

Feasibility study on the sustainable energy potential of LECO pilot community Purkijaur

2019-03-22

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Content

Feasibility study on the sustainable energy potential of LECO pilot community Purkijaur	1
Introduction.....	2
Geography and climate	3
Final energy use baseline inventory.....	9
Pilot community Purkijaur final energy use	10
Pilot community Purkijaur Renewable Energy Potential	11
Agricultural biomass.....	12
Heat pump.....	13
Pellet or wood stove	14
Solar energy.....	14
Windpower.....	18
Small scale co-generation	Fel! Bokmärket är inte definierat.
Transport sector	21
Scenario for sustainable energy in Purkijaur	22

Introduction

The LECO-project shall respond on the needs of remote communes and settlements for a sustainable energy supply. For this purpose, an approach shall be developed to use as far as possible existing renewable resources for the energy supply improving building stock standards by combining new technologies with locally available natural resources. In order to create synergetic effects to the local economy and social coherence it is intended to base the project on Local Energy Communities (LECo) either as municipal enterprise or as a cooperative. As far as available local companies shall be involved in investments and thus upgrade their skills for future activities in the energy business. The project shall deliver a set of locally adapted concepts for Community based energy solutions in remote areas.

Ensuring a reliable, sustainable and affordable energy supply is particularly challenging in the remote and sparsely populated communities in Norrbotten, especially due to their low critical mass and issues linked to the harsh climatic conditions of many parts of the area. As consequence of access to relatively cheap energy historically a firm tradition of energy efficiency and high-yield insulation of buildings is missing.

LECO project intends to make use of the concept of “energy villages” which has been developed and implemented in a broad range of German and Austrian communities. These villages are often situated in rural and remote regions and face similar problems to communities in Northern Sweden, specifically problems of depopulation, a decrease of economic activity and a loss of jobs in the communities. By implementing local sustainable energy solutions and thus creating both added regional value and new innovative business concepts this trend could be stopped. An essential part of the work done was on empowerment of people.

Geography and climate

Jokkmokk is a city with the centre just over 110 km inland from the Gulf of Bothnia, situated at the Arctic Circle. Jokkmokk has ca. 5000 inhabitants on a large area of 19 474 km². Around half of that area is National parks.

The big rivers in the municipality produce about 11-13 TWh electricity per year. However, the plants belong to the governmental company Vattenfall in Stockholm and taxes are paid there. Only a small compensation for the negative impacts of hydro power plants and dams are paid to local communities by Vattenfall.

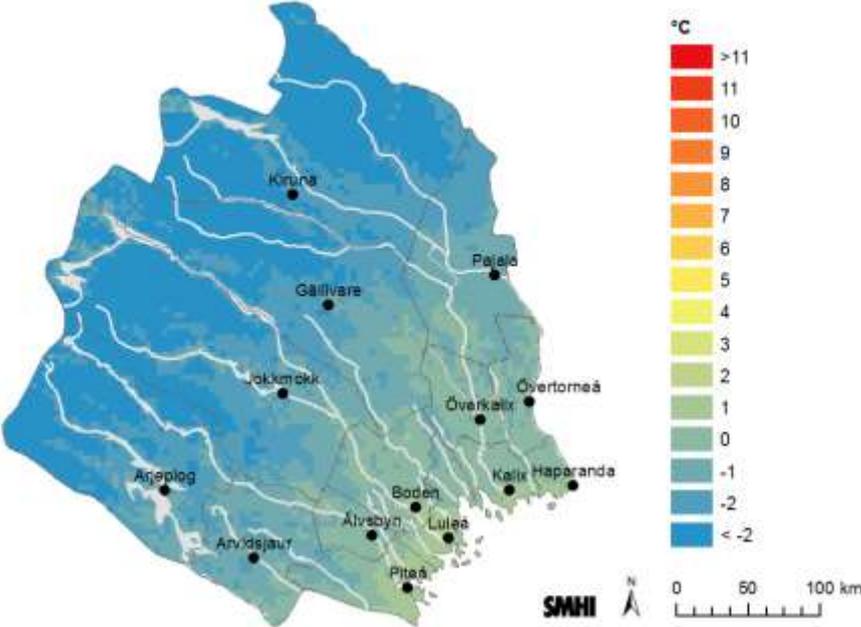
The pilot Purkijaur is a village within Jokkmokk municipality's boundaries with about 90 inhabitants (2017). It is situated about 20 km from Jokkmokk centre. Purkijaur has been inhabited since the Stone Age and the first settler arrived in 1677. During his stay in the Lapland mountains Carl Linnaeus travelled through the village. During the early 20th century, a steamboat was established along the Little Lule River from Purkijaur to Kvikkjokk. In 1884, the famous Nordenskiöldsrace started in Purkijaur¹ and since 2016, the modern ultra-skiing race Nordenskiöldslppet has its start here.

At a first meeting in Purkijaur with the village association and the LECO team, the possibilities of both improving the energy performance of the buildings and producing electricity with solar energy or wind were discussed. An interesting object in Purkijaur is the Purkijaur garden, which is owned by the community. The feasibility study will therefore focus on these potentials mainly.

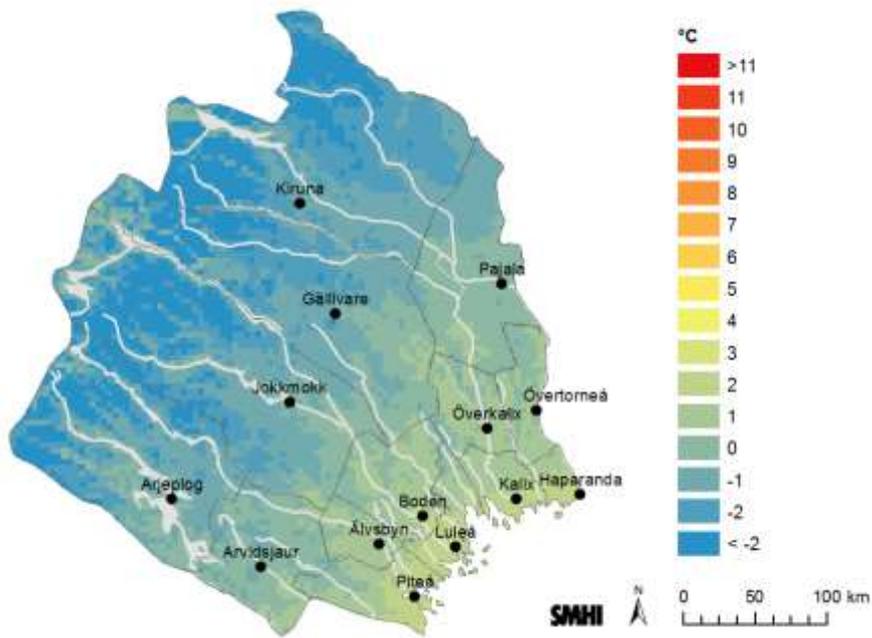
¹ During the polar explorer Adolf Erik Nordenskiöld's second Greenland expedition in 1883, two of the participants, both Sami men from the Jokkmokk mountains, explored the ice covered continent's inner unknown regions. They skied 460 kilometers in 57 hours. Upon his return, nobody believed what Nordenskiöld said about their achievement. It was considered an impossible feat. To prove his tales were true, Nordenskiöld announced a skiing race in 1884 taking place between Jokkmokk and Kvikkjokk and back, a distance of 220 kilometers. Nordenskiöld believed that distance could be covered within 24 hours. Eighteen Samis and settlers took part in the race. The winner, Pavva-Lasse Nilsson Tuorda, crossed the finish line after 21 hours and 22 minutes and Nordenskiöld's scientific honor was restored.

