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

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.

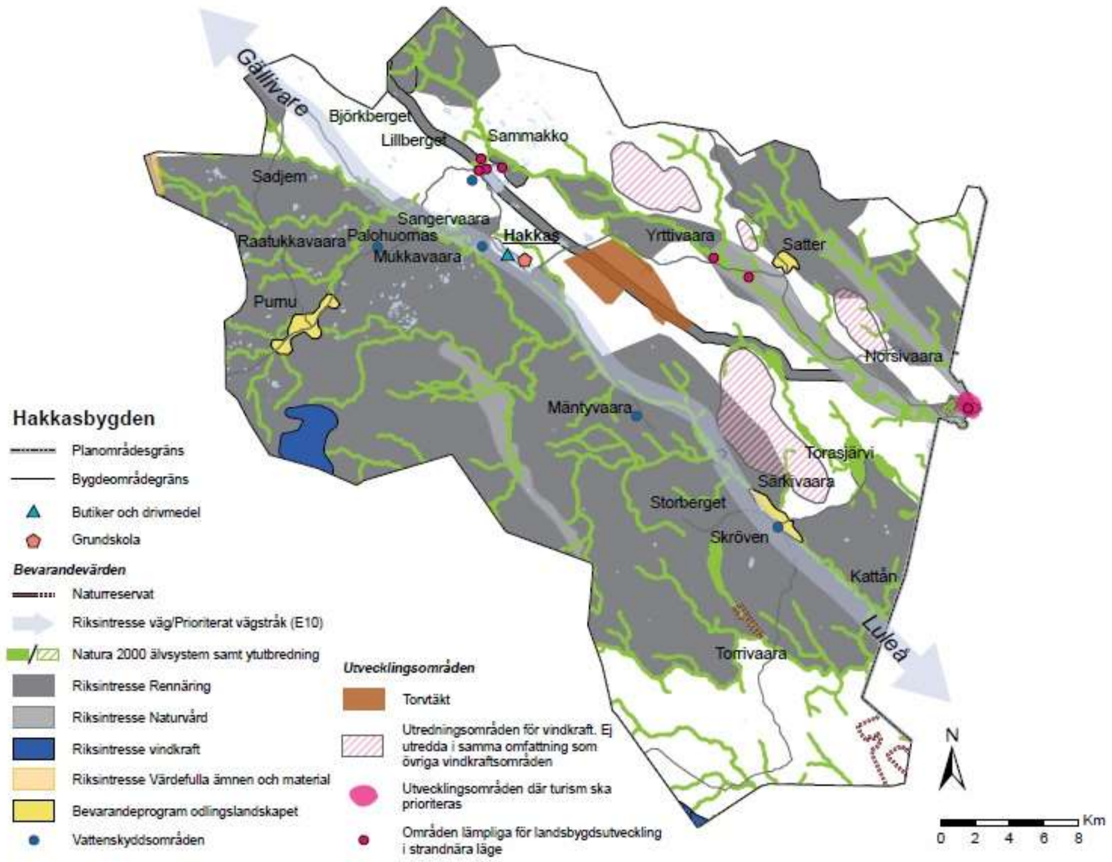
LECO project intends to make use of the concept of “energy villages” which has been developed and implemented in a broad range of German and Austrian communities. These villages are often situated in rural and remote regions and face similar problems to communities in Northern Sweden, specifically problems 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

Gällivare Municipality in Norrbotten County is the third biggest in Sweden with an area of 16,818.22 km2. Gällivare Municipality also hosts an airport. Mining for iron ore, copper and gold are a key business. In 2018, Gällivare had 17,630 inhabitants, of which about 10,000 lived in central Gällivare, another 3,000 in close by Malmberget. However, this is rapidly changing as most parts of Malmberget are going to disappear due to the growing mining area. The governmentally owned company LKAB is obliged to compensate inhabitants of Malmberget by offering a new house or apartment or money for the houses which will disappear.

