Deliverable 3.3.1 Technical report on geothermal energy solutions for decarbonisation

Interreg Co-funded by the European Union
Northern Periphery and Arctic

Table of Contents

Executive Summary

Deliverable 3.3.1 presents a technical report on geothermal energy solutions for decarbonisation in northern regions. The Icelandic Environment and Energy Agency is responsible for the publication of this report, with contributions from partners in Norway and the Faroe Islands.

The report documents three pilot projects that demonstrate how geothermal energy and heat pump technologies can replace fossil fuel–based heating systems in cold climates. The pilots include Grundarfjörður in Iceland, Mørkvedbukta School and Kindergarten in Bodø, Norway, and the municipal heating system in Leirvík, Faroe Islands. Together, these cases provide practical insights into the technical performance, financial implications, and environmental benefits of geothermal-based heating solutions.

In Iceland, the Grundarfjörður pilot shows how geothermal boreholes and heat pumps can eliminate oil-based heating in public buildings. The system now supplies heat to the primary school, sports hall, music school, and swimming pool, removing the need for approximately 130,000 litres of oil annually and reducing carbon dioxide emissions by around 300 tonnes per year. The project also improves energy security and enables expanded public services, such as extended swimming pool operations.

The Norwegian pilot in Bodø demonstrates the integration of geothermal energy wells, heat pumps, and solar power in a new passive house standard school and kindergarten. Monitoring over four years shows a substantial reduction in heating energy demand and confirms high system efficiency, with heat pumps delivering consistent performance. The pilot also highlights the importance of correct system sizing, as under dimensioned wells required increased use of electric boilers during certain periods.

In the Faroe Islands, long-term monitoring of geothermal boreholes and heat pump systems confirms stable performance and seasonal efficiency factors typically between 3 and 4. The Leirvík system illustrates a flexible hybrid approach combining geothermal energy, heat pumps, electric boilers, and thermal storage to optimise costs and utilise renewable electricity. The transition has significantly reduced oil consumption and heating costs, demonstrating the maturity of geothermal solutions in island energy systems.

Across all three pilots, the report shows that geothermal energy is a reliable and scalable solution for decarbonising heating in cold and remote regions. While local geological conditions, building characteristics, and system design influence performance, the results confirm substantial reductions in fossil fuel use, greenhouse gas emissions, and long-term energy costs. The findings provide a strong evidence base for wider deployment of geothermal heat pump systems as part of the transition to sustainable energy systems in northern climates.

Interreg Co-funded by the European Union
Northern Periphery and Arctic

1 Icelandic pilot

1.1 Methods, procedure, and finances of the energy-saving project in Grundarfjörður.

One of the three HYBES initiatives in Iceland is an energy-saving project in Grundarfjörður. This project focuses on harnessing geothermal energy through boreholes funded by the Energy Fund, leading to the installation of heat pumps for the local swimming pool and primary school. Given that Grundarfjörður relies on electricity for heating, resulting in high costs for households, businesses, and institutions, this initiative seeks to reduce expenses while improving energy efficiency.

1.1.1 Methods

The project aims to improve energy efficiency and sustainability in buildings by utilizing hybrid energy solutions. In Grundarfjörður, the focus has been on reducing heating costs and carbon emissions by replacing oil-based heating with a heat pump system powered by geothermal energy.

The method used involved drilling boreholes to access geothermal energy, installing a heat collection system, and integrating heat pumps to supply heating for the local swimming pool, primary school, music school, and sports hall. The new system is designed to provide a more energy-efficient and environmentally friendly alternative to oil heating.

Preparation for the project began in the summer of 2023 and continued into early 2025, when the system became fully operational.

1.1.2 Procedure

The implementation of the energy-saving project in Grundarfjörður began in the summer of 2023 with the drilling of ten geothermal boreholes just south of the town's sports facilities. Nine of these boreholes proved usable, each drilled to a depth of over 230

Interreg Co-funded by the European Union
Northern Periphery and Arctic

meters. A closed-loop heat collection system was installed in seven of the boreholes. In the remaining two boreholes, which showed signs of having more water flow, an alternative solution was considered, using the water directly. This approach is still in development, involving test pumping and adjustments, and results are not yet conclusive.

Five NIBE heat pumps supplied by Fríorka ehf. were installed indoors in the basement of the sports hall, along with three heat storage tanks. The estimated installed power of the heat pumps is 300 kW. In addition, the storage tanks provide approximately 60 kW of backup capacity if needed. The total heating demand of the connected buildings, the primary school, sports hall, and swimming pool was calculated to be around 240 kW.

These buildings, which form a combined complex, had been heated with oil for decades. On January 16, 2025, the new heat pump system was started up for the first time, marking a major milestone in the town's transition from fossil fuels to geothermal energy. Heat is collected from the boreholes, transferred through a system of main pipes and a pipe box, and then delivered to the heat pumps and storage tanks. From there, it is distributed throughout the buildings.

Previously, Grundarfjörður used approximately 130,000 Liters of oil annually for heating these facilities, leading to yearly carbon dioxide emissions of about 230 to 300 tons. With the new system in place, CO_2 emissions from heating are now eliminated. Over time, since the installation of the original oil boiler in 1999 the accumulated emissions from oil combustion are estimated to have been between 5,500 and 7,200 tons.

1.1.3 Finances

The project was funded by the Energy Fund, which provided a 40 million Kroner grant to support the energy conversion of the swimming pool and primary school in Grundarfjörður. The funding covered the costs associated with drilling boreholes, installing the heat collection system, and integrating heat pumps.

Before the energy transition, the heating system relied on oil, which resulted in high costs for heating households, companies, and institutions in Grundarfjörður. The new heat pump system is expected to significantly reduce heating costs and eliminate CO_2 emissions from oil combustion.

Interreg Co-funded by the European Union
Northern Periphery and Arctic

The heating conditions and costs in past years made it impossible to keep the swimming pool open year-round. Only the wading pool and two outdoor hot tubs were heated and operated throughout the year. With the energy transition, there is now an opportunity to expand access, although full-year opening is not yet considered entirely feasible. The coldest 1–2 months of the year may still pose challenges, and the long-term viability will depend on operational experience.

The project represents a substantial investment for the municipality, but the long-term benefits of reducing oil-based heating costs are considerable. The grant support from the Icelandic Energy Fund (Orkusjóður) was critical in enabling the project to move forward with full force, providing both financial relief and the confidence to commit to such a large-scale change.

1.2 Results and outcomes

The energy-saving project in Grundarfjörður has led to significant changes in the town's heating system, particularly for the primary school, music school, sports hall, and swimming pool. These buildings were previously heated using oil, which resulted in high costs and substantial carbon dioxide emissions. Before the transition, the annual oil consumption for heating these structures was around 130,000 Liters, contributing to an estimated 300 tons of CO_2 emissions per year. With the installation of heat pumps, these buildings are now fully heated using geothermal energy, eliminating the need for oil and reducing carbon emissions from heating to zero.

The project also addressed long-standing issues related to the swimming pool. Since its construction around 50 years ago, the pool had not been operational year-round due to the limited capacity of the oil boiler, particularly during the coldest months when heating demands were highest. The high cost of heating further contributed to these restrictions. With the implementation of the new heat pump system, the swimming pool can now remain open throughout the year, providing improved access for residents, though the coldest one to two months may still present challenges. The long-term feasibility of full year operation will be evaluated based on practical experience.

The transition was completed on January 16, 2025, when the heat pumps were activated. The project has not only reduced energy costs but has also demonstrated the

Interreg Co-funded by the European Union
Northern Periphery and Arctic

effectiveness of utilizing local resources for heating. The experience and knowledge gained from this initiative are expected to contribute to further energy conversion projects in the municipality in the coming years.

This project has proven to be an essential and long-awaited step for the town. However, it has not been a simple “plug and play” process. The existing infrastructure such as old control systems and piping in the pool and sports hall required considerable adaptation and problem-solving. Thanks to skilled local professionals, particularly plumbers and electricians, the work progressed successfully despite these technical challenges.

1.3 Discussion

1.3.1 Challenges and variability in success

The energy-saving project in Grundarfjörður encountered challenges related to infrastructure limitations and resource availability. The borehole drilling process revealed that nine out of the ten drilled wells were usable, demonstrating the variability in success when tapping into geothermal resources. Additionally, adapting the existing heating infrastructure to integrate the new heat pump system required careful planning and execution. The high initial cost of the transition, despite funding support from the Energy Fund, was another factor that had to be addressed to ensure the project's feasibility.

Moreover, the swimming pool had faced heating limitations for decades due to the restricted capacity of the oil boiler, particularly during colder months. This issue had previously prevented year-round operation. The successful implementation of the heat pump system resolved this problem.

1.3.2 Impact beyond immediate results

Beyond the direct benefits of reducing heating costs and eliminating carbon emissions, the project has broader implications for the municipality and other rural areas in Iceland. The knowledge and experience gained through the transition provide a foundation for further energy conversion and efficiency projects in Grundarfjörður. The project

Interreg Co-funded by the European Union
Northern Periphery and Arctic

demonstrates how local renewable energy sources can be utilized to improve energy sustainability, serving as a potential model for similar initiatives in other communities.

By replacing oil-based heating with heat pumps, the project contributes to Iceland's broader environmental goals by significantly reducing CO_2 emissions from local infrastructure. Additionally, the long-term reduction in heating costs benefits both the municipality and the residents, making sustainable energy solutions more financially viable. The ability to operate the swimming pool year-round also enhances community services, providing social and recreational benefits that extend beyond energy savings.