The annual mean temperature in Jokkmokk has been -2°C in the period 1961-1990, but due to climate change, the average temperature is increasing in the last decaded and is expected to do so even over the next decades. Maps are showing annual mean temperature. Together with the annual average precipitation, it is the most widely used index to describe the climate.

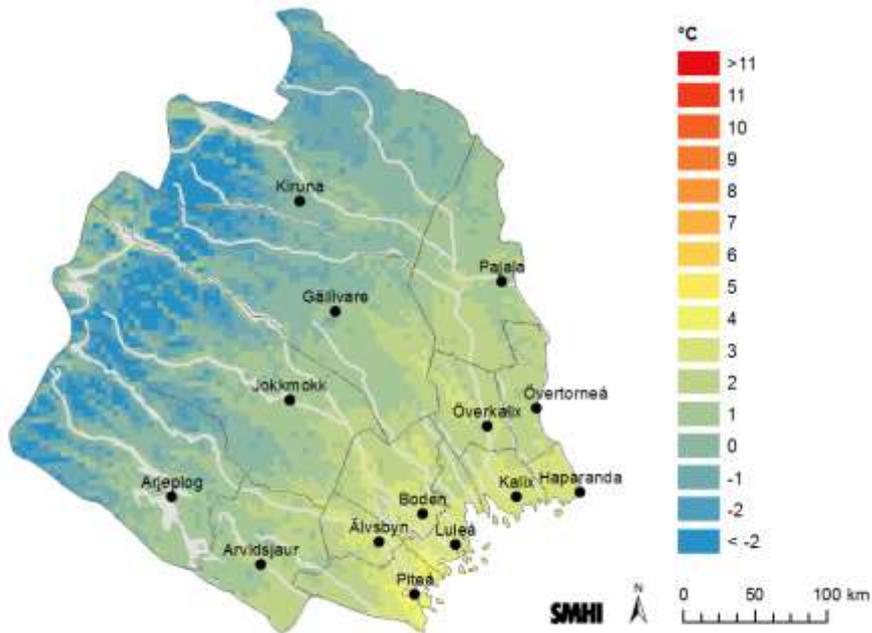
Map 1: Observations 1961-1990, Source SMHI



Map 2: Observations 1991-2013, Source SMHI



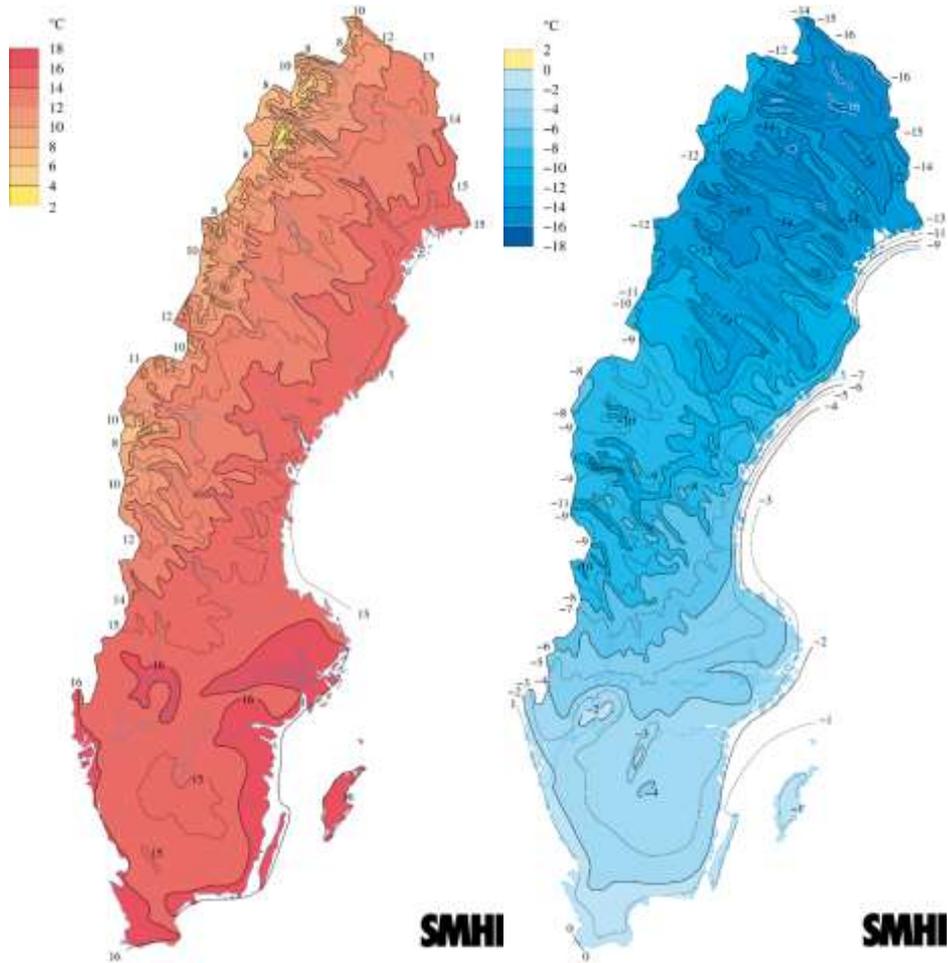
Map 1: Future development according to IPCC scenario RCP 4.5, Source SMHI

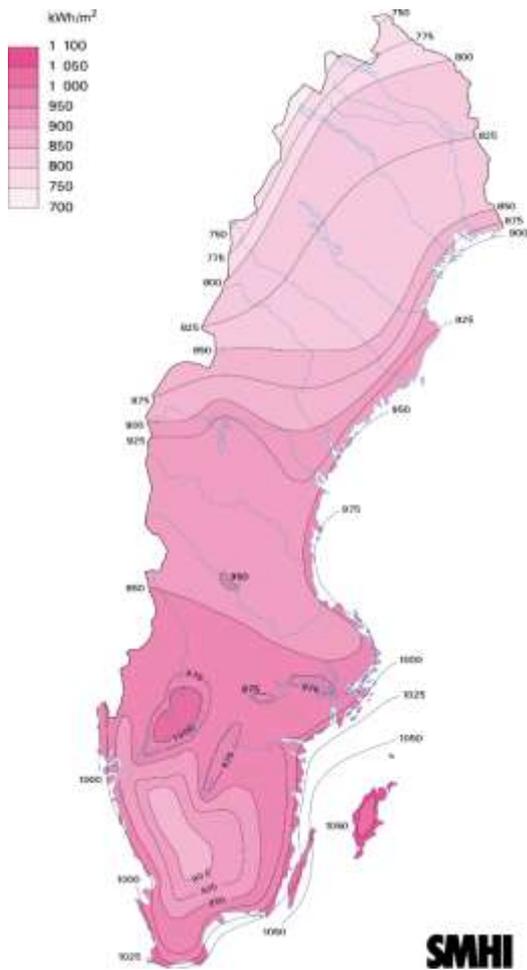


Temperature differs significantly over the year, as the following two maps show:

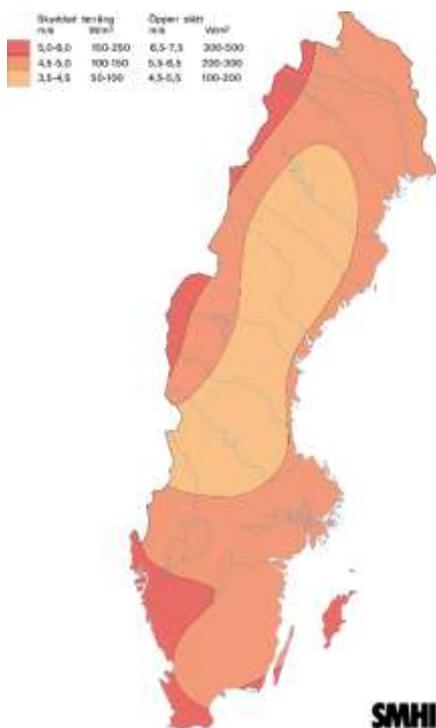
Map 1: Mean average temperature in July (1961-1990)

Map 2: Mean average temperature in January (1961-1990)



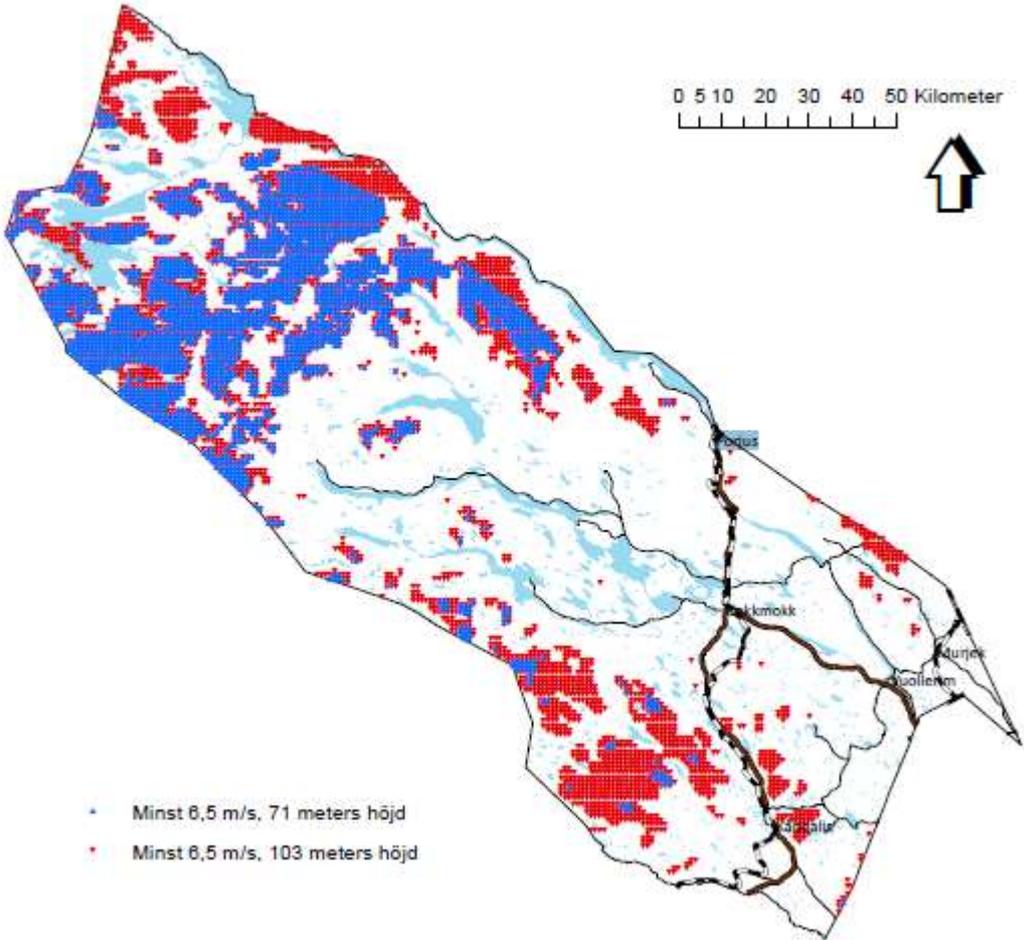


Mean global radiation in Jokkmokk municipality is around 800 kWh/m² with a slightly higher value in the areas closer to the coast and lower in the mountain regions (Source: SMHI).



The wind energy with measurements in 50 m heights, Source SMHI, lies about 4.5 - 5,0 m/s and 100-150 W/m² in sheltered areas and 5.5-6,5 and 200-300 W/m² in more open areas.

Uppsala University did a more detailed map which shows higher wind speed an average in some areas for Jokkmokk municipality.

