A Feasibility Study to Develop Local and Regional Use of Wind Energy on the Kola Peninsula, Murmansk Region, Russia

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1. Summary

The possibilities for wind energy production on the Kola peninsula in north-western Russia were studied in an extensive feasibility study. The Kola peninsula constitutes the Murmansk oblast, i.e. a region with some autonomous features, within the Russian federation.

The wind resources in the region are very good, with annual mean speeds up to 10 m/s on the coast of the Barents Sea. A wind atlas is produced according to the methodology developed at Risø National Laboratories in Denmark and makes it possible to do reliable wind resource assessments and production estimates at prospective sites.

There are more than 30 civil and military settlements located off the common electrical network. In these settlements electricity needs are currently supplied mostly by autonomous diesel power stations. Due to long distances and difficult access transport of fuel is costly and thus power prices are high. In these communities wind turbines could provide both additional energy supply and fuel savings at competitive costs.

The peninsula is powered mainly by nuclear and hydro power stations and there is for the moment no scarcity of power in the electrical network. Power consumption was as high as 17 TWh in 1989 but has decreased to 13–14 TWh in the mid 90's. However, the oldest nuclear reactors are to be closed in the beginning of the 21 century and that will require some actions already today.

Power prices are low compared to general European price levels (about 0.03 ECU/kWh). Although power tariffs are low, there has been a significant increase. According to a presidential decree, prices on fuel and power are to increase further until world market price levels are reached in the beginning of the next century. Given the good wind speeds and foreseen price escalation, wind energy could be feasible already today. The best areas are on the tundra, close to existing hydro power plants.

There is a political interest in wind energy both on a regional and federal level. The interest is highly directed towards powering the remote settlements with autonomous wind-diesels. There is a significantly lesser interest in grid connected production of wind energy.

The remote settlements are, however, not bankable for large-scale investments like in wind energy. Thus a vehicle for implementing, supporting and partially financing must be established on a regional basis. According to preliminary information, such a body is being established.

The work to implement wind energy on the Kola peninsula should continue with demonstration of the technology. These activity should, in the preliminary phase focus on the remote settlements, as the dissemination possibilities are the best, also considering other regions of Russia.

These results and recommendations have been presented to the energy administration of the Murmansk oblast. Throughout the project, there was a good and continuous dialogue with the administration.

The project was funded by the European Union and was performed by members from different EU countries in co-operation with the Russian Kola Science Centre.

2. Objectives

The overall objective of the project was to form a basis and to build the necessary tools for an substantial integration of wind energy into the energy supply system of the Kola peninsula in the Murmansk region of Russia. The objectives of this feasibility study were:

- To verify the wind potential at the Kola peninsula and to establish a wind atlas database.
- To dimension wind based autonomous power supply systems for the remote communities.
- To assess the possibilities for large-scale integration of wind energy.
- To assess the economic potential of wind energy integration.
- To (preliminary) assess the potential of local industry and other business to actively participate in the implementation of wind energy and to identify barriers for doing so; to recommend preparatory actions to reduce these barriers.
- To assess the potential for reduction of the environmental impact of the energy sector by exploitation of wind energy.
- To assess and wake the political and regional interest in wind energy.

Basically all objectives were met, except for some smaller tasks that were halted due to reasons which the project group could not affect.

