generate income by extracting natural gas [1]. Furthermore, the region is uniquely positioned to accommodate a growing global need for fishing and underground raw materials. As the relevance of those factors increases proportionately to the earth's global population, the Arctic will become increasingly important for multipurpose development.

Inexpensive energy is a driver for the sustainable development of any territory, as stated in United Nations Sustainable Development (UNDP) Goal number 7 [2]. Moreover, the energy generation process must be carried out using technologies that have the least negative impact on the environment and its people. Thus, the necessity for renewable energy (RE) sources becomes fully apparent. Limited sunlight during winter months makes solar technologies unattainable; however, there is great potential to utilize the Russian Arctic's wind supply year-round. Russia's coastline accounts for over fifty percent of the Arctic Ocean [3], and according to recent estimates by the Renewable Energy Agency, around twenty percent of offshore wind resources lie within the country's waters [4]. In combination with significant onshore wind potential, Russia could sustain and eventually develop remote and isolated electricity grids by generating electricity from local RE sources. This is important because the Arctic region's ecosystem, the tundra, is hypersensitive to both pollution and climate change.

Due to renewable energy intermittency, most microgrids use a combination of fossil fuel and carbon-free technologies to generate electricity. However, as the cost of batteries declines, more microgrids are relying only on RE sources. Such systems that supply electric power in remote areas are becoming increasingly attractive in North America and Europe, as they are efficient, reliable, and environmentally sustainable. Those qualities are especially important for remote communities, where grid extension is prohibitively expensive. RE, wind in particular, is a reliable resource of power. As such, establishing wind energy as part of microgrid systems brings significant cost reduction and improved system efficiency, while maintaining energy efficacy for rural communities [5].

The main barriers to expanding RE microgrids are deep sociological dependence on conventional energy-driven economies and low political will to change the corresponding supply chains. However, new developments may reduce this dependency. The recent COVID-19 outbreak and subsequent record-low oil prices have demonstrated that reliance on conventional sources of energy is an unreliable and risky enterprise. One after another, global energy companies have been acquiring RE portfolios and reducing their reliance on oil. ExxonMobil, the largest oil and gas company from the US, is spending over $1bn a year researching renewable energy [6]. In 2018, Shell, another major American player, purchased 44% of the US solar power firm Silicon Ranch for $200m and made a $20m equity investment in Husk Power Systems, an India-based renewable power company [7]. Total, a French oil and gas company, invested $500m in renewables in 2019. That represents about 3% of Total's capital expenditures and the plan is to increase it to 20% in the coming years. On March 19, 2020, Total purchased 80% stake in the Erebus floating offshore wind project [7, 8, 9]. There are many more examples of multinational oil and gas companies – including Orsted, Equinor, and British Petroleum – which have invested in wind and solar technologies. An ongoing process of world-wide energy transition is underway.

However, currently the focus of Arctic energy development has mostly been based upon the expansion of natural gas and oil extraction. As stated in the "Basic Principles of Russian Federation State Policy in the Arctic to 2035," extracting natural resources is one of the key goals in the region [1]. Nevertheless, international experience suggests that heavy reliance on natural resources is not necessarily a sustainable practice in the long run [10]. Introducing wind energy into the remote grids of the Russian Arctic under the Development of Territories of Advanced Social and Economic Development (TASED) regime could be a more effective choice, given the negative externalities of conventional forms of energy on the environment.

We have identified two regions in the Russian Arctic, Murmansk and Yamal, where creation of a TASED could yield the greatest impact on both the local communities and the environment, while still bringing return on investments, specifically as it concerns supporting RE microgrids.

Murmansk, the most northwestern region of Russia bordering Norway, is the only region in the country that has both rich wind resources and enjoys ice-free waters. Matured offshore wind technologies could benefit remote settlements by reducing prices for electricity and lowering the environmental impact of diesel-based electricity. In contrast, the Yamal Peninsula is characterized by one of the highest onshore wind speeds in the world. The employment of wind turbines in Yamal will not only reduce the levelized cost of electricity (LCOE) for residents, but could also prove useful for existing natural gas extraction companies. Moreover, Murmansk's fragile tundra ecosystem has deteriorated in the past few decades, due to intensive industrial development, foreshadowing the potential for Yamal's ecosystem health to drastically decline, should planned industrial development be undertaken.