1.4 Conclusion

The energy-saving project in Grundarfjörður marks a significant step toward improving energy efficiency and sustainability in the municipality. By transitioning from oil-based heating to a heat pump system powered by geothermal energy, the town has successfully eliminated its reliance on fossil fuels for heating the primary school, music school, sports hall, and swimming pool. This change has resulted in the removal of approximately 130,000 Liters of annual oil consumption, reducing CO_2 emissions by an estimated 300 tons per year.

The project has also addressed long-standing heating challenges, particularly for the swimming pool, which had previously been unable to operate year-round due to the limitations of the oil boiler and high heating costs. With the new system in place, the swimming pool can now remain open throughout the year, providing better access for residents.

Completed on January 16, 2025, the project has provided valuable knowledge and experience in energy conversion, which will be used to support future energy efficiency initiatives in Grundarfjörður. The successful implementation of this system demonstrates the potential for similar projects in other municipalities, reinforcing the importance of sustainable local energy solutions.

The project has highlighted the critical need for access to expertise in large-scale energy transitions, especially in colder regions like Grundarfjörður, where standard solutions

Interreg Co-funded by the European Union
Northern Periphery and Arctic

may not apply. The municipality sees this effort as part of a broader strategy and is determined not to let the “cold zone” label limit its ambitions. Instead, it aims to continue the transition away from fossil fuels and scale up energy transformation in the coming years.

2 Norway - Bodø

2.1 Description of Pilots Mørkvedbukta School and kindergarten

2.1.1 What is the use of the building and where is it located?

The Hybes geothermal energy pilot in Bodø area is Mørkvedbukta school and kindergarten. This is a new building taken into use late Oktober 2021. The building is located at shoreline 12 km from city centre and has a size of 7333 m^2. The school is a to story building with an area of 5947 m^2, and the kindergarten is built in one level with an area of 1386 m^2

The primary use profile of the school building is from 7 a.m. to 5 p.m., five days a week. In a normal year, there will be a holiday of 12 weeks, in addition to two to three days off in May and two days off in autumn.

Each classroom is expected to have 25 pupils and teachers. Ventilation air volumes are dimensioning for this use. There are two classrooms per grade, a total of 7 grades, and this gives an expected workload of 350 people divided between the school part.

The sports hall will be in use from 9 a.m. to 22 p.m., five days a week. The sport hall has a person load of 40 persons, and the dressing room is dimensioned for 10 persons evenly distributed over the operating time.

The amphitheatre is rented out ten hours a week. The frequency is unknown but opening hour is between 18-21. As a simplification one expects use two hours per weekday with 30-50 people.

Kindergarten is open from 6.30 a.m. to 17 p.m., five days a week and there isn't calculated with holidays. The kindergarten consists of 6 departments, and numbers of children in each department will be between 16-20. In total, this gives an expected person load of 108.

2.1.2 Energy system and energy carriers of Mørkvedbukta school and kindergarten

This report will evaluate the effect and performance of energy wells system in combination with heath pumps technology. We define this renewable energy system as geothermal energy. The Energy Well system consist of 10 wells, each with a depth of 250 meters. The bedrock in Bodø is proven stabile for energy well drillings and isn't disturbed by groundwater flow. Expected effect is estimated to 108 kwh.

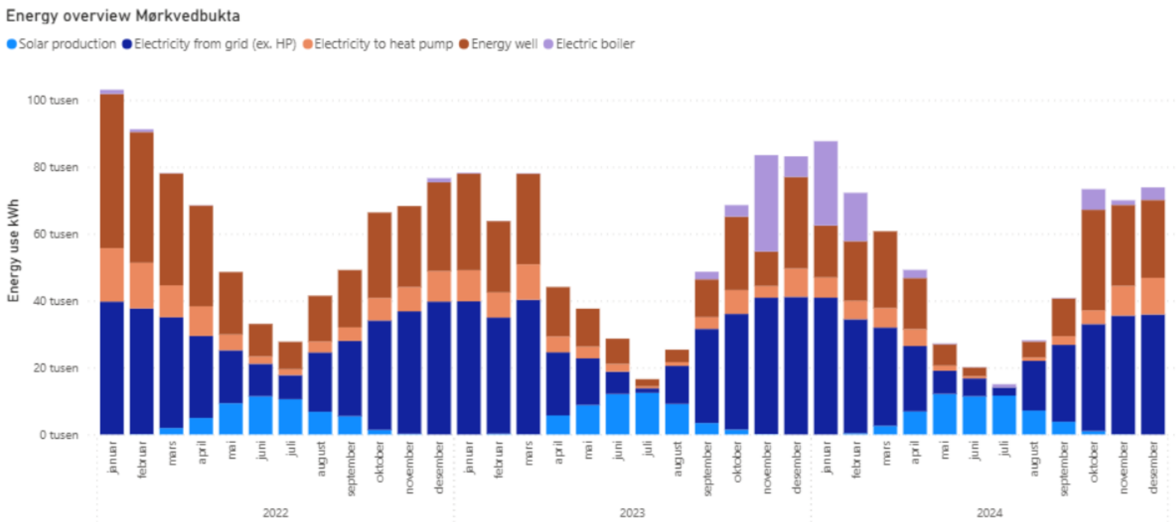
A heat pump system has been established with wells in combination with an electric boiler. The electric boiler is to cover peak load on heating and represent a backup for safety reasons. The heat pump is dimensioned to cover at least 60% of the maximum power requirement. The heat pump infrastructure is estimated to:

- Cover 90-100% of the building's heating needs and delivers "free of charge" refrigeration.
- Collect approx. 70% of the heat from the bedrock.
- Increases the heat from the rock up to underfloor heating and radiator temperature.

Interreg Co-funded by the European Union
Northern Periphery and Arctic

In addition, this pilot also has installed solar installations. On the top roof solar installations cover about 589 m2, which makes it one of the biggest solar installations in artic Norway. It has an installed capacity of 100 kWp (kiloWatt-peak), which means that it can deliver 100 kW (kiloWatt) at optimal solar conditions. Its peak capacity is estimated to an annual production of 60,000-70,000 kWh, which represents 15-20 per cent of the total energy consumption of the building. Figure 1 illustrate the total composition of energy carriers and production volumes for our pilot Mørkvedbukta School and Kindergarten.

Figure 1



In our evaluation of the effect of this geothermal energy pilot the electricity produced from solar installations[1] indirectly have an influence of our analyses because those two Renewable Energy Systems interact with each other.

To evaluate the effect and performance of geothermal energy on different parameters we need to define a baseline. This baseline is based on the analyses and theoretical calculations from construction data, from theoretical calculation of net energy performance and from indoors climate requirements.

[1] Solar energy as an energy carrier is analysed and described in report 3.1.1

2.2 Construction data and energy baseline of Pilot

In planning and design phase of Mørkvedbukta School and Kindergarten several reports were produced to document the technical and energy performance of the building. The presentation and description below are based on these analyses and theoretical calculations which represents our baseline for our evaluation of the geothermal energy system.

The constructions of this pilot, Mørkvedbukta School and Kindergarten, are party concreate beams and partly Cross Laminated Timber (CLT) beams. Walls are insulated timber constructions including I beams. Some parts of the floor are built on poles with hollow core slaps on top. The rest of the floor is built traditionally on the ground.

The buildings energy performance follows the national building regulations TEK 17 and satisfied the demands of passive house requirements NS3701:2012 ("Criteria for passive houses and low-energy buildings-non-residential buildings"). According to TEK17, buildings must be designed and executed in such a way as to facilitate responsible energy use. The energy requirements apply to the heated utility area of the building (BRA). This means that the building must satisfy the requirements set out in sections 14-2 to 14-5 of TEK 17.

Section 14-2 on Energy efficiency requirements demand that the total net energy requirement of the building most not exceed the energy limits of building type. For schools the threshold is 110 kWh/m^2 and for kindergartens the threshold is 135 kWh/m^2.

Section 14-3 on minimum requirements for energy efficiency must meet the U-values shown in the table below:

Table 1:

Minimum demands for U values			
Outer walls	Roofs	Floors on ground	Windows and doors
≤ 0,22 W/(m^{2}K)	≤ 0,22 W/(m^{2}K)	≤ 0,22 W/(m^{2}K)	≤ 0,22 W/(m^{2}K)

Furthermore, § 14-4 in TEK 17 makes the following demands:

- It is not allowed to install heating installations using fossil energy.

Interreg Co-funded by the European Union
Northern Periphery and Arctic

- For buildings beyond 1000 m2 it is required to use flexible energy heating systems preferable to use low temperature heating solutions.
- Flexible energy systems must cover minimum 60 % of estimated heating needs.

For our pilot Mørkedbukta School and Kindergarten passivhouse requirements is valid. However, in addition to TEK 17, also requirements are set for energy demands for heating and cooling, as well as heat loss figures for transmission and infiltration losses. For these estimates local climate is considered when requirements on energy needs are evaluated. It's also assumed that the heated BRA of the building will affect the requirement for heat loss figures.

Estimated energy demands for heating and cooling and transmission and infiltration loss are shown below in table 2

Table 2:

	Mørkved bukta school	Mørkvedbukta kindergaten
Heath loss for transmission and infiltration loss.	0,40 W/m²K	0,40 W/m²K
Highest estimated net specific energy demand for heating	23,2 kWh/m²	28,3 kWh/m²
Highest estimated net specific energy demand for cooling	1,6 kWh/m²	1,6 kWh/m²
Requirements for highest estimated net specific energy demand for lighting	4,5 W/m²K	5,0 W/m²K

To meet transmission and infiltration losses building requirement set specific demands on structural components, as well as the performance of the ventilation unit.

