# D 3.1.1 Report on solar energy solutions for decarbonization.

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## Content

## Summary

In this study of solar energy in Arctic areas we have learned and gained experience from pilots representing a variety of different building types. From sizeable public buildings in Bodø, and social and private rental houses in Cork to off-grid buildings in Western Iceland. Furthermore, the Icelandic case promotes the implementation of a solar energy as a strategy into the Icelandic energy system. Task to standardized instructions for PV installations into the grid, strengthen vocational education to support capacity building and competence on solar installation, a grant and incentive program to scale up solar as energy carrier, has promoted a process and a road map for solar energy towards the year 2030.

All Hybes pilots has documented that Solar energy and PV installations are an efficient energy carrier in Arctic regions as Bodø in Northern Norway, Cork in West Ireland and Northwest regions of Iceland. This is documented though monitoring energy data. To document effects of implemented Solar energy installations it's important to get valid baseline data and to calculate a pre and post situation. Hybes pilots in Bodø have been monitored for three years, Cork Pilot for one year and for the Icelandic pilots we have use estimated calculations because the installations of solar installations were done late in Hybes project.

Compared between Hybes pilots' Solar energy are even more efficient and profitable in Cork than in Bodø and Grimsey. This because solar radiation in Cork makes it possible to produce in average 50 % more solar energy than in the two other arctic district and because energy cost is more than twice in Cork than in Norway and Iceland.

All our pilots shows that solar energy is most efficient if storage is integrated. To achieve most efficient and flexible use of solar energy it's important to integrate storage systems either with batteries or solar installations combined with thermos energy wells. Mørkvedbukta school don't have this possibility, and one insight is that a thermos geothermal system would have allowed storage. For private household it's important that a battery storages system is easy to manage. Cork pilots have experience that this can be a bottleneck.

Therefore, monitoring energy data is important not only to document effects. In general, we also see that continuous monitoring of energy data is important to achieve high degree of energy efficiency and to guide both private and public owners of solar installations to obtain good performance of installed Renewable Energy Systems.

The comparation between the two technologies analysed we have studied, the top roof PV installations versus building integrated PV installations, shows that top roof installations have highest energy production, but that BIPV systems fits better to energy consumptions patterns of buildings in an arctic region as Bodø. This because horizontal solar radiations make the BIPV system most efficient in spring and autumn period. A combination of these two technologies therefor is recommendable.

All our pilots shows that solar energy is an important energy carrier to increase energy safety and to reduce investment in grid capacity in cities and rural areas. Solar will reduce problems in peak period with maximum energy consumptions and avoid heavy

investment in grid infrastructure. To scale up flexible Solar energy installations is decisive to ease grid capacity and overexert grid infrastructure.

Furthermore, the Icelandic case also shows the importance of solar energy in remote and off-grid district to support electrification, business development and decarbonisation.

Finally, our solar pilots have demonstrated that solar contributes substantially to reducing $CO_2$ emissions and contributes substantial to regional and national climate goals.

The transnational learnings from our solar energy pilots give rise to the following two insights:

1. Analysis of actual energy pilot across different arctic areas though monitoring, is essential to shape target transnational learning.
2. Cross regional energy pilots give the possibility of more targeted policy recommendations enabling cost effective, climate efficient and regional sustainable solutions.

## Introduction:

This report describes the efficiency of solar energy with part of departure in four pilot studies across Arctic areas.

The first Hybes solar pilot 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 Bodø city center and has a size of 7333 $m^2$. The school is a two-story building with an area of 5947 $m^2$, and the kindergarten is built on one level with an area of 1386 $m^2$. The solar-system is a top roof solar installation of about 589 $m^2$, with installed capacity of 100 kWp (kiloWatt-peak). The 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. Responsible for chapter one is Bjarne Lindeløv and Eirik Lerum Vigerust.

The second Hybes pilots is the Rehabilitation building located in Bodø. The rehabilitation service is part of preventive health care organisation of Bodø Municipality. Part of the building also serves as living room and flats for elderly. The premises is a 7-floor building with a ground area of 940 $m^2$ and the total building area is 6644 $m^2$. The chosen solar system is a Building Integrated PV system. This system of 380 $m^2$ solar cells is divided into the façade directed to the south-west and south-east. Estimated capacity show that building integrated solar panels will contribute with about 4,2 % of annual energy consumption. Responsible for chapter two are Bjarne Lindeløv and Eirik Lerum Vigerust.

The third Hybes pilot is a rental social home owned by Carbery Housing Association. It's a family home, two storey and located in local authority estate in Fermoy, Cork County. It was built in 2003 and has floor area is 91.79 $m^2$. 10 PV panels on the roof were installed with a capacity of 3,65 kw. Most importantly, a 5-kW battery storage was part of the system, and a grid connection allowed excess energy to be fed to the grid. Responsible for chapter three is Jose Ospina.

The fourth Hybes pilot is a more diverse case. The Icelandic Environment and Energy Agency (UOS) have used HYBES project as an ideal starting point for Iceland's solar energy journey. Part of this is to strengthen vocational education to support the installation of solar. Related to the development of a two-semester curriculum program solar pilot at a technical school has been set up. A 100 square meter classroom where all the energy is obtained from solar cells and a small windmill is used for educational purposes. In addition, a competitive grant scheme has successfully incentivized solar adoption, particularly in off-grid and diesel-dependent areas, aligning with national energy transition goals. These off-grid installations also are used as energy pilots. Responsible for chapter four is Eyrún Gígja Káradóttir.

Methodological we have used energy pilots to explore the effects of solar energy in different arctics context. To do this we have monitor real energy data from solar installations in Bodø, Cork and Northwest Iceland. In addition, we also want to calculate climate effect and how much our pilots contribute to reducing $CO_2$ emissions and how profitable it is to invest in solar. In two of our pilots, we are comparing the efficiency of two technologies, the top-roof PV installations versus building integrated PV installations.

Other topics we study are:

- The importance of solar energy in remote and off-grid districts
- The importance of solar energy to increase energy safety and to reduce investment in grid capacity in cities and rural areas
- The importance of designing solar energy installations with storage possibilities.
- monitoring energy data is important not only to document effects

Chapter five is summing up conclusions and recommendations from Hybes pilots. Responsible for this chapter is Bjarne Lindeløv and Eirik Lerum Vigerust.

# Chapter 1. Bodø Pilot Mørkvedbukta school and kindergarten

## Description of Pilots Mørkvedbukta school and kindergarten: What is the use of the building and where is it located?

The first Hybes solar pilot 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 two-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.

## Construction and energy baseline of Pilot

To evaluate the effect and performance of solar energy on different parameters we need to define a baseline. 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.

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 is designed to meet responsible energy use. The energy requirements apply to the heated utility area of the building (BRA) and must satisfy the requirements defined 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 don't 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 requires that U-values as shown in the table below:

Table 1: Building regulation. Minimum demands for U values

| 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.
- For buildings beyond 1000 m$^2$ 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 passive house requirements is valid. But in addition to TEK 17, also requirements must be meet concerning energy demands for heating and cooling, as well as heat loss figures for transmission and infiltration losses. However, when evaluating energy requirements local climate must be considered, and it's assumed that the heated BRA of the building is affecting the requirement for heat loss figures.

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

Table 2: Estimated energy demands for heating, cooling, transmission and for infiltration loss

| | Mørkvedbukta 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.

Table 3: Estimated U-values for structural elements of school building.

| Building part | U-value | Type of construction |
|---|---|---|
| Exterior wall facing free – Insulated timber frame | 0,14 W/m²K | 250 mm insulated I-stud with 50 mm insulated application, λinsulation = 0.033 W/mK and a tree proportion of 3.75 m/m² |
| Exterior wall facing free – Isolert Cross Laminated Timber | 0,09 W/m²K | 50 mm internal insulated application, 100 mm solid wood 200+230 mm insulated I-stud, λinsulation = 0.035 W/mK and 12% tree share. |
| Exterior wall facing free – Insulated concrete walls | 0,20 W/m²K | 300 mm concrete walls 200 mm insulations. λinsulation = 0.035 W/mK and 12% tree share. |
| Exterior walls under terrain | 0,14 W/m²K (1) | 300 mm concrete walls 150 mm pressure-resistant insulation exterior. λinsulation = 0.035 W/mK. |
| Windows/doors | 0,80 W/m²K | Minimum requirements for passive houses |
| Roof over kindergarten | 0,08 W/m²K | 240 mm CLT cover 450 mm insulation, average thickness λinsulation = 0.038 W/mK |
| Roof over the school | 0,11 W/m²K | 240 mm solid wood cover 300 mm insulation, average thickness λinsulation = 0.038 W/mK |
| Floor aground, level (1) | 0,16 W/m²K (1)(2) | 150 mm pressure-resistant insulation λinsulation = 0.038 W/mK |
| Floor on ground, level (2) School section, axis F-J | 0,14 W/m²K (1)(2) | 150 mm pressure-resistant insulation λinsulation = 0.038 W/mK |
| Ground floor, level (2) Kindergarten, axis L-V | 0,10 W/m²K (1)(2) | 350 mm pressure-resistant insulation, λinsulation = 0.038 W/mK |
| Normalised cold bridge value | 0,03 W/m²K | |

(1) Equivalent U-value including heath resistance to ground.

(2) Includes thermal bridge of foundation wall

## 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/m$^2$ annually for kindergarten and 110 kWh/m$^2$ annually for school buildings, respectively. Calculations of theoretically calculated total net energy demand for the building of 73.8 kWh/m$^2$ and 72.7 kWh/m$^2$, and the 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.

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.

Table 4: Total calculated energy needs Mørkvedbukta School

| **Description of Total Netto energy needs** | **Value** |
|---|---|
| Calculated energy needs to room heating | 13,4 kwh/m$^2$ |
| Calculated energy need from ventilation heating | 14,5 kwh/m$^2$ |
| Calculated energy hot water | 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 5: Total calculated energy needs Mørkvedbukta Kindergarten

| **Description of Total Netto energy needs** | **Value** |
|---|---|
| Calculated energy needs to room heating | 24,4 kwh/m$^2$ |
| Calculated energy need from ventilation heating | 11,4 kwh/m$^2$ |
| Calculated energy hot water | 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$^2$ |

Table 6: Estimated U-values versus regulatory requirements Mørkvedbukta school

| **Description for Mørkvedbukta school** | **Value** | **Require-ments** |
|---|---|---|
| U-value exterior walls (W/m$^2$K) | 0,14 | 0,22 |
| U-value roof (W/m$^2$K) | 0,11 | 0,22 |
| U-value floor against ground and open air (W/m$^2$K) | 0,16 | 0,18 |
| U-value Glass/Windows/Doors (W/m$^2$K) | 0,8 | 1,2 |

| | | |
|---|---|---|
| Leakage rate (airtightness at 50 Pa pressure difference) Air exchanges per hour | 0,3 | 1,5 |

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 6 above shows that minimum requirements for components and leakage figures have been met for Mørkvedbukta school and Kindergarten. Minimum requirements (§14-3).

Table 7: Estimated U-values versus regulatory requirements Mørkvedbukta kindergarten

| **Description for Kindergarten** | **Value** | **Require-ments** |
|---|---|---|
| U-value exterior walls ($W/m^2K$) | 0,14 | 0,22 |
| U-value roof ($W/m^2K$) | 0,08 | 0,22 |
| U-value floor against ground and open air ($W/m^2K$) | 0,10 | 0,18 |
| U-value Glas/Windows/Doors ($W/m^2K$) | 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 $m^2$.

Table:8 Estimated heat loss values Mørkvedbukta school

| **Description for Mørkvedbukta school** | **Value** |
|---|---|
| Heat loss exterior walls ($W/m^2K$) | 0,06 |
| Heat loss roof ($W/m^2K$) | 0,06 |
| Heat loss floor against ground and open air ($W/m^2K$) | 0,09 |
| Heat loss Glas/Windows/Doors ($W/m^2K$) | 0,09 |
| Heat loss thermal bridge | 0,03 |
| Heat loss infiltration | 0,04 |
| Total heat loss | 0.37 |

Table:9 Estimated heat loss values Mørkvedbukta kindergarten

| **Description for Kindergarten** | **Value** |
|---|---|
| Heat loss exterior walls ($W/m^2K$) | 0,06 |
| Heat loss roof ($W/m^2K$) | 0,08 |
| Heat loss floor against ground and open air ($W/m^2K$) | 0,10 |
| Heat loss Glas/Windows/Doors ($W/m^2K$) | 0,09 |
| Heat loss thermal bridge | 0,03 |
| Heat loss infiltration | 0.05 |
| Total heat loss | 0,40 |

The calculated heat loss figure for the Mørkvedmarka School is 0.37 $W/m^2K$ and for the kindergarten 0,40 $W/m^2K$, and the requirements 0,40$W/m^2K$ are thus met. This describes the energy needed to compensate the overall heat loss in the building and to ensure that the desired indoor temperature is achieved.

### Energy system and energy carriers of Mørkvedbukta school and kindergarten[1]

On the top roof solar installations cover about 589 $m^2$, which makes it one of the biggest solar installations in arctic 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.

A heat pump system has been established with wells in combination with an electric boiler, to cover the peak load and as safety. 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.

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.

Figure 2 illustrates how energy is distributed between different purposes as heating and electricity for other uses and from different energy carries as grid, solar, thermal energy divided per year. Figure 3. Shows the similar distribution but divided on consumption pr. month. We will later analyse these patterns in more detail.

Figure 2: Electricity use per year for different purposes included solar production

[1] This description of energy system and energy carriers includes geothermal energy. However, this system is not discussed her but will be analysed in the separate Hybes report 3.3.

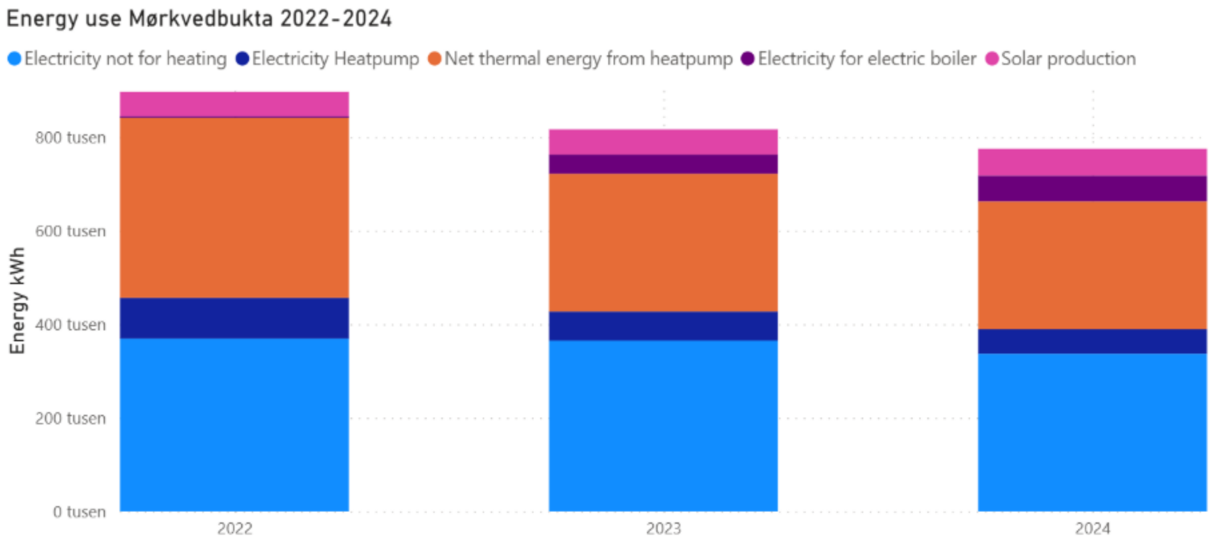
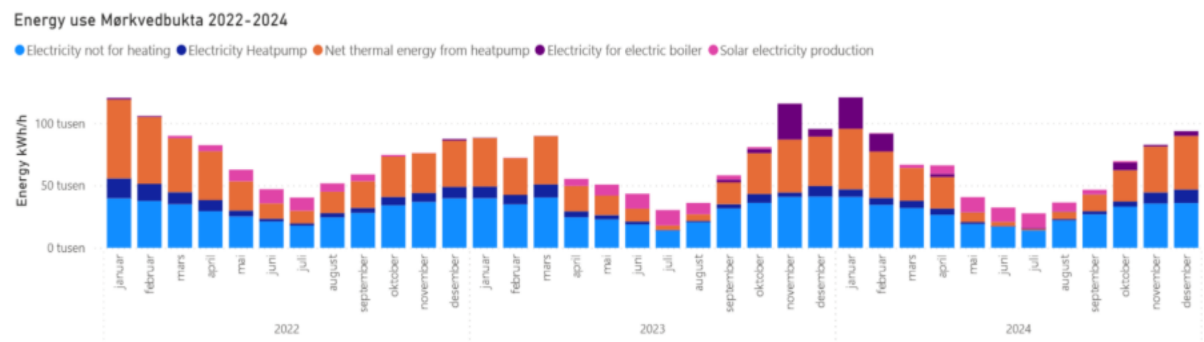



Figure 3: Electricity use per month 2022-2024 for different purposes included solar production




## 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/m$^2$/week. The diagram shows if energy use is on budget or shows energy subobtimalisation/technical defects.
- A bar diagram showing energy use/production pr. energy carrier used for the actual building.
- 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 solar power production pr. Week (Jan. 2022 to Dec. 2025)
- Deviation from optimal solar conditions (100kW)
- Total solar power stored in excess periods.
- Total solar power (kwh) exchanges to grid
- Condition for peak solar productions
- Calculate climate effect on energy use.
- Measure energy efficient task taking technology into use steering light, ventilations.
- Cost calculations and pay off for energy technology investment.
- Obtainment climate and energy goals

## Results and summing up data

We have monitored energy data for Mørkvedbukta school and kindergarten systematically for a four-year period from January 2022 to December 2025. Top roof solar modules covering 589 m$^2$ and with a 100-kilowatt peak were installed during the constructions work that was finished late 2021. 2022 is the first hole year with energy data from the installed solar system.

A solar installation of 100 kWp has a maximum power output of 100,000 watts, capable of generating approximately 400 to 480 kWh of electricity per day depending on optimal solar radiation. Many elements are involved to maximise power output. These elements are:

- the location
- panel orientation
- the direction of shade
- the weather
- the presence of clouds
- the temperature on the roof

As mentioned, the theoretical calculations of solar power estimated an annual production of 60,000-70,000 kWh. Table 10 show the actual energy production from the solar installations to be some less than this estimate but not fare from expected. There has been an increase in solar production of 8,75% during these years from 52229 kWh in 2022 to a peak of 57242 kWh in 2024. In 2022 97% of solar production was used for own consumption and only 3% was exported to grid. In 2024 these numbers were 92,3% for own consumption and 7,7% to grid. Our energy data shows that almost 70% of export to grid from solar productions happen in the summer month June and July.

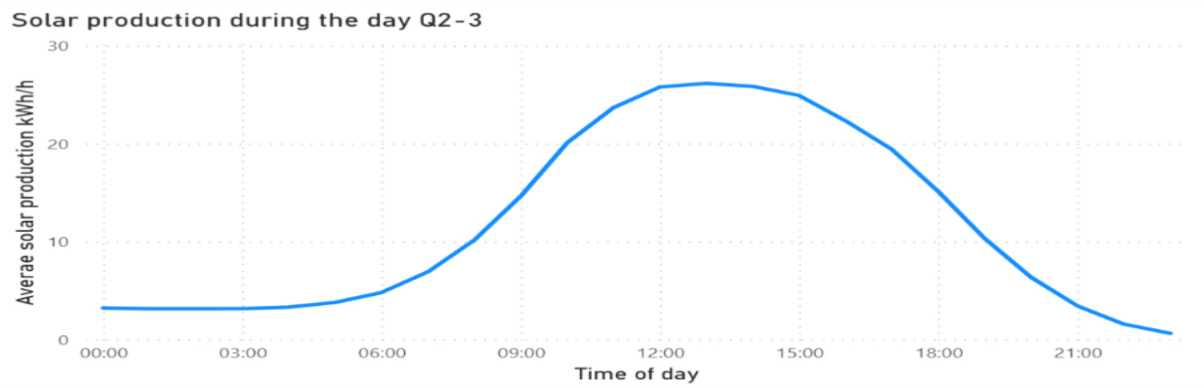
The solar energy is primarily used for the building's own energy consumption. At times when production is higher than the energy need of the buildings, the electricity is exported to the grid. From a cost perspective the most rational choice is to use all solar production to own consumption because spot price of power is very low in summer in Bodø area.