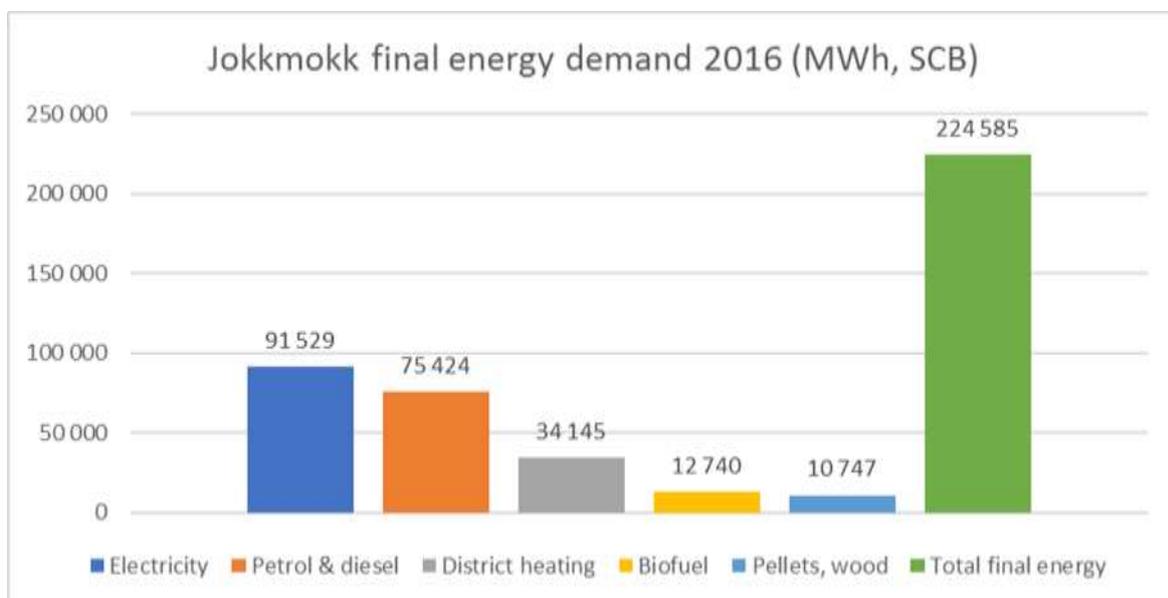


Source: Land-use plan Jokkmokk municipality 2011

Final energy use baseline inventory

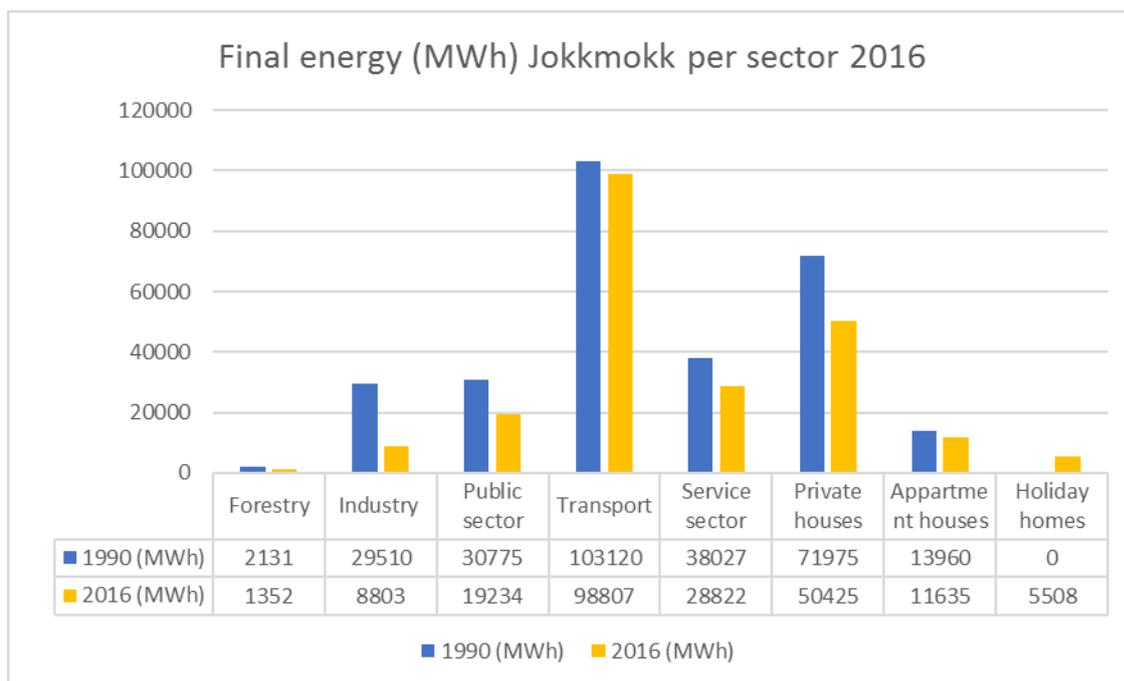
As a first step in the feasibility study a final energy baseline inventory has been done for both Jokkmokk municipality and for Purkijaur community more specific.

Sweden Statistics is providing data on a municipal level, that means for Jokkmokk municipality. The total final energy demand was 224 585 MWh in 2016. The main energy sources are electricity followed by petrol and diesel, mainly for transport. Jokkmokk centre has a district heating plant which serves about 522 customers including most of the municipal buildings. A calculation with average energy prices shows that energy costs for the whole municipality is about 292 000 000 SEK (2016).



Source: SCB data, own graphic

An analysis about the final energy demand per sector shows the high energy demand in the transport sector. The total energy demand has decreased between 1990 and 2016, which is partly due to the decrease in population from 6726 (1990) to 5105 (2016) and the decrease in industrial energy use due to the close down of several bigger industrial production facilities.



Pilot community Purkijaur final energy use

There is no official energy statistic on the level of villages in Sweden. Therefore, as approximation data collected from the community have been used as well as average numbers for buildings in Northern Sweden.

Private home random sample:

Heating system	Building year	Electricity kWh	Pellets kWh	kWh/m ²
Heat pump geothermal	1900	22000		157
Heat pump air to air and direct electric	1933	21000		117
Pellets	1938	13000	45000	363
Heat pump geothermal	1930	26000		96
Heat pump geothermal	1990	15000		71
Pellets	1987	15000	30000	300

The average of energy demand per private home is 31000 kWh a year and this is the expected value for Northern Sweden and is used to estimate the energy demand for the approx. 40 private homes. The community hall uses about 7500 kWh a year (geothermal heat pump).

Compilation of estimated total final energy use in Purkijaur: 1245 MWh

Pilot community Purkijaur Renewable Energy Potential

An analysis on the renewable energy potential for Jokkmokks municipality has been done by the regional energy agency Energikontor Norr and LTU in 2010. The results are listed below:

	Today	Technical potential
Hydropower	12,500,000 MWh/ year	+2,400,000 MWh/year
Forest biomass	60,000 MWh/year	500,000 MWh/year
Wind power	1,800 MWh/year	+20,000,000 MWh/year
Agricultural biomass	0	+25,00,000 MWh/year
Solar (PV and heating)	Small	Big
Heat pump	Unknown	Big
Waste heat	Small	Relevant

However, these are rough estimations, and as one can see significant data are lacking in the field of solar, heat pump and waste heat. This is still the case. Beyond, the study shows only the technical potential, but there are limitations from a legal perspective when it comes to both hydropower, forest and wind power in Jokkmokk municipality. It is also important to consider conflicts with other interests like biodiversity and cultural heritage when planning for new renewable energy:

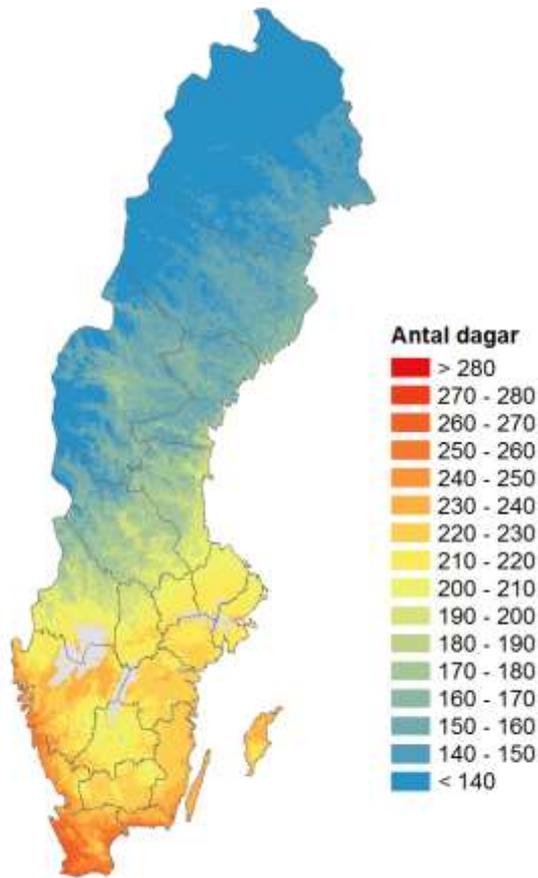
Hydropower: Jokkmokk municipality's big rivers are heavily used to produce electricity. However, a potential for more production in the future is there, due to higher precipitation in the future and more efficient technology in existing plants. Hydropower plants are owned by governmentally owned Vattenfall and do not belong to the community. Hydropower will therefore not be considered in this feasibility study.

Forest biomass: Sweden is one of the forerunners in the use of forest biomass and of residual products from pulp mills etc to produce biofuels. Even the share of bioenergy for heating is high. However, there are target conflicts with both traditional reindeer herding and biodiversity. Therefore, this feasibility study will only calculate projects which can be implemented with sustainable forest biomass.