2.2.1 Theoretical calculation of net energy performance of Pilot

According to the energy framework requirements in TEK17, the maximum energy requirement most not exceed 135 kWh/m² annually for kindergarten and 110 kWh/m² annually for school buildings, respectively. Calculations of theoretically calculated total net energy demand for the building of 73.8 kWh/m² and 72.7 kWh/m². and the

Interreg Co-funded by the European Union
Northern Periphery and Arctic

requirements in TEK17 are thus met. It is emphasized once again that this should not be confused with real energy performance, as this is not the purpose of this evaluation.

Table 3: Total calculated energy needs Mørkvedbukta School

Description of Total Netto energy needs	Value
Calculated energy need to room heating	13,4 kwh/m^2
Calculated energy need from ventilation heating	14,5 kwh/m^2
Calculated energy hotwater	10,1 kwh/m^2
Calculated energy fans	11,0 kwh/m^2
Calculated energy pumps	0,5 kwh/m^2
Calculated energy lighting	9,9 kwh/m^2
Calculated energy technical equipment	13,2 kwh/m^2
Calculated energy room cooling	0,0 kwh/m^2
Calculated energy ventilation cooling	0,0 kwh/m^2
Total calculated energy needs	**72,7 kwh/m^2**
Demanded Netto energy needs from building regulations	110,0 kwh/m^2

Table 4: Total calculated energy needs Mørkvedbukta Kindergarten

Description of Total Netto energy needs	Value
Calculated energy need to room heating	24,4 kwh/m^2
Calculated energy need from ventilation heating	11,4 kwh/m^2
Calculated energy hotwater	10,0 kwh/m^2
Calculated energy fans	9,0 kwh/m^2
Calculated energy pumps	0,7 kwh/m^2
Calculated energy lighting	13,1 kwh/m^2
Calculated energy technical equipment	5,2 kwh/m^2
Calculated energy room cooling	0,0 kwh/m^2
Calculated energy ventilation cooling	0,0 kwh/m^2
Total calculated energy needs	**73,8 kwh/m^2**
Demanded Netto energy needs from building regulations	135,0 kwh/m^2

When evaluating energy efficiency against TEK requirements, net energy demand must be analysed. The following two tables shows calculated energy needs for Mørkedbukta School and kindergarten. (see Figure 2).

Interreg Co-funded by the European Union
Northern Periphery and Arctic

Furthermore, the minimum requirements for building components and leakage figures in TEK17 § 14-3 must be satisfied. Pipes, equipment, and ducts connected to the building's heating and distribution system must be insulated to prevent heat loss. Figure below shows that minimum requirements for components and leakage figures have been met. Minimum requirements (§14-3).

Table 5:

Description for Mørkvedbukta school	Value	Require ments
U-value exterior walls (W/m²K)	0,14	0,22
U-value roof (W/m²K)	0,11	0,22
U-value floor against ground and open air (W/m²K)	0,16	0,18
U-value Glass/Windows/Doors (W/m²K)	0,8	1,2
Leakage rate (airtightness at 50 Pa pressure difference) Air exchanges per hour	0,3	1,5

Table 6:

Description for Kindergarten	Value	Require -ments
U-value exterior walls (W/m²K)	0,14	0,22
U-value roof (W/m²K)	0,08	0,22
U-value floor against ground and open air (W/m²K)	0,10	0,18
U-value Glas/Windows/Doors (W/m²K)	0,8	1,2
Leakage rate (airtightness at 50 Pa pressure difference) Air exchanges per hour	0,5	1,5

Another method to verify passive house requirement refers to highest heat loss figures for transmission and infiltration loss. The regulations demand a measure of 0.40 W/m^2K for both school buildings and kindergartens with heated areas greater than or equal to 1000 m^2.

Calculated heat loss values for the Mørkvedmarka School are shown in table 8 0.40 W/m²K and 0.37 W/m²K, and the requirements are thus met.

Table:8

Description for Mørkvedbukta school	**Value**
Heat loss exterior walls (W/m²K)	0,06
Heat loss roof (W/m²K)	0,06
Heat loss floor against ground and open air (W/m²K)	0,09
Heat loss Glas/Windows/Doors (W/m²K)	0,09
Heat loss thermal bridge	0,03
Heat loss infiltration	0,04
Total heat loss	0.37

Table:9

Description for Kindergarten	**Value**
Heat loss exterior walls (W/m²K)	0,06
Heat loss roof (W/m²K)	0,08
Heat loss floor against ground and open air (W/m²K)	0,10
Heat loss Glas/Windows/Doors (W/m²K)	0,09
Heat loss thermal bridge	0,03
Heat loss infiltration	0.05
Total heat loss	0,40

Also, the Kindergarten meets heat loss requirements.

2.2.2 Indoors climate requirements of Pilot

As the geothermal energy system is designed to cover the heating needs of our pilot Mørkvedbukta school and kindergarten indoors climate requirements are essential. Bodø Municipality has required that the school has 21 °C during the day and 20 °C at night and on weekends and that the kindergarten must have 22 °C during the day and 21 °C at night and on weekends. Furthermore, the sports hall and associated room do not have heating, but only ventilation. The associated changing room areas is defined as a separate zone with the same temperature as the school.

Interreg Co-funded by the European Union
Northern Periphery and Arctic

A balanced air treatment system with filtered and preheated air is installed. There are a total of seven aggregates covering the school and kindergarten. Table 6 summarizes the stated air flows, heat recovery rate and Specific Fan Power (SFP)[2] factor at 80% simultaneously, which is expected normal operation.

Table 6

Aggregatets	Zone	Air flow at 80% simultaneously[3]	Heat recovery rate	SFP factor
360.001	Kindergarten	11572 m^3/h	85,0 %	1,27 $kW/(m^3/s)$
360.002	School	13436 m^3/h	83,9 %	1,65 $kW/(m^3/s)$
360.003	School	12428 m^3/h	84,7 %	1,38 $kW/(m^3/s)$
360.004	School	8812 m^3/h	85,0 %	1,32 $kW/(m^3/s)$
360.005	School	8928 m^3/h	85,2 %	1,27 $kW/(m^3/s)$
360.006	School	11260 m^3/h	85,2 %	1,19 $kW/(m^3/s)$
360.007	School	9700 m^3/h	84,5 %	1,4 $kW/(m^3/s)$

Outside operating hours, in practice, the ventilation unit will turn off. I addition a hot water coil on the ventilation unit is installed. This hot water coil has a delta T[4] of 20 K. No cooling is installed on the ventilation system.

From energy demand we calculate delivered energy and uses system efficiency level in these calculations. This represents the ratio between energy supplied to the energy source and the supplied heat to individual building zones. Typically, the system efficiency of district heating and electricity is below 1 for heat demand, because of heat losses in

[2] SFP is a measure of the electrical power required to move air through a ventilation system. The SFP factor indicates how much power (kWh) is required to move one cubic meter of air per second through the ventilation system.

[3] The air flow rate at 80% simultaneity is an expression of how the air volume should be reduced in ventilation systems in case not all units in a building are used simultaneously. To calculate the air flow rate, multiply the total air flow rate by a factor of 0.8. For example, if a building with 1000 m^3/h air flow is in use at 80% simultaneity, the actual air flow rate will be 800 m^3/h.

[4] ΔT, is a scientific notation for a temperature change or difference. A ΔT of 20K for a hot water coil is often considered a reasonable design or operating parameter, indicating efficient heat exchange. Deviations from this value can suggest issues with water flow, coil performance, or system load.

Interreg Co-funded by the European Union
Northern Periphery and Arctic

the distribution system. Heat pump obtains a value up to 3. Furthermore, it is assumed that each person has a heat supplement of 80 W, except for the sports hall, where the heat subsidy has been increased to 150 W. This is in accordance with the RIF guidelines for thermal indoor climate.

Tabel 7. Summary of relevant ventilation data into real energy calculation.

Agregates	360.001	360.002	360.003	360.004	360.005	360.006	360.007
Zone	Kinder-garten	School	School	School	School	Sports hall	School
Air supply 80 % [m3/h]	11 572	13 436	12 428	8 812	8 928	11 260	9 700
Exhaust 80 % [m3/h]	11 492	13 584	12 280	8 612	8 768	11 300	9 660
Heath recovery [%]	85,0	83,9	84,7	85,0	85,2	85,2	84,5
SFP [kW/(m3/s)]	1,27	1,65	1,38	1,32	1,27	1,19	1,4

Bodø Municipality has required real energy calculation of three different supply air temperatures. The consequences of different supply air temperatures have been tested with supply air temperatures of 19 °C, 20 °C and 21 °C. The exception is for unit for the sport hall, which is stated to have a supply air temperature of 17 °C which is assumed to be fixed.

Tables below are showing energy demand per energy item (space heating/ventilation/tap water, etc.), but delivered energy are presented only per energy product (heat pump and electricity). The operation to calculate delivered energy per energy item has therefore been done manually, to better compare with the figures measured for the building. This is shown in four tables.

