ZEB Project report 33– 2017

Åse Lekang Sørensen, Inger Andresen, Torhildur Kristjansdottir,
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ZEB pilot house Larvik
As Built Report

The Research Centre on
Zero Emission Buildings

SINTEF Academic Press

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Abstract

This report describes the ZEB pilot house Larvik, which was constructed during the autumn 2014. The ZEB pilot house is a two-storey single-family residential building situated near Larvik, Norway. The building was designed by Snøhetta, Brødrene Dahl, and Optimera for demonstration purposes, to show-case and test energy solutions for energy-efficient and plus-energy buildings.

The report describes the building design and major design choices, the building services, the energy supply system and estimated energy need and delivered energy, the operational energy performance, the greenhouse gas (GHG) emissions from materials, as well as the ZEB balance. Further, the report presents information about the indoor climate performance, the design and construction processes, and information about costs.

The ambition level of the building was ZEB-OM, which means that all GHG emissions related to all operational energy use (O) plus embodied emissions from the materials and technical installations (M) are to be compensated for by on-site renewable energy generation. In addition, the building should supply enough energy for an electric car.

An interdisciplinary project team has been involved in the design and construction process. Research was made to reduce the emissions from construction materials, as well as to investigate their ability to contribute to a good indoor climate. A number of active and passive energy measures are demonstrated in the residence. Lessons learned from the project can be helpful for other building projects with ambitious goals.

The energy generation system is based on roof mounted photovoltaic modules for electricity and a combination of different heat sources for thermal energy: a ground-source-to-water heat pump, an air-to-water heat pump in the exhaust of the ventilation shaft, a solar collector system, and two different grey water heat recovery systems.

The calculations show a net energy need for the building of 17,348 kWh per year, or 86.1 kWh/m^2 of heated floor area. The demand for *delivered* energy is reduced due to the different heat sources for thermal energy. The remaining demand for delivered energy was calculated to 7,142 kWh electricity per year, or 35.4 kWh/m^2. The calculated production from the photovoltaic system is in total 19,200 kWh per year.

The GHG emissions are calculated to be 2,650 kg$CO_{2\,eq}$ per year over a 60-year lifetime, or approximately 13.2 kg$CO_{2\,eq}$/m^2 per year. It is estimated that 36 % of emissions come from operational energy use (B6), while 52 % of emissions come from building materials and replacements (A1-3+B4). 12 % of emissions are connected to the use of the electric car.

The calculated emission balance gives a close margin on the ZEB-OM ambition for the ZEB-pilot house Larvik, but not when including 12,000 km with the electric car. Reducing the use of the electric car to 7,600 km gives a balance in the calculated emissions, given the described conditions. The approach is sensitive to methodology for material emission accounting and the choice of electricity emission factors for the import and export of electricity.

Contents

1. Introduction

The ZEB pilot house Larvik is a two-storey single-family residential building situated near Larvik, Norway. The house is owned by the technology wholesaler Brødrene Dahl and construction materials wholesaler Optimera, and designed as a demonstration and exhibition house for energy solutions for energy-efficient and plus-energy buildings. The building is intended to accommodate a family of four to five members.

Figure 1.1 The ZEB pilot house Larvik (photo: Brødrene Dahl/Paal-André Schwital)

The ambition level of the building was ZEB-OM, which can be described as follows (Dokka, Sartori et al. 2013)): "Emissions related to all operational energy use (O) plus embodied emissions from the materials and technical installations (M) are to be compensated by on-site renewable energy generation." M refers to emissions from the production phase of the materials and components (initial and estimates for replacement), normalized over a lifetime of 60 years. In addition, the building should also supply enough energy for the family's electric car.

Saint Gobain's Multikomfort concept formed one of the many base parameters for the design (Saint-Gobain 2016). The focus of the concept is both on comfort issues like indoor air quality and daylight, as well as environmental performance. The building combines a number of active and passive measures, as illustrated in Figure 1.2.