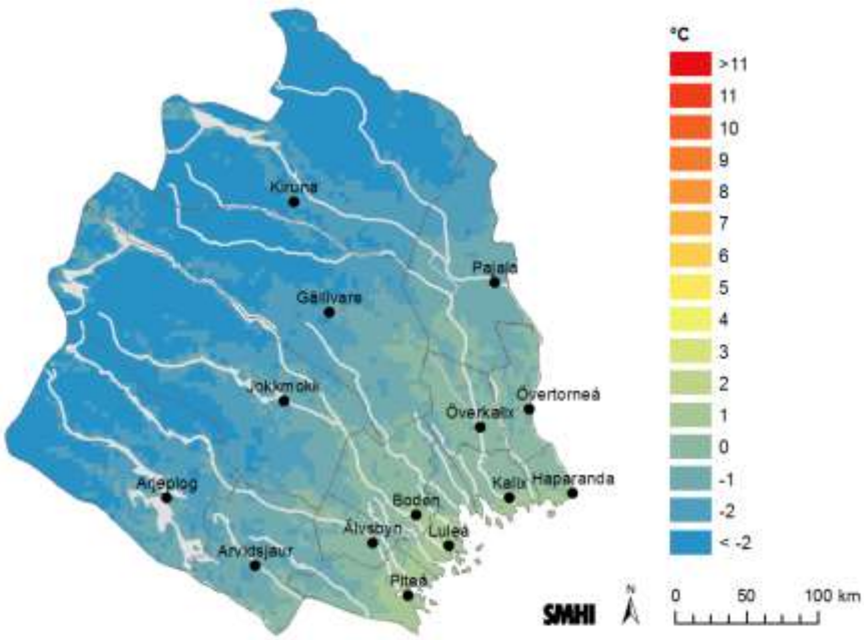
Hakkas is the largest village in Gällivare’s countryside and has about 390 inhabitants but about 700 inhabitants live in the entire Hakkas area. Thera are about 80 companies in the community, of which several working with forestry. Other small companies are a shop, petrol station, library, school, village yard, café. The school is the village's largest workplace. The mining industry in Gällivare employs many people, but locally both forest industry, reindeer herding, school and commercial services offer jobs. The lack of apartment and houses is a barrier for Hakkas to grow, so Hakkas community (association HBB) has taken over a municipal building to rent and bought from Malmberget, a part of Gällivare which is disappearing due to mining, which have moved to Hakkas.

Map over Hakkas area. Source: Gällivare municipality

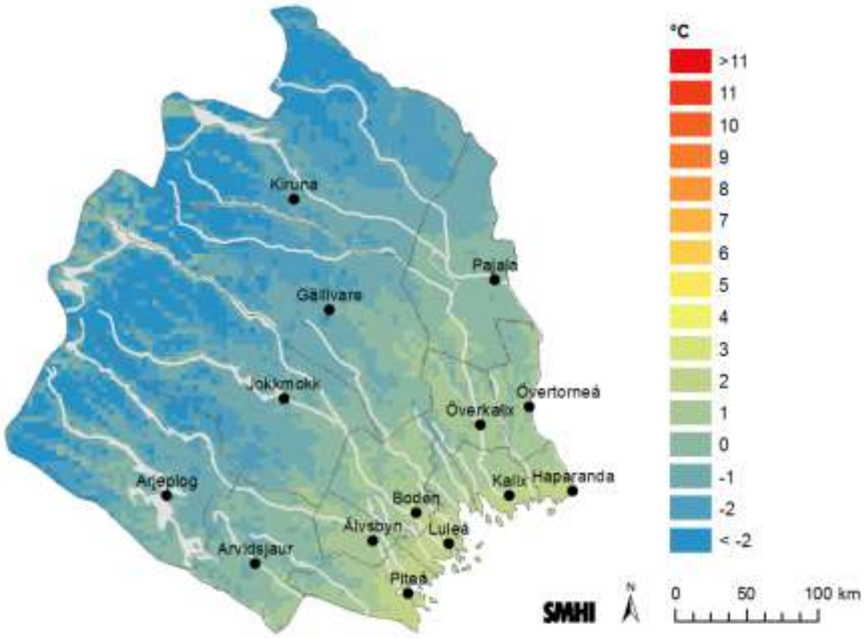


The annual mean temperature in Gällivare has been –2C in the period 1961-1990, but due to climate change, the average temperature is increasing in the last decade and is expected to do so even over the next decades. Maps are showing annual mean temperature. Together with the annual average precipitation,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