Table 8

Air supply Temperature 19 °C		**Heath pump**	**Electricity**	**SUM**
	Energy needs	Share System efficiency Delivered energy	Sharel System efficiency. Delivered energy	Delivered energy
Energy post	kWh	kWh	kWh	kWh
1a Room heating	163 618	100 % 2,45 66 783	0 % 0,81	66 783

1b Ventilation heating	36 599	100 %	2,67	13 707	0 %	0,88	-	13 707
2 Hot water	74 580	100%	2,60	28 685	0 %	1	-	28 685
3a Fan	91 401	0 %	-		100 %	1	91 401	91 401
3b Pumps	3 975	0 %	-		100 %	1	3 975	3 975
4 Lighting	104 472	0 %	-		100 %	1	104 472	104 472
5 Technical equipment.	123 314	0 %	-		100 %	1	123 314	123314
6a Room cooling	32 416	0 %	-		100 %	3,61	8 980	8 980
6b Ventilation cooling	-	0 %	-		100 %	1	-	-
SUM	630 375	109 175					332 142	441 316

Table 9:

Air supply Temperature 20 °C		**Heath pump**			**Electricity**			**SUM**
	Energy needs	Share	System efficiency	Delivered energy	Sharel	System efficiency.	Delivered energy	Delivered energy
Energipost	kWh	kWh			kWh			kWh
1a Room heating	129 903	100 %	2,45	53 022	0 %	0,81	-	53 022
1b Ventilation heating	66 664	100 %	2,67	24 968	0 %	0,88	-	24 968
2 Hot water	74 580	100 %	2,60	28 685	0 %	1	-	28 685
3a Fan	91 401	0 %	-		0 %	1	91 401	91 401
3b Pumps	3 600	0 %	-		100 %	1	3 600	3 600
4 Lighting	104 472	0 %	-		100 %	1	104 472	104 472
5 Technical equipment	123 314	0 %	-		100 %	1	123 314	123 314
6a Room cooling	33 423	0 %	-		100 %	3,61	9 258	9 258
6b Ventilation cooling	-	0 %	-		100 %	1	-	
SUM	627 357	106 674			332 045			438 719

Table 10:

		Heat pump	**Electricity**	**SUM**

Air supply Temperature 21 °C	Energy needs	Share System efficiency Delivered energy	Sharel System efficiency. Delivered energy	Delivered energy
Energy post	kWh	kWh	kWh	kWh
1a Room heating	103 456	100 % 2,45 44 831	0 % 0,81 -	44 831
1b Ventilation heating	191 988	100 % 2,67 34 669	0 % 0,88 -	34 669
2 Hot water	74 580	100 % 2,60 28 685	0 % 1 -	28 685
3a Fan	102 764	0 % -	100 % 1 91 401	91 401
3b Pumps	3 893	0 % -	100 % 1 4 024	4 024
4 Lighting	104 472	0 % -	100 % 1 104 472	104 472
5 Technical equipment	123 314	0 % -	100 % 1 123 314	123 314
6a Room cooling	34 816	0 % -	100 % 3,61 9 505	9 505
6b Ventilation cooling	-	0 % -	100 % 1 -	
SUM	739 283	108 185	344 087	440 901

Table 11

Air supply. Temperature 21 °C and 25% air flow non operational time		**Heat pump**	**Electricity**	**SUM**
	Energy needs	Share System efficiency Delivered energy	Sharel System efficiency. Delivered energy	Delivered energy
Energy post	kWh	kWh	kWh	kWh
1a Room heating	103 456	100 % 2,45 42 227	0 % 0,81 -	42 227
1b Ventilation heating	191 988	100 % 2,67 71 906	0 % 0,88 -	71 906
2 Hot water	74 580	100 % 2,60 28 685	0 % 1 -	28 685
3a Fan	102 764	0 % -	100 % 1 102 764	102 764
3b Pumps	3 893	0 % -	100 % 1 3 893	3 893
4 Lighting	104 472	0 % -	100 % 1 104 472	104 472
5 Technical equipment	123 314	0 % -	100 % 1 123 314	123 314
6a Room cooling	34 816	0 % -	100 % 3,61 9 644	9 644
6b Ventilation cooling	-	0 % -	100 % 1 -	

SUM	739 283	142 817	344 087	486 904

The first three tables show the result with different supply air temperatures, 19, 20 and 21 °C respectively. Table 11 show the result with supply air temperature of 21 °C, but here a calculation has also been done under circumstances that the air flow outside operation is run at 25 % of the maximum air flow, instead of switching it off. From the first three tables we notice that the total energy delivered is relatively similar. This is because less energy is needed for space heating when the supply air temperature increases.

2.3 Methods and monitoring parameters.

Bodø Municipality has invested in an energy monitoring system (EOS), a digital tool that contributes with an overview of energy use. This software program is called E-save and is developed by the IT firm Esave AS located in Rognan. E-save is a central online monitoring and management tool used to optimize energy consumption of the municipal building stock. Energy data is monitored pr. hour or pr. week and energy use of different energy carriers such as solar, geothermal, district heating, and electricity from grid can be measured. Centralised monitoring makes it easy to detect deviations from the norm and make it possible to find the reason why a single building suddenly uses more electricity than normal or that a building uses more electricity than another similar building.

The main purpose of using E-Save is to reduce energy consumption to a minimum in the buildings. This is done as E-Save makes it possible to optimise and upgrade the performance of heat, ventilation, light etc.

To monitor, register and systematise energy data from our pilot Mørkvedmarka School and Kindergarten we use this E-Save tool. E-Save has different visualisation options, which make it possible to show:

- An energy/temperature diagram measuring kwh/m2/week. The diagram shows if energy use is on budget or shows energy sub-optimalisation/technical defects.
- A bar diagram showing energy use/production pr. energy carrier used for the actual building.

Interreg Co-funded by the European Union
Northern Periphery and Arctic

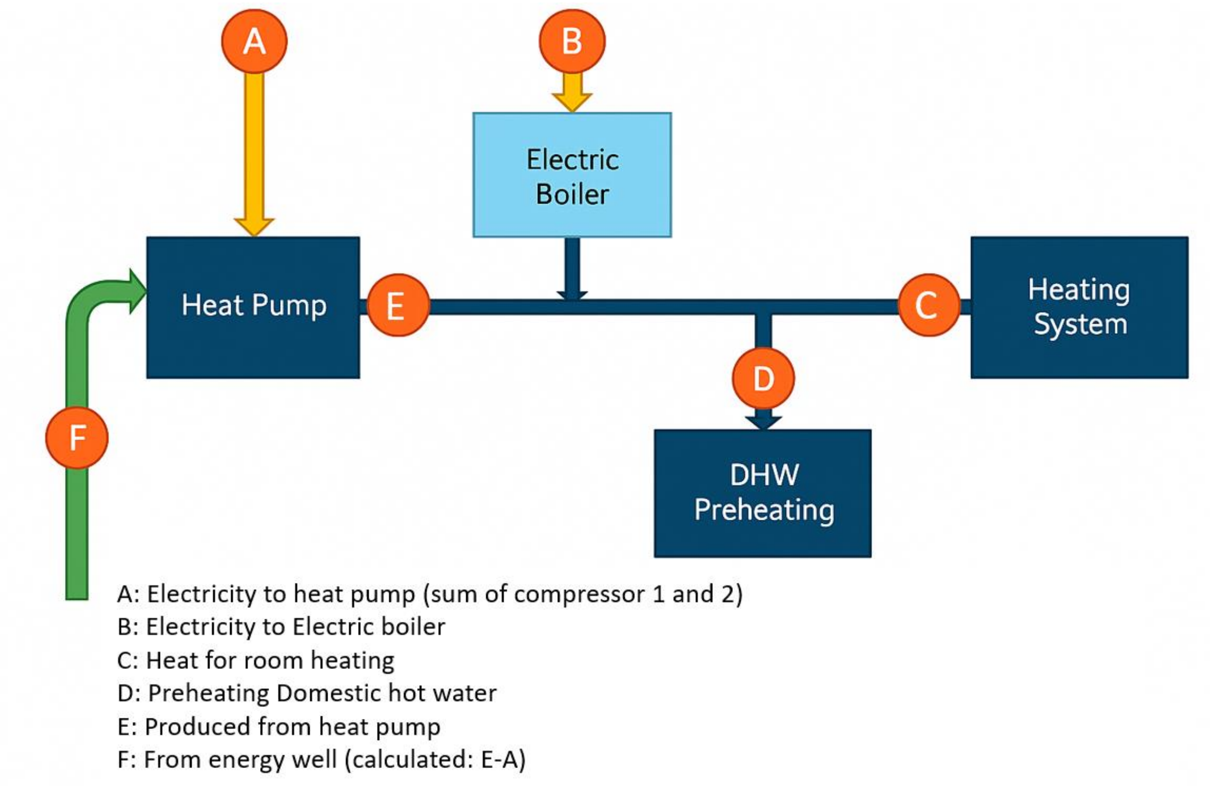
- Accumulated graph showing energy use during the year.