In this article, we outline existing Russian regulations; the benefits of onshore and offshore wind technologies; the social, economic, and environmental concerns of Murmansk and Yamal; and the international experience of RE microgrids. Given the current feasibility of RE in Russia and taking into consideration both existing legislation and potential profitability of RE, we ultimately propose that a TASED be created in the regions of Murmansk and Yamal. The establishment of these territories as TASEDs will enable the development of wind technologies within these regions, which will have high potential for economic return and promote the sustainable development of some of Russia's remote regions.

2. Russian Regulations

Since Russia's power grid is a vertically integrated utility, the government controls not only the generation of electricity, but also its distribution and delivery services. The main document regulating the power industry in Russia is Federal Law 35 "Electric Power Industry," which states that RE could be brought into the power grid, but only if its cost is equal to or lesser than the wholesale price of electricity produced by conventional fossil fuels [11]. There is no economy of scale for RE in Russia to drive the costs down. Moreover, the Russian government subsidizes conventional forms of energy. Thus, market-driven employment of RE in the Russian United Electricity Grid without governmental support is not feasible.

In December 2019, however, the law was revised with some of its components now outlining the development of autonomous energy generation in Russia. RE employment is listed as one of the possible solutions to bringing the cost of electricity down for such remote locations [11]. Yet there are no further clarifications on how to deal with regulatory barriers when commissioning new capacities. To lessen this barrier, we propose creating a TASED, focused on experimental areas for RE development.

In Russian legislature, a TASED is a specially administered area with simplified legal regulation. These territories are aimed at specific spheres, such as high-tech goods production, advanced medical care, and logistics center development. A TASED can be created as a means for commissioning and the subsequent use of electric power generation facilities. This legal regime enables accelerated advanced development and increases economic feasibility, thereby providing special conditions for companies actively introducing RE sources [12]. The current regulatory system in Russia's energy sector requires multiple approvals before putting into operation electric power generating facilities. This complicates and slows down advanced development, implementation, and testing [11]. TASED creation in the Arctic became possible in 2020, after responsibility for Russia's Arctic zone was transferred to the responsibility of the Ministry of Development of the Russian Far East. This ministry is one of the few authorities with the power to create new TASEDs [13].

Creating the aforementioned regulatory conditions would reduce overall risks, thereby providing incentives for companies, organizations, and individuals to implement innovative solutions. These conditions have the potential to accelerate the development of RE in extreme climate conditions and increase its competitive advantage over conventional energy sources. The key advantages of creating a TASED in a couple of experimental regions are:

1. The ability to create new TASED legislation faster than legislation amended at the federal level;
2. The ability to enact flexible support, such as subsidies, relevant to the needs of the specific region, namely the Murmansk Region and Yamal-Nenets Autonomous Okrug, which have different needs in terms of economic, social, and environmental factors; and
3. The ability to remove TASED status when a particular level of RE development in the region has been achieved.

The above-mentioned steps have the capability to substantially increase the development of RE in the Arctic zone, while having minimal impact on financial resources and time constraints, which remains one of the greatest barriers to reforming the Russian Federation Power Grid. Before jumping into the regional analysis, it is important to briefly discuss the basics for both onshore and offshore wind technologies and potential benefits they might bring to Russia's microgrids.

3. Wind Turbine Technologies

Wind energy is the process of producing electricity using differences in atmospheric air pressure and capturing its kinetic energy [14]. Due to the lowering cost and economy of scale effect, wind power is a rapidly developing RE technology. In 1997, only 7.5 gigawatts (GW) of wind energy globally were installed, but this number now exceeds 650 GW. Production of wind electricity doubled between 2009 and 2013, and in 2019 wind energy accounted for over 16% of the electricity generated by RE. Many parts of the world are rich in wind resources, but the best locations for energy generation are usually remote [14]. Both onshore and offshore wind power are maturing technologies that offer tremendous potential for sustainably developing territories.

