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Accessibility of Energy from Renewable Energy Sources for Inhabitants of Arctic Cities[1]

Abstract. The subject of the present research is the assessment of access of residents of Northern cities to energy produced from renewable energy sources (RES). The largest Arctic cities in Russia, Sweden, Norway, Finland, Denmark, the USA and Canada, located above 66 ° 33 ´ North latitude, are analysed. The importance of the study is due to the categorisation of access to RES as a fundamental good in the context of Sustainable Development Goals and fight against climate change. The work uses the index method, followed by ranking cities by the level of access to energy from RES. The following variables constitute the index: variety of operators, variety of types of energy sources, alternatives of energy sources, micro- and macro-generation support. It was found that residents of Kiruna and Tromsø have the best access to energy from renewable sources due to the support of initiatives at all levels, while Utqiagvik has the lowest indicator due to its isolation. Energy from renewable energy sources does not have a significant share in all of the cities under consideration; moreover, the market is often monopolised, which limits the choice and availability of various energy sources. Consequently, it is important to create suitable conditions for developing of RES on all levels, with the focus on micro level (as it makes ordinary people participate actively in the agenda, which is the key to support such remote areas with energy); otherwise it is unlikely to support the cities and territories of the region with energy from RES.

Keywords: energy utilisation, sustainable development, environmental impact, carbon dioxide, Arctic, hydraulic citizenship, renewable energy sources, renewable energy, sustainable development goals, urban planning, urban studies, energy citizenship

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ИССЛЕДОВАТЕЛЬСКАЯ СТАТЬЯ

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Доступность энергии из возобновляемых источников для жителей арктических городов

Аннотация. Предметом данного исследования является оценка доступа жителей северных городов к энергии, производимой возобновляемыми источниками (ВИЭ). С этой целью были проанализированы крупнейшие арктические города России, Швеции, Норвегии, Финляндии, Дании, США и Канады, находящиеся выше 66 ° 33 ´ северной широты. В статье представлен рейтинг доступности возобновляемых источников энергии, принимаемых за фундаментальное благо в контексте целей устойчивого развития и борьбы с изменением климата. При помощи индексного метода было проведено ранжирование городов по уровню доступа к энергии из ВИЭ. В основе индекса лежат следующие переменные: разнообразие поставщиков, разнообразие типов источников энергии, наличие альтернативных источников, государственная поддержка микро- и макрогенерации. Было выявлено, что энергия из ВИЭ наиболее доступна для жителей Кируны и Тромсё; такой результат был достигнут за счет поддержки соответствующих инициатив на всех уровнях. Наименьший показатель отмечен в городе Уткиагвик вследствие его изолированности. Не во всех из рассматриваемых городах энергия из ВИЭ занимает значительную долю рынка. Более того, зачастую рынок монополизирован, что ограничивает выбор и доступность различных источников энергии. Следовательно, важно создать подходящие условия для развития ВИЭ на всех уровнях, особенно на микроуровне (вовлечение индивидов является важным фактором обеспечения отдаленных местностей энергией); в противном случае представляется маловероятным обеспечение городов и территорий региона энергией из ВИЭ.

Ключевые слова: использование энергии, устойчивое развитие, воздействие на окружающую среду, углекислый газ, Арктика, гидравлическое гражданство, возобновляемые источники энергии, возобновляемая энергия, цели устойчивого развития, городское планирование, урбанистика, энергетическое гражданство

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1. Introduction

The relevance of this study is justified by the escalating environmental agenda and, as a result, by changing patterns in consumption. Because of that, environmental friendliness and sustainability of lifestyles and actions become a priority for both individuals and cities and states. The presence of the opportunity itself becomes insufficient for many groups of people; the presence of the stable alternatives becomes important. So, for example, car-sharing, waste sorting are gradually becoming more and more in demand and are perceived as basic goods that fulfil a person's need to defend their values and an eco-friendly lifestyle. Thus, sustainable infrastructure is increasingly becoming an object of political struggle and mixed agency (active participation of residents). This brings sustainable infrastructure closer to the ideas of "hydraulic" and "ecological" citizenship and makes it possible to analyse it through the categories of these concepts. In addition, while developing the ideas of the mentioned concepts, this study attempts to create an index based on them. For the study, the case of sustainable energy systems was chosen, since the energy infrastructure is usually under the control of the state or business; so the analysis of related policy is more objective than of small private initiatives' policy. The case is considered applicable to Arctic cities, since the Arctic ecosystem is the most environmentally vulnerable, while having significant potential for renewable energy sources (RES).