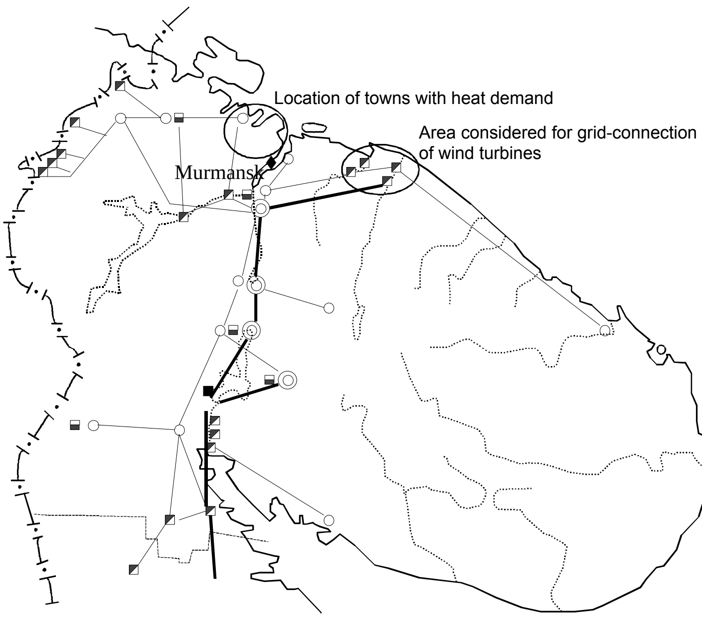


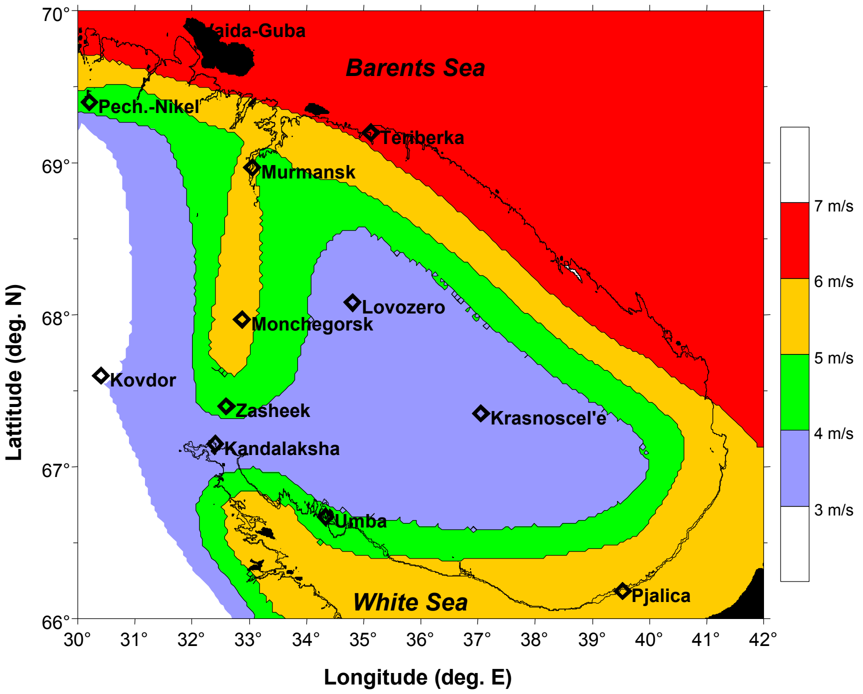
Fig. 1: The public grid on the Kola Peninsula and an illustration of the areas considered for grid connected wind turbines and where there is a heating demand

3. The Kola peninsula

The Kola peninsula is located in the most north-western part of Russia between the 66–70° latitude and 28°30'–41°30' longitude, bordering on Finland and Norway. The peninsula is facing the Barents Sea in the north and the White Sea in the south.

The total energy consumption on the Kola Peninsula has during the 90's been 13–20 TWh/year and in 1995 consumption rose for the first time since 1989. The total generating capacity is 3.66 GW, of which 1.6 GW is hydro and 1.8 GW nuclear power. The mostly public owned power company AO Kolenergo handles all sales and distribution and all production, except for the nuclear power plant from which Kolenergo, however, buys the whole production. 68 % of power and 33 % of heat production is used by the industry and respectively 11 and 52 % by domestic users. Energy prices have, as in Russia in general, been rising steadily for the past years but are still remarkably low, compared to other industrialised countries.

The public grid on the Kola Peninsula reaches more than 90 % of the population. The single line circuit diagram of the electric transmission grid is given in Figure 1, that also shows the areas where wind power might be of interest.



Mean wind speed at roughness class 2, at 25 m height a.g.l.