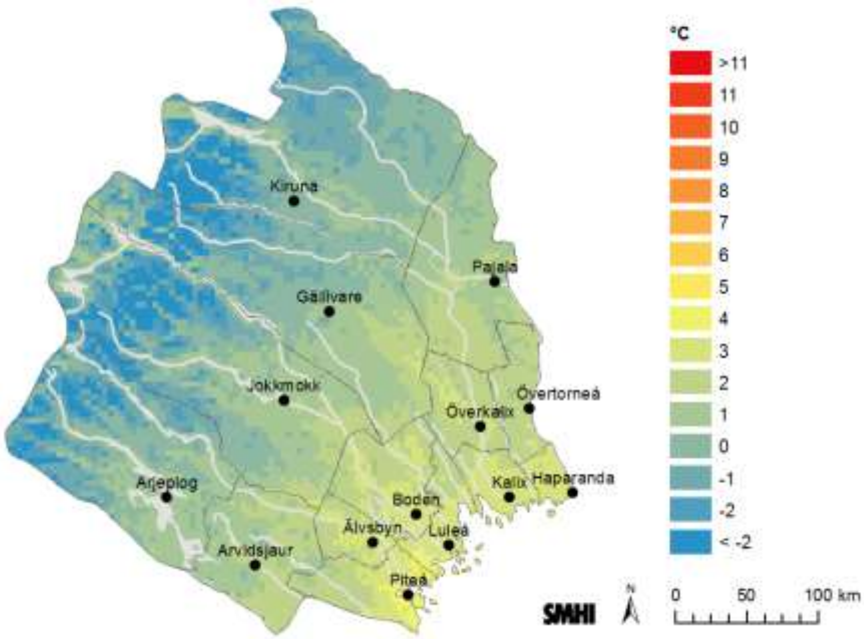
Map 1: Observations 1961-1990, Source SMHI



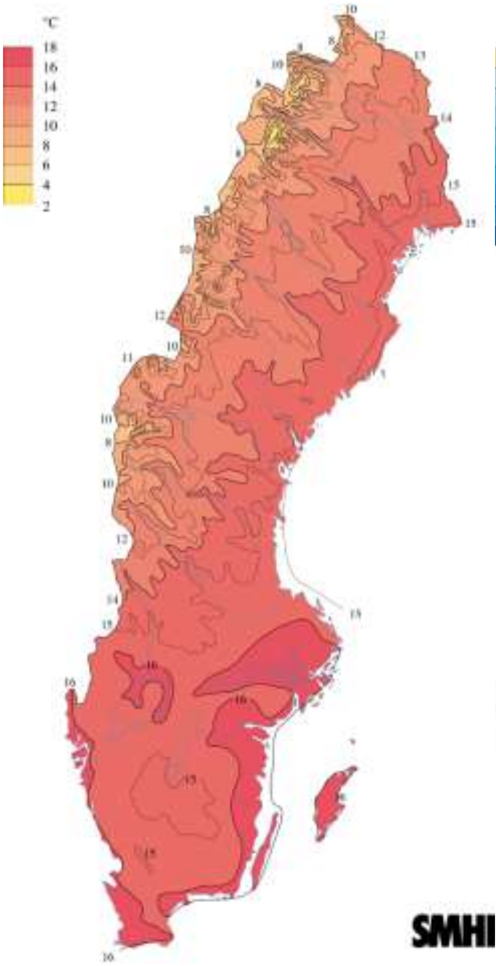
Map 2: Observations 1991-2013, Source SMHI