No work has been identified that directly applies the concept of "hydraulic citizenship" to sustainable technologies. However, the work of Nikhil Anand "Hydraulic City: Water and the Infrastructures of Citizenship in Mumbai" (Anand, 2017) contains not only the initial concept, but also a number of universal theses regarding the role of urban infrastructure in self-identification, urban processes, legal and relationships agents. Thus, the author presents a conceptual and methodological basis for the further development of the problem. In this study, the concept outlined by Anand is applied to sustainable technologies in energy supply. Anand's fundamental idea is to remove the exploitation of urban infrastructures from just physical space, giving it additional meanings and functions in the life of society. Infrastructure is not limited to networks, but is complemented by a number of relationships established in connection with it. Infrastructure, its implementation and operation are associated with the interaction and interests of a number of agents, so it can become the object of manipulation by the government, operator or society. At the same time, infrastructure remains a fundamental good necessary for a comfortable existence; therefore, it is a marker of a kind of recognition of certain groups of the population and territories. For the above reasons, access to infrastructure often becomes the object to the political agenda and struggle, the author calls it a basic political right, and the legal personality that appears due to access is called "hydraulic citizenship" (Anand, 2017).

Another concept on which the present study is based on is "energy citizenship", first outlined by Patrick Devine-Wright in his work "Energy citizenship: Psychological aspects of evolution in sustainable energy technologies" (Devine-Wright, 2007). Devine-Wright's key idea is that with the transition to low-carbon energy systems, public support and assistance are required. Thus, in order to promote energy innovations, residents should not be perceived as an indifferent passive consumer, but as a full-fledged agent, whose actions affect the achievement of energy policy goals. Devine-Wright emphasises the existence of a hybrid relationship between residents and energy companies, noting that residents are not only conscious consumers of innovations, but also political actors (protestors, promoters, forming new practices) (Devine-Wright, 2007).

This study was also influenced by modern concepts related to changing consumption patterns. Among them, the concept of sustainable development, put forward by the United Nations in 2015, as a sequence of the concept of the Millennium Development Goals, was summarised by the organisation in the form of 17 goals (Ruhil, 2017). Some of the goals directly or indirectly relate to providing residents with high-quality sustainable infrastructure, namely: clean water and sanitation, affordable and clean energy, innovation and infrastructure, sustainable cities and settlements, responsible consumption and production, and combating climate change.

This study is based on the research outlined above, taking as a starting point the following: in modern realities, access to sustainable infrastructure is a basic good and a political right of every inhabitant.

Further, it seems necessary to highlight the object and subject of research. The object of research is access to renewable energy sources; the subject of research is the assessment of access to renewable energy sources.

The purpose of this study is to assess the access of residents of Arctic cities to sustainable energy alternatives.

To achieve the goal, the following tasks were set: analysis of the power systems of the cities under study; identification of measures supporting renewable energy in cities; development of an access assessment index based on theoretical concept metrics and power system data; highlighting of the strengths and weaknesses of access to renewable energy sources based on the index.

Consequently, the scientific hypothesis is as follows: cities have unequal availability of energy from renewable sources as a basic need, described by hydraulic citizenship.