Tabel 10: Yearly production of solar energy used to own consumption or exported to grid

| | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|
| Total solar energy production. Own consumption kWh | 50625 | 50421 | 52822 | 52033,7 |
| Total solar energy production. Exported to grid kWh | 1604 | 3052 | 4420 | 4001,4 |
| Total solar energy production kWh | 52229 | 53473 | 57242 | 56035,1 |

Figure 4 shows the pattern of solar production during a day with max production from 10 am to 16 pm. This pattern is derived from how solar panels are positioned. Perhaps this power pattern and distribution isn't ideal because consumption of energy has a peak the start of school day.

Figure 4: Average distribution of solar energy production during the day in 2nd and 3rd




How solar production are distributed during a year is showed in figure 4 that illustrate the power distribution for the year 2023.  As expected for an arctic region as Bodø power production very low from November to end of March. This is the winter period where the sun is positioned low. From mid-April to end of September the production of power from is solar installations are satisfactory and more even distributed.  Figure 4 shows how the production of solar power are distributed across a tree year span from 2022 to 2024. The pattern is the same as described above with some deviations.

Figure 5: Solar energy production during the year 2023

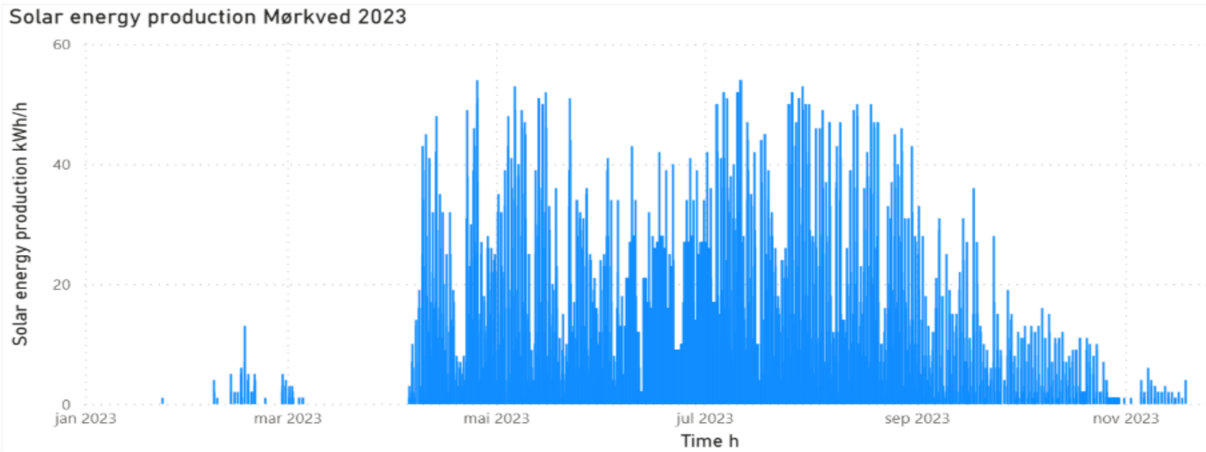
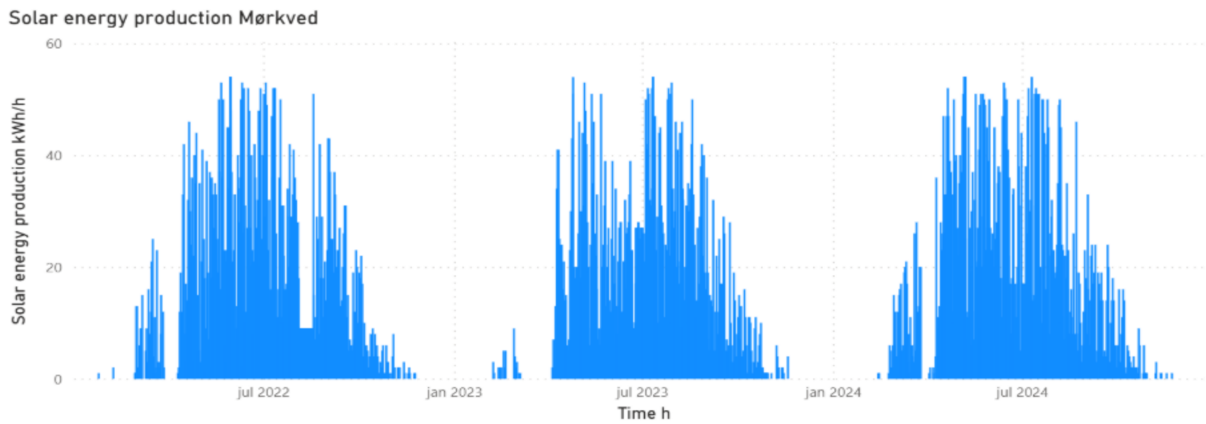
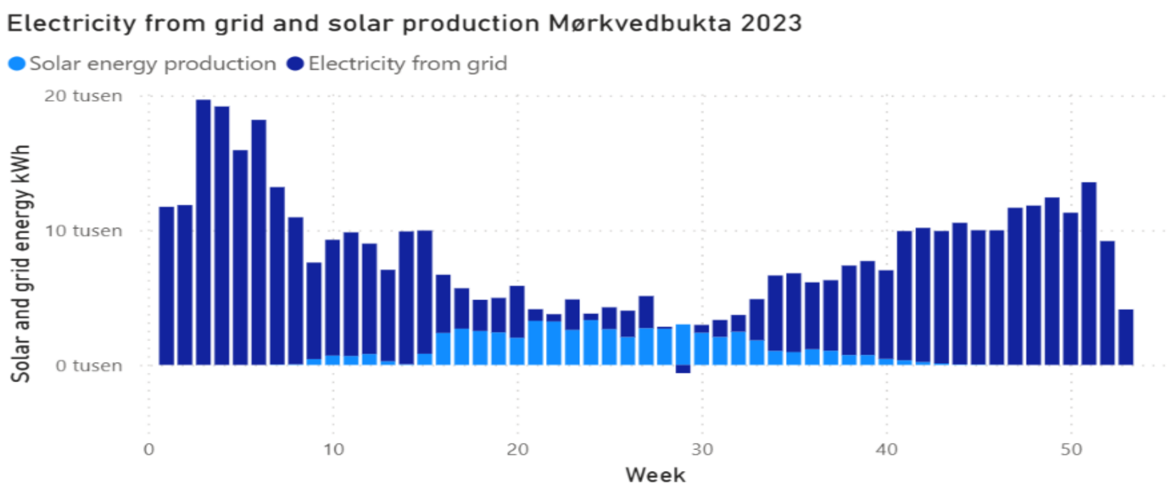



Figure 6: Solar energy production during the period 2022 to 2024




The solar production has contributed 11,4-11,5% of the total energy use of the buildings per year. This production is mainly during the summer months. As can be seen from the graph below for 2023, the solar panels produce a high share of the total electricity need during many of the summer weeks.

Figure 7: Solar energy production of total electricity use.




From table 11 we observe that total energy decreases during monitoring period and consumptions in 2024 is 38768 kWh less than expected from the baseline calculations. This is partly due to, as documented from energy efficiency and heath loss analysis that Mørkvedbukta School and kindergarten demonstrate a high energy performance but it's also a result of active energy management praxis from build owner Bodø Municipality. Of cause some of the variation might also stem from some variation in outdoors temperature between years[2].

Form table 11 we also observe that the building specific solar production increases with 5013 kWh during monitoring period and contributes with an average reduction in energy consumption with 7,41 kWh/m$^2$. Solar as an energy carrier thus contributes substantial to the building energy class scorer.

Tabel 11: Production pattern of Solar energy production per year.

| | **Expected** | **2022** | **2023** | **2024** | **2025** |
|---|---|---|---|---|---|
| Total energy consumption of electrical power kWh | 534634 | 553634 | 529293 | 495866 | 442811,1 |
| Total energy production from solar kWh | 65000 | 52229 | 53473 | 57242 | 56035,1 |
| Total energy consumption minus production from solar | 469634 | 501405 | 475820 | 438624 | 386776,0 |
| Total energy production from solar of total energy use | 12,15 % | 9,43 % | 10,1 % | 11,54 % | 12,65 % |
| Total solar production in kWh/m$^2$ | 8,86 | 7,12 | 7,3 | 7,81 | 7,64 |

A full evaluation of energy class numbers of Mørkvedbukta School and Kindergarten is shown in table 12. Energy class is calculated as net imported energy from grid per m$^2$. That is imported energy from grid minus exported energy to grid. Energy production from renewable energy is carried out as solar and geothermal energy is excluded from this

[2] In our analysis we haven't controlled for variation in outdoors temperature.

number. Net imported energy from grid as kWh/$m^2$ does vary during our monitoring period between 55,31 kWh/$m^2$ and 50,6 kWh/$m^2$. National requirements for energy class A are 75 kWh/$m^2$ respectively 85 kWh/$m^2$ for building category Schools and Kindergartens.

Compared to national requirements, Mørkvedbukta School and Kindergarten documents numbers far below minimum demands for energy class A level. For the year 2022, renewable energy carriers produced nearly the same amount of energy as was imported from the grid. In 2024, renewable energy production represents 60% of imported energy from the grid. Our pilot qualifies passive house standards, but still more tasks are needed to reach zero emission standards and levels.

Table 12 Comparison between electricity use from grid and from renewable energy carriers per year

| | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|
| **Net energy import form grid kWh** | 371051,8 | 405573,5 | 390166,0 | 363101,0 |
| **Contribution from Renewable energy carriers[3] of energy use kWh** | 342512,4 | 240121,0 | 235006,4 | 225032,3 |
| **Net consumption kWh/$m^2$ defining energy class of the building** | 50,6 | 55,31 | 53,21 | 49,52 |

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 solar installations diminishes the need electricity from grid. $CO_2$ emissions can be calculated using a convert factor. In table 13 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 European consumer mix (EU28 + NO) with a convert factor of 132 g/kWh for electricity[4]. In the first case, $CO_2$ emissions amount to 1 ton$CO_2$e per year and in the second case solar production form Mørkvedbukta School and Kindergarten contributes with $CO_2$ savings quell 7,2 ton$CO_2$e per year. 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.

Table 13 Solar energy production contributes to $CO_2$ emissions

| | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|
| **Total energy production from solar energy. kWh** | 52229 | 53473 | 57242 | 56035 |

[3] This includes both solar and energy wells and heat pump systems

[4] A Norwegian ZEB Definition Guideline (Sintef). The ZEB Centre has chosen an average $CO_2$eq factor of 132 g $CO_2$e/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 $CO_2$e/kWh in 2023, indicating a lower-carbon electricity supply, and suggests the grid mix includes a substantial amount of low-carbon energy sources.

| | | | | |
|---|---|---|---|---|
| **Reduction in $CO_2$ emissions (132g$CO_2$e)[5] ton$CO_2$e** | 6,894 | 7,058 | 7,555 | 7,397 |
| **Reduction in $CO_2$ emissions (18g$CO_2$e)[6] ton$CO_2$e** | 0,940 | 0,963 | 1,030 | 1,009 |

Own production of solar power reduces cost form the electricity bill. To calculate these cost savings, we use a convert factor of 0,8 NOK pr. kWh. Table 14 shows average cost savings of NOK 43450 pr year. The Solar installations have a lifetime of 30 years. Compered to investment cost of solar installations including mounting of NOK 1681498 shows that the investment has been profitable.

Table 14: Cost saving from solar energy production

| | **Produced solar energy (kwh)** | **Calculated cost savings coming from solar production in NOK** |
|---|---|---|
| **2022** | 52229 | NOK 41783 |
| **2023** | 53473 | NOK 42778 |
| **2024** | 57242 | NOK 45794 |
| **2025** | 56035 | NOK 44828 |

[5] Emission factor 18g$CO_2$e is calculated for electricity, Norwegian consumer mix including production and transportation.
[6] Emission factor 132$CO_2$e is calculated for electricity, European consumer mix (EU28 + NO) including production and transportation.

## Chapter 2. Bodø Pilot Rehabilitation building

### Description of Pilots Rehabilitation building: What is the use of the building and where is it located?

One of Hybes energy pilots is the Rehabilitation building located at Gamle Riksvei 18. The rehabilitation service is part of preventive health care organisation of Bodø Municipality. Part of the building also serves as living room and flats for elderly and is functionally integrated in the neighbouring nursing institutions Stadiontunet. The premises is a 7-floor building with a ground area of 940 $m^2$ and the total building area is 7160 $m^2$.

1st and 2nd floor contains of two gyms, two smaller treatment rooms, a small therapy pool, meeting rooms, training kitchen, offices and expedition. The collective in Gamle Riksvei 18 is organized under Stadiontunet nursing home. The collective is located on the 3rd floor and 4th floor. There are 15 single rooms on each floor with shared kitchen and living room. The collective also provides home services to residents in the 5th-7th floor. The collective is staffed with 24-hour service and provides services by decision of the Allocation Office. It is the Allocation Office that prioritizes housing in the collective.

Late 2010ties it was decided to make a deep retrofit of the rehabilitation building and it was decided to highlight and implement climate and energy tasks during this retrofit process. Energy efficient goal was to reach nearly passive house standard of the rehab building. Maintenance inspection of the building concluded that the windows facing southwest were characterized by moisture penetration. As the remaining windows was assumed to have approximately 5 years back of service life it was considered to replace all windows. In addition, it was acknowledged that facades also had moisture penetrations, and that the wind barrier needed to be replaced.

Rehabilitation building after retrofit and energy task

The retrofit decision concluded with the following task: To post-insulate outer walls with 150 mm additional insulation, to replace all windows, to establish a new wind barrier and to replace part of the southeast and southwest facades with building integrated solar panels (BIPV). The reason to choose solar energy as energy source reflects the energy consumption pattern of the rehab building. The user profile shows that the highest energy requirement has its peak at the middle of the day. This pattern is in favour of solar and especially BIPV installations. This even though façade energy production would be influenced by the local shadow from Stadiontunet nursing home. To reduce this shadow effect BIPV panels are mounted from third floor and up on the rehabilitation building.

### Construction and energy baseline of Pilot

To evaluate the effect and performance of solar energy on different parameters we need to define a baseline. In planning and design phase of Rehabilitations building 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.  This baseline will reflect theoretical calculations of passive house requirements for the building, expected energy consumption post deep retrofit and energy efficient task, LCC and LCA evaluations of the retrofit and energy task.

I the planning process a technical evaluation of passive house requirement after implementation of retrofit and energy measures was done. These calculations on minimum requirements for individual buildings components are shown in table 1.

Table 1: U-value for individual building components

| **Building element** | **Value existing building** | **Value building after retrofit** | **Values demanded Passive house** |
|---|---|---|---|
| U-value outer walls | 0,33 W/(m²K) | 0,18 W/(m²K) | 0,22 W/(m²K) |
| U-value windows/doors | 2,0 W/(m²K) | 0,8 W/(m²K) | 0,80 W/(m²K) |
| Thermal bridge values | 0,12 W/(m²K) | 0,09 W/(m²K) | 0,03 W/(m²K) |
| Airtightness[7] (air changes per hour) | 3,50 $h^{-1}$ | 2,50 $h^{-1}$ | 1,5 $h^{-1}$ |
| Specific fan power (SFP) [kW/m³/s] | | 2,0 kW/m³/s | 0,6 kW/m³/s |

Conclusions are that the building after retrofit won't fully satisfy passive house criteria and demands. However, if the ventilation system were replaced, the system would likely obtain a heat recovery of over 80% and a Specific fan-power value would fall to near passive house standard.

Also heat loss from the building body was estimated. In table 2, the u-value numbers show that heath loss will be just above passive house standard of 0,40 λ with a total heath loss of the Rehabilitations building of 0,46 λ.

[7] Air changes per hour (ACH) at a 50 Pa pressure difference

Table 2: Estimated heat loss values Rehabilitation building

| **Heath loss** | **U-value** |
|---|---:|
| Heat loss figures exterior walls | 0,09 |
| Heath loss roof | 0,02 |
| Heat loss figures floor on ground/against the open | 0,01 |
| Heath loss figures glass/windows/doors | 0,08 |
| Heath loss thermal bridge | 0,09 |
| Heath loss infiltration | 0,16 |
| Total heath loss | 0,46 |
| **Passive house demand heath loss table** | **0,40** |

## Theoretical calculation of net energy performance of Pilot

The energy profile of the Rehabilitations Building before retrofitting and renewable energy task consisted of electricity from the power grid and heating from district-heating. Electricity from the grid comes from regional hydro power plants, and the district-heating plant produces heat from wood pellets.

To evaluate the energy effect of energy efficient tasks, we calculate energy use before and after implementation of tasks. The total use of power before retrofit has been calculated using an online energy monitoring system (EOS), E-save, to monitor energy use. Bodø Municipality has invested in this a digital tool to get an overview of energy use. Energy use before energy task is calculated as an average of total power use for the period 2013[8] to 2021. This calculation is shown in table 3, with an average power use 1367928,47 kwh and power use pr. $m^2$ of 191,05 kwh/$m^2$.

Table 3: Calculated average power use for the period 2013-2021

| **Year** | **Total power use kwh** | **Power use kwh/$m^2$** |
|---|---|---|
| 2013 | 1468508,01 | 205,10 |
| 2014 | 1386871,42 | 193,70 |
| 2015 | 1426674,40 | 199,26 |
| 2016 | 1354702,39 | 189,20 |
| 2017 | 1259897,39 | 175,96 |
| 2018 | 1402260,82 | 195,85 |
| 2019 | 1196222,96 | 167,07 |
| 2020 | 1383099,76 | 193,17 |
| 2021 | 1433119,07 | 200,16 |
| **Average** | **1367928,47** | **191,05** |

The figures below show the energy use divided into different sources 2022-2024 per year and per month. District heating counts for approximately 50 – 60% of total energy consumption, with large variation over the year. In winter, the share of energy from

[8] First year with district heating to Rehabilitation building is 2013. 2021 was the last year before retrofitting work started up in 2022.

district heating goes up to 75% of the total energy use, and down to 25% in the summer. Electricity consumption has relatively low variation over the year, with slightly higher consumption in the winter than summer, while the district heating takes up much of the added energy need during the cold months. Solar production happens between March and September.