Wind power: Legal restrictions for the use of wind power in Jokkmokk municipality are high due to an airforce base close by and the huge areas which are national parks. So far, only one single wind power plant has been built, all other planned projects have not been realised. However, this feasibility study will take into account a small community owned windpark and will look into the possibility of small-scale wind power.

Agricultural biomass

This is an interesting option specifically in case of Purkijaur, which has some agricultural used land and where also the only farm in Jokkmokk (milk cows) is located.



However, due to its Arctic climate, the growing season is relatively short, as the map shows (around 150 days), and trees are growing slowly. However, studies have been done in Northern Sweden with crop growing of *Phalaris arundinacea*, sometimes known as reed canary grass. It is a tall, perennial bunchgrass, which grows good on poor soils and can easily be turned into bricks or pellets for burning in biomass power stations.

However, there is limited access to farming machines and equipment as well as interest or local knowledge. Therefore, this feasibility study will not include agricultural biomass.

Source: SMHI

Heat pump

In a study from 2017, Petter Johansson (KTH) says that “Currently, more than half of all Swedish single-family houses have an installed heat pump and more heat is supplied by heat pumps in Sweden than in any other nation. [...] As of 2015, Sweden had the greatest amount of heat production from heat pumps per capita of any European nation, and many heat pump markets in other European countries are 10 to 20 years behind the Swedish market in development.”²

Even in Jokkmokk municipality, heat pumps are used frequently. Many houses which have direct electric heating have been complemented with air-to-air heat pumps. There is no register over these installations. Geothermal heat-pumps and downhole heat exchanger become more and more frequent. Officially, installations have to be announced and approved by the municipality, but in fact, many installations are not registered.

However, there is a technical potential for more heat pumps, incl. heat pumps taking energy from lakes, possibly even ground-water. A calculation for both air-to-air heat pump and for geothermal heat pump for a private home (120 m²) in Purkijaur shows that both investments are profitable with a pay-back of 4 years for air-to-air and 8 years for geothermal heat pump.

Air-to-Air heat pump	
Saving kWh/year	4 000
Electricity price SEK	1,5
Saving SEK/year	6 000
Investment SEK	25 000
Pay back in years	4
Geothermal Heat pump	
Saving kWh/year	17 750
Electricity price SEK	1,5
Saving SEK/year	26 625
Investment SEK	200 000
Pay back in years	8

² Johansson, Petter KTH, Skolan för industriell teknik och management (ITM), Industriell ekonomi och organisation (Inst.), Hållbarhet och industriell dynamik. ORCID-id: [0000-0002-2748-7993](https://orcid.org/0000-0002-2748-7993) <http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1151181&dswid=5826>

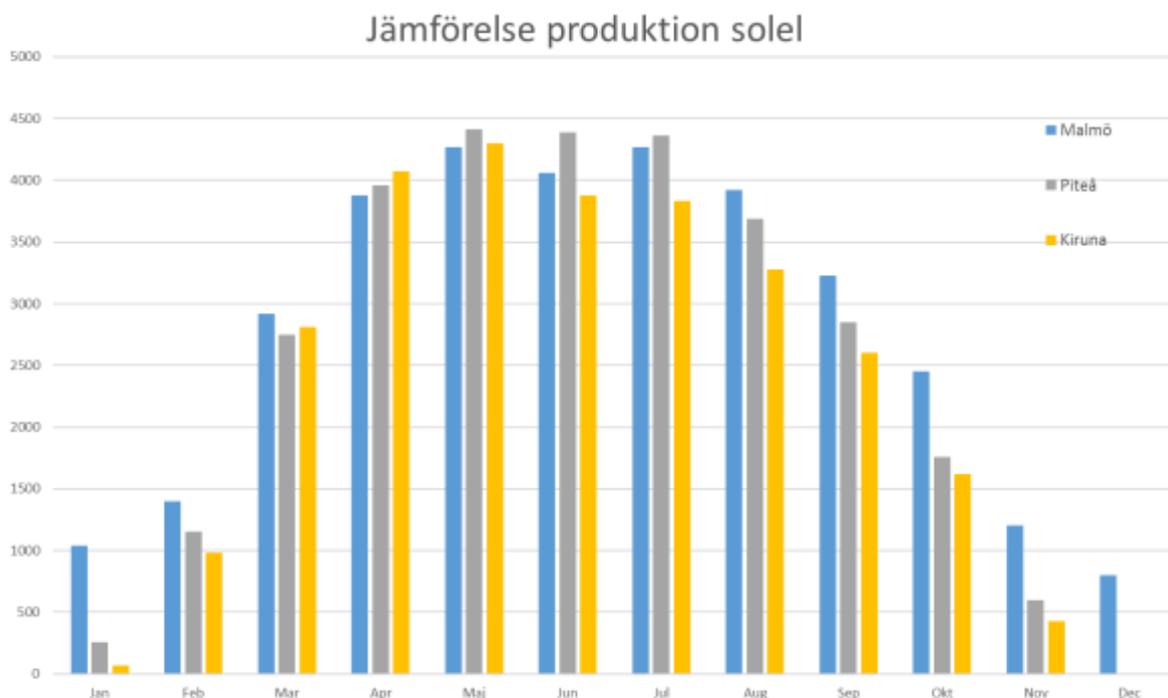
Pellet or wood stove

As mentioned above, private homes in Purkijaur might not have central heating, but direct electric heating. However, a number of houses has a chimney which can be used to combine with a pellet or wood stove. This is a possibility if an investment in a central heating system is too expensive. On the downside is that both pellets and wood stoves need work. If assuming that it is possible to use a modern stove regularly in winter times the following savings are possible:

Energy demand	30000
Saving kWh/year	9 000
Electricity price SEK	1,5
Savings SEK/year	7 290
Investment SEK	30 000
Pay back years	4

Solar energy

Solar energy can be used to produce electricity (PV) and to produce warm water for heating or shower etc. However, due to the high latitude (67 degree) number of solar hours during winter are small to zero. Comparing the production of PV in Malmö (southern Sweden) and Kiruna (northern Sweden inland) shows that there is despite this fact a significant potential for PV production.