2. Methodological and Informational Basis of the Study

In terms of methodological tools for this study, analytical, inductive and index methods should be distinguished. The analytical method was used when examining the existing power systems of the declared cities for the availability of access to renewable energy sources; it should also be noted that this method was applied to highlight the main features of the policy (at the state, regional and municipal levels) in relation to renewable energy sources. Based on the inductive method, generalised conclusions were obtained regarding the aggregate access of residents of the declared cities to renewable energy sources. Finally, the index method was applied to form a ranking of access to renewable energy sources as a fundamental benefit among residents of the considered Arctic cities. Thanks to this method, Arctic cities with the best access for residents to renewable energy sources were identified. The proposed index is based on the values of the diversity of energy operators in the cities under consideration, the diversity of types of energy sources, the availability of a choice between traditional and renewable energy sources, the availability of support for micro- and macro-generation of RES at various levels, etc.

As a part of this study, 7 states were selected: Russia, Sweden, Norway, Finland, Denmark, the USA and Canada. On the territory of the respective states, the largest cities located above 66 ° 33 ´ N (cities beyond the Arctic Circle that are included in the Arctic region) were selected. In each country only one largest city (according to population)

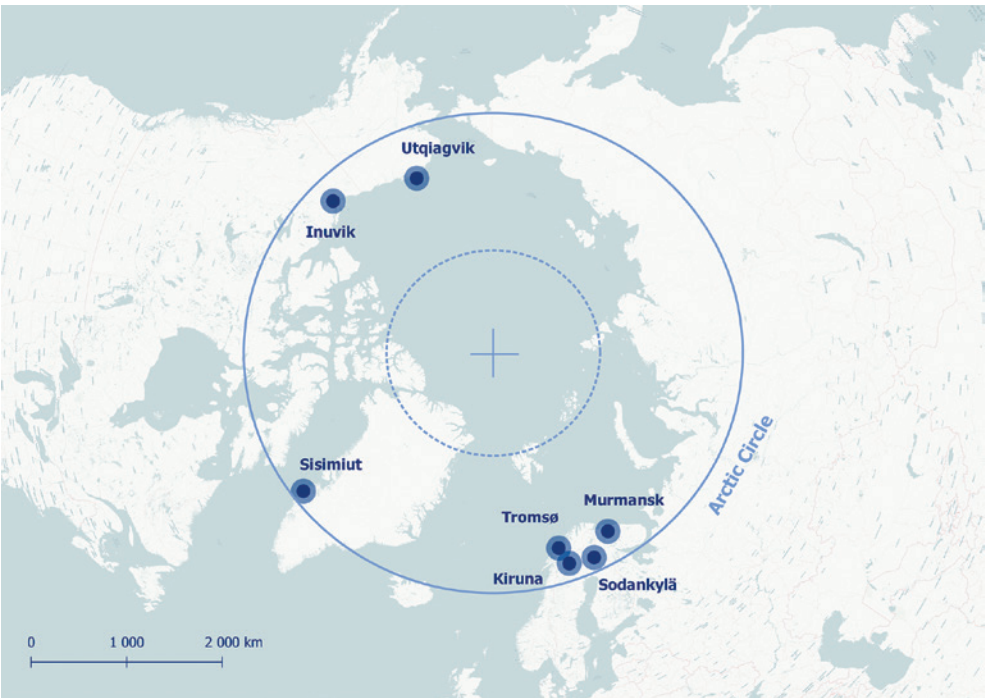


Fig. 1. *Location of the cities under study compared to the Arctic Circle*

Table 1

Information on the cities under study

Name	Country	Coordinates	Population	Reference
Inuvik	Canada	68 ° 21´ N 133 ° 43´ W	3,100 (2021)	(Frigault & Giles, 2020)
Kiruna	Sweden	67 ° 51´ N 20 ° 13´ E	23,000 (2019)	(Szpak, 2019)
Murmansk	Russia	68 ° 58´ N 33 ° 05´ E	295,400 (2021)	(Degai et al., 2021)
Sisimiut	Denmark	66 ° 56´ N 53 ° 40´ W	5,600 (2020)	(Fris Skovsen et al., 2021)
Sodankylä	Finland	67 ° 25´ N 26 ° 35´ E	8,200 (2021)	(Lassila, 2021)
Tromsø	Norway	69 ° 39´ N 18 ° 57´ E	77,000 (2020)	(Morseth & Hopstock, 2020)
Utqiagvik	USA	71 ° 17´ N 156 ° 47´ W	4,900 (20200	(Tysiachniouk, 2020)

is chosen because of great difference in population size of respective countries. Iceland is not included in the corresponding list generated for the study, since there are no large cities in Iceland located above 66 ° 33 ´ N (Sandvík on the island of Grimsey is the largest, however, it is not a city, but a settlement that has only 60 inhabitants).