Figure 1: Changes in distribution patterns of energy carries 2022-2024

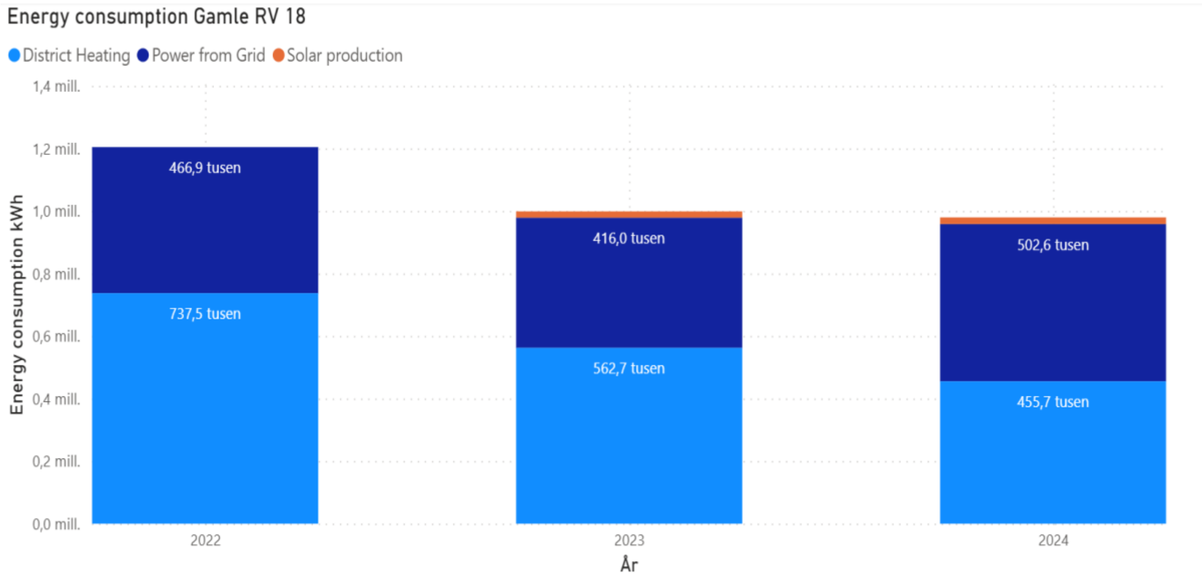
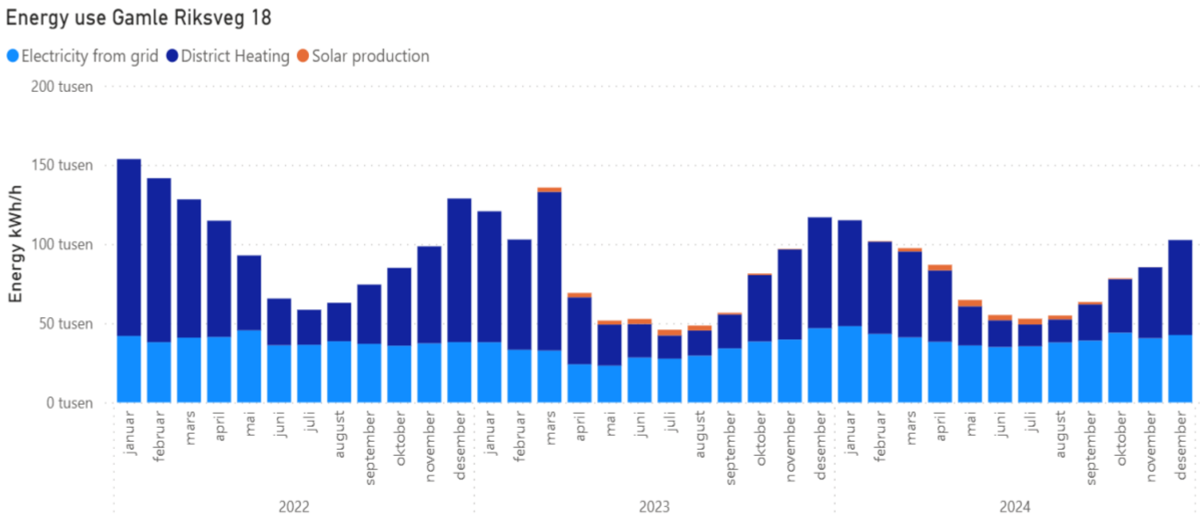



Figure 2: Monthly changes in distribution patterns of energy carries from 2022 to 2024




As mentioned above, the energy consumption pattern, with the highest energy requirement in the middle of the day, fits well with electricity from solar cells. The chosen renewable energy task was to install 380 $m^2$ with solar cells divided into the façade directed to the south-west and south-east. Theoretical calculations have been done to estimated power contributions from BIPV installations[9]. These calculations show that building integrated solar panels will contribute with about 4,2 % of annual energy consumption or 37 255 kWh pr. year. The simulation showed that shadow from nearby buildings reduces production by about 25%. The calculations are shown in table 4. The estimated annual production figures were made before BIPV supplier was chosen. As the supplier later calculated solar production capacity of BIPV installations they reduced production peak substantially.

Table 4: Theoretical calculations of projected BIPV installations

| | Facade east | Facade west |
|---|---:|---:|
| Area solar panels | 146 $m^2$ | 228 $m^2$ |
| Energy production | 730 kWh/kWp | 675 kWh/kWp |
| Number of solar modules | 101 | 148 |
| Installed effect | 27 kWp | 43 kWp |
| Annual production | 37 255 | |
| Share of annual energy consumption | 4,2 % | |

One of the essential calculations in the planning process to upgrade the Rehabilitations building has been to estimate needed power use after implemented energy efficientcy tasks. Table 5 shows calculated power from grid, heating needs from district heating and own power production from BIPV installations. The central number is a net energy requirement. An energy efficient of 126 kwh/$m^2$ is far below national building requirement of TEK 17, which for nursing homes allows 195 kwh/m2 and is also beyond passive house standard of 131 kWh/$m^2$

Table 5: Calculation of power use after implementation of energy efficiency tasks

| **Calculated power use after task implemented** | | |
|---|---|---:|
| Power from grid | 338398 kwh | 47,3 kwh/$m^2$ |
| District heating | 542609 kwh | 75,8 kwh/$m^2$ |
| Sola power own prod. | -37255 kwh | -5,2 kwh/$m^2$ |
| Net delivery of power | 843752 kwh | **117,8 kwh/$m^2$** |

### Life Cycle Cost evaluation

Before decision to implement deep retrofit and BIPV installation Life Cycle Cost (LCC) was calculated. The LCC analysis calculates the present value of investment costs and all costs for management, operation, maintenance and replacement during the useful life. This also includes the BIPV installations.

The methods used for the LCC calculations are based on Norwegian Standard NS 3454:2013 – "Life cycle costs for buildings, principles and classification." (Norconsult

[9] When installing an BIPV installation it is important that the inverter for the solar cells is placed in cool environments, and on non-flammable material. Furthermore, air gap behind the solar cells normally should be 100 mm, but the climate in Bodø dictates that it might be possible to reduce the gap size

report 2020) This is based on the present value method. By doing the LCC calculations the following main assumptions are made:

1. A risk-free interest rate of 2.0% p.a. and a risk premium of 2.0% p.a. is used, which represents a discount rate of 4% p.a.
2. Electricity price is set to 0.8 NOK/kWh. This electricity price represents the lowest value in a sensitivity analysis. Furthermore, energy prices are considered to have a low increase. Calculations also assume a reduced production as solar cells lose effect over the years. The assessment is considered to provide realistic overall earnings over time. Price of district heating is set to 0,75 NOK/kwh
3. Façade plates outer than BIPV modules are reused of existing panels. It is assumed that when reused, the facade panels will be painted before reassembly and that they will need one coat of paint after 20 years. The LCC calculations show price difference in investment and maintenance.

The table below lists building elements included in cost calculations in addition to the lifetime of these elements. Excluded from cost calculations are rig, service, dismantle and exchange of windows and wind barriers.

Tabel 6: Building elements included in LCC analysis and the lifetime of each element.

| **Analysis** | **Included cost** | **Lifetime** |
|---|---|---|
| BIPV | Module<br>Inverter<br>Connections to Ignition distributor<br>Assembly | 30 years |
| Insulation of old constructions<br><br>Exchanges of windows | Insulation<br>Studding<br>Assembly<br><br>Windows<br>Assembly | 40 years<br><br>30 Years |
| Existing wall plates<br><br>New wall plates | Dismantle of existing wall plates<br>Painting and mounting<br><br>Dismantle of existing wall plates<br>Material cost<br>Mounting of new wall plates | 40 Years |

As shown in table 7, the current values of building elements involved in energy efficient tasks are positive. This indicates that neither additional insulation, exchange of windows, replacement of façade plates nor BIPV installations have proven profitable (Norconsult report 2020).

Tabel 7: Estimated LCC calculation

| **LCC-Calculations** | **Investment cost** | **Yearly savings** | **Current value** |
|---|---|---|---|
| BIPV | Nkr. 1 967 700 | Nkr. -24 760 | Nkr. 1 539 549 |
| Additional Insulation | Nkr. 2 159 872 | Nkr. -78 421 | Nkr. 607 708 |
| Windows | Nkr. 2 858 432 | Nkr. -74 494 | Nkr. 1 633 337 |

| | | | |
|---|---|---|---|
| Reuse of existing facade plates | Nkr. 1 745 016 | Nkr. 0 | Nkr. 1 745 016 |
| TOTAL | Nkr. 8 731 020 | Nkr. -177 675 | Nkr. 5 525 610 |

## Life Cycle Assessment analysis

To evaluate the effect of energy efficiency tasks implemented, one also made a Life Cycle Assessment analysis of the Rehabilitation Building. As this project has a high environmental and climate profile, it was essential to calculate emission data.

The purpose of LCA calculations was thus to quantify greenhouse gas emissions measured in $CO_2$ equivalents ($CO_2e$) from material use in deep retrofit and renewable energy tasks. For BIPV, retrofitting and replacing windows, the savings represent saved energy. For the facade panels, savings represent savings in reuse of existing panels compared to new facade panels.

Methodological greenhouse gas calculation is in line with NS 3720 for greenhouse gas calculation for buildings (Norconsult report 2020). NS 3720 establishes a common life cycle model for buildings shown in table 8.

Tabel 8:

| **Production stage** | | | **Implemen-tation stage** | | **User stage** | | | | | | | | **End of life** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | A2 | A3 | A4 | A5 | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | C1 | C2 | C3 | C4 |
| **Raw materials** | **Transport** | **Production** | **Transport** | **Build Mounting** | **Use** | **Maintenance** | **Repair** | **Replacement** | **Renovation** | **Power use** | **Water use** | **Transport** | **Demolition** | **Transport** | **Waste disposal** | **Disposal** |
| X | X | X | X | | | X | | X | | | | | | | | |

Depending on the purpose of the LCA calculation, we can decide to include or exclude life cycle stages or describe these scenarios where project-specific information is missing. The table above shows the stages involved in the Life Cycle Assessment. For the Rehabilitations building we include material actual in used and we include emissions from new material made use of (Norconsult report 2020).

Calculating emissions for electricity we use a convert factor of 132 g/kWh[10]. For district heating, the convert factor is set to 18g/kwh.

[10] A Norwegian ZEB Definition Guideline (Sintef). The ZEB Centre has chosen an average $CO_2e$ factor of 132g $CO_2e$/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 $CO_2e$/kWh in 2023, indicating a lower-carbon electricity supply, and suggests the grid mix includes a substantial amount of low-carbon energy sources.

Tabel 8: LCA calculations and estimated $CO_2$ emissions after energy efficiency task

| **LCA-calcu0lations in ton $CO_2$e** | **Emissions from task implemented ($tonCO_2e$)** | **Reduction in emissions pr year ($tonCO_2e$)** | **Emissions after end of life ($tonCO_2e$)** |
|---|---|---|---|
| BIPV | 103,26 | 4,91 | -44,05 |
| Additional insulation | 17,85 | 1,88 | -57,43 |
| Windows | 103,37 | 1,68 | 53,08 |
| Reuse of existing facade plates | 2,39 | 0,00 | 2,39 |
| TOTAL | 226,86 | 8,47 | -46,02 |

The main picture of the LCA analysis as shown in table 8 is that the energy efficiency task has a substantial contribution to reducing $CO_2$ emissions with an estimated total reduction of 46,02 $tonCO_2e$. Solar BIPV installations and additional insulations is main contributor to this result, while replacing windows don't have a positive emissions balance between energy savings and material use. This is also confirmed by LCA data estimating when the different tasks arrive emissions neutrality. As shown in table 9 post-insulations tasks reach emission neutrality after 10 years and BIPV after 23 years.

Table 9 Energy efficient tasks and how many years to reach emission neutrality

| | **Savings pr. Year ($kgCO_2e$)** | **Emission material ($kgCO_2e$)** | **Neutral emission effect (years)** | **End of life (Years)** |
|---|---|---|---|---|
| Additional insulation | 1,88 | 17,85 | 10 | 40 |
| BIPV | 4910,4 | 103257,3 | 23 | 30 |
| Windows | 1,68 | 103,34 | 61,5 | 30 |

The choice to keep and reuse exiting façade and upgrade them has minor emissions consequences according to the LCA analysis as shown in table 10.

Table 10: Estimated emission from reuse of existing facade plates

| | **Emission (kg $CO_2/m^2$** | **Emission material ($tonCO_2e$)** |
|---|---|---|
| Reuse of existing facade plates | 0,33 | 2,39 |

## 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 Rehabilitation building we use this E-Save tool. E-Save has different visualisation options, which make it possible to show:

- An energy/temperature diagram measuring kwh/m$^2$/week. The diagram shows if energy use is on budget or shows energy subobtimalisation/technical defects.
- A bar diagram showing energy use/production pr. energy carrier used for the actual building.
- Accumulated graph showing energy use during the year.

The parameters we are monitoring:

- Total power use kwh/m$^2$ pr. Year. (Jan. 2023 to Dec. 2025)
- Total solar power production pr. Week (Jan. 2023 to Dec. 2025)
- Deviation from optimal solar conditions
- Total production from district heating (Jan. 2023 to Dec 2025)
- Total heating needs
- Condition for peak solar productions
- Calculate climate effect on energy use.
- Measure energy efficient task taking technology into use steering light, ventilations.
- Cost calculations and pay off for energy technology investment.
- Obtainment climate and energy goals

## Results and summing up data

We have monitored energy data for the Rehabilitations building systematically for the three years period January 2023 to December 2025. BIPV installations were installed and started to produce energy to the building week 10 2023. To create a full year of data, we estimated electricity production for the first nine weeks of 2023. This estimate is calculated as average BIPV energy data from equivalent periods for 2024 and 2025 and added to productions data for 2023. As shown in table 11, this is only a minor correction as solar production is low for this period.

Table 11: Estimation of production data from BIPV installation first 9 weeks of 2023

| | BIPV production kwh/m$^2$/week | BIPV production kwh |
|---|---|---|
| 2024 week 1 – week 9 | 0,072 | 513,2 |

| | | |
|---|---|---|
| 2025 week 1 – week 9 | 0,065 | 463,9 |
| Average | 0,068 | 488,55 |

For the monitoring period of four years table 12 shows the amount of electricity produced by BIPV facades. Compared with the calculated baseline the production has not reach expected level. Numbers are approximately 40% less than estimated and reach in 2024 a production of 21277 kWh compared with estimated baseline 37255 kWh. The contribution of kWh/m$^2$ is about 3 kWh.

Tabel 12: Production from BIPV façade elements

| | Baseline | 2023 | 2024 | 2025 |
|---|---|---|---|---|
| **Sola production** | 37255 | 20571,15 | 21277,2 | 19194,7 |
| **Sola use kWh/m2** | 5,203 | 2,872 | 2,969 | 2,68 |
| **Sola % of total energy use** | 4,2 % | 2,07 % | 2,19 % | 2,12 % |
| **Emissions tonCO2e 132** | 4,91666 | 2,71544 | 2,80859 | 2,5337 |

The reason for lower power production from BIPV façade installations than expected we find when we examine the patten for peak production as shown in table 13.

Table 13: Periods with peak production from BIPV installations

| | Week | Peak kWh | Temperature |
|---|---|---|---|
| 2023 | 12: 20-26 March | 891 | -2,59 |
| | 13: 27 March-2April | 1024 | -2,51 |
| | 18: 1-7 May | 895 | 3,53 |
| | 26: 26 June-2 July | 1105 | 16,76 |
| | 30: 24 July-30 July | 1022 | 15,84 |
| 2024 | 16: 15-21 April | 1212 | 2,16 |
| | 17: 22-28 April | 1073 | 4,46 |
| | 18: 29 April-5 May | 920 | 8,13 |
| | 21: 20-26 May | 1204 | 12,91 |
| | 24: 10-16 June | 1025 | 13,84 |
| | 29: 15-21 June | 960 | 19,49 |
| 2025 | 17: 21-27 April | 905 | 2,3 |
| | 29: 14-20 July | 1294 | 19,71 |
| | 30: 21-27 July | 910 | 18,71 |
| | 35: 25-31 July | 925 | 13,66 |

The figures 3 and 4 below shows the BIPV production 2023 and 2024 per hour and the weekly production in 2024. It shows solar production happens approximately between week 6 and 43, where the significant production is from week 10 to 41. The production per hour is quite high from early in March, and the maximum production does not get much higher throughout the summer. Looking at accumulated production per week, the production however is higher in the summer months, which is reasonable with longer days and generally more sun.

Figure 3: BIPV production 2023 and 2024 per hour

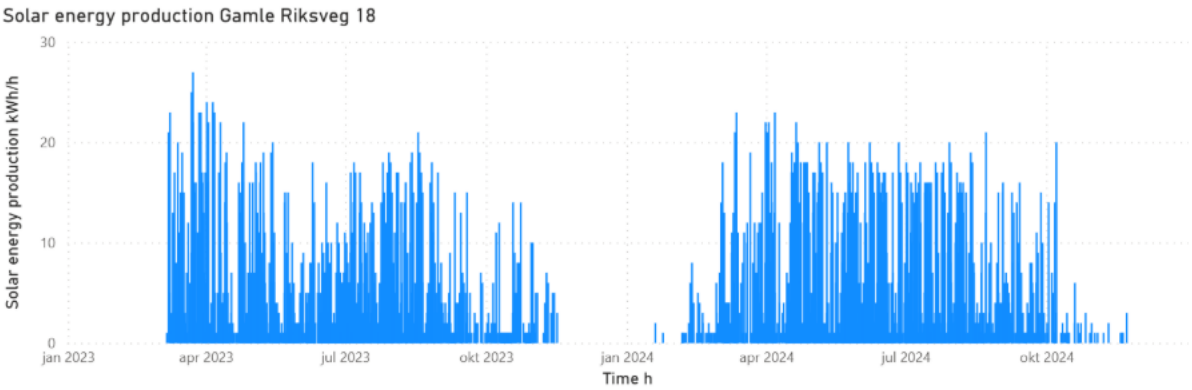
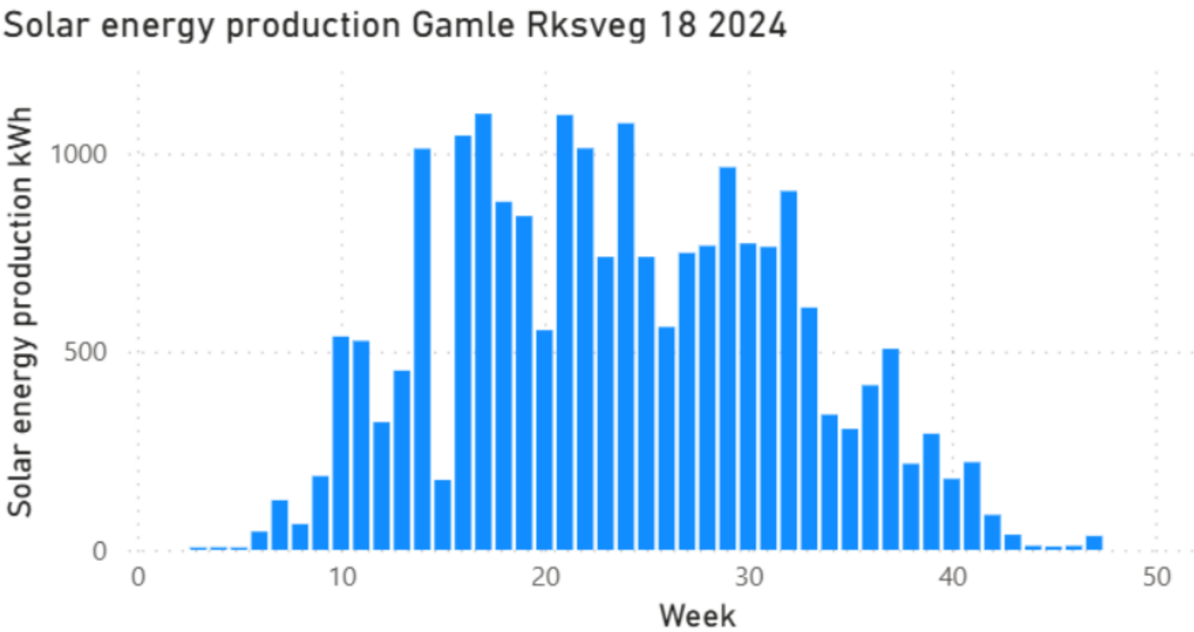



Figure 4: Solar energy production per week for 2024

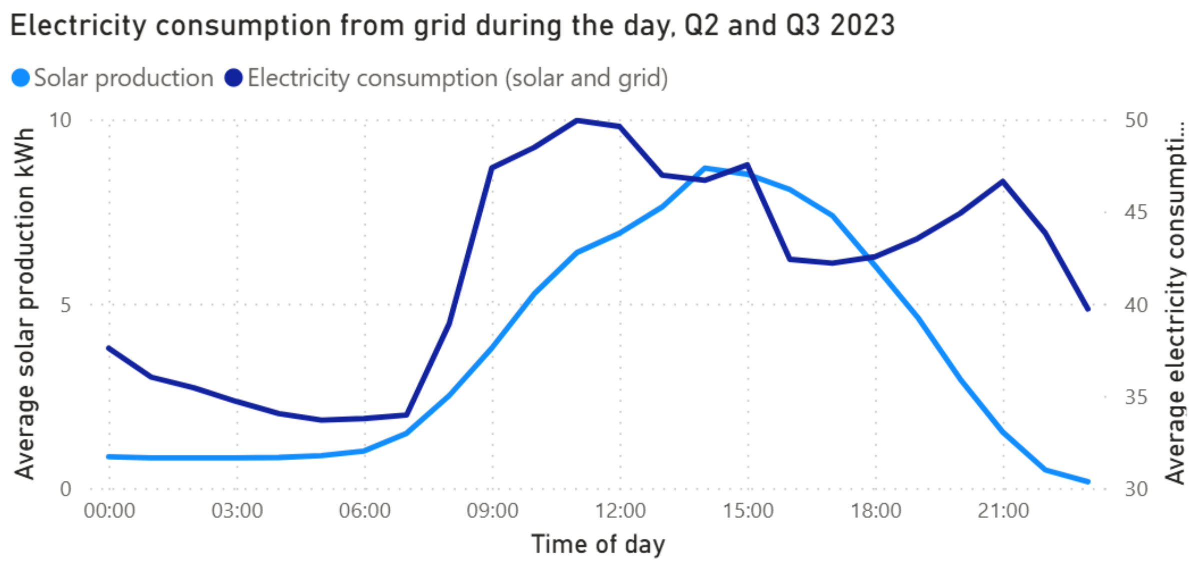



Power production patten shows that solar has its peak production in the period from April to May and in July. This is concurrent with the fact that BIPV installations are most efficient with horizontal Solar radiation. In arctic Bodø this is the fact in spring period and in the midnight sun month of July. Building integrated PV installations is not that efficient when solar radiation is vertical. Also, at low and even at minus temperature BIPV has high efficiency. Because BIPV panels have max productions with horizontal sun radiation, shadow effects from the neighboring building will cause minor solar production for Rehabilitation building.