Fig. 2: Estimated wind resource variation over the Kola Peninsula. Mean velocities refer to roughness class 2, 25 m a.g.l. The wind speeds referring to 50 m a.g.l. are approximately 15 % higher than the values referring to 25 m. The wind resource implicated by the shading in areas outside the Kola Peninsula itself is purely due to the graphical technique, and is not supported by the present study.[4]

4. Wind resources

The wind resources were estimated based on the wind atlas method from the European Wind Atlas [1, 2] and the associated software tool WASP. Wind data from 12 meteorological station were available to the project as shown in Figure 2. Six are coastal stations: Pechenga-Nikel, Vaida-Guba, Teriberka, Pjalica, Umba and Kandalaksha; three are inland stations: Krasnoscel'e, Lovozero and Kovdor; while the remaining three belong to the "large valley" category: Murmansk, Monchegorsk and Zasheek.

From these data the map in Figure 2 was prepared giving the estimated variation of the wind resource over the peninsula. The wind atlas indicates rather good wind resources along the north coast (>6 m/s), the south coast and in the valley region between Murmansk and the White Sea (5–6 m/s). In the eastern inland, on the other hand, the wind resource is low (< 4 m/s).

5. Integration of wind energy

5.1 Grid integration of wind energy

The area east of Murmansk, in close vicinity to the four hydro-power stations Upper and Lower Teriberka and Upper and Lower Serebranskaja), was suggested as a target area for the analysis on grid connected wind turbines. Network calculations were carried out to investigate the possible capacity of wind energy that could be installed in the existing grid. Five sites were chosen for possible installations of wind farms:

- 2 sites close to hydro power stations, one at Tumannyy (1) and one at Serebrjanskie (2)
- 3 sites along the line L401 from Murmansk to Serebrjanskie, marked a, b and c.

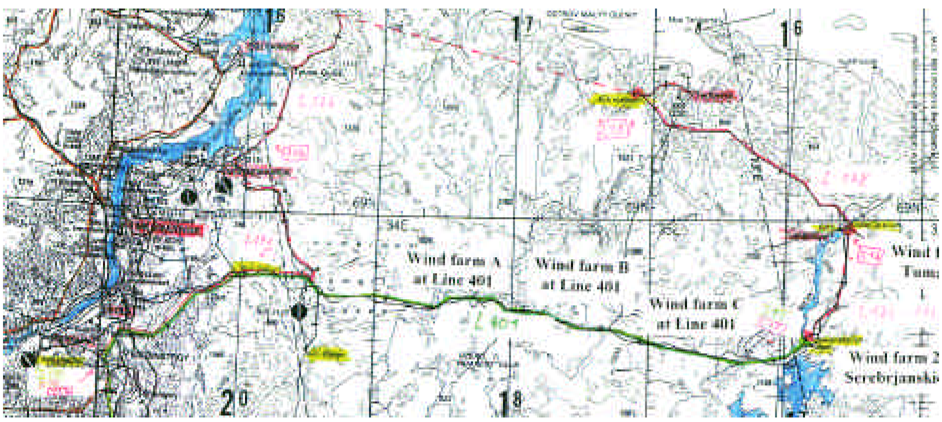


Fig. 3: Topographic map of the region east of Murmansk

Figure 3 gives an geographic view of this area and the corresponding voltage lines. The area east of Turmannyy and Serebrjanskie shows the highest wind speeds of the five sites under consideration and is therefor of high interest.

Data and charts on the public grid was presented at an early stage. An initial analysis was done for a couple of pre-selected sites, representative for the area and ”visibly” the most natural sites. The analysis was carried out on basis of charts, maps, discussions with Kolenergo and partially site visits. The complete high voltage grid on the Kola peninsula was taken into the network model "DigSILENT". The investigated voltage levels are 350 kV, 150 kV and 120 kV. Those network nodes were included in the network model, that are close to the wind farm installation areas or close to the consumers in the Murmansk region. The network nodes in the outer areas of the grid are represented mainly by joint cluster.