Thus, the following cities were chosen (Fig. 1): Inuvik, Kiruna, Murmansk, Sisimiut, Sodankylä, Tromsø and Utqiagvik. More detailed information about cities under study is presented in Table 1.

In the context of the study, it is of paramount importance to consider the energy systems of these cities. Further, we will designate the features of those.

3. Results and Discussion

3.1. Energy Systems of Cities and Support of Renewable Energy Sources

3.1.1. Tromsø

The first city proposed for consideration is Tromsø in northern Norway. It has been recognised as a city since 1794, but the first settlements appeared as early as the I-II millennium BC. The city is a major fishing port, research cluster and tourist destination (Heimtun & Haug, 2022). The local energy system does not include traditional sources of fossil fuels (oil, gas, coal), but is entirely based on RES: wind power plants (WPP), solar power plants (SPP) and hydroelectric power plants (HPP). WPP and HPP account for the largest share in the production volume — 281 MW and 200 MW, respectively. Solar energy is currently underdeveloped, it accounts for 0.67 MW, however, according to recent studies, the potential of SPP in Tromsø is high (Eikeland et al., 2020). The existing energy system is closely integrated into the Norwegian common energy market and thus forms part of an interstate network linking Norway and Sweden. An important feature of the system is the ability to create a combined micro-generation system at the private consumer level, thanks to the Enova project.

Moving on to the issue of state and municipal regulation of RES, the following support mechanisms should be noted. The first of them is the

Client + system, which assumes micro-generation (independent production and consumption of electricity at the level), in return, the household is provided with a reduced tax rate and the opportunity not to pay commission for electricity. However, it is obligatory to sell the surplus produced energy to a specific supplier. The second mechanism is the certification of industries using only renewable energy sources in their activities. The products of companies with green certification are marked with a special sign. Those goods that do not have this mark cannot be purchased by state and municipal institutions, are less often supplied abroad and, as a rule, are less interesting to buyers. The third mechanism is the Enova project. This is a system of gratuitous targeted subsidising of micro-generation. A resident is issued NOK 28,750 for the installation of his own energy production. The fourth mechanism is the promotion of macro-generation of renewable energy sources by the municipality (support for construction, profitable lending, and so on).

3.1.2. Murmansk

Next, we will consider the features of the power system of the Russian northwestern city of Murmansk that was founded in 1915 as a polar port city. Today, the economic specialisation of the city is based on fishing and fish processing, heavy industry, and trade (Mitroshina, 2019). It also serves as a base for nuclear-powered icebreakers. The main share of heat is produced in the traditional way and is represented by combined heat and power (CHP), which accounts for 75 % of the city's heat supply. Electricity is produced by nuclear power plants (NPPs) and HPPs with a capacity of 1760 MW and 268 MW. Even though the existing energy infrastructure in the Russian Arctic is characterised by remoteness and, often, isolation, and the main sources of electricity and heat supply are hydrocarbons and some nuclear energy projects, Murmansk is one of the centres for RES deployment. So there are wind farm projects that are currently at the implementation stage due to the high wind energy potential of the territory (Minin & Furtaev, 2020) that will produce extra 700 MW. In addition, a number of other renewable energy sources are located on the territory of the Murmansk region, but they supply the entire constituent entity, therefore, it is not possible to estimate the share attributable directly to the city of Murmansk. However, it can be noted that they are also represented by HPPs (total capacity of 1133 MW), therefore, regardless of the share of Murmansk in consumption, regional renewable energy sources do not diversify the type of source. Significant monopolisation is one of the distinguishing features of the Murmansk network. The operating CHP and HPPs are projects of PJSC Gazprom, the entire infrastructure is included in the unified energy grid of the Unified Energy System of Russia. That is, the consumer has virtually no choice of operator.