The maximum production per hour since the solar panels were installed has been 27 kWh/h, accounting for 39% of theoretical peak capacity. With solar panels divided over the two facades, production is not expected to meet the theoretical peak capacity, considering this a fair, but not high utilization of peak capacity. All the highest production hours are in March and April, between 13-16 in the afternoon.

Looking at how production is divided during the day, we have looked at the average production per day in the second and third quarters of 2024. It shows that production rises from around 6.00 and stays at high production around 10-18, with peak production around 15.00. The figures below show peak production during the day (blue line), with the average electricity consumption pattern for the same period as a reference (purple line) (not using the same scale). Peak consumption happens some hours earlier than peak production, but overall, the patterns go quite well, with significant production in a large part of the consumption period.

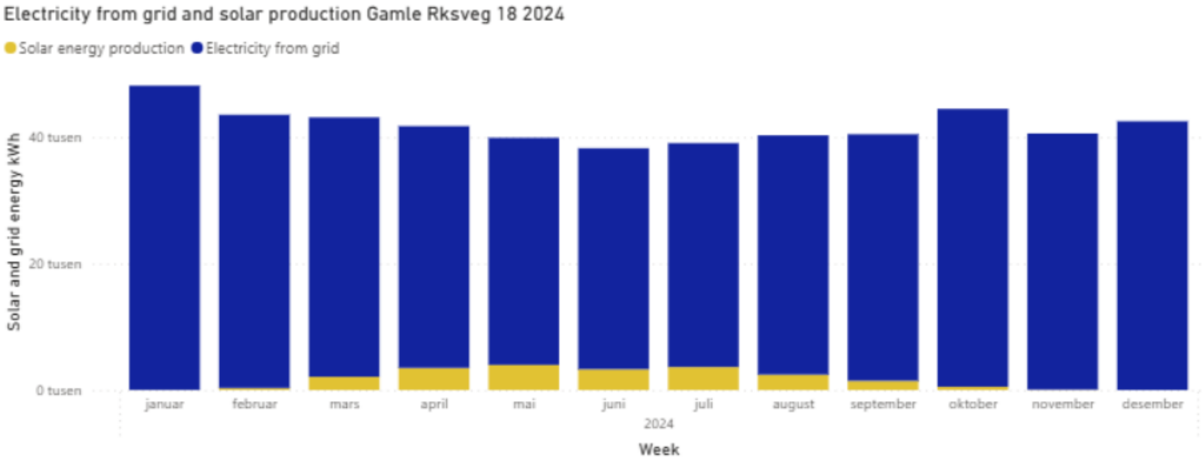
Figure 5: Comparison between patterns for solar production and electricity consumption




When looking at solar production compared with the electricity consumption in the building, we see that solar energy makes up a small share of the total electricity use from March to September. The electricity use is the lowest at the time when solar production is highest, but the variation in electricity consumption is low throughout the year. The low electricity variation is due to the use of district heating, which has much higher peaks in the winter.

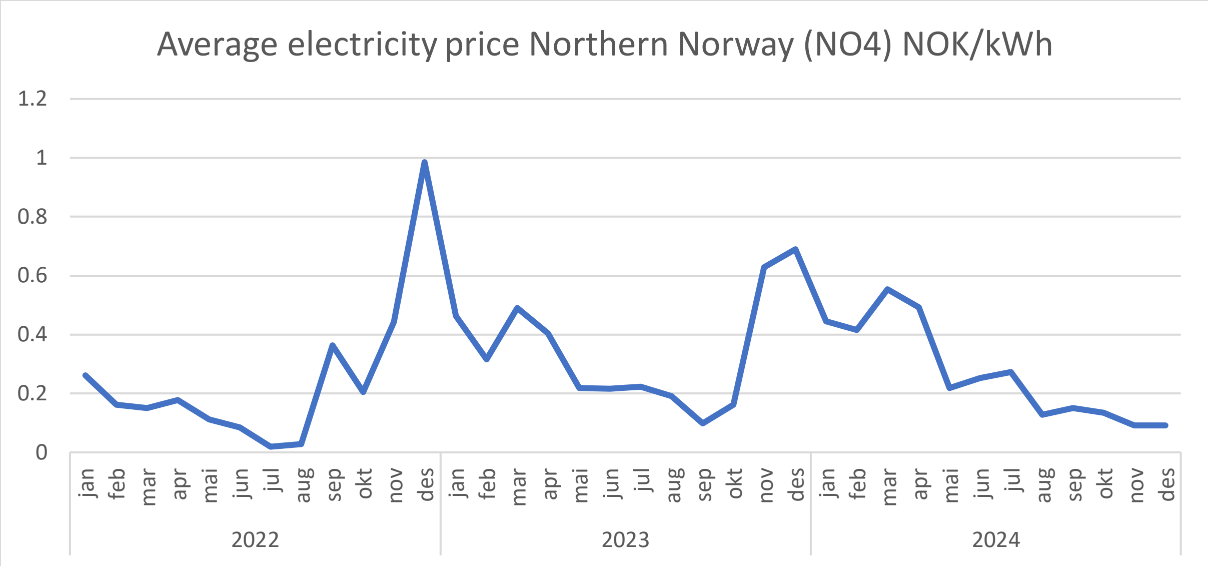
Electricity and solar production data show that in 2023-2024 the BIPV produced more energy than is needed in the building for a total of 12 hours during the two years, with a maximum of 9 kWh higher production and an accumulated export of 24,6 kWh. Power export to the grid can be complicated and not profitable. The 12 hours of export is, however, a low number.

Figure 6 Monthly solar production as part of electricity consumption from grid 2024




Combining the solar production data with electricity prices in Northern Norway for the same period, it is possible to get an impression of the economy of the solar production. The actual electricity price is more complicated than just the price to the power company itself, and a larger share comes on top to the grid company. The pattern is, however, similar. Electricity prices are typically high in late fall and winter, and can stay quite high in March and April, before decreasing towards the end of the summer. Solar production early in the year can therefore have economic benefits over later energy production. Taking this into account, the choice of façade mounted solar panels has the benefit of catching the spring sun efficiently, even though it may have lower efficiency as the sun goes higher on the sky during the summer.

Figure 7: Average electricity price Northern Norway between 2022 to 2024




Even with the modest solar production produced at Rehabilitation building, the contribution to reducing $CO_2$ emissions still is substantial. As shown in table 12, reduction is calculated to approximately 2.8 ton$CO_2$e.

Installing BIPV façade elements was part of deep retrofitting and other energy efficient tasks. In total energy efficient tasks have demonstrated great results in obtaining reduction in $CO_2$ emissions. Table 14 shows power use before and after energy efficient tasks and power use divided between power from grid to electricity use and district heating for heating purposes.

Baseline data are calculated as average energy use for the period 2019-2021 and to calculate emissions for electricity and district heating we use a convert factor of 132 g/kWh for electricity and 18g/kWh for district heating. We present these calculations in table 15 and table 16.

Reduction in total energy use from grid and district heating compared with baseline numbers for total energy use shows for 2023 a reduction of 25.6% and for 2024 27,3%. The equivalent reduction in $CO_2$e compared with baseline is 16% for the year 2023 and 4% for 2024. The reason for a lesser reduction in $CO_2$e in 2024 is the change in power use with a large increase in electricity use from grid and a considerable decrease in district heating. This change in pattern is due to the installation of a new heath recovery ventilations system in mid-2023. Heath recovery increases power needs but reduces heating needs from district heating. Another reason for the rise in electricity needs is deliberate decisions to exchange the car fleet from fossil to electric cars. Charging for electrical cars is included in power production numbers from grid. For the year 2025 the reduction in $CO_2$ emissions is back to 12.4%.

Table 14: Development of energy efficiency and calculated emissions compared with baseline

| | Power from grid (kwh) | District heating | Total energy use | Energy use kWh/$m^2$ | Emission based on energy use (ton$CO_2$e) |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Baseline | 466080,38 | 871400,45 | 1337480,6 | 186,80 | 77,2078 |
| 2023 | 414840,00 | 560237,00 | 995 159,5 | 139,02 | 64,84 equals 16% reduction |
| 2024 | 499776,90 | 451731,00 | 972 784,6 | 135,88 | 74,10 equals 4% reduction |
| 2025 | 453203,80 | 434464,00 | 887 667,8 | 123,98 | 67,64 equals 12,4% reduction |

Table 15: Average total energy use before implemented energy efficiency tasks

| | Power from grid kWh | District heating kWh | Total energy use kWh |
|---|---|---|---|
| 2019 | 463850,96 | 732372,00 | 1196222,96 |
| 2020 | 481910,57 | 901189,19 | 1383099,76 |
| 2021 | 452479,61 | 980640,15 | 1433119,07 |
| Average | 466080,38 | 871400,45 | 1337480,60 |

Table 16: Average total emission from energy use before implemented energy efficiency tasks

| | Emission from electricity (ton$CO_2$e) | Emissions from district heating ton | Total emissions from energy used (ton$CO_2$e) |
|---|---|---|---|
| 2019 | 61,2283 | 13,1827 | 74,411 |
| 2020 | 63,6122 | 16,2214 | 79,8336 |
| 2021 | 59,7273 | 17,6515 | 77,3788 |
| Average | 61,5226 | 15,6852 | 77,2078 |

Do we now compare the theoretical calculation for energy savings made with actual energy savings we realise that the actual savings are far higher than expected as shown in table 17. This will also influence the cost calculations made.

Table 17: Differences between theoretically calculated energy and real energy consumption data

| | Theoretical calculations expected data | Real numbers 2024 data |
|---|---|---|
| Energy use before energy task | 1074912 kWh | 1337480,60 |
| Energy use after energy task | 881007 kWh | 972784,60 |
| Energy savings | 193905 kWh | 364696,00 |
| Energy savings % | 18 % | 27,27 % |

The difference in energy use between theoretical calculations and real numbers are 170791 kWh. A simplify calculation using the kWh price of Nkr. 0,8 contributes to additional cost savings of Nkr. 136.632 pr. year. Taking this into account to the Life Cycle Cost analysis we find that the energy efficient task implemented for Rehabilitations building at least will be cost neutral. The same argument also is valid as a comment to the Life Circle Assessment. As we see in LCA model table 8, power use at the user stage isn't included. As our monitoring data recognise the reduction in energy use is substantially higher than expected. This indicates that $CO_2$ emissions will reach a higher level than the theoretical calculations to justify. Estimated this energy data shows that approximately half of energy use is derived from grid and half from district heating. Additional savings in $CO_2$ emission pr year then amount to 12,8093 ton$CO_2$e compared to theoretical LCA calculations.

Table 18: Difference between energy efficiency in theoretical and real energy consumption data

| | Theoretical calculation | 2023 | 2024 | 2025 |
|---|---|---|---|---|
| **Energy use kwh/m$^2$** | 123,1 | 139,0 | 135,9 | 123,9 |
| **Solar production kwh/m$^2$** | 5,2 | 2,9 | 3,0 | 2,7 |
| **Energy standard** | 117,9 | 136,1 | 132,9 | 121,2 |

One of the most impressive achievements of the Rehabilitations pilot is the building after a deep retrofit combined with installing BIPV façade has improved its energy standard to passive houser standard. For 2025 energy use kwh/m$^2$ was reduced to 123,9 kwh/m$^2$ as shown in table 18.

# Chapter 3. Cork Pilot: 6 The Grove, Fermoy, County Cork

## Carbery Housing Association – RED Wolf Project Pilot

## Introduction

The CHA pilot covered 4 properties owned by Carbery Housing Association (CHA), a community based social housing association based in Cork, Ireland. It was partly financed by the RedWoLF (Renewable Energy Without a Load Following) Project under the Interreg NWE Programme (60%) and the Association's rental income (40%)

### Climate

Cork County experiences a mild oceanic climate characterized by mild winters, cool summers, and abundant rainfall. Temperatures rarely drop below freezing or rise above 25°C (77°F). The region also faces increased risks of extreme weather events like flooding and coastal erosion due to climate change. Cork's climate is generally mild and wet, but it is also experiencing the impacts of climate change through more frequent and severe weather events.

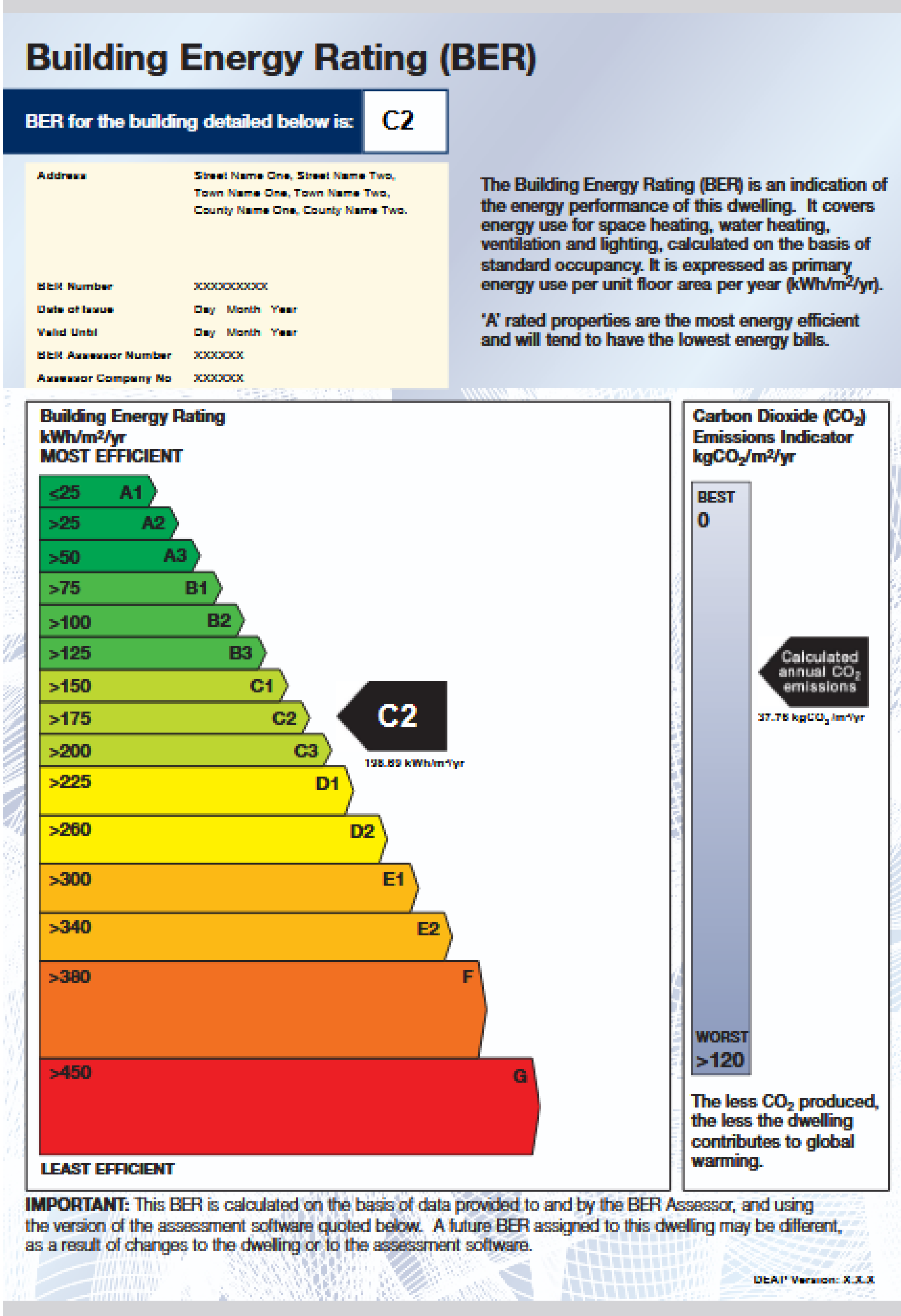
### Stock Condition

Cork City and County housing displays similar conditions to the rest of Ireland. Housing stock is mostly older, built from the late 1800's to 1980's, and a growing number of new homes. Existing homes are in urban and peri-urban centres of Cork City and County, and are mostly of traditional design and construction, ranging from stone cottages in rural and semi-rural areas to block-built bungalows, terraced homes and two storey homes in cities and villages, and more recently timber frame block and brick clad terraced and detached homes.  Around 60% of the housing stock was built before 2000 and ranks low on energy efficiency (see Table 1 below). Hearting is usually from fossil fuel sources, either coal or peat, and more recently oil and gas. None of the properties purchased by CHA had been retrofitted or had heaty pumps or any other non-fossil fuel-based source of energy installed. No CHA homes were all-electric, as electricity has been considered too expensive for space heating in comparison to cheaper fossil e fuels.

## Energy rating of existing properties in Ireland (all Counties)

Energy Efficiency measurement in Ireland is usually measured out through the Building Energy Rating (BER) system, which is derived from the EPBD Directive.

Figure 1: BER rating energy and $CO_2$ equivalents (source SEAI 2019)




## Building Energy Ratings Trends by period of construction

**Table 1** (below) shows estimated BER rates on existing homes based on a sample of the Irish housing stock in 2019. 60% of houses hold a medium to low energy rating, which highlights the necessity of energy upgrades of older properties to meet recently established targets.