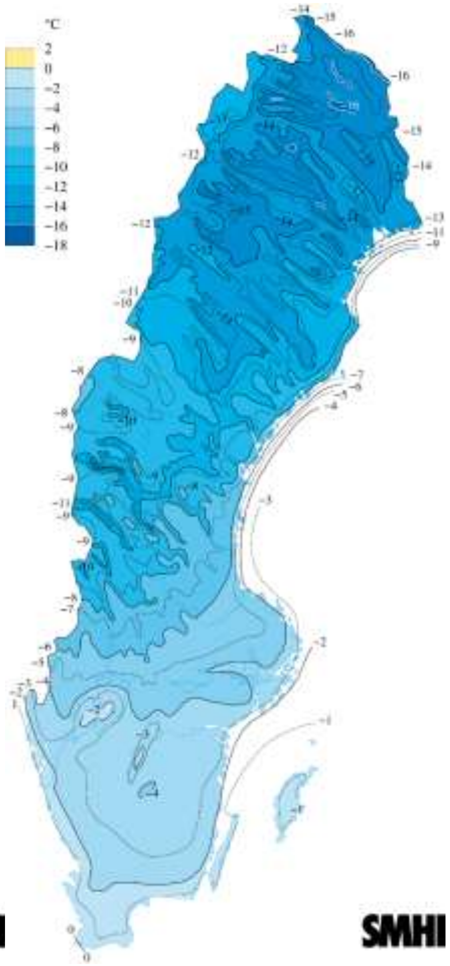


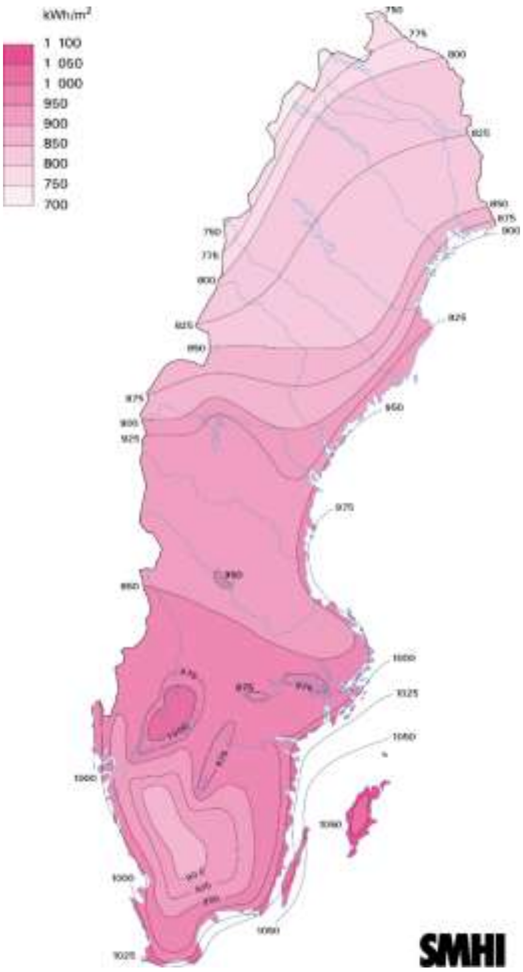
Map 1: Future development according to IPCC scenario scenario RCP 4.5, Source SMHI



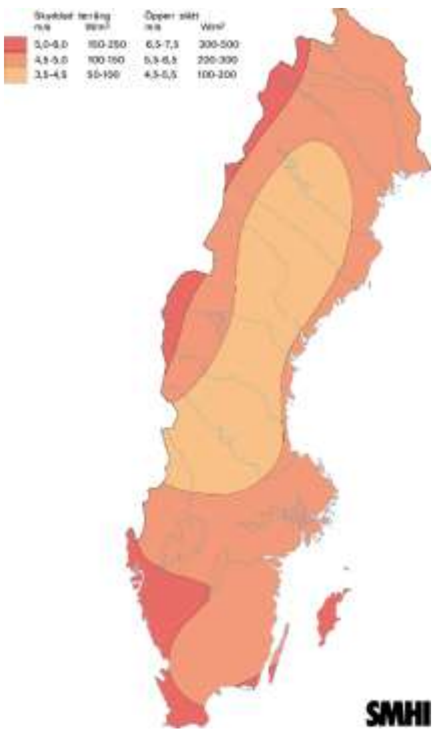
Temperature differs significantly over the year, as the following two maps show:
Map 1: Mean average temperature in July (1961-1990)
Map 2: Mean average temperature in January (1961-1990)







Mean global radiation in Gällivare 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).