Thus, the state largely regulates the issues of energy production, all programmes are implemented at the federal, not the municipal level. Among the support measures are the following. First, the plan to subsidise the construction of large renewable energy sources until 2036. The state has also set targets for the rate of introduction of renewable energy sources, which should stimulate the development of such. In addition, the state covers the difference in the cost of electricity produced by RES compared to traditional sources. Thus, the consumer does not feel the difference in the price of electricity after the introduction of RES. Finally, in the context of macro-generation, it is necessary to mention the establishment of a fixed price for electricity produced when it is sold to the state for up to 15 years, so, the operator does not depend on price fluctuations in the electricity market (Konovalova, 2018). If we talk about micro-generation, then the state issues a permit for the sale of generated electricity to the grid. At the same time, the owners of these renewable energy sources are exempt from the tax burden (Konovalova, 2018). It should also be noted that there is a simplified procedure for the placement of micro-generation facilities in the case of choosing RES over traditional energy generators (Konovalova, 2018).

3.1.3. Sisimiut

The next considered power system belongs to the city of Sisimiut, a Danish city in the Greenland Autonomous Territory. The city was founded in 1764, but the first settlements appeared 4000 years ago (Thuesen, 1999). The basis of the city's economy is fishing and fish processing, as well as tourism, however, it is planned to develop the aluminium industry. A distinctive feature of the city's power system is complete autonomy, since the networks of all Greenland cities are isolated from each other. The basis of the city's electric power industry is an HPP (15 MW), but today a project for the introduction of RES is at the stage of implementation and a part of a wind farm (one turbine) with a capacity of 0.025 MW has already been installed. Heat supply to the city is provided by a waste incineration plant. As for micro-generation projects (Luc et al., 2016), they proved to be unprofitable during the experiment in 2005–2006 with the introduction of self-sufficient houses

(Rode et al., 2009). This is a popular practice, but for Sisimiut it is ineffective as it does not justify the costs caused by low energy efficiency due to geographic characteristics.

Support is provided at several levels: state and autonomous. Denmark supports micro-generation. Despite the unprofitability of this type of system for the end user, it is beneficial for the state, since it does not require extensive energy networks and does not imply the supply of fuel from Denmark. Autonomy initiates a number of macro-generation projects, since this will lead to achieving energy independence from Denmark, which supplies hydrocarbon fuel to most of Greenland's cities (which is also significant in the context of global warming, observed in Greenland in the thinning of the ice sheet (Winsor et al., 2015), so autonomy is forced to give up energy sources that contribute to global warming).

3.1.4. Kiruna

Another city that is proposed for consideration in this work is the Swedish city of Kiruna. It was founded in 1900 as an industrial city. The basis of the city's economy is the mining industry, tourism is of lesser importance (Stihl, 2022). Space research is actively underway, and a spaceport for suborbital flights is planned to be located in the city. The key components of the city's energy system are the Vietas HPP (306 MW) and the wind farm within the municipality (78 MW), which provide the city with electricity. Another significant object of the energy system is the Tekniska Verken i Kiruna AB CHP, which provides the city with central heating and, by analogy with other Swedish cities (Stoyanov, 2019), operates by incinerating waste (50 %) and consuming industrial gases and surplus heat from the LKAB enterprise (20 %). Since the mid-2010s, the city has been implementing a project for the introduction of "passive" houses on full self-sufficiency in cooperation with the leadership of the municipality, the University of Luleå and the Nordic Construction Company.

RES support is carried out at the state level through incentives such as a quota system and a green certificate trading system (Johansson et al., 2016) similar to Norway. Another mechanism is subsidising photovoltaic SPPs, in which the state allocates funds for their construction. As for micro-generation, there are tax incentives for such RES: a reduction in property tax when using wind micro-generation, no taxes on electricity production at RES facilities with a capacity of less than 50 kW. It is also necessary to note the activities of LKAB aimed at supporting renewable energy sources and participating in the work of the district heating system in order to reduce the environmental impact, as well as investing in the "relocation" (Szpak, 2019) of the Kiruna city centre due to threats to residents associated with the economic activities of the mining company ore under the territory of the city.