3.1. *Onshore Wind*

The world's first modern wind farm was just 0.6 MW, consisting of 20 wind turbines rated at 30 kilowatts each, installed in southern New Hampshire in December 1980 [15]. By 2020, global onshore wind energy capacity skyrocketed by a thousand percent to over 650 GW [16]. One of the main arguments in favor of using onshore wind turbines for electricity generation is their environmental friendliness. While building wind turbines involves some CO2 emissions, once running, they have a very low carbon footprint. Moreover, onshore wind has a limited physical impact on the environment: it does not poison the land or release any known toxins; it can be farmed around; and, once removed, it leaves almost no impact.

Countries from all continents, with the exception of Antarctica, have incorporated wind technology into their national electricity grids; in some countries – such as the UK, Ireland, Portugal, and Spain – the share of wind energy has reached 25-30% [16, 17]. In the first quarter of 2020, Denmark produced half of its electricity from wind farms. Wind farms are even the new norm within the Arctic. In Alaska, the first two turbines were installed by Yukon Energy in 1993 on Haeckel Hill. Today, hundreds of turbines rotate in most of the Arctic Council member states, and Russia is now joining the table [18]. At the end of 2019, Enel, an Italian energy company, began construction of the largest wind energy project within the Arctic Circle. Named Kolskaya farm, it is expected to have 201 MW of capacity and will be able to power 25% of Murmansk [19, 20, 21].

The capacity factor, or unitless ratio of actual electrical energy output over a given period of time to the maximum possible electrical energy output over that period, of an average wind farm is around 35% as of 2020 [22]. That is lower than coal factories (45-50%), but higher than gas turbines (8-13%) or diesel in the US (15-20%) [22, 23]. Over the last decade, the onshore capacity factor has increased by over 25%, while the levelized cost of electricity (LCOE) has dropped by 25%. International Renewable Energy projects that by 2030 the capacity factor will reach 55% and LCOE will drop by another 10-15% [22, 17].

Pricewise, in 2019 Bloomberg New Energy Finance (BNEF) forecasted onshore wind costs at $47/MWh for new-build onshore wind. LCOE for onshore wind is already currently competitive compared to all other generation sources (including fossil fuels) and is expected to decline further in the coming decades, falling within the range of $0.03 to $0.05/kWh by 2030 and $0.02 to $0.03/kWh by 2050 [24].

Onshore wind is more environmentally friendly than conventional forms of energy and is a mature technology that, according to most estimates, will push coal and other conventional forms of energy from the electricity market in the coming decades. Arctic microgrids powered by wind are a sustainable form of development that would help to not only reduce cost for local residents and businesses, but also lessen the burden of industry on the environment.

3.2. *Offshore Wind*

Offshore wind farms differ from their onshore counterparts in that they are located in open seas. Due to stronger and more stable winds at sea, offshore wind farms can produce more energy than ones onshore [4]. The number of offshore projects has drastically increased since the end of the 20th century. The first offshore wind project began in Denmark in 1991 and played an important role in the future of offshore wind farms [4]. Almost all current European offshore wind farms are in the Baltic and North Seas, because of their more suitable climates. However, wind farms designed for operation in icy conditions have also been developed and implemented. The first Arctic offshore wind farm was built in Tahkoluoto, Pori, Finland. Starting electricity production in August 2017, that wind farm consists of 10 turbines, each with a capacity of 4.2 MW [25].

Higher capacity factors and overall production rates make offshore wind farms more suitable to turn into base load generators (providing the minimum level of demand on a power grid over a period of time) in the long run [26]. Offshore wind farms could be built in deeper waters as well, which would yield even more stable outcomes. The production of offshore wind electricity is becoming more efficient and cost-competitive as wind turbine technology is constantly developing. Offshore wind turbines can produce up to 40% more energy than onshore wind turbines, because of higher and more continuous wind speeds. At the end of 2019, there were over one hundred offshore wind farms in Europe, consisting of over 6,000 turbines capable of producing over 27 GW of energy [27]. Other regions are increasing their offshore wind turbine capacity as well. China has boosted its investment in offshore wind energy to satisfy the country's growing need for energy [27, 4].