Voltage levels at maximum and minimum load on the grid were calculated on base of the load flow and impedance situation given in the network maps for all relevant network nodes. The higher voltage levels occur for the low load situation. Five network nodes were chosen to give a representative monitoring of the grid situation. The nodes Serebrjanskie 215 and Tumannyy 216 were selected because of their vicinity to the two suggested sites for wind farms close to hydro power stations and to the villages Tumannyy and Serebrjanskie. Kolskaja 700 was selected, because it is a gate to the region around Murmansk. Murmansk 653 reflects the voltage situation directly in the main consuming areas. The node Zapoljarnyj 721, close to the Norwegian border, reflects the voltage situation in the far branches of the grid. The voltage changes due to fluctuating operation or cut-off of the wind farms is assumed not to exceed a level of 5 %, to guarantee a sufficient voltage quality for the consumers.

To investigate the influence of different types of installation 39 network calculations were performed. The different type of WT's concerned are turbines with induction generators and WT's with generators systems able to control reactive power (i.e. inverter systems). The induction type WT's are producing inductive reactive power, a generation of -25 Mvar reactive power is assumed for a wind farm of 100 MW or 200 MW. The WT's with reactive power control are calculated with either no or capacitive reactive power generation.

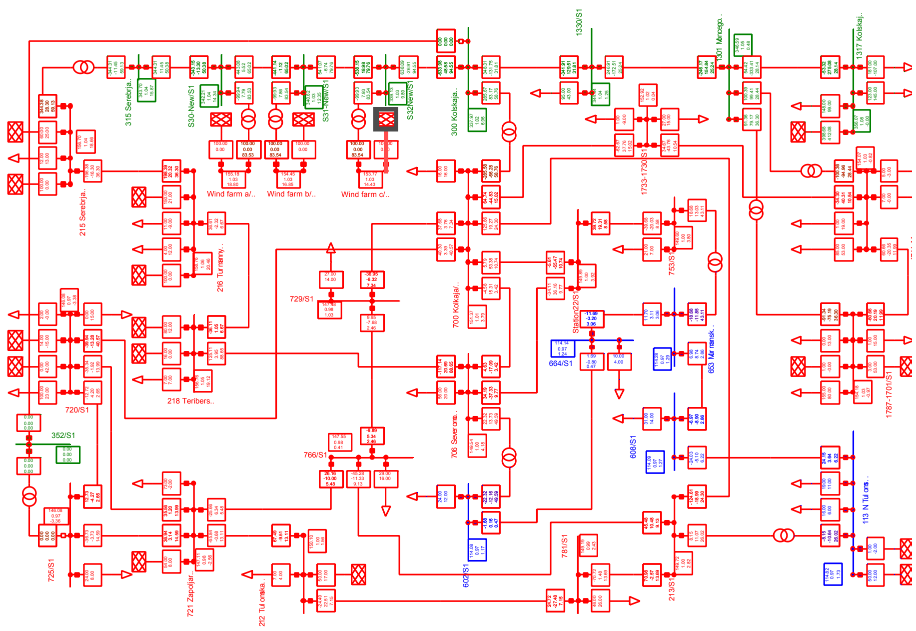


Fig. 4: Maximum load at installation of five wind farms 100 MW each in Tumanny, Serbrjanskie and and three sites along Line 401, cos j =1 (green = 350kV-level, red = 150 kV-level and blue = 120 kV-level).

For example figure 4 shows a network calculation with a wind energy installation of 500 MW, five wind farms of 100 MW each, in Tumanny, Serbrjanskie and three sites along Line 401. The results for the monitored nodes are depicted in Tab. 1. The deviations of voltage from the situation without wind farm installations are given for maximum and minimum load conditions in the grid. A maximum deviation of -4 % occurs for the node Serebrjanskie 215, which is within the acceptable limits.

Voltage changes (in % of nominal voltage)					
Kolskaja 300	Kolskaja 700	Serebrjanskie 215	Tumannyy 216	Murmansk 653	Zapoljarnyj 721
-3/0	-3/0	-4/+1	-3/+1	-3/+1	-3/+1

Tab. 1: Change in voltage levels compared to the situation without wind farm installations, for two load situations: maximum / minimum loading of the network.

The calculations were separated into five categories each consisting of an number of different wind farm configurations. The installable capacity for each wind farm configuration depends on which of the five sites are chosen for installation of 100 or 200 MW. The maximum power possible to be installed are listed in Tab. 2. The results show that the capacity depends very much on the reactive power generated by the WT's. In addition configuration d and e were calculated with a different interconnection of high voltage lines, demonstrating the influence on available capacity for wind energy.