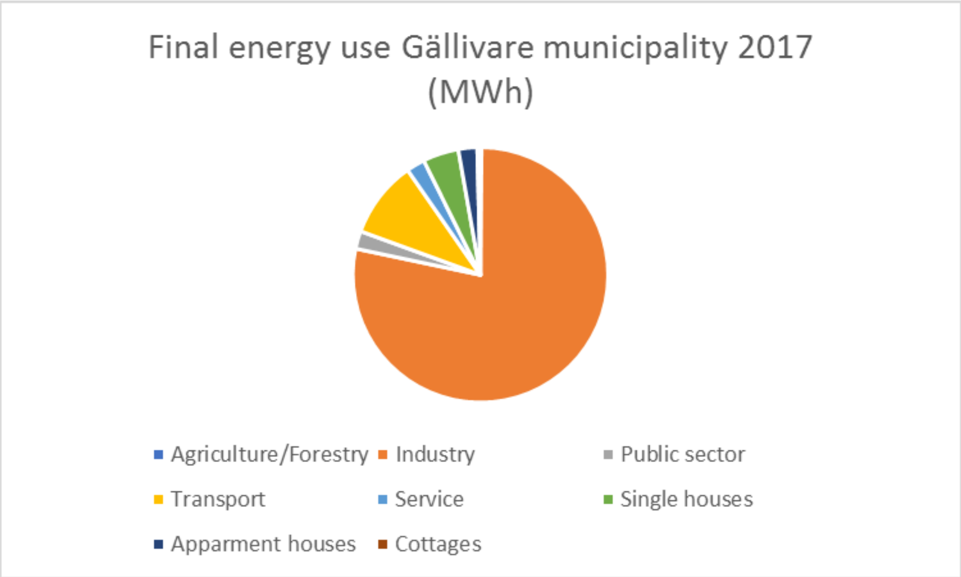


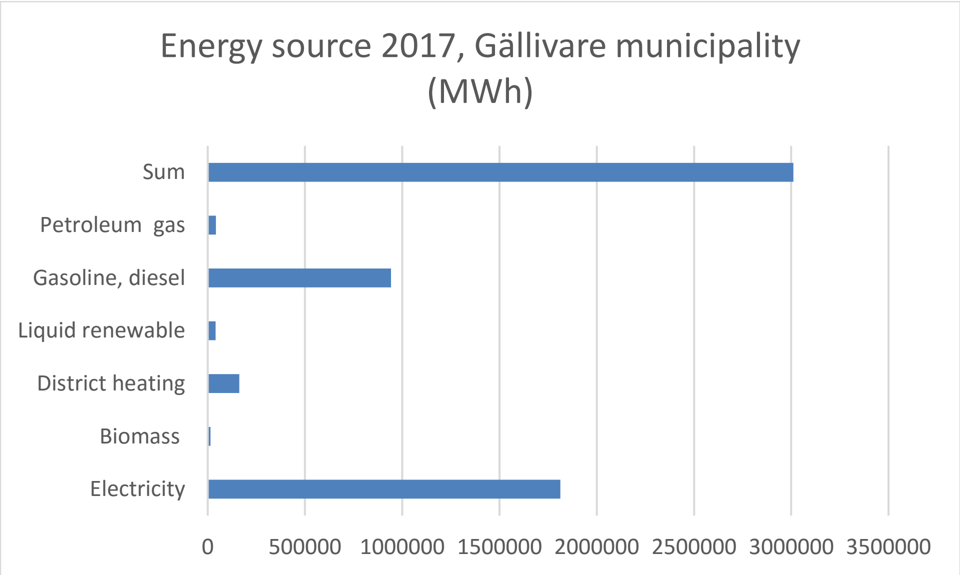
The wind energy with measurements in 50 m heights, Source SMHI, lies about 5,0 m/s and 100-150 W/m2 in sheltered areas and 5.5-6,5 and 200-300 W/m2 in more open areas.

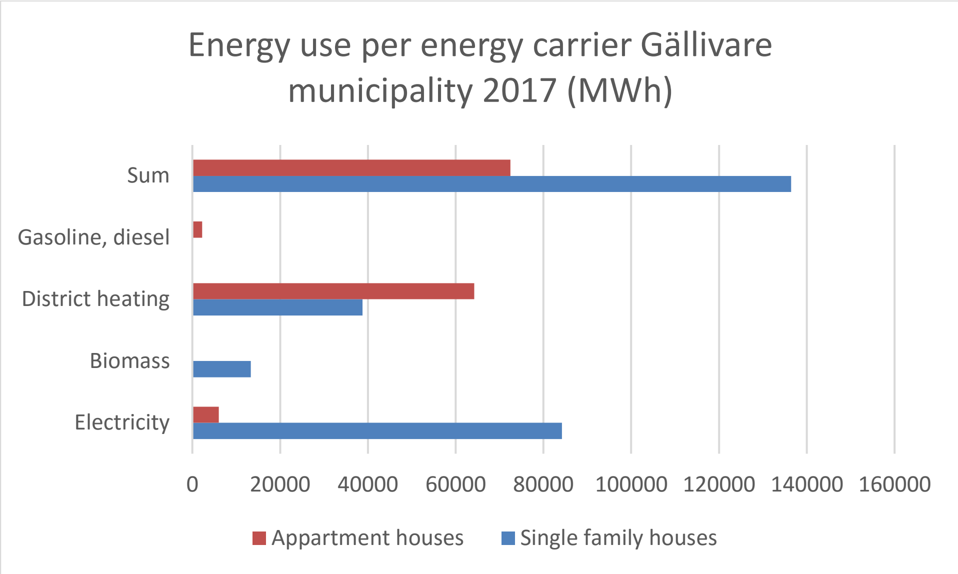
When it comes to wind power on an industrial level, so is Gällivare interesting for a range of wind power companies. The Lehtirova wind power farm of the the wind power company OX2 is situated in in parts of Gällivare and Pajala municipalities. A total of 41 wind turbines have been built on an area of about 4000 hectares. A small share of the profit goes to the local land owners and communities. Even Vattenfall is planning to built a wind park of about 150 plants.