As for the price, new-build offshore wind has seen the fastest decrease in costs of any RE source. According to BNEF, in 2019, its global benchmark price went down by 32% from the previous year to $78/MWh [24]. LCOE of offshore wind is already competitive in certain European markets (e.g. Germany, the Netherlands, France) and is maturing to compete in other European and Asian countries as well (notably the UK and China). It is forecasted that by 2030 costs will have fallen within the low range of costs for fossil fuels, specifically coal and gas [27, 24, 4].

4. Russian Arctic Regions

The Russian Federation is home to numerous Arctic regions that face immense challenges in providing reliable energy to their inhabitants. The Murmansk and Yamal Regions are two such areas. Both of these regions have harsh climates that make energy transport and storage difficult, but have ample wind resources and high potential for the creation of a TASED via the implementation of RE microgrids.

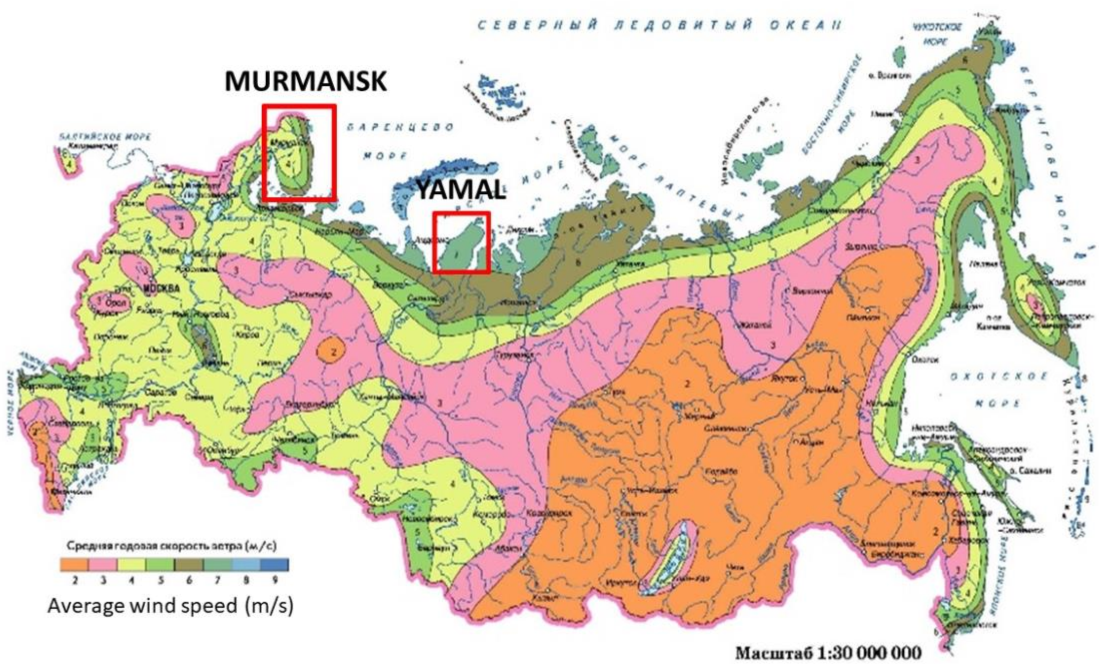

Image 1: Murmansk and Yamal regions and average wind speed [28]

4.1. *Murmansk Region - Offshore Wind*

Despite extreme latitudes at around the 70th parallel north, Murmansk, located in the northwestern corner of Russia, is heavily influenced by the warm Gulf Stream and, consequently, the surrounding Barents Sea area never freezes. Additionally, there are several areas with shallow waters of less than 60 meters. That makes Murmansk the only region in Russia suitable for cost-effective offshore wind electricity generation. Moreover, the territory of the Barents Sea coast is one of the windiest sites in Europe; average wind speeds exceed 8 meters per second. In addition, the seasonal maximum of wind speeds coincides with seasonal peaks in energy consumption [29].

Russian authorities recently approved the Kolskaya Wind Farm, and, once commissioned in 2022, it will be able to produce enough electricity to power a quarter of the houses in Murmansk [20]. That is a significant milestone for RE development in Russia. However, this station will be connected to the United Russian Power System, which has no effect on small and remote settlements and their power microgrids along the shore where residents have to rely on diesel generators. Experimental development of an offshore wind demonstration project under the TASED umbrella could be an economically feasible solution for local microgrids. Furthermore, an offshore wind farm is one of the most reliable RE technologies and could potentially help solve Murmansk's multiple environmental challenges.