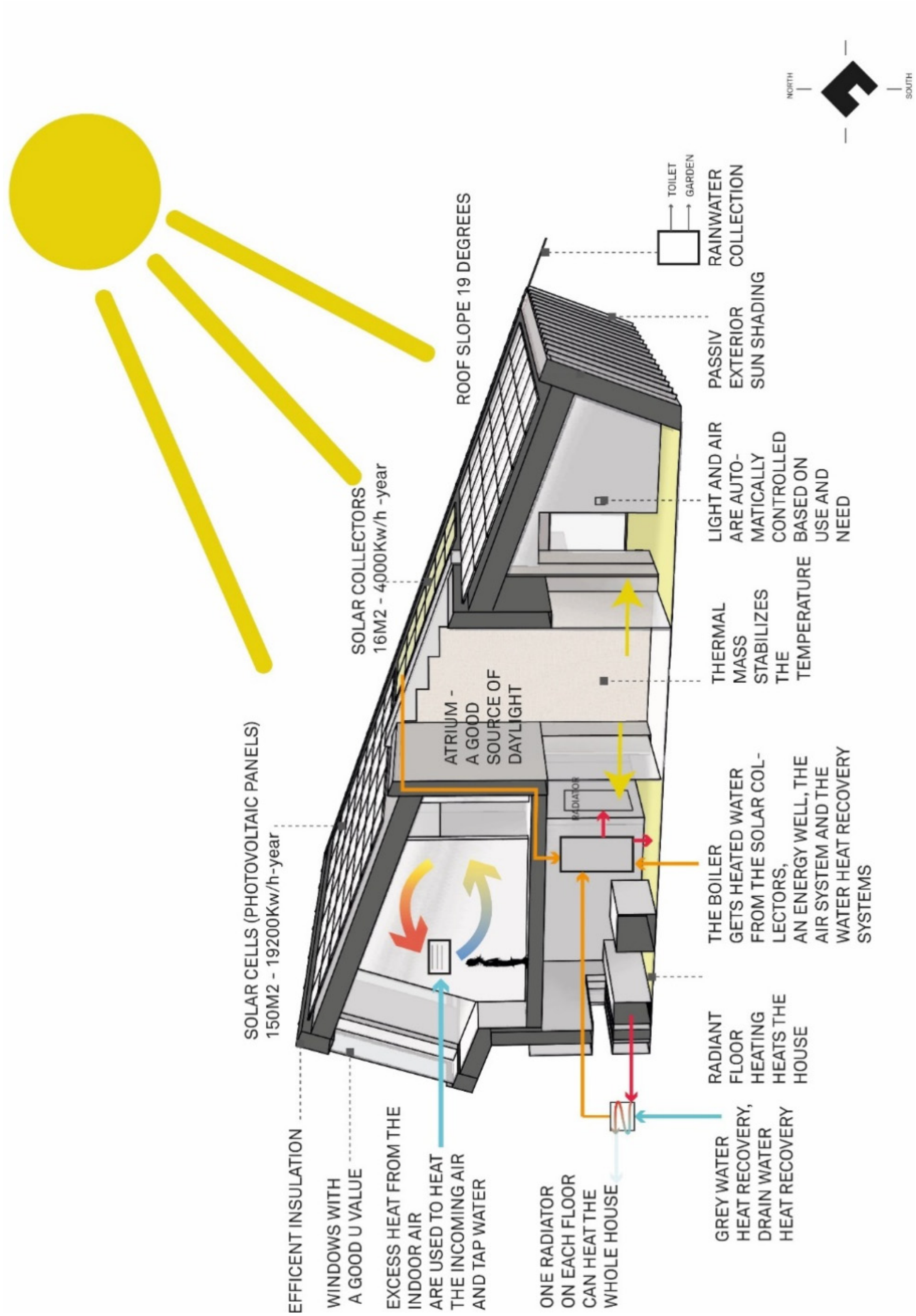


Figure 1.2 Illustration of the building concept for the ZEB pilot house Larvik. Source: Snøhetta.