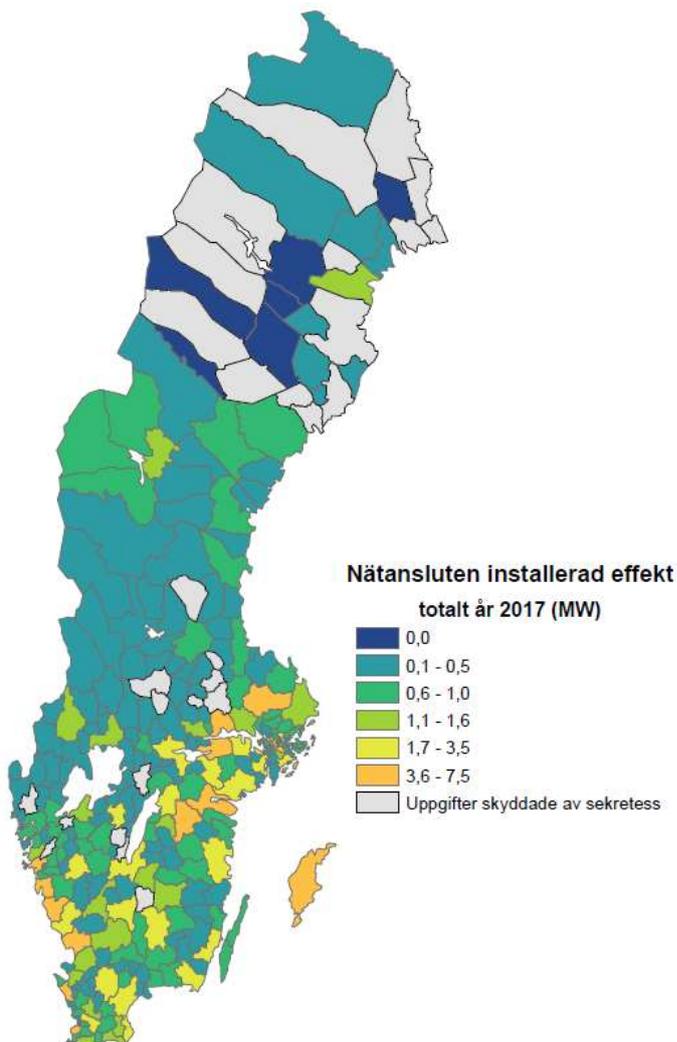
Source: Piteå Energi

Solar heating

A calculation for solar heating for private homes shows that an investment is profitable, however, the pay back time is relatively long. There are no subsidies for solar heating.

Solar heating incl. Warm water boiler SEK	45 000
Energy production kWh/year	2 500
Income per kWh	1,5
Income per year	3 750
Lifetime	25
Total income	93 750
Payback	12

Photovoltaic



Sweden is lagging behind in PV development, in general, but even more in Northern Regions as the map shows. This is also due to the subsidy system: Sweden does not have a system of guaranteed feed in tariffs. Instead, income from PV plants comes from a variety of sources and is limited by a set of rules to some extent. More details below.

Swedish subsidy and support system for Photovoltaic

There used to be a subsidy on the investment of 30% for plants up to a certain size and production, but the future is unclear in the very moment of writing this feasibility study due to a change in government after 2018 years' elections.

When it comes to the operational income, so is the Swedish subsidy system designed to encourage the use of the produced electricity in the own building rather than selling it to the grid. The value of a single kWh produced PV electricity which is used in the own building varies significantly between buildings and operation. It depends on what this kWh would have cost if it has been bought. It also depends on how much electricity is used and when. A restaurant with a high use of electricity lunch time during summer might have good use of PV other types of business or community buildings might not have.

It is important to know that the price per kWh electricity usually varies in Sweden between summer and winter and for different types of supply contract. As PV production is on top in summer, it is when a bought kWh probably is cheaper than in winter. However, an important part of electricity costs are the costs for the grid. When a PV kWh is used in the own building, part of these costs will not be accounted for which increase the profit of PV production. However, the system makes it difficult to calculate profit in a general way for all types of buildings.

In the following table one can read details on possible income and/or cost reduction from PV:

What?	Limits to get subsidy
30% investment subsidy	Maximum cost of 37 000 plus VAT per kWp; max 1,2 miljon SEK per plant.
Tax reduction of 60 öre per kWh for electricity sold to the grid.	Tax reduction will be given only for that much as the user is also buying from the grid in kWh. Max. 18.000 SEK per year. Max fuse 100 ampere.
No costs for channeling PV electricity in the grid	PV plant max 43,5 kWp and main fuse not more than 63 ampere. You may not channel more electricity to the grid than what you buy from the grid within a year.
No tax on PV electricity	PV plant may not be bigger than 255 kW
No VAT	You may sell electricity (and other services, goods etc) for not more than 30 000 SEK per year (exklusive VAT).
No income tax	Income from selling PV incl. other income from the building may not be more than 40 000 kronor per year.
Electricity certificate	Price for certificate is market base. One certificate per MWh, income for 15 years.
Origin certificate	Price for certificate is market base. One certificate per MWh.
Selling electricity	Usually a higher price the first year, than spot price

Compensation for benefits for the grid	Grid owner have to pay for the benefit of not using the grid by producing and using own produced PV
Using own produced electricity instead of buying	Corresponding with the cost you would have paid for electricity, besides the cost that you have for being connected to the grid.

Calculation: PV plants for family homes in Purkijaur

A calculation for a PV plant for private homes in Purkijaur shows that the investment is profitable in case of a south to south-east oriented roof, however, with a relatively long pay-back time. The income per kWh is depending on a range of factors and can be lower. No replacement of the power inverter nor other repairs nor degradation have been taken into account.

PV plant 5kW, incl. 30% subsidy in SEK	70 000
Energy production kWh/year	3 360
Income per kWh	1,5
Income per year	5 040
Lifetime	30
Pay back	14

Calculation for bigger buildings

A calculation for PV plant for a bigger building, south-oriented roof, 45 degree, would result in the following with a payback of about 9 years, under the same economic framework as for the private homes. Solar plant: 13 kW

Investment, 30% subsidy in SEK	150 000
Energy production kWh/year	11 122
Income per kWh	1,5
Income per year	16 683
Lifetime	30
Total income	500 490
Profit	350 490
Pay back	9

Calculation for a bigger plant with 80 kWp

This plant is possibly not on a roof but on the ground, would result in a production of about 72 519 kWh per years. However, due to the Swedish subsidy system, a significantly lower income of only 41 711 SEK has been calculated compared to the 13 kWp plant on roof. Under the given parameters, the pay back would be 16 years. Such a project would heavily depend on a lower investment cost, where the plant is situated and how the electricity will be used.

PV plant	80 kW
Energy per year kWh	72 519
Investment cost, 30% subsidy	698 800
Income per year	41 711
Pay back years	16

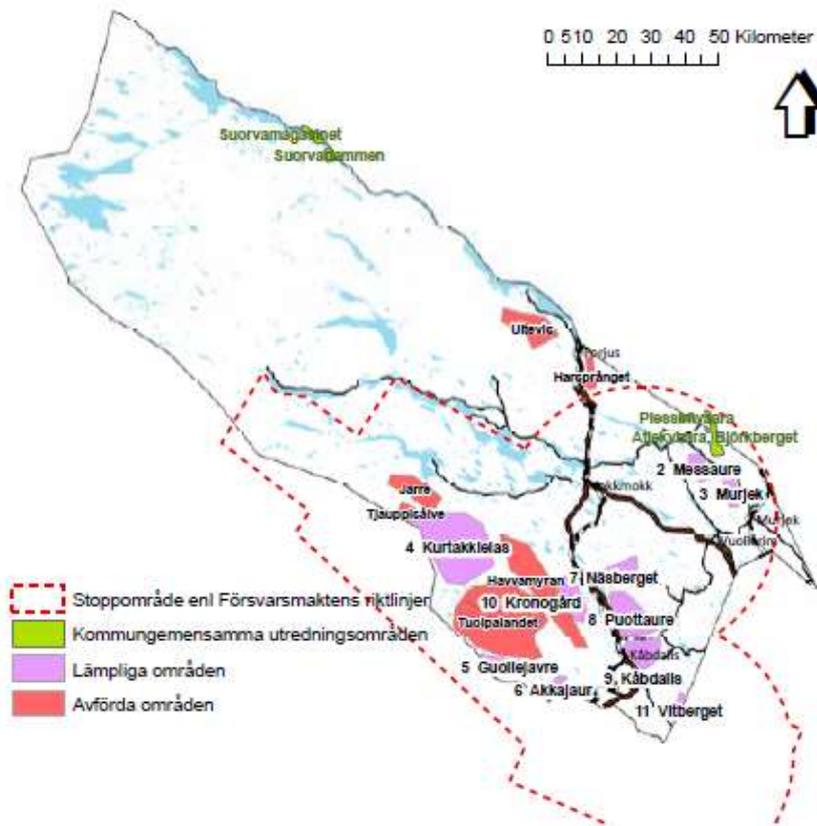
Windpower

Windpower is a very interesting renewable energy source with a well-established market and knowledge base. Jokkmokk municipality land-use planning document from 2011 includes a rough estimation about how many wind power plants theoretically could be built in areas which are suitable from a municipality perspective. This is, areas with no heavy land-use conflicts:

	Storlek kvkm	Antal verk	Effekt GW	Produktion GWh
Harsprånget	26	65	0,325	650
Messaure	36	90	0,45	900
Murjek	33	82,5	0,4125	825
Kurtakkielas	344	860	4,3	8600
Näsberget	63	157,5	0,7875	1575
Kronogård	70	175	0,875	1750
Puottaure	109	272,5	1,3625	2725
Kåbdalis	64	160	0,8	1600
Guollejavre	44	110	0,55	1100
Akkajaur	23	57,5	0,2875	575
Vitberget	18	45	0,225	450
TOTALT	830	2075	10,375	20750

Source: Jokkmokk municipality land-use plan 2011

However, due to an airforce base within the borders of Jokkmokk municipality, plans for bigger windpower plants have been stopped so far in any case.



Source: Jokkmokk municipality översiktsplan 2011. The red dotted line marks the airforce area.

However, as a community-owned wind park technically is possible close by Purkijaur but also in a greater distance in another place within Jokkmokk or the neighbouring municipalities, this feasibility study includes a calculation of a wind park.

Land-based windpark

A 3 MW windpower plant with the average number of 2400 hours of full production per year produce about 7 200 MWh a year³. Three different scenarios are shown here:

Kind of project / Number of 3 MW plants	Installed effect MW	Produced MWh per year	Production in 20 years
1	3	7 200	144 000
5	15	36 000	720 000
84	252	604 800	12 096 000

³ <http://vindstat.nu/stat/index.htm>

According to Swedish Energy Agency, typical costs for land-based wind power are about 11-30 Mio SEK per MW installed wind power. Cost for production per kWh differ a lot but are calculated to be 0,4 – 0,5 SEK /kWh in the reference case with a total production below 20 TWh. However, Vattenfall reports about an investment of 3,5 billion SEK for 84 windpower plants, which would be a cost of about 4 Mio SEK per plant, which would be very much cheaper⁴. This shows, how difficult it is to calculate for such an investment. How much a wind power plant is producing depends heavily on the specific wind situation at the site. This information is not available currently for the feasibility study. So no investment calculation can be done at this point.

Small-scale windpower

In Sweden, the following rules apply for small-scale windpower:

The maximum height to set up a wind turbine without a building permit is 20 meters, the rotor diameter must be no more than 3 meters, and it must be accommodated lying lengthwise within its own plot boundary. In order to avoid building permits, the wind power plant must not be mounted on a building. It is also important to consider the rules for the maximum permissible sound level in relation to neighbors

A so-called farm wind power plant is defined as a wind turbine with a total height of 20-50 m or a plant whose rotor diameter exceeds 3 m. In order to build such a wind turbine, building permits are required according to the Planning and Building Act and the associated regulations. Building permits are handled by the municipality's building committee.

The Swedish network for wind power publishes each year a market study for small scale windpower, which includes plants up to 100 kW. In 2017, 9 different types of plants are included in the report, but the number of installed plants in Sweden is small, often not more than 20 and max. 100 for one type of plant.

The key problem for small-scale wind power is the low wind speed which often does not exceed 4-5 m / s. The production is pretty low, while the investment costs are comparatively high. This might also be a result of low numbers of plants built, so possibly the investment cost can go down as they did for PV if a mass production would start. Other barriers to overcome are the lack of experience in the region, no good or best practice examples and probably even the fact that service – if something goes wrong – is far. A calculation with one of the most installed types of wind power shows, that it is difficult to make this investment profitable under today's framework conditions.

⁴ <https://www.svt.se/nyheter/lokalt/norrbottn/vattenfall-planerar-for-ny-vindkraftspark-i-norrbottn>

Windstar 3000, 3 m Rotor	3 kW vid 12 m/s
4 m/s årsmedelvind produktion kWh	3 680
Investering	75 500
Pris El	1,5
Inkomst per år	5 520
Livstid	15
Återbetalning	14
Total vinst	7 300

Transport sector

The energy baseline inventory shows clearly that the energy need for transport in Jokkmokks is high. However, this is also an area which is difficult to tackle. Long distances and a sparsely populated area make public transport difficult and non-economic in many cases to serve the needs of the inhabitants. On the other hand, are gas and diesel prices very likely to increase, also due to Swedish government tax and environmental policies, so to reduce the need for transport and replacing fossil fuels by using locally produced renewable energy would be of high interest. Electric cars have proven to be usable even in cold climate and by longer distances⁵. According to the national emission database RUS⁶ used every inhabitant in Jokkmokk 261 liter of diesel and 320 liter of gasolines in 2016. For Purkijaur (684 inhabitants), this means a total of 397 415 liter of fossil fuel to a cost of approximately 6 Mio SEK a year and an energy need of 3646 MWh of energy for transport.

Diesel	Gas	
178 851	218 564	l
10	9	kWh/l
1 751	1 895	MWh

A first step to more sustainable transport modes could be a community owned cooperative electric car-pool, which also includes electric bicycles. As the total impact on the energy need for transport is difficult and likely to be small in the beginning and investment and operational cost can vary a lot, no further calculations are done at this point.

⁵ CELLER-i project <https://www.alvsbyn.se/naringsliv/eu-internationalt/aktuella-eu-projekt/celler-i/>

⁶ <http://extra.lansstyrelsen.se/rus/Sv/statistik-och-data/korstrackor-och-bransleforbrukning/Pages/default.aspx>

Scenario for sustainable energy in Purkijaur

Energy efficiency

The technical energy efficiency potential for buildings in Purkijaur is assessed to be high. This is due to the high average age of building in Purkijaur with almost no new builds. However, the economic potential has to be assessed significantly lower, as houses are cheap in Purkijaur. High investment costs are difficult to justify. However, experience show that change of behaviour and small investments can lead to savings of about 10 percent in private homes. For the community hall, a certified energy expert has listed a number of profitable energy efficiency measures to low costs. Purkijaur community expressed a high interest in an insulation campaign which also would include the community hall. Therefore, the energy efficiency potential is set to 15% of todays demand.

Total final energy use in Purkijaur 2016: 1245 MWh

Scenario Total final energy use in Purkijaur 2025: 1058 MWh

Solar energy

To assess the total potential for solar energy in Purkijaur, it is assessed that 13 of the private homes have roofs oriented to south-west, south or south-east and will use both solar heat and PV. For apartment houses, only PV is calculated. In addition, a bigger plant of 80 kWp is calculated. The total installed PV capacity is assessed to 750 kWp.