The parameters we are monitoring:

- Total power use kwh/m^2 pr. Year. (Jan. 2022 to Dec. 2025)
- Total energy production from energy wells pr. week (Jan. 2022 to Dec. 2025)
- Total energy uses for heating pumps pr. week (Jan. 2022 to Dec. 2025)
- Total energy use for electric boiler pr. week (Jan. 2022 to Dec. 2025)
- Total energy use for heating and hot water pr. week (Jan. 2022 to Dec. 2025)
- Netto energy supply pr. week (Jan. 2022 to Dec. 2025)
- Netto energy supply kWh/m^2
- Calculate climate effect on energy use.
- Measure energy efficient task taking technology into use ventilations.
- Cost calculations and pay off for energy technology investment.
- Obtainment climate and energy goals

The figure below shows the heating central for Mørkvedbukta School and Kindergarten from energy wells to heat pump and electric boiler to preheating and heating. Monitoring spots are marked with capitals A to E and energy production for the energy wells are calculated as energy from Heat pump (E) minus power to operate heat pumps (A)

Figure 2: The diagram describes how the system is set up, and how data is given in ESAVE from sensors and calculations:



2.4 Results and summing up data

We have systematically monitored geothermal energy data for Mørkvedbukta School and Kindergarten a four-year period from January 2022 to December 2025. 2022 is the first hole year with energy data from the heating central and the Energy Well system consisting of 10 wells, each with a depth of 250 meters. The capacity of heat pump infrastructure is estimated to cover 90-100% of the building's heating needs and collect approximate 70% of the heat from the bedrock. The bedrock in Bodø is proven stabile for energy well drillings and isn't disturbed by groundwater flow. Expected effect is estimated to 108 kwh.

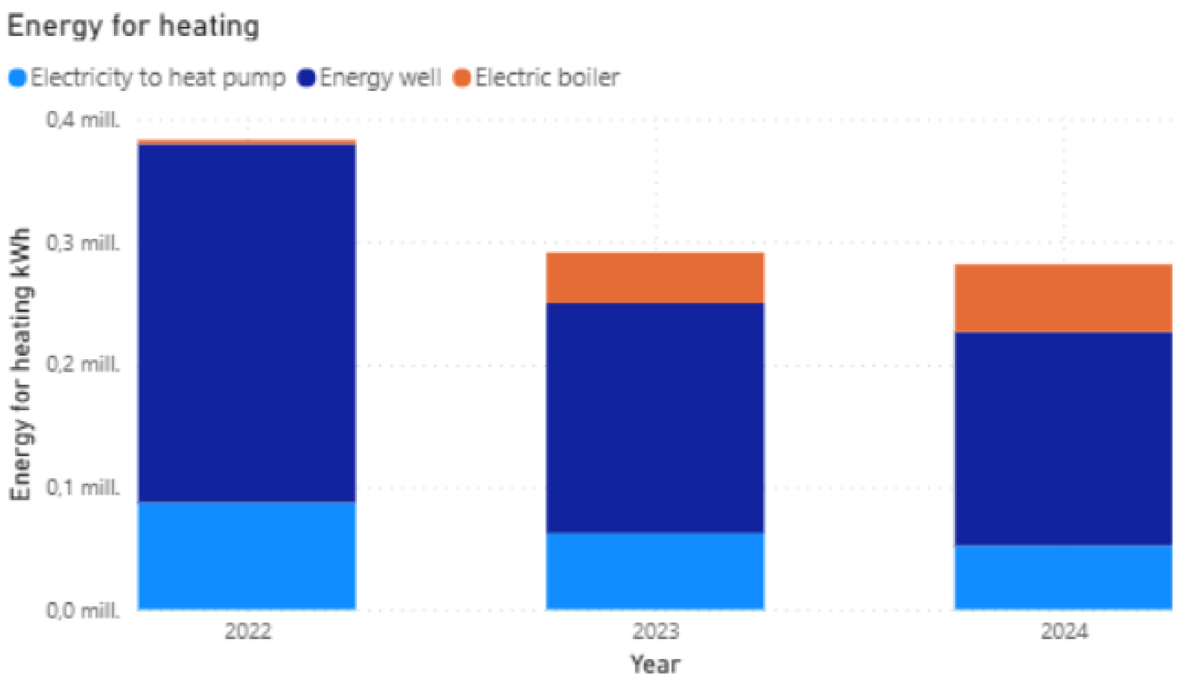
We have evaluated the quality of date in discussions with E-save, responsible company for monitoring energy data. Because of different measuring methods used for registering data from the heat central system E-save has controlled and adjusted data for the years 2022 and 2023. Form the inauguration of the school November 2021 until November 2023 energy data has been reconstructed by E-Save because data wasn't measured online. In addition, one of the electric meters wasn't installed as monitoring started up 2022, but first later in the actual period. Form November 2023 to February 2025 data has been imported from SD data. These data haven't been imported on weekly basis which makes weekly registration more inaccurate. From February 2025 all data is registered contemporary online.

Another important fact to pinpoint is that it seems that planned and dimensioned capacity of numbers of energy wells isn't optimised to manage heating demands of the buildings. We will come back to the consequences of this later.

We now will draw up some main findings from our energy data. Firstly, monitoring data shows a yearly decline in energy use for heating. Total energy for heating comes from adding energy production from energy wells, energy used to operate heat pumps and energy use for the electric boiler as illustrated below in figure 3.

Interreg Co-funded by the European Union
Northern Periphery and Arctic

Figure 3: Total energy for heating per year



In absolute numbers table 12 shows that the total energy use for heating and hot water decreases with 134997,3 kWh from 2022 to 2025 which equals a reduction of 35 %.

Table 12:

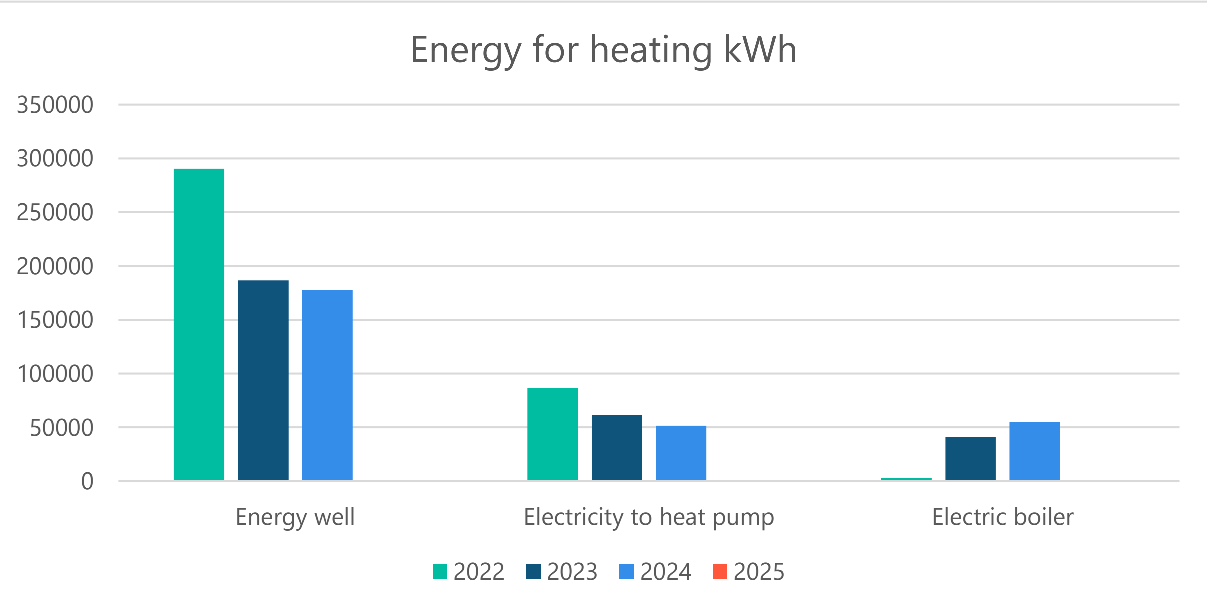
	2022	2023	2024	2025
Total energy production from energy wells. kWh	290283,4	186648,0	177764,4	168997,2
Total energy uses for heating pumps. kWh	86272,2	61858,0	51494,8	59529,0
Total energy use for electric boiler. kWh	3127,6	41085,4	55222,3	16179,7
Total energy use for heating and hot water. kWh	**379683,2**	**289591,4**	**284481,5**	**244705,9**

However, we find a substantial variation in monitoring period between heating from energy wells and heating from the electric boiler. Most of total heat production in 2022 and 2025 was produced and delivered from the energy well system, and with almost no

Interreg Co-funded by the European Union
Northern Periphery and Arctic

use of the electric boiler. For the year 2023 and 2024 the energy from the well decreased while the electric boiler has contributed more.

Figure 4:



In absolute numbers table 13 shows a reduction from energy wells of 122519 kWh and an increase in production of heat from the electric boiler of 52095 kWh. Heating (kWh) from the electric boiler in percentage of energy production from energy wells increasing from 1,1% in 2022 to 31,2% in 2024 and back to 9,6% in 2025.