Category	**possible capacity**
Wind farms with inductive reactive power of -25 Mvar at an active power of 100 MW each	300 MW
Wind farms without reactive power generation; 3 sites with 200 MW each	700 MW
Wind farms with capacitive reactive power of +25 Mvar at an active power of 100 MW each	300 MW
Wind farms with inductive reactive power in changed grid constellation of -25 Mvar at an active power of 100 MW each	400 MW
Wind farms without reactive power in improved grid constellation; 3 sites with 200 MW each	800 MW

Tab. 2: Maximum installable wind farm capacity for 5 different categories.

In summary it can be stated that the high-voltage grid connecting of the hydro-power stations to the national network is fairly strong and according to network analyses up to 800 MW of wind power can be connected without grid reinforcement.

From the gathered technical and energy policy information it is evident that large amounts of wind energy can be produced in the Murmansk region, provided that the right actors find the incentive to start the development process. Energy productions costs are, on a global level, relatively low today. However, provided a relatively moderate cost escalation of 4 %/a wind energy is on the bring of being feasible, with an IRR of 5,25 % in Murmansk and 7 % in Tumannij.

5.2 Autonomous and small scale wind energy

In large areas of Russia, the order of 70 % of the land area, the majority of communities are either not connected to a common electricity distribution networks, or they are connected to the end of long and vulnerable feeder lines. These areas are very sparsely populated, but a considerable proportion of vital activities in Russia takes place there. It is estimated that some 40 % of the foreign currency earning activities such as e.g. fishing and mining are based in such areas, and therefore the activities of the present study may have widespread implications [3].

In the administration of the Murmansk region there is strong emphasis on the needs of local communities. The power supply situation for these communities is very difficult, not least due to high costs and difficult logistics of the fuel supply, and the administration therefore emphasises the need for autonomous and small scale local wind power generation. There are at least more than 40 such locations in the Kola Peninsula, some of them with their own autonomous power supply while others are connected to the periphery of the public grid.

Several types of autonomous and local consumers have been identified in Kola Peninsula during the initial phases of the project. The prospective wind energy system opportunities can be summarised into three main groups:
The first group consists of installations under administration of the Russian North Fleet, although each category is under its own administrative units.

- Lighthouses: Small very high reliability (hybrid) systems, 1–10 kW
- Frontier posts: Medium size systems, 50–100 kW
- Met stations: Small high reliability systems, 10–50 kW

These cases have relatively high requirements to system reliability and stability as well as to power quality standards since continuous power supply is essential for providing the specific services required by the Russian North Fleet. In that case the cost of energy is not considered the most critical factor and the technical and administrative infrastructure is considered quite high.

The second group consists of installations serving mainly the heating supply of communities or public and military installations which have their heating needs served by oil fired boiler houses. There are two typical categories:

- Stand alone wind turbines for heat and/or electricity supply, 150 kW and upwards
- Electricity producing wind turbines connected to existing power supply with electrical heaters as base load, 150 kW and upwards.

Typical sizes of boilers are in the range 600 to 1000 kW, and wind energy is considered a viable supply or even replacement of the oil burners.

These cases are quite different from the previous ones because electrical energy is used to produce thermal energy, and therefore requirements considering system reliability and power quality may be less severe. In these cases cost of energy is the main factor affecting the decision of a wind turbine installation for supplying thermal energy instead of an oil boiler.

The third group consists of installations in settlements, fishing villages and kolkhozes. They are often independent communities with seemingly a high degree of autonomy and independence also in their administration of energy supply options and plans. There are two typical categories:

- Village power type systems, 50–500 kW or more, intended for autonomous power supply of isolated communities.
- End-of-line systems, 300–500 kW or more, intended for local grid connection to weak and sometimes unreliable lines at the end of the distribution system.

The representatives for these sites expressed the need for additional clean and cheap energy, and also demonstrated a strong will to see such a development. Consequently these types of sites could and should be included in an eventual demonstration programme.