Final energy use baseline inventory

As a first step in the feasibility study a final energy baseline inventory has been done for both Gällivare municipality and for Hakkas community more specific.
Sweden Statistics is providing data on a municipal level, which are checked and processed within the Energy Loupe tool by the regional energy agency. The overwhelming energy use in Gällivare is in the industry and building sector, which is dominated by mining companies, followed by transport. When it comes to energy sources, so are electricity and gasoline most important. Relevant for LECO is also the more specific use in single family houses and apartment houses. There is a high need of electricity for single family houses.



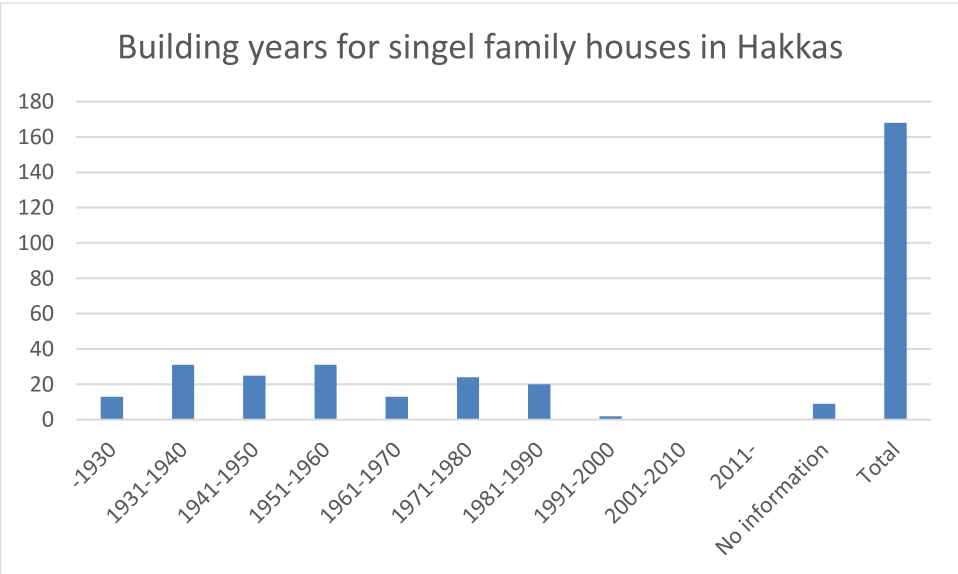




Source: SCB data, Energy Loupe http://norr.energiluppen.se, own graphic

Pilot community Hakkas community hall energy need

As in many other communities in Northern Sweden, almost no new buildings in the last decades have been built in Hakkas. That leads to a general higher energy need for buildings due to a less developed energy performance back then.



Nowadays, there is a lack of housing in Hakkas which limits possibilities to attract new inhabitants. The local association of Hakkas "Hakkasbygdens Boende" plays a key role in the further development of the community. The association is engaged in the local management of the gas station, in housing projects and is also LECO partner in development an energy project. Key to the project is developing the community building "Bygdegården" together with some other buildings nearby to an energy efficient district heating. Today, there are several biomass and electric boilers in use in different buildings, which could be connected and / or replaced by one central boiler. An open question is, whether the heating of the nearby school, which is municipally owned could or should be included in such a district heating system. The key buildings for a potential district heating are

- Community hall, pellets boiler 30 kW, electric boiler 20 kW, ca total energy use 110 000 kWh/year, of which 85 000 kWh are heat from pellets
- Apartment house, pellets boiler 50 kW, electric boiler 90 kW, water heater 8 kW
- Function room for senior citizens, electric boiler
- Municipal school, pellets boiler
- Some further private homes which could be connected to a potential grid

A district heating system would allow for energy efficiency gains, a higher share of bioenergy and a higher proportion of community gains. However, there are still some barriers, among others limited time resources due to other important building projects in the community and the need for an agreement with the municipality whether to include the school in the projects.