3.1.5. Sodankylä

Finally, the last city that is proposed to be considered within the framework of the European Arctic is the Finnish city of Sodankylä that was founded in 1893. The main source of income for the city's economy is the service sector, with a small share of agriculture and forestry, as well as gold mining (Haq et al., 2020b). The basis of the city's electric power system is a network of HPPs (7 objects, with a total capacity of 118.9 MW), which provides 90 % of the city's electricity demand (Kiviniemi, 2014), as well as the Yukaselka wind farm with a capacity of 27 MW. At the same time, the basis of the thermal power system of Sodankylä is the 34 MW Seitateella CHP, which uses peat (49 %), wood (48 %) and oil (3 %). As part of the CHP analysis, it should be noted that the high level of carbon dioxide emissions from peat burning requires more environmentally friendly solutions, in connection with which a project is being developed to transfer this CHP to biogas (Haq et al., 2020a). Also at the stage of development and modelling is a project to create a combined geothermal power plant in Sodankylä, which will become the basis of the city's district heating (Haq et al., 2021). Finally, it is important to mention the project proposed by the University of Vaasa to introduce a system of industrial symbiosis, which should reduce the energy needs of Sodankylä and also make the production cycle closed (Haq et al., 2020b) (in general, the concept is similar to the existing systems in Swedish cities of Kiruna and Luleå (Stoyanov, 2019)).

If we talk about government support, it is represented by subsidising research and investment projects in the field of renewable and sustainable energy. There is also a system of grants and tenders to support RES and a system of investment in the implementation of RES by farms. However, in general, the state rather adheres to a neutral policy in relation to RES. At the municipal level, energy efficiency is monitored in order to find the most profitable and effective solutions that would reduce the costs of the municipality and its residents.

3.1.6. Utqiagvik

Within the North American continent, the largest polar city in the United States is Utqiagvik.

Registered as a city in 1959. The economy of the city is largely based on oil production, a small share belongs to tourism and crafts, which are the most active during the midnight sun (Anderson, 2021). An important feature of the city is its isolation (by analogy with many other cities of the Arctic zone, however, this situation is most clearly manifested in Russia (Stoyanov & Sakharova, 2020), such isolation leads to deliberate limitations in the choice of electricity suppliers and sources of energy production), within which communication with the rest of the communities are carried out by air and sea routes. Thus, the city's energy system is closed, the only source of electricity is the Barrow gas-fired TPP with a capacity of 20.3 MW. There is no centralised heat supply, the buildings are heated using natural gas. All energy infrastructure facilities belong to a single municipal cooperative company BUECI, respectively, consumers do not have a choice of a supplier of heat and electricity. The lack of renewable energy sources is due to low wind speeds, which makes the construction of wind farm stranded, and the low level of insolation makes the potential use of the SPPs ineffective.

As for the various types of support for RES, the key one is at the level of the state of Alaska and at the state level. Thus, it is necessary to mention the existing system of standards for RES (RPS), thanks to which the state government can require the utility company to provide a certain share of electricity produced from RES, for which tax incentives can also be provided. On the other hand, the state provides loans with a reduced interest rate for the creation of renewable energy facilities, as well as grants for the implementation of similar projects. Otherwise, government support is limited to fluctuations in the political course, within which the United States resorts to both support for hydrocarbon energy and support for RES.