**Table 1: BER Ratings by Period of Construction**

*% of row*

| Period of Construction | A | B | C | D | E | F/G | Total |
|---|---|---|---|---|---|---|---|
| | Energy Rating | | | | | | |
| 1700-1949 | 0 | 3 | 12 | 18 | 19 | 47 | 106,549 |
| 1950-1999 | 0 | 5 | 34 | 33 | 16 | 12 | 379,532 |
| 2000-2019 | 11 | 21 | 49 | 14 | 4 | 1 | 331,835 |
| **Total** | **4** | **11** | **37** | **24** | **11** | **12** | **817,916** |

Source: CSO (2019)

*Table 1: BER ratings of existing homes (Central Statistics Office 2019)*

Carbery Housing Association (CHA) purchases properties for social housing through under the government's Mortgages to Rent Programme (MTR), which is aimed at rescuing homeowners that are unable to meet their mortgage repayments. CHA secures private or public loan funding, and a local authority standing loan (called CALF – Capital Assistance Loan Funding) to purchase the distressed properties from the finance agencies that own them, in this way keep residents housed in their own homes paying a affordable means tested rent. The houses purchased under this programme are almost entirely existing properties, built from 1900 to 1980. Most of these properties have BER ratings of less than BER D (250 kWh/m$^2$/yr) down to BER F (380 kWh/m$^2$/yr)

CHA is committed to ensuring properties are retrofitted to an acceptable standard that is also affordable to residents, and to promoting the decarbonisation of its housing stock. However, it is limited by the funds available from its rental income to carry out the required works

## Pilot Project Properties

The 4 pilot properties retrofitted as part of REDWoLF Project, were all existing homes purchased under the Mortgages to Rent Programme, selected by CHA. They were:

- 6 The Grove Fermoy, County Cork – BER D1
- Ard Carrig, Myrtleville, County Cork - BER E2
- 51 Hawrthorn Mews, Cork City – BER D2
- 11 Larchfield Rd, Cork City - BER C2

The specification for works was drawn up by Technical Partners in the project, and locally IT Sligo Department of Engineering. After public tendering, the CHA pilot was awarded to Eurotech Renewables. The works were mired errors in the specifications and some installation errors, mainly as result of lack of knowledge and experience on the part of consultants and contractors. There were also difficulties arising from resident's lack of experience in managing the electricity supplies.

As a result, for some periods since installation, some properties have been off-line or turned off. These issues were mainly related to the lack of knowledge and experience on the part of consultants, contractors, and tenants interacting with the system, rather than the system itself.

One property of the group that did not face significant negative issues that could distort monitoring results, was 6 **The Grove Fermoy, County Cork**, where installation was technically accurate and the residents were willing and able to deal with their own energy management. As a result, for the purposes of this report, we will consider this property as best practice and the default pilot case.

### 6 The Grove, Fermoy, County Cork

The property is a rental social home owned by Carbery Housing Association and rented out to former homeowners under the Mortgages to Rent Programme. It is a family home, two storey and attic, three bedrooms end semidetached, located in local authority estate in Fermoy, Cork County. It was built in 2003. The floor area is 91.79 $m^2$. The property is concrete block built, with cavity wall (100mm external, 100mm cavity, 100 mm internal). It has internal leaf & plasterboard finish. Solid internal ground walls, timber stud wall on first floor. Timber pitched roof with 150mm insulation on ceiling. Windows are PVC 12mm double-glazed windows

When purchased the property had oil-fired central heating as primary space heating, timeclock & room stats and secondary heating with a solid fuel open fire. Estimated pre-works primary energy consumption (excluding appliances): was BER D1, or **235.29 kWh/m²/yr**. Total energy consumption per year of Cork Pilots will thus sum up to **21597,3 kWh**. At the time of purchase a D1 rating was higher than average for properties owned by CHA.

The yearly costs of power and heating to the property before retrofit has been estimated as **€ 1,850 per year** (Tabel 2). Table 2: Estimated ton$CO_2$e emissions and energy cost related to energy rating norm.

| Energy Rating | Tonnes $CO_2$* | Cost (€)* |
|---|---|---|
| **A** | 1.1 | €380 |
| **B** | 2.2 | €800 |
| **C** | 3.7 | €1,300 |
| **D** | 5.4 | €1,850 |
| **E** | 7.2 | €2,500 |
| **F/G** | 10.2 | €3,600 |

Sources CSO (2019)

The reduction in cost of energy per annum was estimated at € 800/p/yr (See table 2)

Figure 2; BER rating energy and $CO_2$ equivalents for pilot before retrofit and energy tasks

# Building Energy Rating (BER)

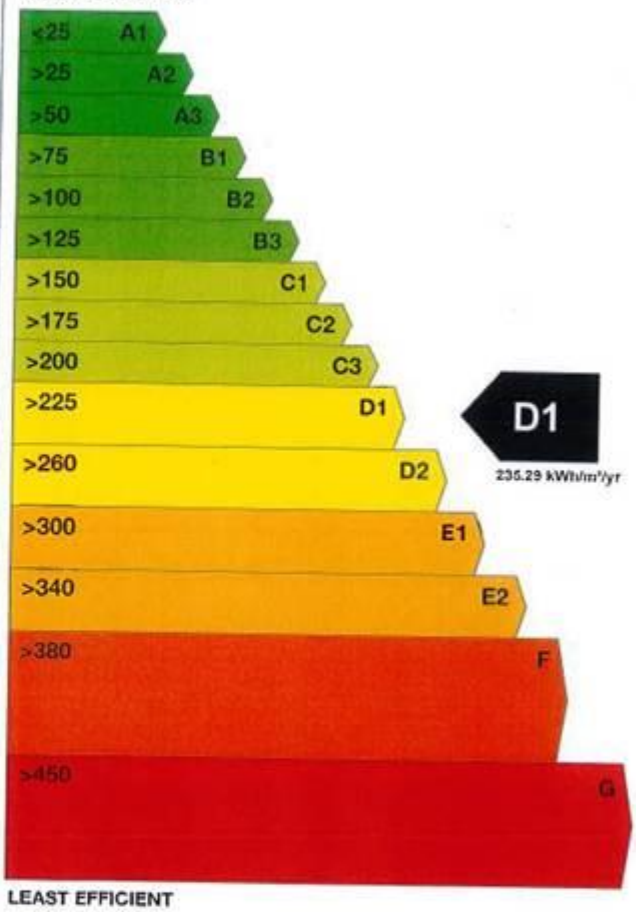
**BER for the building detailed below is: D1**

| | |
|---|---|
| **Address** | 6 THE GROVE<br>DUN EALA<br>FERMOY<br>CO. CORK |
| **BER Number** | 110279072 |
| **Date of Issue** | 05/10/2017 |
| **Valid Until** | 05/10/2027 |
| **Assessor Number** | 104332 |
| **Assessor Company No** | 104158 |

The Building Energy Rating (BER) is an indication of the energy performance of this dwelling. It covers energy use for space heating, water heating, ventilation and lighting, calculated on the basis of standard occupancy. It is expressed as primary energy use per unit floor area per year (kWh/m²/yr).

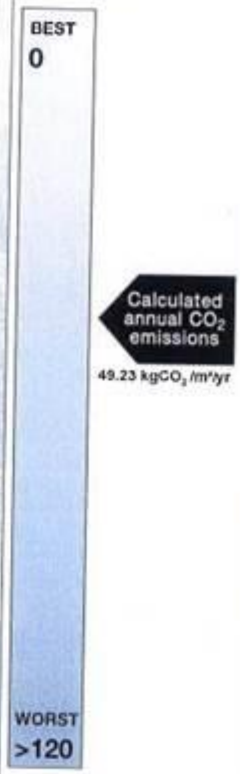
'A' rated properties are the most energy efficient and will tend to have the lowest energy bills.

**Building Energy Rating**
**kWh/m²/yr**
**MOST EFFICIENT**




**LEAST EFFICIENT**

**Carbon Dioxide ($CO_2$) Emissions Indicator**
**$kgCO_2/m^2/yr$**




The less $CO_2$ produced, the less the dwelling contributes to global warming.

**IMPORTANT:** This BER is calculated on the basis of data provided to and by the BER Assessor, and using the version of the assessment software quoted below. A future BER assigned to this dwelling may be different, as a result of changes to the dwelling or to the assessment software.

DEAP Version: 3.2.1

## Retrofit proposal and Implementation of Renewable Energy System.

The selection of the four properties was made after a survey and consultation with tenants and on the basis that the BER rating was to be as close to a" C" as possible, so expensive insulation or airtightness measures would be required for the system to be effective.

### Default Option fossil based versus flexible energy solutions in cost perspective

If CHA simply replaced the boiler and radiators (default option/base line) costs would be:

| | |
|---|---|
| - Boiler | € 4,000 |
| - Radiators (6 x € 540 @) | € 3,240 |
| - Installation | € 3,000 |
| Total cost to CHA | € 10,240 |

No grants would be available for these works, dependency on fossil fuel would continue and there would be little $CO_2$ reduction and the BER would remain the same, D1

The options available for decarbonization were:

1. **Alternative: SEAI Grant supported deep retrofit and installation of a heat pump (Cost calculations)**
   This would have 50% grant support from SEAI. In order to be eligible for a grant for heat pumps, CHA would have to agree to a fabric retrofit insulation package to bring the properties up to a BER B2, standard in addition to the costs of installing the heat pump  This is required by SEAI to ensure the heat pump is effective and to keep electricity costs affordable, as a results of the neat pump having to be set to its maximum to heat the property effectively. The costs of "deep retrofitting" and heat pumps installation would be at least amount to € 60,000. The maximum SEAI grant available for this work would be 50%, that is total cost to CHA of € 30,000

2. **Alternative: The REDWoLF Installation (Cost calculations)**

| | |
|---|---|
| Solar panels, batteries, Immersion heater and Modems (per specification) | € 22,259 |
| Minor retrofit works | € 3.000 |
| Total cost of installation | € 25.259 |
| ERDF Grant (60%) | € 15.155 |
| Total Costs to CHA | **€ 10,103** |

The RedWoLF Project provided 60% of the capital costs of PV panels, battery storage, storage heaters, smart meter, day/night tariff, and AI remote energy sensing and energy management. Installation made this an affordable option of the Association.

The installation of the solar energy system was made possible thanks to CHA being a full Partner in the Interreg NWE Project, approved under Priority 2 Objective SO3 of Call 7 (2019).

The EU subsidy made this installation a cost-effective option that could allow CHA to achieve an acceptable level of comfort at a similar cost to simply replacing the oil boiler and radiators, while ensuring the substitution of the fossil fuel-based oil heating system.

The system was designed and specifications drawn up by technical Partners in the EU project. The CHA Red Wolf specification for works drawn up by IT Sligo.

### Flexible energy: The system design and equipment installed

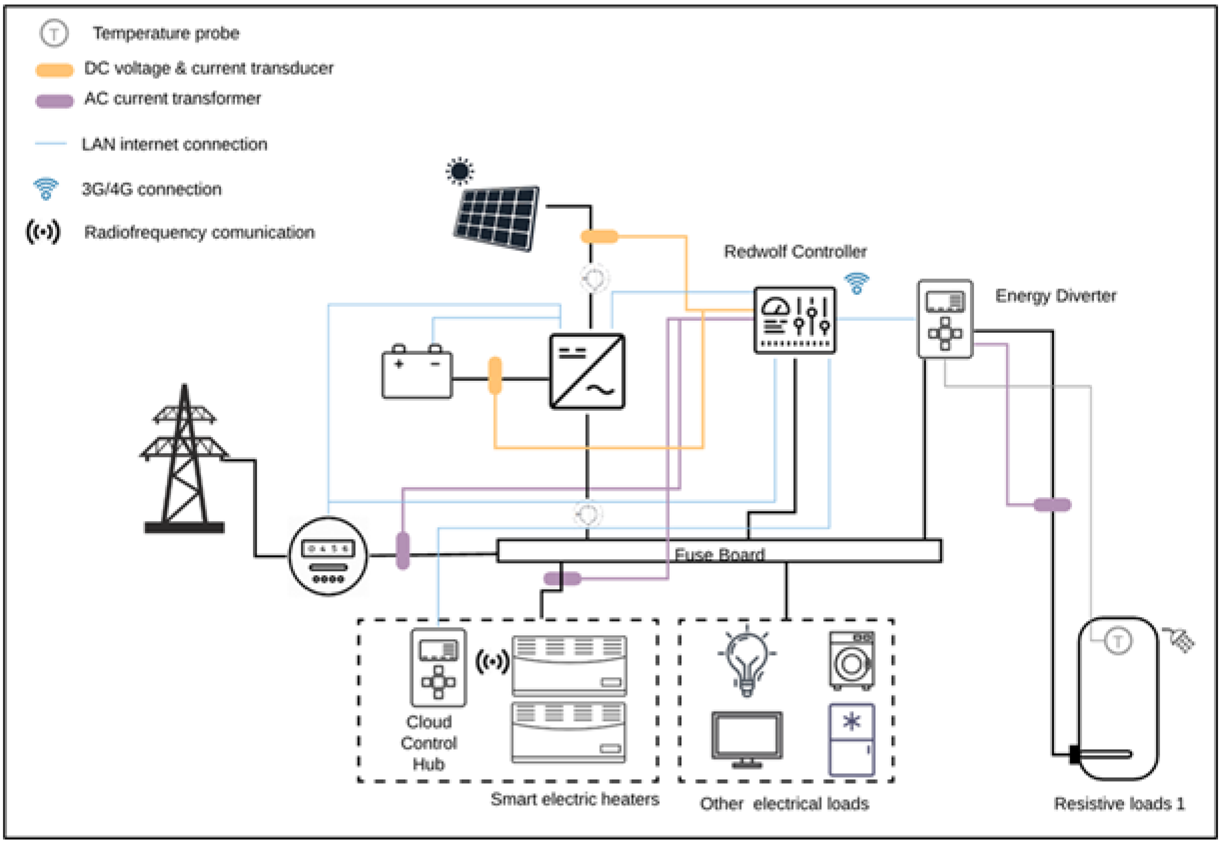
10 PV panels on the roof were installed on the roof. Battery storage was 5 kW battery in the loft. Generated electricity would be used to run appliances during the day. Around 5 storage heaters would be charged up primarily at night (using low peak energy from the grid). A grid connection would allow excess energy to be fed to the grid, as well as topping up of the batteries at night if required. An immersion heater would also store energy in the form of hot water, which would be available on demand.

The RED WoLF system configuration will include the following main components:

- Solar PV modules
- Module mounting system
- DC and AC wiring, including connectors & junction boxes/string combiners
- DC and AC switch-disconnectors (isolators)
- Battery Energy Storage System (BESS)
- Hybrid PV Inverter & Battery Inverter/charge controller
- Storage Heaters with local controls
- Down-Flow Fan Heaters (for some dwellings)
- Bathroom Panel Heater (for some dwellings)
- Electrical protection
- Energy Meters (Main Incomer, Hot Water Tank, Storage Heaters)
- Independent 3G/4G network to facilitate Client's control requirements and off-site monitoring via the IT Sligo Red Wolf project server
- GET2132MX Controller (supplied by Client)
- Cloud Hosted SCADA System

This integrated and flexible renewable energy systems is illustrated on the figure 3 below.

Figure 3 Design of flexible renewable energy system of pilot



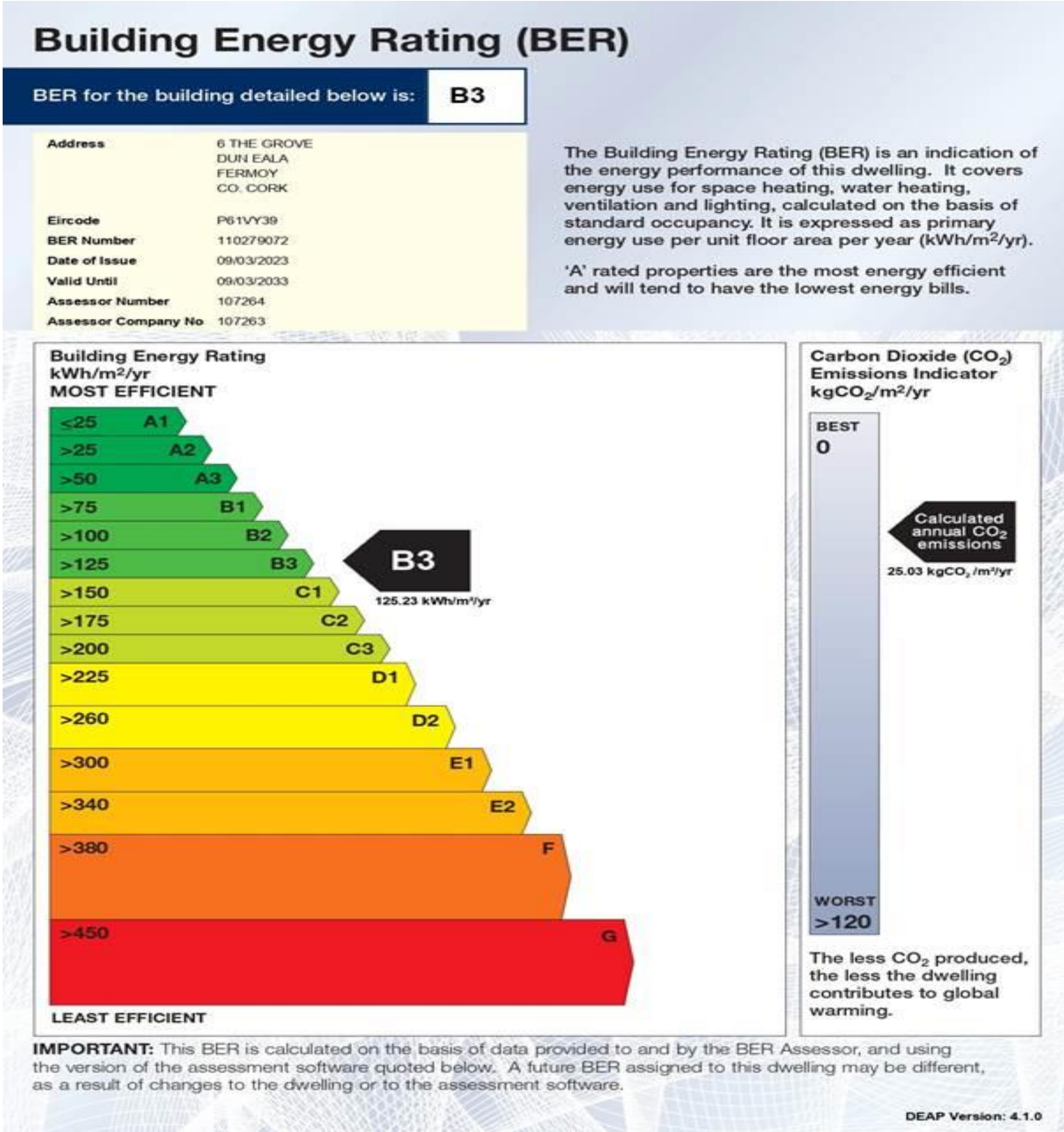

## Post Works energy consumption and costs

Primary Energy Consumption (excluding appliances) after post-works energy tasks are calculated to 125.23 kWh/m$^2$/yr. This results in a building energy rating of B3 compared with the pre-work status of D. Total yearly energy consumption after implementation of energy efficient task is 11494,9 kWh, which represent a reduction of 46,8% in energy use.

The current energy costs to the household is @ € 260 per two-month period. The day rate for electricity is € 0.40 cents a unit's day rate, and € 0.20 cents unit night rate, The feed in rate is €0.25 cents.

There is a direct connection to the Grid through supplier Electric Ireland. – Excess electricity, not used for storage, water heating and appliances is fed into the Grid and credited to the resident's account.

Figure 4; BER rating energy and $CO^2$ equivalents for pilot after retrofit and energy tasks




## Monitoring Approach

The inverter installed has a Modbus RTU interface to accommodate local data logging and control via the GET-2132MX.

In addition, the inverter installed has monitoring and data logging capabilities for specified key parameters (see below).

The inverter is connected to an online portal via the internet via 3G/4G connection, to allow data-logging and with appropriate user-interface presenting performance analytics accessible remotely.

The inverters also have an in-built fault detection system, whereby an alert is sent to the email of a designated responsible person, to notify them when there has been a fault in the system, and it is not generating power as designed.