The Murmansk region has the most environmental concerns of any Arctic region, with regards to air pollution, hazardous waste, and resource depletion from excessive mining, causing detrimental harm to ecosystems and human health [30]. Moreover, the region's economy has suffered from environmental degradation. One of the region's most prosperous industries, fishing, has been hindered due to wastewater pollution from mining [31]. According to statistics from Norilsk Nickel, it emits some 70,000 tons of sulfur dioxide on a regional level per year, which causes severe environmental degradation to the surrounding tundra ecosystem [32, 33]. In addition, the Murmansk port, which is located in the city, receives coal, the ash of which pollutes not only the city itself, but the surrounding coastal area. Moreover, Murmansk is a strategic port in the Russian Arctic and overuse of water transport including by military, industrial, and cargo ships has led to threatening levels of pollution of Barents Sea waters [33]. Despite these environmental concerns, since the early 2000s the Russian government has been interested in developing a natural gas field there, known as the Shtokman field.

UNDP has already noted that the Murmansk region would benefit socially, economically, and environmentally by integrating energy efficiency programs. Specifically, environmentally friendly sectors were found to draw in greater investment and promote job creation [30]. With the introduction of new green technologies, such as offshore wind, the region has the potential to increase investment and development capacity, while keeping in mind social, economic, and environmental concerns.

The creation of a specially administered TASED in Murmansk and introduction of offshore wind energy technology to local microgrids would bring positive social and economic externalities to the region, including many societal benefits not captured in their market price. Namely, the reduction in coal ash pollution would decrease sickness and, therefore, diminish the number of missed work days and early deaths. Also, the technology would contribute to reduced dependency on diesel, and, therefore, lower electricity prices for local residents [34, 35, 36]. As for the environment, developing offshore wind based microgrids would:

1. Improve air quality in the coastal areas;
2. Slow down water pollution in ports;
3. Lower CO_2 emissions from burning fossil fuels; and
4. Act as biodiversity reefs for the fragile Arctic marine ecosystem.

Should it take such a favorable position for the region, Murmansk could become a geographic pioneer in the offshore wind industry and capture all the outlined benefits associated with that. As the technology is still maturing and there are just a few projects currently in the Arctic, the Murmansk Region and Russia could propel research and the development of the industry overall. In the long run, that could both add generation capacity to reach the national goal of 2.5% of RE by 2040, as well as attract international investments.

4.2. *Yamal Region - Onshore Wind*

The Yamal Peninsula is a peninsula in northwestern Siberia. It is surrounded by the Kara Sea and the Baydarata Bay to the west, the Gulf of Ob to the east and southeast, and by the Malygina Strait to the north. Yamal is not connected to the United Electricity Systems of Russia and local communities have autonomous sources of energy [37]. Most of the power stations use diesel for electricity production. While that is better for the environment than diesel-based generators, wind still represents a method with less potential negative impact on the region's natural environment. Moreover, Yamal has some of the richest wind resources in the world. The Peninsula's onshore wind speeds exceed 7 meters per second [37]. Due to significant annual ice build-up in the Kara Sea, offshore wind technology is not economically feasible for the region. Bringing onshore wind stations to local microgrids, in contrast, would bring the following advantages to the grid:

1. Less environmental impact in comparison to gas turbines;
2. Quick installation and low maintenance and operation costs; and
3. Assistance to the natural gas industry.

Unlike Murmansk, which has already experienced environmental degradation from mineral extraction, Yamal's environment has the potential to be further degraded, due to potential oil and gas production [31, 38]. As of 2012, the Yamal-Nenets Autonomous Okrug has accounted for 90% of Russia's and over 20% of the world's gas production [39]. Gazprom, Russia's largest natural gas producer, views Yamal as a new gas production center. According to the company's financial estimates, Yamal will produce up to 360 billion cubic meters of gas per year [37]. However, this form of industrial development has serious consequences on the tundra ecosystem, as well as on the indigenous population.