Table 13

	2022	**2023**	**2024**	**2025**
Total energy production from energy wells. kWh (F)	290283,4	186648	177764,4	168997,2
Total energy uses for heating pumps. kWh (A)	86272,2	61858	51494,8	59529,0
Heat output (F+A = E)	376555,6	248506	229259,2	228526,2
Total energy use for electric boiler. kWh	3127,55	41085,4	55222,3	16179,7

Energy use for electric boiler in % of energy production from wells	1,1	22	31,1	9,6
Coefficient of Performance (COP) (E/A)[5]	4,4	4,0	4,45	3,84

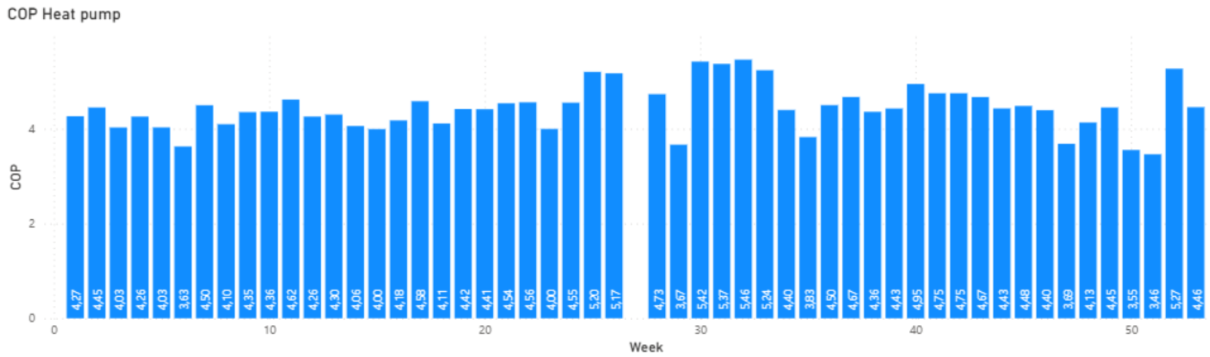
At the same time, we can see that the Coefficient of Performance (COP) of the heat pump for the whole year is relatively constant, around 4,2. This shows that the heat pumps have been delivering around the same level of efficiency for the whole operational time. A higher COP indicates that the heat pump is more efficient, meaning it produces more heat than every unit of electricity it consumes. Normally the COP value will be between 3 and 4, which indicates that COP value of 4,2 is at a high-performance level. As shown in table 13 COP is calculated as a ratio of the heating output to the electrical energy input[6].

Looking at the average COP for the heat pump divided over the years, weeks of the year, the COP mostly varies between 4 and 5 throughout the year. During the summer the low energy use for heating makes the COP unreliable, leading to data is less reliable because the energy for heating is low heat pump for the whole year is relatively constant, varying between 4 and 5. Data for summer 2024 varies a bit more than earlier years, but except from that the heat pumps has been delivering around the same level of efficiency for the whole operational time.

[5] Capitals letters used in table 13 (F,A,E) refers to illustration shown in figure 2.

[6] The basic formula is $COP = \frac{\text{Heat Output}}{\text{Electrical Input}}$

Interreg Co-funded by the European Union
Northern Periphery and Arctic



The reason why we see this shift from energy well to electric boiler is that the well system is not probably dimensioned to the heating needs of Mørkvedbukta school and Kindergarten. After the extracting of heat from the energy wells during the first year it was acknowledged that the bedrock got cooler. This is a consequence when boreholes are not deep enough or of too few energy wells have been drilled to meet the energy requirement of heating. A consequence of this is that the temperature in the bedrock becomes much lower than calculated which will lead to reduced efficiency. If it gets so cold around the borehole that it can freeze, undersized boreholes can lead to damage to the collector tubes by ice formation in the borehole. To avoid these consequences, it was decided to reduce the extracting of energy from the well system and instead make more extended use of the electric boiler. Because of under-dimensioned well-system, it has been decided to drill six new wells. This will be done early 2026.

From table 14 we recognize that energy from the energy well system in 2022 contributes with 39,6 kWh/m^2. Compared with value for energy class for the building of 50,6 this is a substantial contribution. Even though energy wells produce less power for heating from 2023 and 2025 for the same reason discussed above, still energy supply represents 24 kWh/m^2. Because of total reduction in energy use the energy class of Mørkvedbukta School has dropped below 2022 level to 49,52 kWh/m^2

Interreg Co-funded by the European Union
Northern Periphery and Arctic

Table 14

	2022	2023	2024	2025
Total energy production from energy wells. kWh	290283,4	186648	177764,4	168997,2
Netto energy supply kWh/m²	39,6	25,5	24,2	23,0
Energy class of the building	50,6	55,31	53,21	49,52

Table 15 and 16 confirm the consequences of the under dimensioned energy well-system. The pre-estimated calculations two performance was formulated: 1. The performance of heat pumps was to contribute with 90 to 100 % of the total energy use for heating and hot water and 2. The performance of energy wells must contribute with at least 70 % of total energy use for heating and hot water. For the first performance goal only 2022 and 2025 match requirements output, while 2023 and 2024 have an output of respectively 85,8 % and 80,6 % 2024 and thus demonstrate a performance level far below expectations to reach more than 90 % of heating needs from heat pump capacity.

Table 15

	2022	2023	2024	2025
Total energy use for heating and hot water. kWh	379682,6	289591,4	284481,5	244705,9
Total energy production from heat pump. kWh.	376555,0	248506,0	229259,2	228526,2
Total energy use for electric boiler. kWh	3127,6	41085,4	55222,3	16179,7
Energy production from heat pump of total energy use for heating and hot water	**99,2 %**	**85,8 %**	**80,6 %**	**93,4 %**

The same pattern is echoed in table 16 showing that the percentage of heating from energy wells of total heating needs declines from 76,5 % in 2022 to an average level of 65,4 % for the three subsequently years, which is below the expected level of at least 70 %. Thus, these numbers shows that the energy well underperform because of the mismatch between numbers of wells and heat pump capacity.

Interreg Co-funded by the European Union
Northern Periphery and Arctic

Table 16

	2022	2023	2024	2025
Total energy use for heating and hot water. kWh	379683,2	289591,4	284481,5	244705,9
Total energy production from energy wells. kWh	290283,4	186648	177764,4	168997,2
Heating from energy wells in % of total heating needs	**76,5**	**64,5**	**62,5**	**69,1**

One of the main reasons to invest in renewable energy like solar is to reduce CO_2 emissions from energy. The production of electricity from energy wells installations diminishes the need electricity from grid. CO_2 emissions can be calculated using a convert factor.

Table 17

	2022	2023	2024	2025
Total energy production from energy wells. kWh	290283,4	186648	177764,4	168997,2
Reduction in CO_2 emissions (132gCO_2e)[7] tonCO_2e	38,317	24,638	23,465	22,308
Reduction in CO_2 emissions (18gCO_2e)[8] tonCO_2e	5,225	3,360	3,200	3,042

In table 17 above we use two different convert factors. The first convert factor represents electricity Norwegian consumer mix with 18 g/kWh, and the second convert factor is the

[7] Emission factor 18gCO_2e is calculated for electricity, Norwegian consumer mix including production and transportation.

[8] Emission factor 132CO_2e is calculated for electricity, European consumer mix (EU28 + NO) including production and transportation.

European consumer mix (EU28 + NO) with a convert factor of 132 g/kWh for electricity[9]. In the first case CO_2 emissions differ between 5,225 tonCO_2e in 2022 to 3,2 tonCO_2e in 2024. In the second case power production form energy wells at Mørkvedbukta School and Kindergarten contributes with CO_2 savings quell 38,317 tonCO_2e in 2022 and 23,465 tonCO_2e in 2024. The fact that the international energy system is getting still more integrated and transcend national borders is an argument to use the European consumer mix factor.

[9] A Norwegian ZEB Definition Guideline (Sintef). The ZEB Centre has chosen an average CO2eq factor of 132 g CO_2eq/kWh for electricity in the operational phase of the building's lifetime of sixty years. This value is significantly lower than the EU average of 242 g CO_2eq/kWh in 2023, indicating a lower-carbon electricity supply, and suggests the grid mix includes a substantial amount of low-carbon energy sources.

Interreg Co-funded by the European Union
Northern Periphery and Arctic

3 Faroe Islands

3.1 Introduction of the pilot project in Faroe Island

The Faroe Islands are located at 62° North latitude, and the cold climate necessitates heating where people live all year round. For several hundred years, peat, coal, and (drift)wood were the primary energy sources for heating and cooking. From around 1950 onwards, oil became the main energy source for heating.

In the early 1970s, researchers began to draw attention to climate change caused by fossil fuels. International cooperation to reduce the impact on the climate began under the auspices of the UN in 1992.

With the desire to move away from fossil fuels, heating came into focus as one of the major oil consumers. From around 2005, heat pumps began to replace oil burners in the Faroe Islands. A dramatic increase in the oil price in 2007-2008 led to the installation of many air/water heat pumps. Around the same time, the Energy Department at Jarðfeingi (Faroe Islands Geological Survey) began investigating heat pump systems that derived energy from geothermal boreholes.

3.1.1 Methods

There was no experience in the Faroe Islands of drilling for geothermal heat, and thus, Swedish specialists were called upon to help drill the first geothermal boreholes and to conduct studies on the prospects for using this for heating private homes and other buildings. In June-September 2008, a total of 12 geothermal boreholes were drilled at 5 different buildings in Tórshavn, Sandavágur, and Tvøroyri. Detailed investigations were conducted on the volume of water in the boreholes, the type of rock, and how heat conduction in the rock was measured. Trials and simulations were carried out to determine the heat capacity and how deep the geothermal boreholes needed to be, depending on the amount of heat energy required for the various buildings.

Interreg Co-funded by the European Union
Northern Periphery and Arctic

Based on the trials, it was estimated that the minimum distance between each geothermal borehole should be at least 20 meters, and that the borehole could yield 25 W/m and an annual output of 115 kWh/m. It was also estimated that a geothermal system would have an SPF (Seasonal Performance Factor – the system's overall annual efficiency) between 3 and 4. This means the geothermal borehole can provide 3–4 times as much heat energy compared to the electrical energy used to drive the system. For example, if a building requires 30.000 kWh of heat energy per year and an SPF of 3 is assumed, then 7.500 kWh comes from electricity and 22.500 kWh from the geothermal borehole. To obtain this energy from the geothermal borehole, the borehole must be at least 22.500/115= 196 m deep. A borehole that is 196 m deep can yield 196*25= 4.900W, which is sufficient for a typical private home.