Pilot community Hakkas Renewable Energy Potential

As Hakkas community decided work on the idea of a biomass district heating for some key community buildings in the first hand, this feasibility study will not investigate the potential of high-investment projects like wind power, hydropower or agricultural energy crops, nor the potential of small-scale CHP, as the market for this technology is clearly underdeveloped in Sweden.

Heat pumps

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.[1]

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 must 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) shows that both investments are profitable with a pay-back of 4 years for air-to-air and 8 years for geothermal heat pump.

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[1] 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 http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1151181&dswid=5826

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

Pellet or wood stove

As mentioned above, private homes in Hakkas 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:

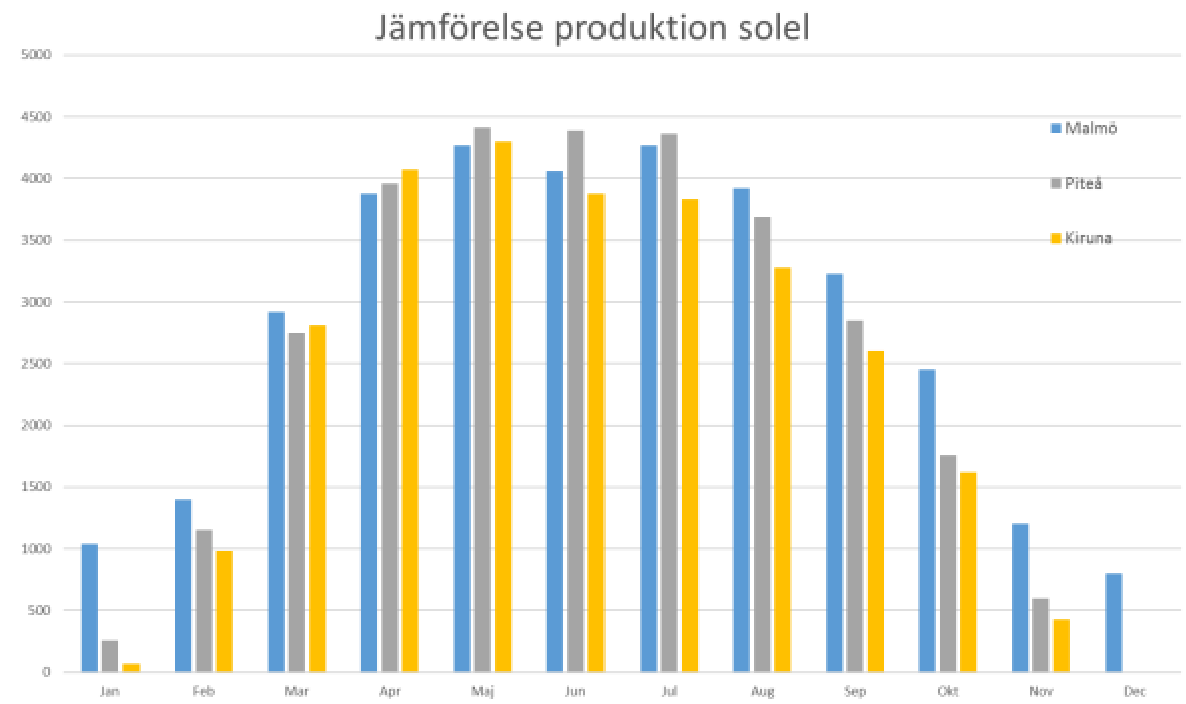
Energy demand	30000
Saving kWh/year	9 000
Electricity price SEK	1,5
Savings SEK/year	7 290
Investment SEK	30 000
Pay back years	4

Solar energy

A combination of biomass and solar energy in the project is interesting for the following reasons:

- While heating demand is high in winter, it is low summer times. By using solar for warming hot water for summer needs, it could be possible to shut down the biomass boiler for a time during summer.
- While the biomass system would deliver heat, it does not deliver electricity. The Photovoltaic market in Sweden is now more developed than ever and PV becomes an available solution for everybody.

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 the 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.