Industrial development of the tundra ecosystem has a substantial impact on the region's natural rugged terrain. A change in the terrain of even a couple of meters can drastically change patterns of drainage, vegetation distribution, and snow levels, ultimately impacting plant phenology and reindeer grazing conditions [40]. Indeed, the bottlenecks created by the ecosystem are essential for reindeer migration patterns. These bottlenecks are naturally more elevated and drier, so are often used for industrial development, particularly for oil and gas extraction [41]. Regional development has also been shown to have a long-lasting impact on reindeer behavior, including the abandonment of calving grounds [42].

It is imperative to consider the potential impact that oil and gas production can have on the local population with regards to reindeer herders. The local indigenous community, the Nenets, have been highly impacted by these changes in the environment. In Yamal, reindeer husbandry still depends on and supports a nomadic lifestyle, which leads to a host of social and environmental considerations for the region, separate from those found in urbanized European and Western society [41]. Utilizing over 70% of the Yamal-Nenets Autonomous Okrug for reindeer migration, the industrial development caused from oil and natural gas extraction has had major ramifications on the cultural heritage of the Nenets people [43].

While the development of onshore wind does present the potential to create a more balanced environmental, social, and economic climate in Yamal, there are a few factors that warrant further consideration. As mentioned previously, infrastructural development in tundra ecosystems, oil and gas-related or otherwise, often select sites critical to reindeer migration, as well as sites that are utilized for camps (chums) or are considered sacred to the Arctic's indigenous peoples [41]. Perhaps most crucially, a study conducted in Sweden determined that wind turbines caused reindeer disturbance, particularly impacting calving sites and habitat selection [44]. Therefore, wind turbine construction in Yamal must first prioritize reindeer migration patterns, the locations of indigenous settlements, and sacred sites prior to wind turbine and microgrid development. The necessity of this analysis is confirmed by the Russian Federation's ratification of the Convention on the Elimination of All Forms of Racial Discrimination, which reaffirms Russia's dedication to preserving indigenous ways of being [45].

When considering the sustainable economic, environmental, and social factors of the Yamal peninsula, it is crucial to take into consideration both current environmental strains from industrialization and concerns of cultural preservation. The transition from fossil-fuel generated electricity to wind energy has the potential to serve as a more equitable alternative to current regional development; however, it must also conserve the cultural and environmental heritage of the region to the fullest degree possible.

5. International Experiences

The increasing demand of RE microgrids globally has altered traditional energy structures and electric distribution grids. This increasing demand is caused by the growing availability of generators utilizing energy from renewable sources, namely wind energy. Major power-consuming states in the US are beginning to formulate policies that support the use and implementation of microgrids as a way of increasing reliance on RE, improving efficiency, lessening energy transport costs, and decreasing carbon emissions. Some American states have already developed and implemented various policies regarding RE microgrids, in order to steer and tailor these microgrids to their specific needs. Specifically, remote Alaskan localities have successfully integrated wind energy in their existing energy microgrids. The experience and successes of RE microgrid deployments in these areas can serve as a model for similar implementation in the regions within Russia that could benefit from them the most [46].

Like Russia's remote Arctic regions, Alaska faces a challenge of delivering and utilizing energy in freezing climates. In recent decades, Alaska has overcome these challenges via the implementation of microgrids and currently has the highest number of microgrids of all US states. Alaska has had to innovate in its implementation and use of RE microgrids for optimal functionality. This innovation stems from the need to provide reliable electricity and from the expensive nature of delivering fuel to such harsh climates. For Alaska, the cost of delivering energy was enough for the state to seek alternatives in energy. The state's overall experience offers critical lessons in sustainable development for similar regions like Yamal and Murmansk [46].