3.1.7. Inuvik

Finally, the last city to be considered is the Canadian city of Inuvik. The city was founded in 1953 as a replacement for the previous administrative centre, which suffered from floods. The basis of the city's economy is shaped by the oil and gas extraction, service sector, tourism and crafts (Young, 2016). Its electric power base is made up of two TPPs: one on liquefied natural gas that is imported from the south as part of an environmental project of the Energy Corporation of the Northwest Territories) with a capacity of 8 MW and one on diesel fuel with a capacity of 6.06 MW. However, since 2020, a transfer of diesel power plants to biofuels is being carried out as part of the programme for the introduction of clean energy for rural and remote communities (CERRC). Also, the construction of a wind farm with a capacity of 1.8–2.2 MW by the Northwest Territories Power Corporation was expected to be complete by the fall of 2022; this project will reduce the consumption of diesel fuel within the TPP by 36 %. However, the construction of this RES facility is associated with a number of litigations due to illegal and improper use of the territory conceived for breeding livestock as a place for the construction of wind farms. In terms of micro-generation, Kuby Energy is installing photovoltaic panels and energy storage systems to create independent self-sustaining buildings. All renewable energy projects in Inuvik are aimed at reducing dependence on natural gas, which has an excessively high cost (more than 10 times the cost of that in the southern states of Canada) (Coates & Landrie-Parker, 2016).

If we turn to support for RES, support at the federal level is realised. Thus, for the Northwest Territories, an energy strategy was developed until 2030, within the framework of which it is planned to reduce the consumption of traditional energy resources for electricity production by 25 % in order to reduce greenhouse gas emissions and increase the share of RES in heat production by 40 %. Accordingly, at the federal level, many projects are being implemented, invested from the federal budget for the introduction of RES, in particular, one can refer to the previously mentioned RES, TPPs on LNG and TPPs on biofuels. In general, the bulk of projects are focused on macro-generation, while micro-generation is not supported at the legislative and investment levels.

3.2. Index of availability of renewable energy sources

The next step in the study is to develop an index of the availability of RES. The index metrics are developed based on the categories of concepts of "hydraulic" and "energy" citizenship, the values of the metrics are assigned in order of priority:

$$RES\_access\_index = 0.1variety\_provider + 0.2variety\_supply + 0.3alternative + 0.2support\_micro + 0.2support\_macro, \quad (1)$$

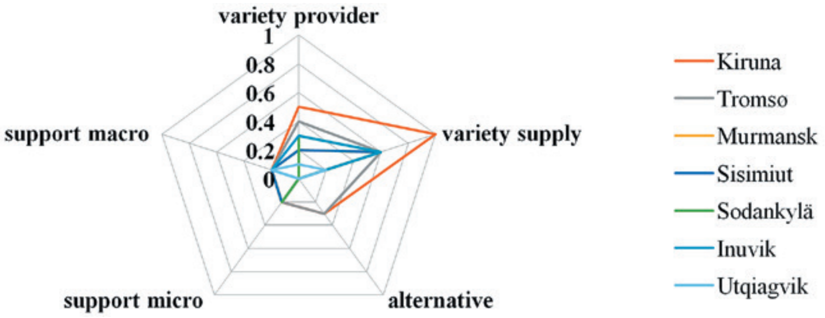
where:

1. variety_provider — variety of operators (each operator = 1);
2. variety_supply — variety of types of energy sources (each source = 1);
3. alternative — residents have a choice between traditional and renewable energy sources / access only to renewable energy sources (binary indicator, 0 — no, 1 — yes);

Table 2

Ranking according to index for availability of RES

place	city	RES access index	variety provider	variety supply	alternative	support micro	support macro	legend
1	Kiruna	2.2	0.5	1	0.3	0.2	0.2	strong
2	Tromsø	1.7	0.4	0.6	0.3	0.2	0.2	weak
3	Murmansk	1.2	0.2	0.6	0	0.2	0.2	
3	Sisimiut	1.2	0.2	0.6	0	0.2	0.2	
4	Sodankylä	1.1	0.3	0.6	0	0.2	0	
4	Inuvik	1.1	0.3	0.6	0	0	0.2	
5	Utqiagvik	0.5	0.1	0.2	0	0	0.2	



4. support_micro — availability of state / municipal support for RES micro-generation (binary indicator, 0 — no, 1 — yes);

5. support_macro — availability of state / municipal support for RES macro-generation (binary indicator, 0 — no, 1 — yes).

The column "legend" provides description of markers for the strongest and weakest aspects of renewable energy policies that promote or hinder the availability of alternative sources for residents.

Results of the assessment of the cities studied based on the equation (1) are presented in Table 2.