**The system monitors:**

- Instantaneous Power Generation (kW)
- 5-minute interval Generation (kWh)
- Daily Generation (kWh)
- Monthly Generation (kWh)
- Annual Generation (kWh)
- DC Line Voltage(s) (V)
- Output Frequency (Hz)
- Output Voltage (V)

Objectives of monitoring the Cork pilots has been:

- To ensure the effective operation of the generation, storage and energy use systems.
- To better manage the inputs and outputs
- To better advise residents on better energy management
- To validate the cost benefit value of the system

CHA continues to monitor results of the reading from each home on a periodic basis. This helps technical faults to be identified, repairs and adjustments caried out. Though monitoring and feedback, suggestions for better energy use are communicated to residents.

One of the aims of the monitoring was also to develop an algorithm (based on the normal energy use of the systems) that can be used to control the use of appliances. The overall results will be used to validate the cost benefit of the system. And the payback period will be calculated from the figures obtained.

## Implementation and monitoring from Cork Pilot

In cooperation with GLAS energy of Kildare, Ireland, we, in Hybes project, have monitored the energy production and use at our four RED Wolf houses. Here we present a snapshot from a recent two-day period, to illustrate the data being gathered. We will use the data output from one house as a basis for explanation and discussion and include data outputs for the other three houses at the bottom of the document.

**Figure 2.** The above data is for the property at 6 The Grove, Fermoy, Co. Cork.

The top graph shows import and export to the grid as green, above the line means import from the grid, below the line means export to the grid. Blue is off-peak storage heater use; yellow is electricity produced by solar panels and orange is energy going into the water boiler.

The lower graph shows data on battery charge level. The green boxes show energy totals for the two-day period in mid-winter. In this example, the solar panels produced a total of 17.4 kWh, the storage heaters used 57.2 kWh (half price, as off peak), while the total grid import was 72 kWh. Export to the grid was 2.87 kWh, while 4.57 kWh went to the water heater.

Monitoring of performance of the system was maintained throughout 2024 form 3 properties, 6 The Grove, Millstreet and Ard Carrig, Myrtleville, County Cork and 11 Lichfield Rd., Cork City. Continual monitoring was not possible on one property, 51 Hawthorns Mews due faults in the installation.

| 6 The Grove | | | |
|---|---|---|---|
| Total values pulled directly from inverter: | | | |
| **Parameter** | **Value** | **Unit** | **Timeframe** |
| Battery charge | 3864 | kWh | Total |
| Battery discharge | 4943 | kWh | Total |
| Grid import | 15765 | kWh | Total |
| Grid export | 2767 | kWh | Total |
| House load | 24581 | kWh | Total |
| PV generation | 10585 | kWh | Total |
| PV generation | 3809 | kWh | 2024 |
| | | | |
| Last year's PV generation as % of total | | | 36% |
| | | | |
| **Inferred 2024 values** | | | |
| **Parameter** | **Value** | **Unit** | **Timeframe** |
| Battery charge | 1390 | kWh | 2024 |
| Battery discharge | 1779 | kWh | 2024 |
| Grid import | 5673 | kWh | 2024 |
| Grid export | 996 | kWh | 2024 |
| PV generation | 3809 | kWh | 2024 |

| Ard Carrig | | | |
|---|---|---|---|
| Total values pulled directly from inverter: | | | |
| **Parameter** | **Value** | **Unit** | **Timeframe** |
| Battery charge | 3724 | kWh | Total |
| Battery discharge | 4363 | kWh | Total |
| Grid import | 38631 | kWh | Total |
| Grid export | 1836 | kWh | Total |
| House load | 48022 | kWh | Total |
| PV generation | 11805 | kWh | Total |
| PV generation | 3430 | kWh | 2024 |
| | | | |
| Last year's PV generation as % of total | | | 29% |
| | | | |
| **Inferred 2024 values** | | | |
| **Parameter** | **Value** | **Unit** | **Timeframe** |
| Battery charge | 1082 | kWh | 2024 |
| Battery discharge | 1268 | kWh | 2024 |
| Grid import | 11224 | kWh | 2024 |
| Grid export | 533 | kWh | 2024 |
| PV generation | 13953 | kWh | 2024 |

| 11 Larchfield | | | |
|---|---|---|---|
| Total values pulled directly from inverter: | | | |
| **Parameter** | **Value** | **Unit** | **Timeframe** |
| Battery charge | 3523 | kWh | Total |
| Battery discharge | 4524 | kWh | Total |
| Grid import | 14173 | kWh | Total |
| Grid export | 3654 | kWh | Total |
| House load | 21416 | kWh | Total |
| PV generation | 9972 | kWh | Total |
| PV generation | 2978 | kWh | 2024 |
| | | | |
| Last year's PV generation as % of total | | | 30% |
| | | | |
| **Inferred 2024 values** | | | |
| **Parameter** | **Value** | **Unit** | **Timeframe** |
| Battery charge | 1052 | kWh | 2024 |
| Battery discharge | 1351 | kWh | 2024 |
| Grid import | 4233 | kWh | 2024 |
| Grid export | 1091 | kWh | 2024 |
| PV generation | 6396 | kWh | 2024 |

*Figure 3- Estimated use and generation of energy in 2024 (source; Glas Technology 2025)*

*Note: The first section provides the total energy usage to date (Dec 2025) and an estimated o the PV generation for 2024. The second section gives the estimated energy usage and generation for 2024 only*

## Conclusion of Monitoring

As can be seen from the above data, even in mid-winter, the solar panels are producing a useful amount of energy. In summer, this customer had very small bills, sometimes receiving positive bills, as well as having abundant hot water on most days.

Perhaps the most useful aspect of the monitoring system was to help the tenants fine-tune their storage heaters. Setting up the heaters to heat the houses economically was a problem with which all our tenants struggled. CHA installed Glen Dimplex Quantum storage heaters, a premium brand, but the mechanical reliability of these devices was not 100%.

Tenants had difficulty setting the heaters to produce the right amount of heat, at the correct time. As CHA could monitor the level and time of energy input, we were able to assist them with this. However, CHA's experience with this process makes us unsure that modern programable storage heaters are the best option for installation in tenant housing. Having to wait at least 24 hours to judge whether previous adjustments was successful or not has led to considerable confusion and stress for tenants, and required careful monitoring by CHA, to eventually get the storage heater settings right.

### Overall Conclusions

A small community-based housing association (CHA), piloting a fossil fuel free domestic heating and energy system, aiming to reduce costs, significantly reduce the $CO_2$ footprint and generate new electricity to feed into the grid. It also applies IT, smart sensing and AI at a micro-level. In doing this CHA is pioneering an affordable alternative to outdated gas or oil builders, and is a direct competitor to heat pump installation, with none of its drawbacks.

We believe that the Red Wolf system and other systems like it will one day become the norm for domestic power. Non-generating electric-based heating systems, such as heat pumps, perpetuate our dependency on grid-based electricity supplies and if they continue to proliferate, will increase the pressure on existing grid supplies to the extent of making them unstable. This is of course exacerbated by increasing demands from servers and other energy intensive applications.

Currently it is imperative to increase renewable energy generation, but at the same time the grid cannot be the sole source of storage. Grid congestion is creating serious problems for suppliers, especially in winter, where normal electricity peak times are dark.

The decentralized and localized distribution system proposed in Red Wolf is ideal for offsetting peaks as well as reducing long distance transmission, and the export of renewables when demand is low. Shared storage could create a buffer to offset blackouts and make them less likely on a large scale.

## Chapter 4- Iceland pilot

### User description of pilot and climate context descriptions

As things stand today in Iceland, producing electricity with solar cells for direct feed-in to the national grid is not yet feasible. However, when users install cells to reduce their own consumption, the benefits are threefold: users save electricity purchases, transport costs, and taxes.

The Icelandic Environment and Energy Agency (UOS) therefore considered the HYBES project an ideal starting point for Iceland's solar energy journey. The project began by mapping the current situation, learning from neighbouring Denmark, and using the Living Labs model to bring together all stakeholders in the electricity system. The goal was to jointly address the obstacles preventing solar energy from becoming a recognised and viable option for energy production—particularly for residents in regions where heating relies on electricity or oil. Under the Living Labs framework, the project pursued an ambitious path, focusing on analysing the feasibility of solar energy deployment and identifying both barriers and opportunities.

Preparatory work for The Icelandic Environment and Energy Agency began in September 2023 when Danish experts in solar energy projects visited and conducted several micro workshops in the East, North, and Reykjavík. This step was essential duel, to the limited domestic knowledge of solar energy projects in Iceland. Following these workshops, The Icelandic Environment and Energy Agency organized a series of meetings to introduce grant programs, provide installation instructions guidance, and address challenges in connecting solar power into the national grid.

The first of these Living Lab sessions (Living Lab model), titled "Introduction to PV-Grants," took place on January 2024 at Orkugarður in Akureyri, with an online option via Teams. This session targeted key stakeholders, including Iceland's major distribution companies; Rarik, HS Veitur, Orkubú Vestfjarða, Veitur, and Norðurorka, as well as Landsnet, the national grid operator, and the House and Building Agency (HMS). The meeting addressed challenges related to grant accessibility and highlighted the need to strengthen vocational education to support the installation of solar and other micro-generation technologies.

UOS´s HYBES activities further focused on developing clear and standardized instructions for PV installations and addressing long-standing ambiguities. A key issue was the absence of unified guidelines for integrating PV systems into the grid, whether for private use or for selling surplus power back to the grid. To address this, the environmental and energy agency hosted several meetings throughout the year.

In May, a key meeting with the Ministry of Environment and Energy and the National Energy Regulatory authorities laid to groundwork for standardized installation guidelines. In June, distribution companies and Samorka, Iceland's Association of Energy and Utility Companies, collaborated on detailed installation procedures. A broader stakeholder meeting in July included PV equipment retailers, ensuring all relevant stakeholders had access to uniform installation protocols.

## A Clear Path for PV Integration- Instructions

According to all stakeholders, these activities were essential in clarifying the previously confusing processes related to PV installations. In the past, various agencies often passed responsibility back and forth when asked for installation guidelines. The environmental and energy agency therefore focused on developing a clearer and more coherent roadmap for installing PV systems, available to both private homeowners to large-scale energy producers.

The HYBES project fits into Iceland's broader renewable energy goals by addressing bottlenecks in PV adoption, creating structured educational pathways, and clarifying regulatory processes. Through these meetings and collaborations with key players across the energy and education sectors, the environmental an energy agency played a leading role in making solar power a viable component of Iceland's renewable energy future.

In October 2024 the Environmental an Energy agency published on their website a set of instructions for the owners of the micro and small-scale power plants. These guidelines cover system design, selection of equipment, contract with the distribution company (distribution system operator), registration with the housing and construction authority (HMS), and data submission to the national Energy Regulatory authority (ROE). Instructions are divided into two parts:

- Electricity production below 16 A (below 12 kW)
- Electricity production over 16 A x 3 (12-100 kW)

It is noted that these guidelines are part of an experimental project and may not apply to all users. The most recent update was issued on 20 September 2024, and it is recommended that the instructions be revised regularly as new regulations or conditions emerge. HMS has now been given the responsibility to create a road map for solar energy in Iceland for the year 2030. As part of this work, these guidelines will be reviewed, and the next organized meeting is scheduled for January 2026.

## Empowering Future Installers- Education

In May 2024, the environmental and energy Agency partnered with Verkmenntaskólinn á Akureyri (VMA), a vocational college, to explore funding opportunities for solar installation education. The collaboration aimed to create hands-on learning environments for future PV installers, which is needed to support Iceland's solar energy ambitions.

Additionally, a significant meeting with Rafmennt, the national electrician educational body, took place at the end of September 2024. This session focused on developing a structure approach to PV installation education, ensuring that future electricians and installers were well-equipped to meet the increasing demand for solar energy solutions.

Subsequently, VMA received a grant for solar cells and a battery system to be installed in the school. The goal is to make the classrooms energy independent, enabling students to learn directly from a functioning system and to work on various related projects. The solar cells have already been installed, as part of the solar cell project, teachers at the school have set up a sustainable classroom. It is a 100 square meter classroom where all the energy is obtained from solar cells and a small windmill. In addition, a charging bank has been installed. The classroom is connected to an outdoor area with solar panels, a wind turbine, and heat exchangers, with the possibility of further increasing the number of solar panels or wind turbines if needed.

*Figure 1 Solar cells on the roof of VMA*

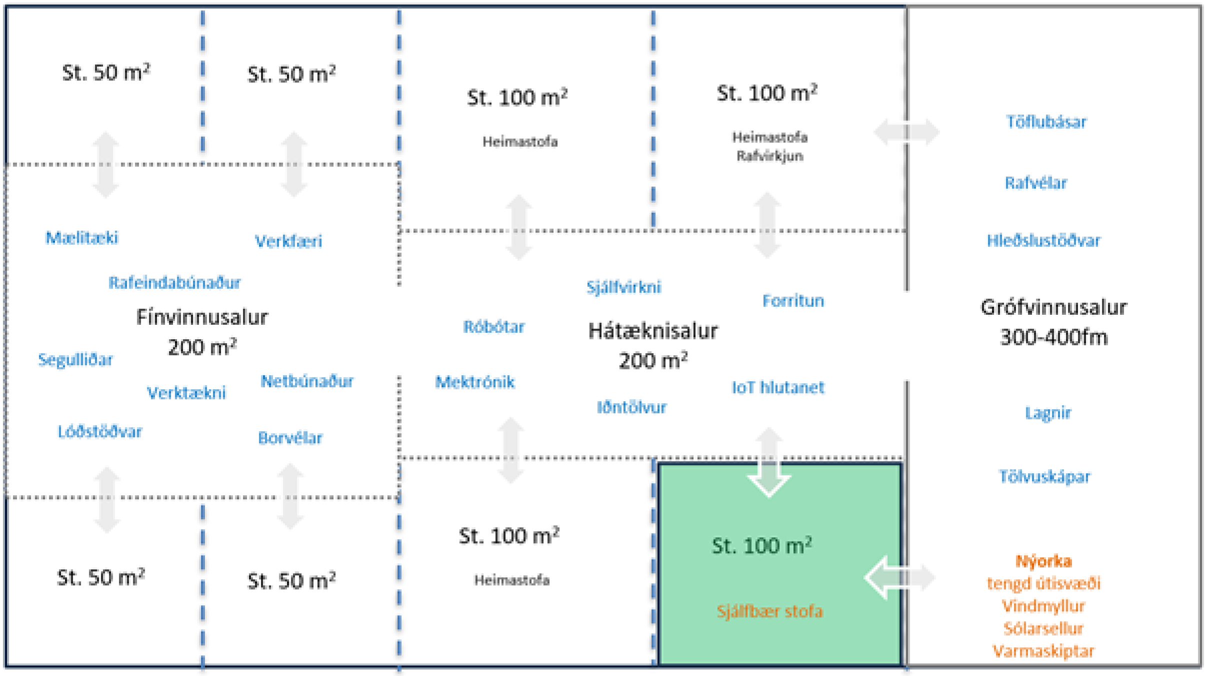



*Figure 2 Sustainable classroom - coloured green*

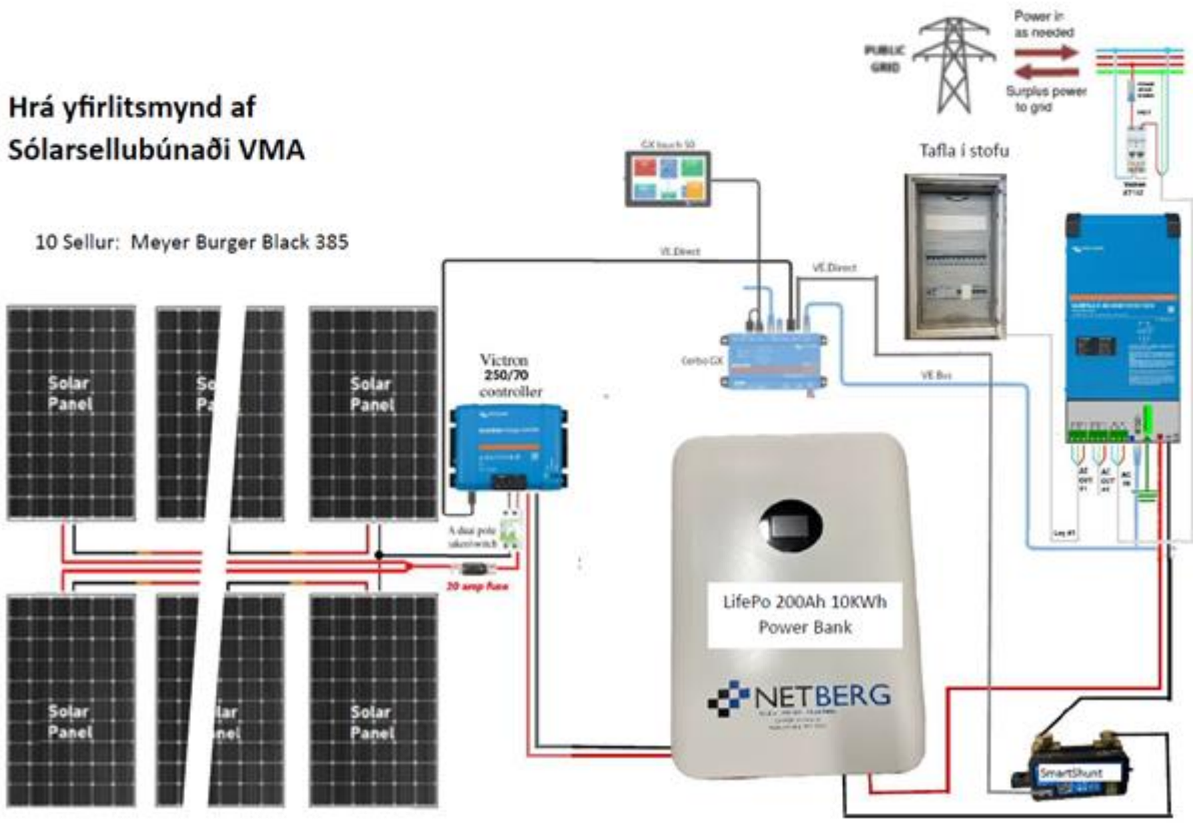



*Figure 3 Overview of the solar cell system in VMA*

Since the installation and use of solar cells in VMA is to be part of the school's curriculum, teachers at the school's electrical engineering program have compiled examples of how the solar cell project will be integrated into the curriculum.
The following points show how the solar cells have been connected to the curriculum throughout the academic years.

**1-2nd semester – Basic Law**

Ohm's Law, Power, Current, Voltage

- DC Voltage/Current Measurements from SmartShunt
- Battery and Power Supply as a Basic System

Power Loss, Wiring, Safety

- MPPT Measurements and Understanding Maximum Power
- Measuring Power Loss and Voltage Drop

**3-4th semester – Protection and DC/AC and UPS**

Students connect small circuits themselves

- Operation of battery → shunt → inverter
- Safety theory and circuit understanding

Introduction to MultiPlus-II

- UPS testing and waveform (surge)
- VEConfigure basic settings

**5-6th semester - System connection and monitoring**

Cerbo-GX and VRM portal

- Real-time energy and voltage data
- Connection to house systems – theory and design

Final project:

- Design of your own system
- Calculations and efficiency

VMA is participating in the Green Erasmus project together with schools from Croatia, the Netherlands, Turkey and Portugal. In that project, VMA will welcome 50-60 students and teachers in May 2026, where the solar panels and the sustainable classroom will be part of the participants' program.

It has been proposed that the Environmental and energy Agency continue supporting the school in expanding the solar energy system, as well as to explore the possibility of going on a study trip to Grímsey to support the development of the solar energy infrastructure there. On December 11th a meeting was held with VMA and Rafmennt. The outcome of the meeting was that Rafmennt will prepare a proposal regarding how the Environment and Energy Agency can support how best to advance education in new energy technologies and the opportunities associated with them.

### The Solar Grant Program- Pilot

In October 2024, the Energy Centre launched a competitive grant program for solar panel installations, open to all applicants regardless of residence or occupation. The grant covers up to 50% of material costs and is paid out after installation upon submission of invoices. Due to high demand, the Energy Centre received 90 applications, far exceeding the project's available budget.

Funding was allocated based on the greatest state and user interest. Priority was given to off-grid properties, users on rural electricity rates, and electrically heated areas. Consequently, funded projects were either off-grid or located in areas where electricity is generated by diesel generators. These solar cells help reduce oil consumption and greenhouse gas emissions, aligning with governmental energy policies.