In Alaska, microgrids serve thousands of people within regional grids, the largest of them being the Railbelt Grid. This area spans approximately 600 miles and serves many metropolitan areas. What makes it so important is that the battery of this microgrid was the largest in the world at the time of its installation. The battery prevents energy outages by taking over when natural gas use is interrupted. It has prevented almost 800 outages since 2003 for over 300,000 individuals. After all, reliability is a crucial factor of sustainable development and such a battery can offer just that to Russia's remote Arctic [46]. Interestingly, RE is implemented in Alaskan microgrids largely absent of government orders. They are generally decisions put forth by electric utility companies for purely economic reasons. RE use in such areas is simply cheaper and more profitable than diesel fuel. Since 2003, diesel fuel has been slowly but increasingly replaced by wind power electricity in Alaskan microgrids. The town of Kipnuk, Alaska is an important case study in the examination of successful wind energy microgrid implementation [47].

Kipnuk is a small town in western Alaska and one of the most remote locations in the United States. The town's roughly 700 residents require energy to cook meals, light their roads, and heat their homes, just like any other people around the world. Kipnuk relied on diesel fuel to meet its energy needs for decades, similar to a myriad of locations in Siberia and the Russian Arctic. The town only had access to such fuel during a small window in the summer, when the nearby river thawed, allowing oil transport ships to deliver. Such conditions mean that transport and storage of fuel is unreliable and unsustainable [47].

Image 2: Kupnik RE Microgrid, Alaska [48]

In 2019, Kipnuk's local energy company installed wind turbines and electric heating systems within the diesel powerhouse to decrease reliance on fossil fuels. These systems are intended to work as part of a hybrid energy apparatus that make use of both types of fuel. In this system, use shifts regularly between wind energy and diesel energy, depending upon the conditions. For example, during periods of strong winds, diesel use is decreased. This allows the community to maximize efficiency from both sources of power. Reliable access to energy is not the only benefit

Kipnuk has experienced from the implementation of this hybrid energy system. The community has also reduced carbon emissions, saved thousands of dollars on energy transport costs, and even gained new employment opportunities through the system. Yamal and Murmansk likewise are regions that have great potential for RE microgrids powered by strong local Arctic winds [47].

The Russian Federation's approach to the promotion and utilization of RE microgrids can be modeled after Alaska's experience. Both regions have similar needs, climate, and challenges. Just as Alaska has shown promise in harnessing both onshore and offshore wind power, so can Russia's Arctic regions. Creating a TASED in the Yamal and Murmansk regions can beneficially integrate wind electricity on a small scale in these regions. Further, these microgrids can do more than just provide electricity to the regions' inhabitants. They can also help these areas shed dependence on fossil fuels, while paving the way for sustainable development and eliminating the expenses associated with the transportation and storage of diesel fuels in these harsh climates. These benefits alone can be critical pieces of development for these Russian regions.

6. Conclusion

While the potential for Arctic wind energy development is still in its infancy, this article presents a potential avenue, which the Russian Federation could follow, in order to achieve sustainable development of the Arctic region. Specifically, this piece proposes the creation of TASEDs in the Arctic regions of Murmansk and Yamal, in order to facilitate the development of wind-powered RE microgrids.

On the governmental level, a TASED can be used as a means to fast track regional development by bypassing existing Russian regulations. Most notably, TASEDs have the capability to maintain profitability without compromising on time or innovation. As concerns innovation, this paper has touched upon the benefits of both onshore and offshore wind turbine technologies, emphasizing their potential for profitability and efficiency.

The regions of Murmansk and Yamal each present unique social, economic, and environmental concerns for both regions, while at the same time display potential for wind turbine development. In particular, there is need for offshore wind technologies in Murmansk and onshore wind technologies in Yamal to account for the technological and efficiency concerns of wind turbine development, while maintaining a need to return to a more balanced, healthy ecosystem in Murmansk, and to conserve the present environmental and social integrity of Yamal.

Finally, this piece addresses the international experience of RE microgrids, specifically the case study of Kipnuk, Alaska. This example highlights the feasibility of wind powered RE microgrids as a means to promote rural sustainable development through a hybrid electrical system.

In conclusion, this work maintains that a more sustainable future is possible for Russia through the establishment of wind powered RE microgrids in the Arctic regions of Murmansk and Yamal. Not only will the creation of these microgrids promote sustainable development of Russia's most vulnerable regions, but it will also allow for future innovation and efficiency for RE development. Pre-existing legislation, such as TASED, has the ability to establish the foundation for this innovation and development, which will ultimately yield net positive social, economic, and environmental results.

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