What	MWh/year
13 private homes, solar heating + 5 kW PV	78
1 bigger building, 13 kW PV	11
Bigger PV plant, 80 kW:	72
Sum	161

Heat pump and bioenergy

For heat pumps, it is assessed that 10 private homes will invest in an air-to-air heat pump, and another 5 in ground or geothermal heat pump. For bioenergy, it is assumed that 5 private homes invest in wood or pellets stove as a complement to direct electric heating.

What	MWh/year
20 Air to air heat pump	40
5 Ground heat pump	177
5 Wood or pellets stove	45
Sum	272

Wind Power

For wind power, different energy production scenarios have been calculated, however, now wind measuring has been done and no economic calculation is possible at this point.

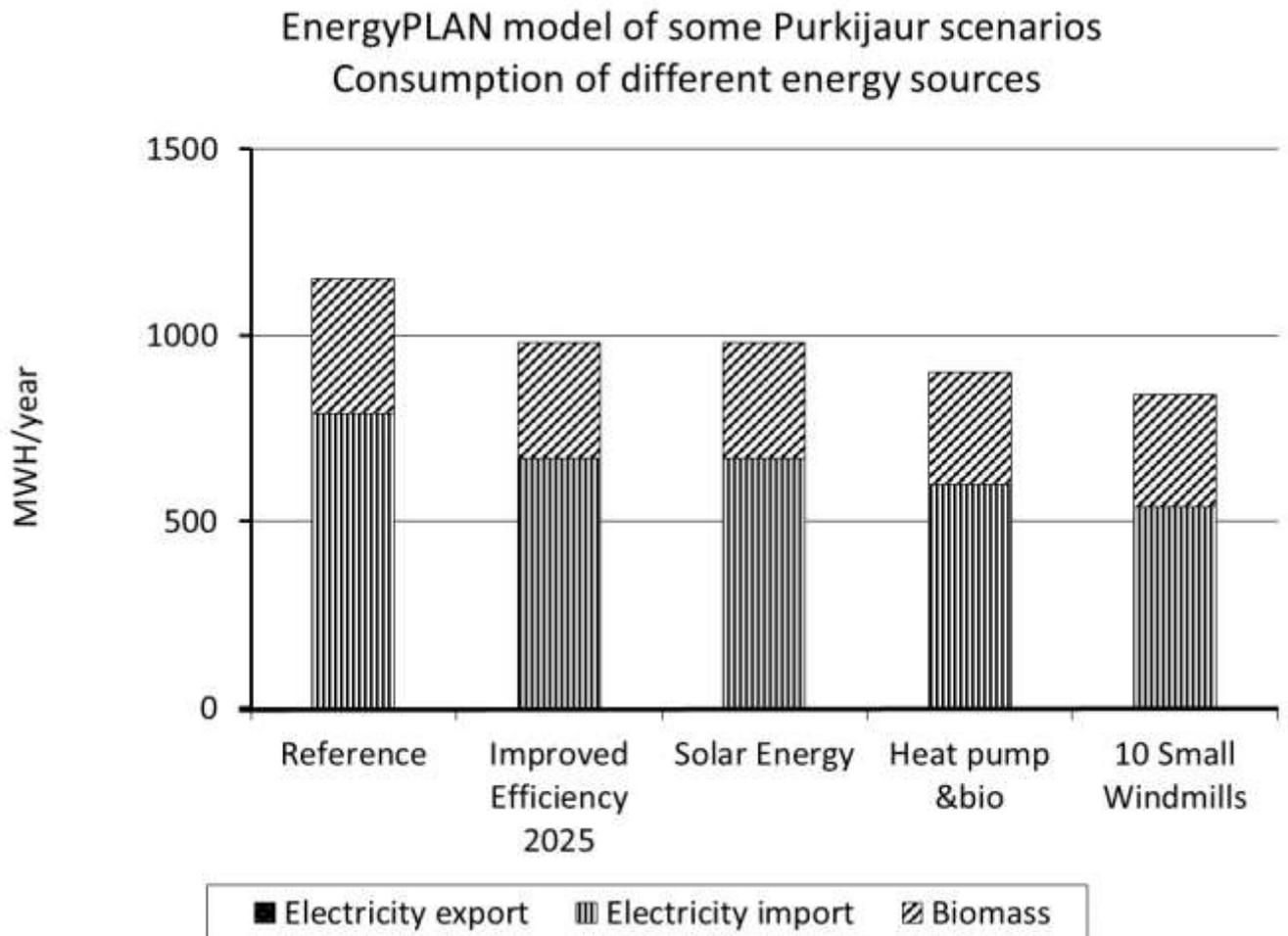
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84	252	604 800	12 096 000

Small-scale windpower:

If, despite the economic limitations, a pilot wind park for small-scale windpower will be erected, it might be possible to produce up to 50 MWh per year with about 10 smaller wind power plants.

Import and export

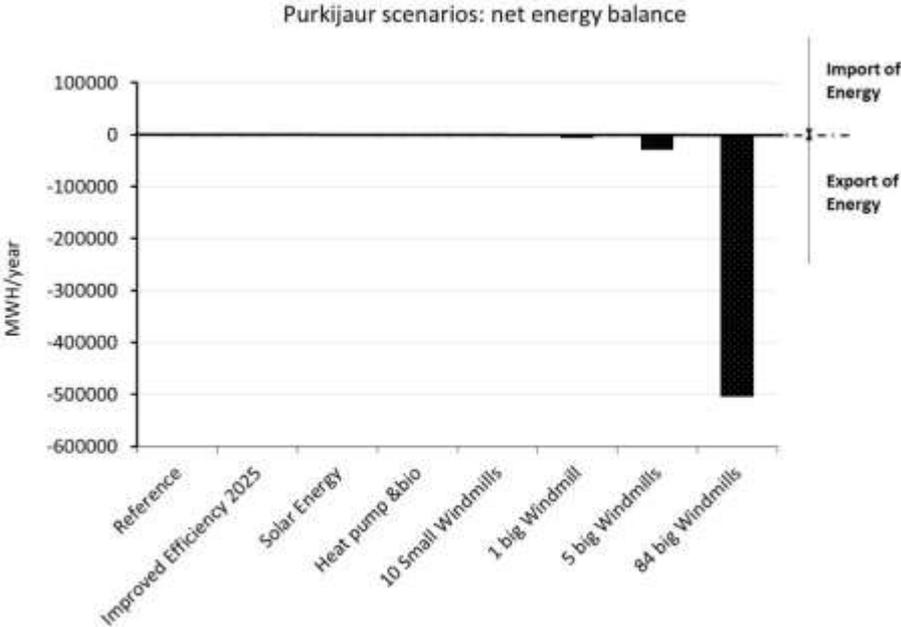
LTU did a calculation for different scenarios with the global energy planning tool EnergyPlan. The figure below shows how the consumption of different energy sources is influenced with gradual improvements according to the scenario description (see above)



Wind power is only shown with small windmills (Otherwise the scale would make it difficult to read the differences up to the installation of windmills). We see that the effect of the big windmill is a combination of less consumption from and export to the net.

The EnergyPLAN model for wind power uses a correction factor to compensate for the non-linear behaviour of the Windspeed vs power curve. This can be calculated e.g. by comparing effect and yearly output for real windmills in the area. The same factor as the one used in Vuollerim and Porjus was used: 0,4927.

Next picture shows the net effect (Import minus export of Energy) for all scenarios.



We see that Purkijaur becomes a net exporter of energy with one or more 3MW windmills.