Of the 90 applicants, 29 received an approved grant, which makes the total amount of grants 26 million ISK.

By the end of 2025, eleven recipients had completed their installations and received funding. Three applicants cancelled their construction and therefore declined the grant. Six grantees have already started construction and installation of equipment and expect to complete the grant in the spring of 2026. Nine grantees aim to start their construction in the spring of 2026. Many of these projects are in very remote areas, where transporting equipment or securing tradespeople can be challenging.

Due to the success of the solar energy grant, work has now begun defining how solar energy systems can be included as an eligible cost for those who have already applied for a grant for a heat pump. These grants are available only to residents in areas with direct electric heating, where the state already subsidizes electricity costs for home heating. However, a key requirement is that the state must gain a net benefit from improved energy efficiency.

### Monitoring data from applicants

It was not originally intended to monitor data from all of those who received solar cell recipients. However, the grantees have signed agreements permitting data request once the solar panels have been installed for each project.

To give insight into the projects that received funding, information from six projects in different parts of the country has been compiled. Projects have also been chosen where there are different levels of utilization of housing, everything from a large cow farm to small summer house.

Since it has not been long since the grantees began producing solar energy, it is not possible to publish reliable and comparable production figures. However, information on estimated annual production has been compiled based on the available assumptions.

The production criteria used for calculations are obtained from the actual production of solar energy in Grímsey, which is the northernmost part of Iceland. There is a 10-kW solar power plant that faces south and the average annual production there has been 9000 kWh per year, and therefore the criterion of 900 kW for each installed kilowatt has been used for the calculation on estimated annual production.

For the cow farm where the solar cells face west and east, the estimated production figures that the applicant provided in the grant application are used.

| Project name | Direction | Usage of the premises | System size in kW | Estimated annual production kWh | Decarbonization kg $CO_2$ íg |
|---|---|---|---|---|---|
| **Garður** | West/East | Farm | 43,5 | 12.400 | 29.363 |
| **Illugastaðir** | South | Summer house | 3,0 | 2.700 | 2.025 |
| **Akureyjar** | South | Eiderdown production | 1,22 | 1.098 | 824 |
| **Arney** | South | Eiderdown production | 10 | 9.000 | 6.750 |
| **Binnulundur** | South | Studio for art therapy | 3,3 | 2.970 | 2.228 |
| **Siglunes** | South | Summer house | 1.74 | 1.566 | 1.175 |

## Information from the beneficiary

### Garður

The project was about producing solar energy on the farm Garði in Eyjafjarðasveit. In 2007 a barn was built on the farm with milking and feeding robots. Today, the farm maintains around 150 dairy cows, 150 bulls for meat production and 150 calves and heifers in rearing. The farm's electricity consumption is around 340,000 kWh per year. The farm also operates an oil-powered backup generator, which is used during power outages or when maintenance work is carried out on the electrical system.

The solar energy system consists of 43.5 kW of installed power or 48 light panels that are located on the roof surfaces of outdoor buildings.  Annual production is estimated at 12,400 kWh.

This system enables the residents to generate a portion of their own electricity on site for direct consumption. In addition, on-site production and storage reduce reliance on the backup generator, as solar energy can partially replace its function. This leads to lower fossil fuel use and contributes to reduced emissions.

*Figure 5 Solar energy system in a large cow farm in Eyjarfjörður.*

### Illugastaðir

Summer house association K-21 applied for a grant for installation of solar energy processing for a summer house complex near Illugastaðir in Skálmafjörður in the Westfjords. The area is not connected to the electricity distribution system, and it is not considered feasible to invest in that project under the current conditions due to the high costs. Electricity demand in the area has increased significantly with the arrival of electric vehicles, making solar energy a suitable alternative, especially since usage is highest between April and October.

A 3.0 kW system was installed, mounted on a tiltable frame. The system has been very well received by the K-21 association and has enabled substantial modernization of the site. It has also significantly reduced the use of LPG gas, which was previously the main energy source at Illugastaðir.

*Figure 6 Solar energy system for a summer house complex in Illugastaðir.*

## Akureyjar

Akureyrjar is an island in Breiðarfjörður where there is an eider nest and collected eider down. The island is off grid and has been using a three-phase, 80 Hz, 20 KW diesel generator as their main energy source. It consumed 2.7-3 liters of oil per hour. It took at least 30 l. per day and up to 65-70 l if it was running for 24 hours.

A letter from a beneficiary when UOS reached out to hear how things are going:

*"The solar cell system was installed in the summer of 2025 along with a Websco heating system on both floors, which uses approx. 3 l of oil per day, with solar cell electricity. The solar cells are connected to 220 W battery and are perfectly sufficient for the freezer, the refrigerator, the heat (a mixture of solar cells and oil), TV, coffee machine, toaster, light in the rooms and charging rooms for computers and phones.*

*The charge on the lithium battery went down to approx. 65-70% at night, but then went up immediately, when the light or the diesel generator was starting. It is enough to run it for about ½ hour to get the tank up to 100% energy.*

The main challenge now is pumping and heating water, which remains unresolved. The diesel generator is still needed for that purpose.

*Some days we didn't turn on the diesel generator at all, as water had been collected in tanks and then the solar cell electricity was enough for all our needs, when few people were there.*

*Given that this new solar cell system has exceeded expectations, we are determined to solve this with water, either with more solar panels, or a water pump with less electricity. The main problem is that the pump takes so much to start.*

*Before, we were using an average of approx. 40-50 l of oil per day, but now we are down to 3-4 l for the Websco heaters, and 2 l for the diesel generator, or approx. 6 l in total. Besides the luxury of having the refrigerator always running, and no worries about the freezer, and then when the diesel generator starts up, the old house electricity takes over* *completely automatically, without human intervention and without conflict because the gadgets don't have to be run from scratch.*

*This is just pure genius.*

*Regards Lilja"*

*Figure 7 Solar energy system for small work facilities on the small island of Akureyjar in Breiðarfjörður, where there is a collection of eiderdowns.*

## Arney

Arney is an island in Breiðarfjörður where there is an eider nest and collected eider down. The island has historically relied on a diesel generator as its sole energy source, consuming around 70 liters per 24 hours—or approximately 26,000 liters per year under full operation. The owners therefore sought to transition to a hybrid system using both solar and wind energy, as solar production is not available from November to February. During periods when neither wind nor sunlight is sufficient, the diesel generator will charge the batteries, though the goal is to minimize its use as much as possible.

A letter from a beneficiary when UOS reached out to hear how things are going:

*"I am sending you with this mail pictures of the production of electricity in Arney, which has been very successful, the diesel generator has not had to produce electricity since the beginning of June and thus has not been polluting the environment."*

*Greetings from Stykkishólmur*

*Guðbrandur Björgvinsson"*

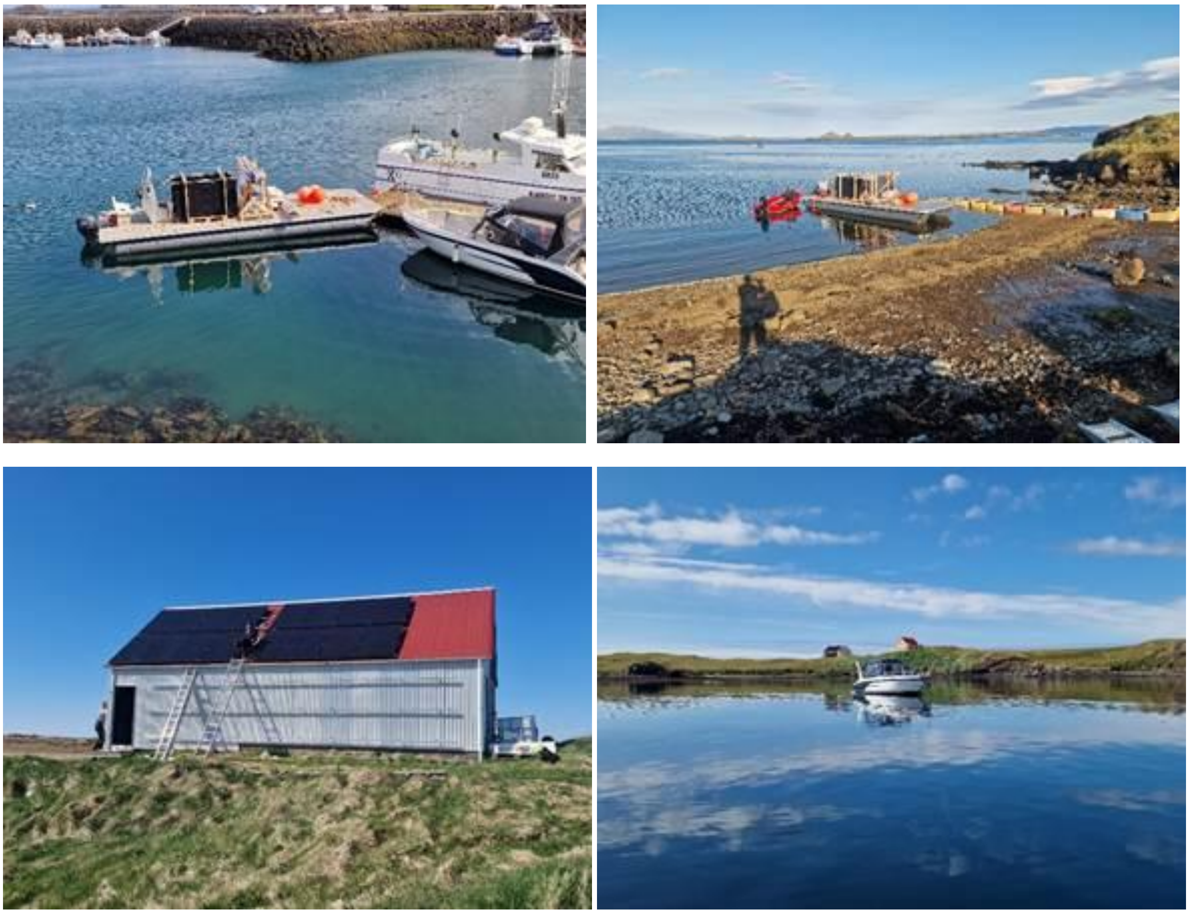


*Figure 8 Solar energy system for work facilities on the island of Arney in Breiðarfjörður, where there is a collection of eiderdowns.*

### Binnulundur Eyvindará

Binnulundur is a residence located 5 km from Egilsstaðir, intended to serve as a studio for art therapy. The natural surroundings make the location ideal for such activities. The site is not connected to the electricity grid; although a cottage has been installed and prepared for use, the nearest electrical cabinet is too far away, and the cost of applying for a transformer from the utility is inefficient.

The size of the system and the arrangement of the equipment is suitable for the energy needs of the activity, such as lighting, electric heating at a small 400w oil pan, links for coffee machine, low energy water pump and necessary tools.

A letter from a beneficiary when UOS reached out to hear how things are going:

*"After the installation of the system this summer, it has been fun to monitor the production, but I have been getting to know this new possibility in electricity production. To recap, I have 6x 550W solar panels, a 5.2kWh battery and about a 5kW inverter with a built-in controller.*

*This summer I was trying to adjust the usage so that the battery didn't fill up because then the production dropped, as the cells don't produce if there is no place for energy.*

*I therefore had a powerful electric heater of 1.6 kW which I could put in remotely when the sun was shining and the output was far above normal use (lights, radio, mini fridge, general links). The roof is about 9° but optimal position for solar energy production would be about 42°. Large trees stood close to the house and shaded the cells, so we mostly took them down last summer.*

*Regards Emil Kristófer Sævarsson"*

## Siglunes Siglufirði

This project concerns a small summer house in Sigulufjörður, a fjord in the northwest part of Iceland. The land was previously wasteland and therefore not connected to the electricity distribution system. A summer house complex is being developed in the area, and the owners therefore want to set up environmentally friendly energy infrastructure for future development on the site.  Sigules 3 is a small log cabin that was transported to the location. To initiate the development of sustainable energy solutions in the area, the owners applied for a grant to install a small solar system that could serve as a model for the next houses to be built. Because the building is small, only four 435 W solar panels were installed, along with control equipment and batteries. The system has a total capacity of 1.74 kW.

*Figure 10 Solar energy system at the summer house Siglunes 3 at Sigulufjörður.*

## Evaluating climate and energy goals

- Experience of Solar energy uses in arctic regions in Iceland.
- Experience of Solar energy as technology and building knowledge in the region.
- Development in guidelines regarding installing and connecting energy from solar panel to the grid.
- Implement the solar energy grant in the existing electric heating support scheme.

## Conclusions:

The solar energy pilot project highlights both the opportunities and challenges of implementing renewable energy solutions in Arctic regions. While direct integration into the electricity grid remains unfeasible, the initiative demonstrates the benefits of local energy consumption, reducing reliance on fossil fuels, lowering emissions, and improving energy security. The competitive grant scheme has successfully incentivized solar adoption, particularly in off-grid and diesel-dependent areas, aligning with national energy transition goals.

The project also underscores the importance of hybrid energy solutions, as solar alone cannot meet year-round energy needs in high-latitude environments.

## Chapter 5 Comparison between Hybes pilots on solar and conclusions

### Introduction:

In this study of solar energy in Arctic areas we have learned and gained experience from pilots representing a variety of different building types. From sizeable public buildings in Bodø, and social and private rental houses in Cork to off-grid buildings in Western Iceland. Furthermore, the Icelandic case shows the implementation of a solar energy strategy for the Icelandic energy system. Task as standardization of instructions for PV installations into the grid, strengthen vocational education to support capacity building and competence on solar installation, a grant and incentive program to promote and scale up solar as flexible renewable strategy nationally, has promoted a process for a. road map for solar energy in Iceland for the year 2030.

All Hybes pilots has documented that Solar energy and PV installations are an efficient energy carrier in Arctic regions as Bodø in Northern Norway, Cork in West Ireland and Northwest regions of Iceland. Pilots have demonstrated that solar contributes substantially to reducing $CO_2$ emissions and that it's a profitable investment to install and use solar as a renewable energy solution.

To document effects of implemented Solar energy installations its important gets valid baseline data and to calculate a pre and post situation. Hybes pilots in Bodø have been monitored for three years, Cork Pilot for one year and for the Icelandic pilots we only use estimated calculations because the installations of solar installations were done late in Hybes project. Monitoring energy data is important not only to document effects. In general, we might conclude that continuous monitoring of energy data is important to achieve high degree of energy efficiency and to guide both private and public owners of solar installations to obtain good performance of installed Renewable Energy Systems.

### Conclusions Bodø Pilots

Energy data from Mørkvedbukta School and kindergarten shows that total energy consumption decreases during monitoring period and consumptions in 2024 was 38768 kWh less than expected. This due to good energy management and optimalization of the energy system. The Solar production approach expected production level in 2024 with 57242 kWh. Total energy production from solar as part of total energy use was 11,54 %. Hybrid energy solutions, like solar, cannot meet year-round energy needs in high-latitude environments, but together with installed geothermal energy systems nearly half of energy consumption is covered. Solar energy contributes to making the building more sustainable, making it less dependable of grid and lower energy class beyond passive house standard. The contribution to climate goals and $CO_2$ emissions vary depending on which convert factor is used. If we only look at emission in a locale context Mørkvedbukta school contributes with 1,030 ton$CO_2$e less emissions, but if we the reference is a broader integrated European energy context the solar production at this building contributes to lower $CO_2$ emission with 7,555 ton$CO_2$e. In a cost perspective investment in pays within the lifetime of solar installation of 30 years. Considering receiving subsidy for installing solar energy the investment pays within approximate 20 years

After a deep retrofit combined with installing BIPV façades, the energy standard measure of the Rehabilitation building has improved to nearly passive houser standard with 131 kWh/m2. This achievement is mainly due to retrofit tasks that dramatically has reduce energy consumption. Compared with baseline numbers for total energy use for 2023 shows a reduction of 25.6% and for 2024 a reduction of 27,3%. Energy data shows that approximately half of energy use is derived from grid and half from district heating.

The production of energy from BIPV installations plays a minor role because of the modest size of these. Our monitoring data also shows that compared with the calculated baseline the production has not reach expected level. Numbers are approximately 40 % less than estimated on 21277 kWh. The maximum production per hour since the solar panels were installed has been 27 kWh/h, accounting for 39 % of theoretical peak capacity. However, with solar panels divided over the two facades, production is not expected to meet the theoretical peak capacity, considering this a fair, but not high utilization of peak capacity.

The main experience with BIPV installations is that this technology is most efficient when solar radiation is horizontal. In arctic Bodø this is the fact in spring period and in the midnight sun month of July. Even at minus temperature BIPV has high efficiency. These patterns go quite well, with significant production in a large part of the consumption period.

Even with the modest solar production produced at Rehabilitation building, the contribution to reducing CO2 emissions still is substantial with a reduction of approximately 2.8 tonCO2e. The reference to Life Cycle Cost analysis made we finds that the energy efficient task implemented for Rehabilitations building at least will be cost neutral.

### Comparison between technologies

The solar installations on the two pilot buildings in Bodø are set up in quite different ways. It is not easy to compare the two pilots directly, but looking at each of them compared to the other gives some insight into how the different setups perform over the year and day. The table below summarizes properties and performance of the two pilots.

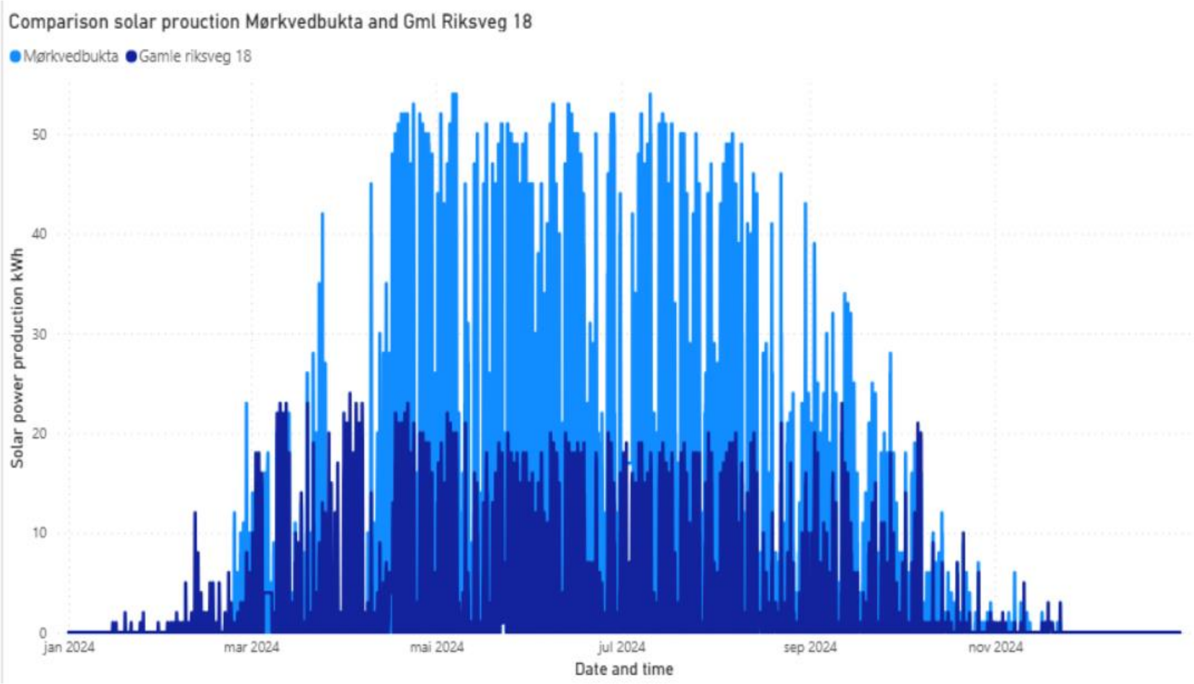
Table 1

| | **Mørkvedbukta school** | **Rehabilitation building Gml.Rv.18** |
|---|---|---|
| Area Solar panels installed (sqm) | 589 | 374 |
| Estimated production kWh/y | 60 000 – 70 000 | 37 200 |
| Measured production kWh | 57 242 | 21 277 |
| **Measured production kWh/sqm** | **8,1** | **3,0** |
| **Share of estimated production** | **88 %** | **57 %** |
| Estimated peak production kWh/h | 100 | 70 |
| Measured peak production kWh/h | 54 | 27 |
| **Share of estimated peak production** | **54%** | **39%** |
| **When is production high** | **May-July** | **March-April** |

In terms of yearly production, peak production and how well the system perform compared to estimated, the installation at Mørkvedbukta show higher performance on all. As can be seen in the graph below, showing solar production per hour in 2024, the production at the rehab building starts production early in the spring, and does not go higher during the summer, even though the number of hours and days with sun keeps increasing. Mørkvedbukta's solar installation has increasing production throughout the spring, with high production during all summer – following more the weather and hours of sun. This makes the Mørkved installation give high production over the year, with the majority produced in the summer.