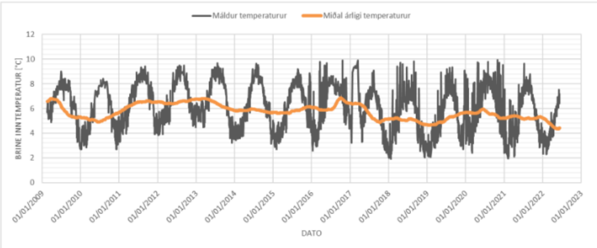
3.1.2 Procedure

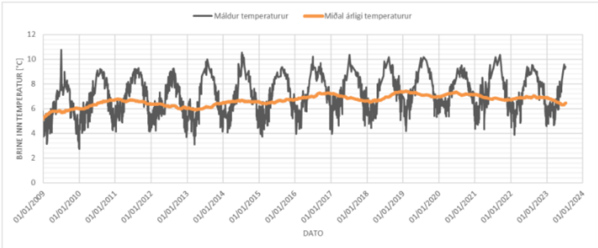
In connection with the test drilings in 2008 the conected heating system were monitored in detial. The energy flow from the borehole was measured with Kamstrup (Danish) energy meters, which measure the water (brine) flow and the inlet and outlet temperatures. Similar energy meters were used to measure the heat energy supplied from the heat pump to the building. Meters were also installed to measure the electrical energy consumed by the heat pump, and temperature sensors were set up outdoors and indoors. All data was collected via mobile phone data link into a database provided and maintained by Kamstrup and sent to the institution upon request. Data collection began in October 2008.

3.2 Results and outcomes

Because the ground source heat energy systems were new to the area, many questions arose. A major question was whether the ground source borehole would cool down when heat was extracted. This can be visualized using the collected data starting in 2008. The image below displays the long term (2009-2024) temperture of the water coming up from the borehole over the past 15 years (Ritter 2024). The temperature is around 4-6°C in winter when the heat pump draws the most energy from the ground but increases again up to 9-10°C during the summer. It is assumed that the large volume of water that flows in the ground adds heat to the borehole each summer.

Interreg Co-funded by the European Union
Northern Periphery and Arctic





From the data also the long term performanc can be seen. In the table below the average COP/SPF ower a long period is shown. As expected the SPF is around 3-4.

Name	Timeframe in days	COP over timeframe / SPF
Atli Nattestad	1897	3.74
Jarnhold Nattestad	4159	2.98
Jarðfeingi	4054	2.73
Kirkjan á Strondum	1954	5.30
Klæmint Klein	3994	2.88
Petur Hammer	4159	3.01
Tannlæknamiðstøðin	4159	3.99

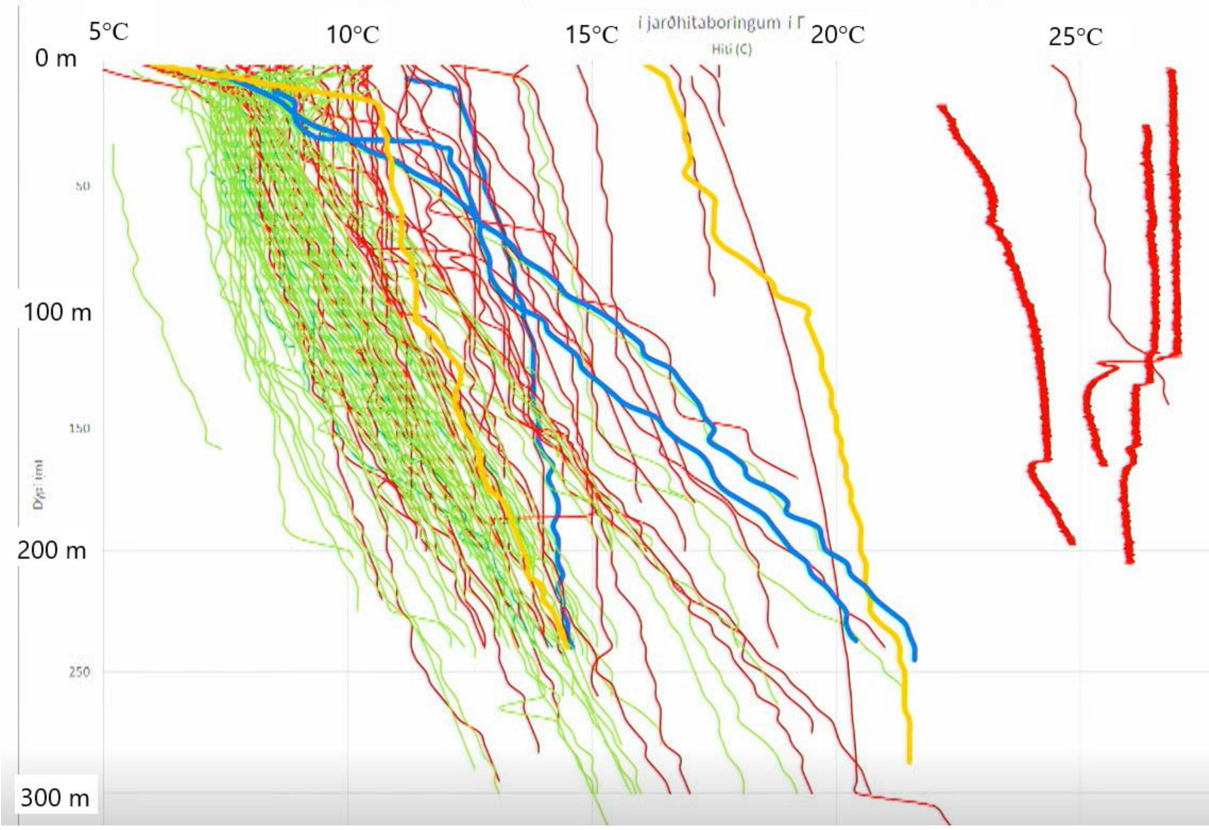
Today several companies offer ground source bore holes and heat pumps systems. The are work is undertaken by modern machinery as shown below.

Interreg
Co-funded by the European Union
Northern Periphery and Arctic

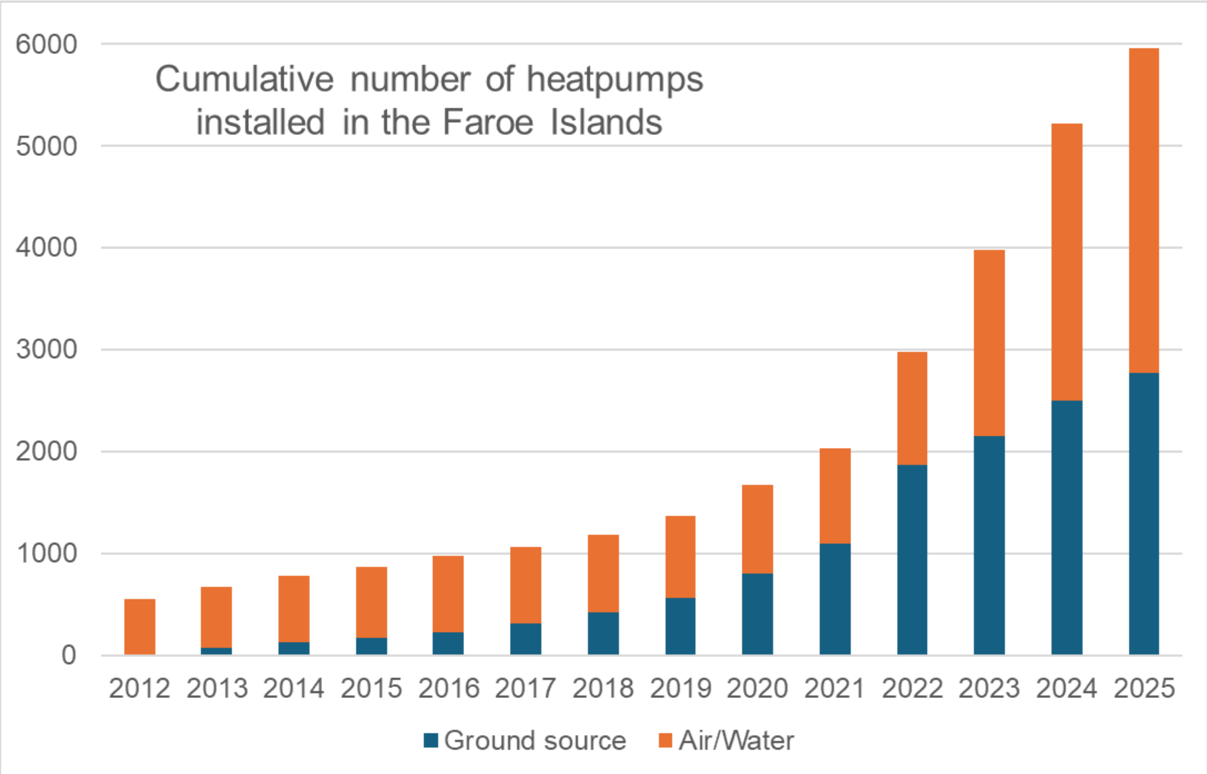
Some difficulties have been encountered over the years. In some municipalities there were problems from drilling dust that was clogging the drain system. This has been solved by using containers that collect most of the drilling dust.

With the large number of holes drilled a range of learnings has been achieved. Some areas have exceptiopnal high temperatures with water running up from the hole with at temperature of more than 25°C, se figure below (from Ólavsdóttir 2025). Generally, the heat is around 7-10°C at the surface and increases with around 3°C per 100m drill depth.