It can be concluded that there is presently a recognised need for generating capacity and fuel replacement (for both electricity and heat production) in Kolkhozes and other private enterprises with autonomous and end-of-line power supply. Wind energy is technically feasible in these applications, in the form of wind turbine retrofit to existing diesel plants in simple and robust wind diesel architectures, and a strong commitment exists towards utilisation of wind energy in the Kolkhozes.

Wind energy may also be economically viable in connection with autonomous power supply, given the present real cost of energy, but with the uncertainties in the economical parameters, in particular real fuel costs and marginal value of additional energy supply, a decision on implementation is really a political decision that can only be made by those responsible for the energy supply of the communities.

6. Recommendations

6.1 Autonomous wind energy systems

Given the recognised needs the study recommends that a task force (or other entity) should be formed in the Murmansk region to establish the organisational and financial framework necessary to make the Kolkhozes bankable.

6.2 Grid connected wind energy systems

With the present surplus capacity there is no short term need for additional generating capacity in the Kolenergo grid. Although utility grade wind energy is technically feasible for grid connected operation, grid connected wind energy cannot with present rates and tariffs provide an economically feasible basis for electricity production by an independent power producer.

This may change within the next decade, as electricity rates & tariffs approach market levels and existing generating capacity is phased out. With the wind resource identified by the study the cost of energy from modern utility grade wind turbines is competitive to the cost of energy from e.g. modern coal or oil fired power plants. Wind energy has a lead time of the order 10 years, depending on the development in rates & tariffs, and wind energy is a long time investment with a 20 year economic life.

Thus it is recommended that efforts should be made to familiarise Kolenergo (and the administration) with the issues related to integrating wind energy into the power supply system. A working group with participation from Kolenergo and western utilities with experience in wind energy integration could be a useful forum for this.

6.3 Demonstration projects with international financing

Demonstration projects should be implemented with international funding and financing with the aim to carry on towards large scale implementation. This requires that bankability of the private enterprises has been established, especially regarding kolkhozes and that a commitment has been made and experiences have been gained of how to integrate wind energy in the power supply and that there is a vast potential for the experience from wind energy demonstration in the Murmansk region to be utilised in the entire Russian North, through federal programmes such as “Energy Supply for the Northern Territories” and “Renewable Rural Energetics—2000".

6.4 Discussion with the regional authorities

The findings and recommendations of the project were presented by the project group to representatives of the administration of the Murmansk oblast, potential users and developers of wind energy on the Kola peninsula. The results and proposals were profoundly discussed with the audience consisting of representatives of the local and the regional administration and the potential users of wind energy.

Representatives of the energy administration of the Kola peninsula concluded, that the issue on the use of wind energy on the Kola peninsula deserves attention and support. The use of wind energy is primarily of interest in remote coastal dwellings which presently have great difficulties in their fuel procurement. Rationalised use of wind turbines makes saving of expensive organic fuels possible and in the end it will lower the production cost of energy.

Possible large scale application of wind power plant as a part of the electrical system of Kola would be of considerable interest for future development of the energetics in the region. Even though the energy system has surplus capacity at the moment, development of wind energy should be started well in advance, before energy will become a deficit.

As a comment to proposals on continued activities after the concluded feasibility study the regional administration notified, that a regional law on energy savings has recently passed and that a fund for energy investments has been founded, to collect the capital for financing energy installations in the Murmansk oblast.

The Regional Administration is ready to be the legal body for external investors to give a guarantee for the implementation of demonstration projects proposed by the group. Analogous guarantee can also be given by the Energy Investment Fund, eligible to be mediator e.g. between a fishery farm (or any other small consumer of energy) and an external investor.

6.5 Conclusions

A body that can provide sufficient guarantees to establish the bankability necessary for financing investments in remote kolkhozes with funding from international funding resources is needed. This is acknowledged by the regional administration, which has initiated the work to establish such a body.
Once bankability is established, national and international funding can be applied for to implement wind energy demonstration.

7. References

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[4] Ole Rathmann, Wind Atlas Analysis for 12 Meteorological Stations on the Kola Peninsula