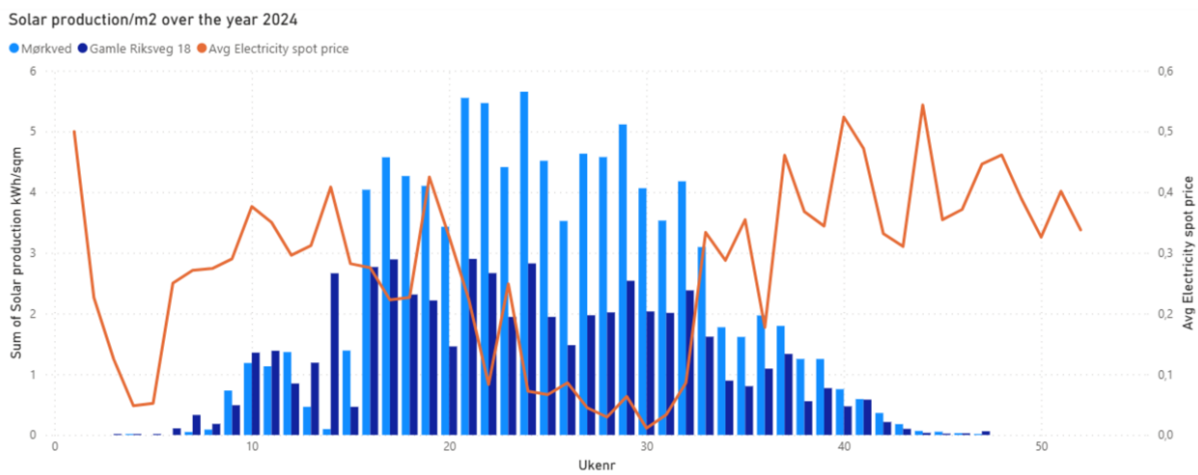
Figure 1:

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



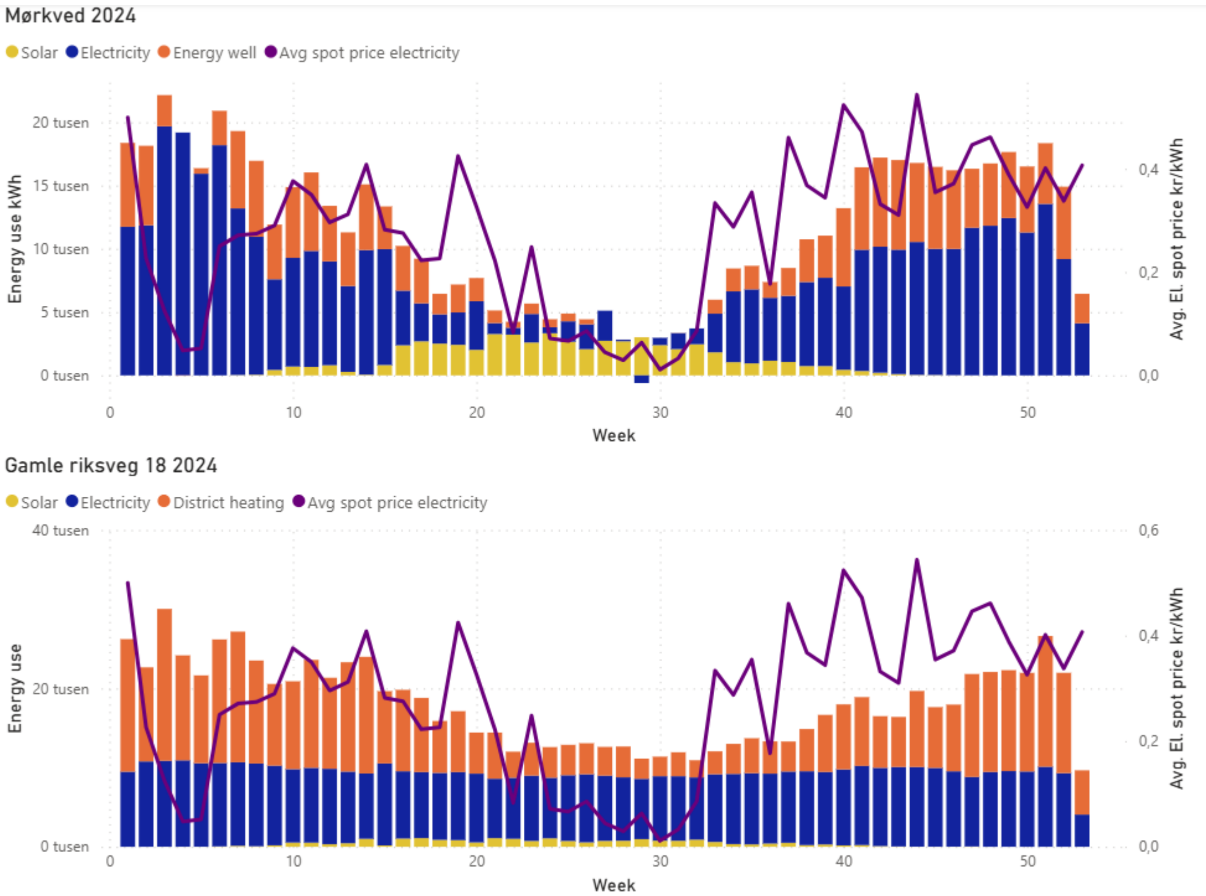

When taking the energy consumption over the year into account the solar production can be compared with how much energy is needed. The figure below shows the solar production at the two pilots in the same figure as a graph showing the average electricity spot price per week. It shows that the energy prices are generally highest in the winter months, with lower prices in the summer. The energy price correlates to a large degree with consumption. Production early and late in the year can therefore be seen as high value production. The production during the summer, when the Mørkvedbukta installation has the highest production, is also the time when the production is least "needed".

Figure 2:




Below are also graphs showing how much the solar installations contribute with in each of the pilots. At Mørkvedbukta solar energy make up a significant share of the total energy need during the summer, while the rehabilitation building gets a small share of the electricity covered by the solar production. During second and third quarter of 2024, solar energy production made up 30% of the total energy consumption at Mørkved, and 5% at the rehabilitation building (9 % and 2 % over the year). Mørkved had close to 500 hours of solar export in 2024, while the Rehab building only close to no export in 2024. This shows that the dimension of the solar installations is very different, where the Mørkvedbukta installation is dimensioned to cover much of the energy use in the summer, while the installation at the rehabilitation building is dimensioned to only contribute with some energy.

Figure 3:

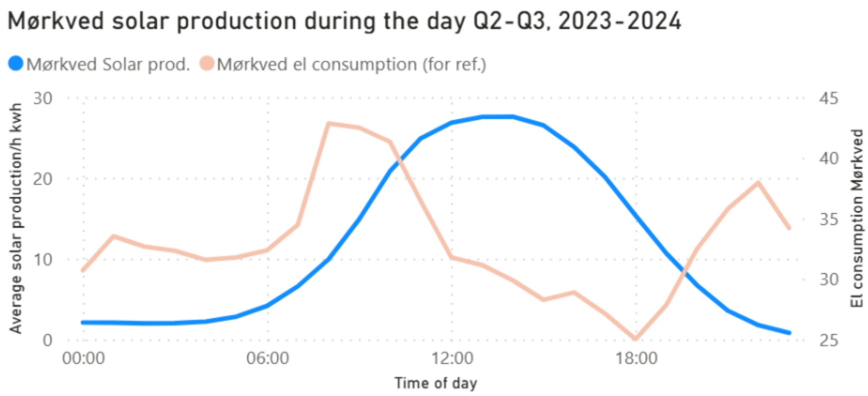


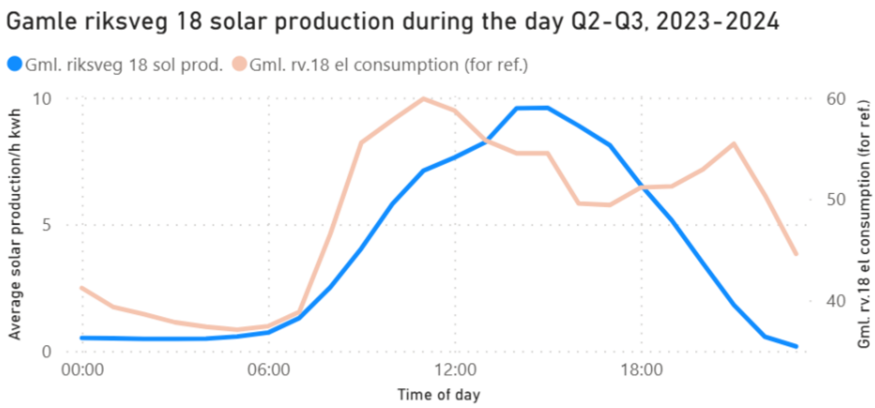
Looking closer into the energy production compared to consumption during the day also vary depending on how the solar installation is set up. The figures below show the consumption and production in the two buildings, showing that peak consumption happens a few hours before the solar production peaks, but also meeting the demand well, especially at the rehabilitation building. This is relevant when designing the solar installation – especially if the installation is dimensioned to cover a large share of the energy consumption.

In the case of Mørkvedbukta this information shows that it could for example show that the production could meet the demand better if the roof panels were directed more towards the early sun; that it could be relevant to investigate possibilities to decrease the consumption peak and even more out to later in the day; or consider the use of a battery to make it possible to delay the use of the solar production.

At the rehabilitation building we know that there are very few hours of higher production than consumption during the year, and that all the solar power is consumed momentarily. Measures like the ones suggested above will therefore be less relevant in the rehabilitation building and would only be worth considering with larger scale solar installation. ¤

Figure 4:




These analysis shows that the design of the solar installation matters how the production performs during the year and day. It is important to have a good understanding of the energy consumption of the building and consider the purpose of the solar panels when planning a solar installation, to make it meet the demand as good as possible. The data from the two pilot buildings in Bodø can be useful learning examples for future planning of new solar installations.

## Conclusions Cork Pilot

The point of departure of Cork pilot is to show the potential of energy efficiency tasks and the use of flexible renewable energy systems (RES), in resident houses with low medium to low energy ratings. About 60% of Irish houses is within this category and most Irish houses have fossil-based heating systems. This shows the potential of this study. The Cork pilot: 6 the Grove, Fermoy in Cork, illustrates a case combining retrofitting with the substitution of a fossil fuel-based oil heating system.

The flexible RES system consisted of 10 PV roof panels including a battery storage entity of 5 kW and an immersion heater to store energy in the form of hot water. The Pilot was built in 2003 and has a floor area is 91.79 $m^2$. The included storage function makes this pilot different the two Norwegian pilots.

The energy data shows also in the Cork pilot promising results using solar as a flexible energy carrier. Table 2 shows an estimated reduction in power use of 46,8 % after retrofit and installation of the flexible RES installations.

Table 2

| | Power use kWh/m$^2$ | Power use for Pilot |
|---|---|---|
| Before energy task | 235,26 | 21594,5 |
| After energy task | 125,23 | 11494,9 |
| Estimated reduction | 46,8% | 10099,6 |

Furthermore, $CO_2$ emissions were estimated to be halved, with a reduction of 2,227 ton$CO_2$e as show in the table below.

Table 3

| | Emissions kg$CO_2$/m$^2$/yr | Emissions for Pilot 91,79 m$^2$ |
|---|---|---|
| Before energy task | 49,29 | 4524,33 |
| After energy task | 25,03 | 2297,50 |
| Estimated reduction | 49,22% | 2226,83 |

Compared with accurate monitoring data for 2024 this picture is confirmed even though the reduction in net power consumption is insignificantly higher than the estimated numbers. Monitoring data as shown in tables below. The energy rating of 130,3 kWh/m$^2$/yr still represents a building energy rating in the upper end of B3 (Table 4).

Table 4

| Import from grid | Power production from solar | Net power consumption | Energy rating |
|---|---|---|---|
| 15765 kWh/yr | 3809 kWh/yr | 11956 kWh/yr | 130,3 kWh/m$^2$/yr |

Table 5

| | Net power consumption | Reduction in power consumption | Energy rating |
|---|---|---|---|
| Estimated | 11495 kWh/yr | 46,8% | 125,2 kWh/m2/yr |
| Monitored | 11956 kWh/yr | 44,6% | 130,3 kWh/m2/yr |

The solar installations contribute a substantial part and reduce power consumption from the grid with 22,7% (Table 6).

Table 6

| | |
|---|---|
| Power production from solar | 3809 kWh/yr |
| Brutto consumption of power | 16807 kWh/yr |
| Solar production as share of Brutto consumption | 22,7 % |

Even in mid-winter period energy production from the PV system is satisfactory. Data for two days in February 2024 shows that solar energy produces about 1/5 of energy consumption. In summer the PV system almost produced enough energy to cover heating and hot water consumption. In a cost perspective this customer had very small bills, sometimes receiving positive bills, in the summer

As we notice from the Rehabilitation pilot building in Bodø retrofit also in the Cork case contributes significantly and slightly more than solar installations with a reduction in power use of 4787 kWh/yr. (Total power before energy tasks – Total power after energy tasks Table 6)

Table 6

| Net import from grid | Solar production | Total power consumption after energy tasks | Total power consumption before energy tasks |
|---|---|---|---|
| 12998 kWh/yr | 3809 kWh/yr | 16807 kWh/yr | 21594 kWh/yr |

One of the essential lessons from the Cork pilot was that monitoring energy consumption of the pilots made it possible for Carbery Housing Association (CHA):

- To ensure the effective operation of the generation, storage and energy use systems.
- To better manage the inputs and outputs
- To better advise residents on better energy management and thus help the tenants fine-tune their storage heaters.
- To validate the cost benefit value of the system

EU funding made this flexible PV system a cost-effective installation replacing and substitution the fossil fuel-based heating system. Also, for the household the shift in energy system resulted in affordable energy bills for owners and tenants.

In the future with still more electricity use these Flexible RES systems with storage capacity will provide a necessary relief of grid and avoid destabilizing grid infrastructure. The decentralized and localized distribution system will be ideal for offsetting peaks.

## Conclusions Iceland

The **Icelandic** Environment and Energy Agency (UOS) considered the HYBES project an ideal starting point for Iceland's solar energy journey. This strategy has targeted the following issues:

- The need to strengthen vocational education to support the installation of solar
- The need to develop standardized instructions for PV installations
- The need for unified guidelines for integrating PV systems into the grid. That is guidelines for private use or for selling surplus power back to the grid

The environmental and energy agency therefore focused on developing a clearer and more coherent roadmap for installing PV systems, available to both private homeowners to large-scale energy producers. Hybes activities have addressed bottlenecks in PV adoption, created structured educational pathways, and has clarified regulatory processes to develop a road map for solar energy in Iceland for the year 2030.

As part of the educational focus a two-semester curriculum program is developed and solar pilot at a technical school has been set up. A 100 square meter classroom where all the energy is obtained from solar cells and a small windmill is used for educational purposes.

At Grímsey, North-western part of Iceland, UOS has established solar pilot. A 10-kW solar power plant facing south demonstrates under optimal conditions a production capacity of 9000 kWh per year. Based on experience from this pilot a grant program for solar panel installations is launched in October 2024. Priority was given to off-grid properties.

While direct integration into the electricity grid remains unfeasible, the initiative demonstrates the benefits of local energy consumption, reducing reliance on fossil fuels, lowering emissions, and improving energy security. The competitive grant scheme has successfully incentivized solar adoption, particularly in off-grid and diesel-dependent areas, aligning with national energy transition goals.

29 projects have received an approved grant. Many of these projects are in very remote areas. Projects have also been chosen where there are different levels of utilization of housing, everything from a large cow farm to small summer house.

### Lessons learned

- The solar energy pilot project highlights both the opportunities and challenges of implementing renewable energy solutions in Arctic regions. While direct integration into the electricity grid remains unfeasible, the initiative demonstrates the benefits of local energy consumption, reducing reliance on fossil fuels, lowering emissions, and improving energy security. The competitive grant scheme has successfully incentivized solar adoption, particularly in off-grid and diesel-dependent areas, aligning with national energy transition goals.

- The project also underscores the importance of hybrid energy solutions, as solar alone cannot meet year-round energy needs in high-latitude environments.

## Main conclusion and lessons from all Hybes pilots

Hybes pilots' documents that the use of Solar energy in buildings are both energy and cost efficient. However, compared between Hybes pilots' Solar energy are even more efficient and profitable in Cork than in Bodø and Grimsey. This because solar radiation in Cork makes it possible to produce 50 % more solar energy than in the two other arctic district and because energy cost is more than twice in Cork than in Norway and Iceland.

All our pilots shows that solar energy is most efficient if storage is integrated. Mørkvedbukta school don't have this possibility, and one conclusion is that a thermos geothermal system would have allowed storage. In future Bodø municipality want to explore this option.

For private household it's important that a battery storages system is easy to manage. Cork pilots have experience that this can be a bottleneck. Therefore, some support systems are needed.

Comparison between PV technologies from Bodø pilots shows that BIPV systems fits better to energy consumptions patterns for the building, and is most efficient in

- Solar energy is an important energy carrier to increase energy safety in cities. Solar will reduce problems in peak period with maximum energy consumptions and avoid heavy investment in grid infrastructure.
- The Icelandic case shows the in remote and off-grid district and places solar energy are essential for electrification, business development and decarbonification.
- In all pilots funding was essential for implementation of solar installations.
- Cork has up to 50 % more effect than in arctics areas in northern Norway and Iceland

## Recommendations

1. To document effects of implementing Solar energy installations its important gets valid baseline data and calculate a pre and post situation.
2. Continuous monitoring of energy data is important to achieve high energy efficiency and to guide both private and public owners of solar installations to obtain good performance of installed Renewable Energy Systems.
3. To achieve most efficient and flexible use of solar energy it's important to integrate storage systems either with batteries or solar installations combined with thermos energy wells.
4. To scale up flexible Solar energy installations is decisive to ease grid capacity and overexert grid infrastructure. This is needed to limit future expanding investments in regional grid infrastructure.
5. Hybes pilots shows that flexible solar energy solutions are recommendable because these solutions are cost effective and reduce $CO_2$ emissions contribution to regional and national climate goals.
6. Compared between Hybes pilots' Solar energy are even more profitable in Cork (Ireland) than in Bodø (Northern Norway) and Grimsey (Northwest of Iceland). This because Cork (Ireland) solar power production is 50 % higher than in the two other arctic district and energy cost is more than twice in Cork than in Norway and Iceland.
7. The comparation between the two technologies top roof PV installations versus building integrated PV installations shows that top roof installations have highest energy production, but that BIPV systems fits better to energy consumptions patterns of buildings, because this technology has high effect in spring and

autumn period. A combination of these two technologies therefor is recommendable.

8. The Icelandic case shows the in remote and off-grid district and places solar energy are essential for electrification, business development and decarbonization.
9. Regulation encouraging instruments as instructions, increase educational capacity and competence and grant program is necessary when addressing bottlenecks in PV implementation and scale up.

## Transnational Learning

1. Analysis of actual energy pilot across different arctic areas though monitoring, is essential to shape target transnational learning.
2. Cross regional energy pilots give the possibility of more targeted policy recommendations enabling cost effective, climate efficient and regional sustainable solutions.