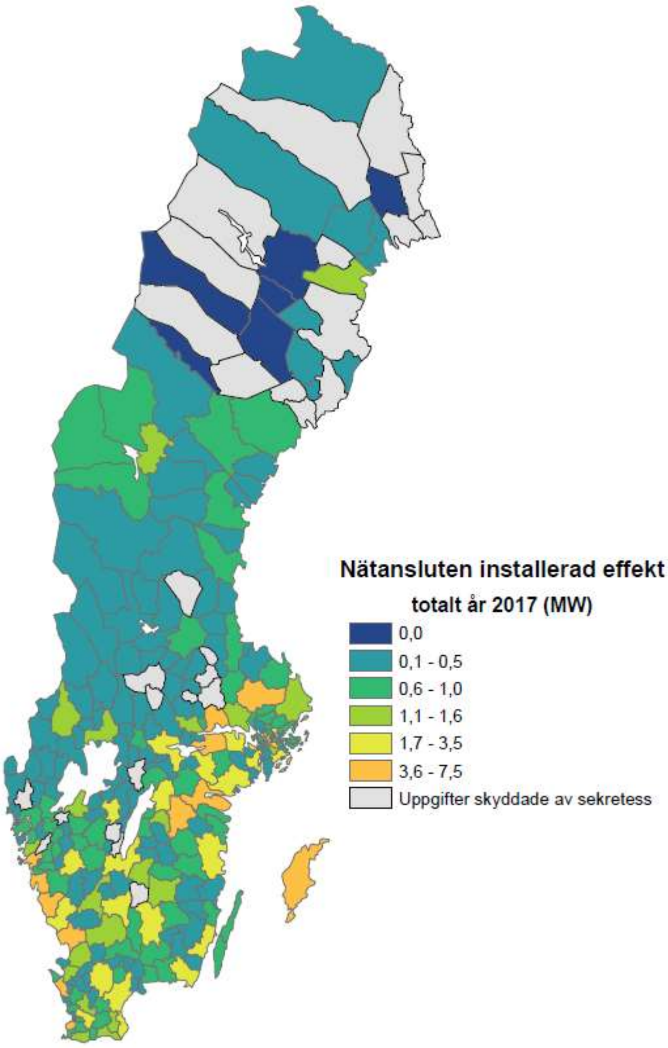
Source: Piteå Energi

Solar heating

A combination with a biomass district heating would deliver significant advantages, as lower number of start/stop for the biomass boiler, higher efficiency, lower costs etc. It is possible to combine with several solar heating systems distributed or a central one. This decision needs a more in-depth analysis. 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 certficate per MWh, income for 15 years.
Origin certificate	Price for certificate is market base. One certficate 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 Hakkas
A calculation for a PV plant for private homes in Vuollerim 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

Transport sector
The energy need for transport in Northern Sweden 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, gas and diesel prices are 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 distances[2].
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.

Scenario for sustainable energy in Hakkas

Energy efficiency

The technical energy efficiency potential for buildings in Hakkas is assessed to be high. This is due to the high average age of building in Hakkas with almost no new builts. However, the economic potential has to be assessed significantly lower, as houses are cheap in Hakkas. High investment costs are difficult to justify. However, experience show that change of behaviour and smaller investments can lead to savings of about 15 percent. In companies and similar facilities, 10 to 30 % are possible. Due to a lack of data, the total energy demand for Hakkas is assessed based on numbers for Gällivare municipality broken down to the number of inhabitants in Hakkas (700 for the whole community) and average numbers for energy efficiency potential as above[3].

Sector	Final energy 2017 (MWh)	Scenario 2025 in WMh
Agriculture/Forestry	163	130
Public sector	2 698	1 888
Service	2 795	1 957
Single houses	5 416	4 874
Cottages	470	399
Total	15 199	9 249

Source: Own calculations

Solar energy

To assess the total potential for solar energy in Hakkas, it is assessed that 30% 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.

[2] CELLER-i project https://www.alvsbyn.se/naringsliv/eu-internationellt/aktuella-eu-projekt/celler-i/
[3] Industry as most important sector for Gällivare is not considered for Hakkas, as the industry is concentred to other areas.

What	MWh/year
52 private homes, solar heating + 5 kW PV	304
10 bigger buildings, 13 kW PV	111
Bigger PV plant, 80 kW:	72
Sum	487

Heat pump and pellets or wood stove

For heat pumps, it is assesse that 50 private homes will invest in an air-to-air heat pump, and another 25 in ground or geothermal heat pump. For bioenergy, it is assumed that 15 private homes invest in wood or pellets stove as a complement to direct electric heating.

What	MWh/year
Air to air heat pump	100
Ground heat pump	177
Pellets or wood stove/fireplace	135
Sum	412