The original index does not appear to be exhaustive; its results should be filtered through socio-economic indicators: population size, total energy consumption by population and industries, as well as the cost of green energy, taking into account average statistical salaries/wages.

Summing up, it should be noted that access to sustainable energy alternatives is being developed in all the cities considered (Fig. 2), but to a different extent and has its own peculiarities.

In some cities, this process is dictated by economic expediency and is initiated from above. In

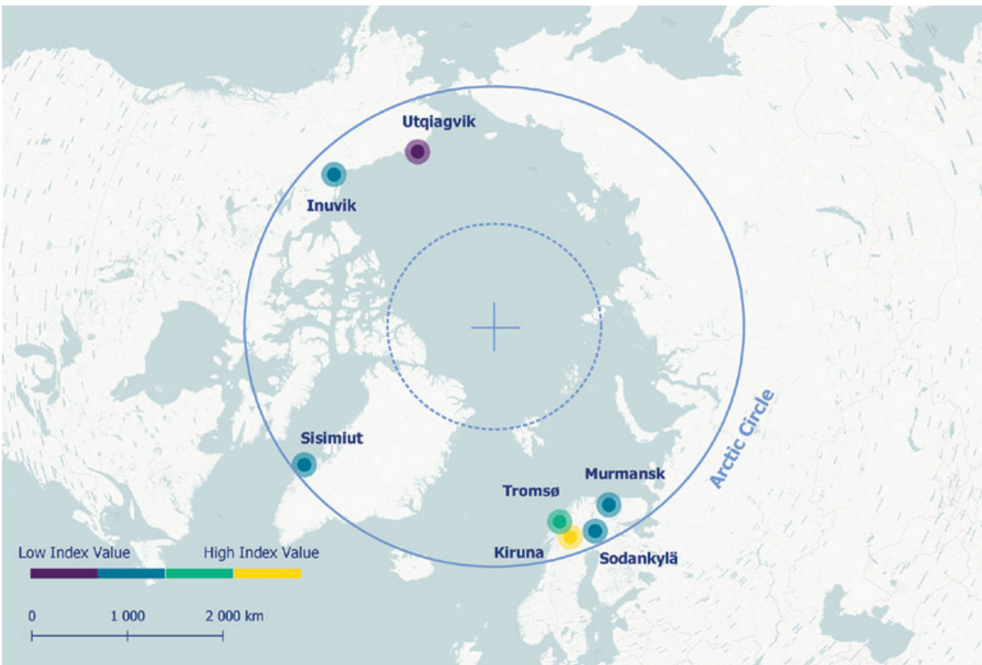


Fig. 2. *Index comparison of cities under study*

other cities, it is additionally supported by the society (political activity or micro-generation). RES prevail in energy supply only in some cities (Tromsø, Kiruna, Sisimiut, Sodankyla). The power systems of most cities are characterised by a monopoly or an oligopoly, while energy sources (including RES) can be diversified within the network of one company. Most cities support the introduction of RES at both the macro- and micro-levels with various economic incentives. At the same time, it should be noted that only in Tromsø and Kiruna residents are provided with an alternative (or only RES operate). This is the most important metric, as it shows the possibility of residents for abandoning traditional energy sources and influencing the energy system through demand.

4. Conclusions

Summing up the study, the following conclusions can be drawn. As for theoretical significance, the research proposes to expand the concept of hydraulic citizenship applicable to the availability of RES as a basic need.

As for practical significance, it was proved that the cities under study have unequal availability of energy from RES as a basic need. This is determined by both governmental policy and the availability of the necessary infrastructure and energy needs. The developed index can be used in assessing the availability of energy from RES for the population in various cities and countries. It can be useful when conducting energy planning at the municipal level and assessing the contribution of various cities to national, regional or global efforts to achieve Sustainable Development Goals 7, 11, 13 and 17. The need to use this or a similar index is dictated by the current conditions in which clean energy is becoming a basic need of the population.

As already mentioned, in the future it seems possible to refine the index, taking into account socio-economic indicators, so that the index will become more useful not only for the public, but also for private sector.

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