Interreg Co-funded by the European Union
Northern Periphery and Arctic



By the end of 2025, about 6,000 heat pump systems have been installed in the Faroe Islands, approximately half being water/air systems and half being geothermal systems (see figure below).



3.2.1 Case Description - The Heating System in Leirvík

For many years, preparations have been underway for a non-oil-based heating system for buildings in Leirvík (1,040 inhabitants), both public and private. Fríðfinnur Jónsson has been a pioneer with support from the Energy Department at the Environment Agency. Studies were conducted on various heat pump solutions, where heat is taken from the sea, from geothermal boreholes, or from the air.

In 2020, Denmark held the presidency of the Nordic Council of Ministers, and this came with a grant of 45 mill DKK, of which the Faroe Islands received a share. It was decided to use a part of this for the energy project in Leirvík, thereby accelerating the green energy transition. The Energy Department at the Environment Agency took on the coordination of the work, while Eysturkommuna (the Municipality of Eystur) participated with funding. PB Consult assisted in preparing the final system design and tender, which Demic won. The

Interreg Co-funded by the European Union
Northern Periphery and Arctic

contract with the municipality was signed on 20/7/2021. The system was handed over to Eysturkommuna on 12/4/2023.

The energy system did not become as comprehensive as previously planned, but only encompasses two municipal buildings, namely the school and the elderly care home Giljagarður.

The school in Leirvík is originally from 1929 but was extensively expanded in 1962, 1982, and again in 2010. Today, it is a modern school of about 2.052 m2. It has about 130 students and 12 teachers.

The elderly care home Giljagarður was completed in 2004 and is 584 m2. It has space for 10 residents and 8 staff members.

The school and Giljagarður together used about 70,000 liters of oil per year for heating, which is now saved. The heat now comes from geothermal boreholes and electric-powered heat pumps.

The picture below is from Leirvík, with the school to the right and Giljagarður to the left. The new heating system is housed in the new building in the centre.

The heating system in Leirvík is complex, allowing for the maximum use of renewable energy when available, thereby reducing surplus energy, e.g., from wind. In addition to a conventional heat pump system, there is also a large water storage tank that can be heated by both heat pumps and an electric boiler.

Interreg Co-funded by the European Union
Northern Periphery and Arctic

The heating system also has a special prerequisite: electricity is obtained at a specially low price when SEV (the main power company) signals that there is a lot of renewable energy in the system. Both the heat pump and the electric boiler receive this special lower electricity price.

The heating system includes:

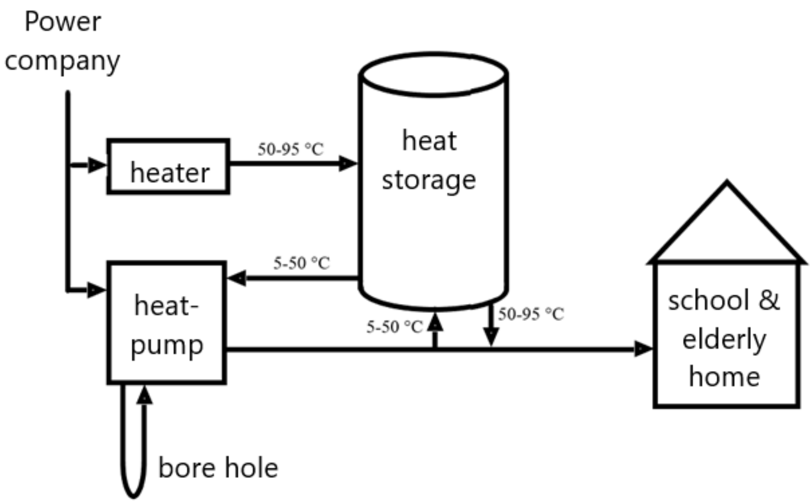
- 17 geothermal boreholes, 300–400m each, totaling 5,400m.
- Four heat pumps of the Fighter 1345-60 type, each with two stages of 30kW.
- Two electric boilers, 100kW hvør.
- Two water tanks of 40 m3 and 25 m3, totaling 65 m3.
- CTS system (monitoring and control) with heat sensors, flow meters, etc.

The heating system can operate in several stages, depending on whether a low electricity price is available and how hot the heat tank is. The stages are:

- **A:** Heat pumps draw heat from boreholes and supply heat to buildings.
- **B:** Heat pumps draw heat from the tank (5-50 °C) and supply heat to buildings.
- **C:** Heat pumps draw heat from boreholes and supply heat to tanks (5-50 °C).
- **D:** Electric boilers heat tanks (50-95 °C).
- **E:** Tanks supply heat to buildings (50-95 °C).

The heating system is depicted below

Interreg Co-funded by the European Union Northern Periphery and Arctic



A range of parameters have been monitored and collected. From the data calculations have been made to compare the current system with a system based on oil heating and a sytem using a conventional setup of heat pump system. There has been a range of challenges to obtain contious data from the system as data needs to be collected not only from th local sytem but also from outside.

Data from 2024 is shown in the table below.

Month	Current System (DKK)	Oil Heating (DKK)	Heat Pump (DKK)	Heat Produced (kWh)	Electricity (kWh)	COP	Flex Price (%)	Power heater (kWh)	Outdoor temp. (°C)
2024-01	29.666	91.195	51.100	86.610	27.988	3,09	0,00	67	4,4
2024-02	37.876	87.299	48.917	82.910	28.337	2,93	0,00	133	3,8
2024-03	39.951	81.203	45.501	77.120	34.517	2,23	1,39	5.217	5,7
2024-04	38.556	71.926	40.303	68.310	30.427	2,25	4,58	6.885	5,8
2024-05	26.906	55.195	30.928	52.420	19.835	2,64	10,83	603	11,4
2024-06	27.503	47.844	26.426	44.790	26.805	1,67	25,28	6.023	11,4
2024-07	21.427	37.397	19.735	33.450	17.770	1,88	27,22	3.529	13,6
2024-08	28.861	44.200	24.284	41.160	20.059	2,05	32,22	6.705	13,0
2024-09	30.534	61.215	34.910	59.170	26.203	2,26	33,06	3.491	10,6
2024-10	40.748	73.531	41.235	69.891	35.548	1,97	41,67	8.260	8,3
2024-11	41.931	76.713	44.091	74.731	41.842	1,79	59,17	14.539	7,3
2024-12	56.191	84.978	47.477	80.470	48.730	1,65	68,06	21.224	5,0
Total 2024	**420.151**	**812.697**	**454.909**	**771.031**	**358.059**	**2,15**		**76.675**	

The current system has produced heat at about half the cost of an oilbased system. However, the current system is only slightly better than a conventional heat pump system. The COP of the system is much lower than expected. The electrical boilers do not improve the heating costs as the the heat pump is much more efficient, even tho the COP is low.

Interreg Co-funded by the European Union
Northern Periphery and Arctic

4 Conclusion

This report demonstrates that geothermal energy and heat pump solutions can play a decisive role in decarbonising heating systems in cold-climate regions, although the pathways and outcomes vary between countries.

Iceland

The pilot project in Grundarfjörður illustrates how geothermal heat pumps can successfully replace oil-based heating in public buildings. The transition has eliminated the use of approximately 130,000 litres of oil annually and reduced CO_2 emissions by around 300 tonnes per year. Beyond the environmental benefits, the project has resolved long-standing operational challenges, particularly for the swimming pool, and has built valuable local expertise for future energy transitions in other municipalities.

Norway(Bodø)

The Mørkvedbukta school and kindergarten pilot in Bodø emphasises the importance of integrated energy planning in new buildings. Geothermal energy wells, heat pumps, and a large rooftop solar installation are combined with high-performance building envelopes that meet passive house standards. The results indicate that geothermal systems can cover most heating needs with low delivered energy per square metre. Advanced energy monitoring and control systems further enable continuous optimisation of energy performance over time.

Systematic monitoring from 2022 to 2025 confirms stable operation of the ten 250-metre energy wells and consistently high heat pump efficiency. The data show a clear decline in heating energy demand over time, while also highlighting the importance of reliable monitoring and correct system sizing. Periods of increased electric boiler use revealed that the energy wells were slightly under dimensioned, leading to plans for additional boreholes to improve long term performance.

Overall, the Bodø pilot demonstrates that geothermal systems, when properly dimensioned and supported by robust monitoring, can deliver stable, efficient, and low-emission heating for large public buildings in cold climates, while providing valuable operational insights for future projects.

Interreg Co-funded by the European Union
Northern Periphery and Arctic

Faroe Islands

In the Faroe Islands, the development of geothermal heat pump systems has followed a gradual, evidence-based approach supported by long-term monitoring. Studies show stable thermal performance and seasonal efficiency factors (SPF) typically between 3 and 4. With thousands of systems now installed, geothermal solutions have become a mature technology. The Leirvík heating system highlights how geothermal boreholes, heat pumps, electric boilers, and thermal storage can be combined into a flexible and resilient energy system, delivering substantial cost and emission reductions compared to oil-based heating, despite some efficiency challenges.

Taken together, the cases show that there is no single solution suitable for all contexts. Successful decarbonisation of heating depends on tailoring geothermal and heat pump technologies to local geological conditions, building characteristics, and energy system structures. Nevertheless, across all three countries, geothermal-based solutions have proven to be a robust and effective cornerstone for reducing fossil fuel dependence, lowering emissions, and improving the long-term sustainability of heating systems in northern regions.

Interreg Co-funded by the European Union
Northern Periphery and Arctic