Table 1.1 Key data for the ZEB pilot house Larvik

Key Data	
Name and address	The ZEB pilot house Larvik ("Multikomfort-house"), Ringdalveien 18, 3270 Larvik, Norway
Location data	Latitude 59°12'N, Longitude 10°15'E. Annual ambient temperature: 7,6 °C, Solar horizontal radiation: app. 950 kWh/m^2/year. Reference Climate: Sandefjord Torp
Building type	Single-family residential building. Residential show case - centre of competence
Heated floor area	201.5 m^2
Project type and ambition level	New construction, ZEB-OM + electric car
Building owners	Brødrene Dahl AS and Optimera AS
Design team	Brødrene Dahl (energy concept), Optimera (building construction), Snøhetta (architect), and the ZEB Research Centre (energy and GHG emissions)
Construction company	Espen Staer AS
Supporting companies	Bergersen Flis, Geberit, Glava, Grohe, Gustavsberg, Ifö, Porgrund, Intra, Lyngson, Nilan, Oras, Oso, Pipelife, Schneider Electric, Uponor, Villeroy&Boch, VPI, Grundfos, Lighthouse Company, Aubo, Barkevik, Bergene Holm, Boen, Elfa, Fischer, Gyproc, Isola, Moelven, Natre, Paslode, Velux and Weber
Design phase / Construction phase	January-June 2013 / September 2013-September 2014
Opening	September 2014

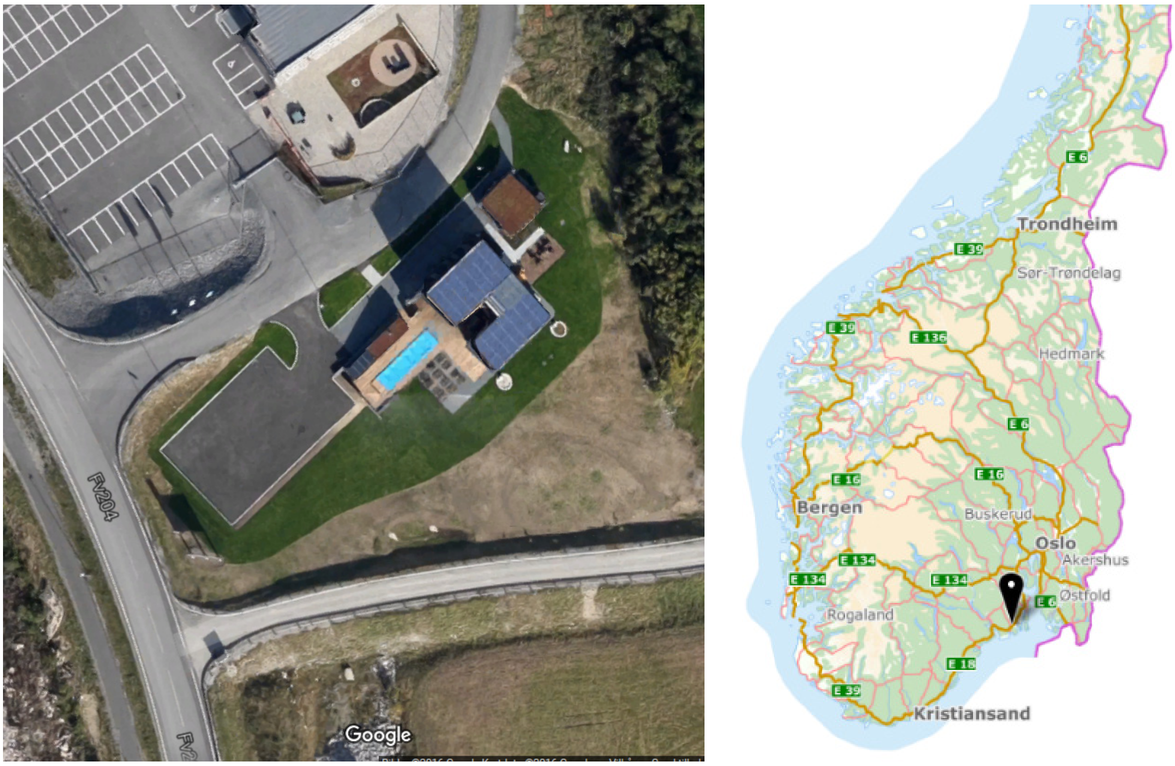


Figure 1.3 Location of the ZEB pilot house Larvik. The building is located beside a Brødrene Dahl warehouse. The parking area is for visitors to the pilot house. Source: Google maps.

2. Building Design

2.1 Final Building design

2.1.1 Building location and form

The building has a 201.5 m^2 heated floor area. The roof has a characteristic slope for solar panels and collectors, where the orientation of the roof is south-east facing with a tilt angle of 19°.

Key dimensions for the ZEB pilot house are listed in Table 2.1.

Figure 2.1 The ZEB pilot house Larvik (photo Snøhetta)

Figure 2.2 Building location. Source: Snøhetta.

Table 2.1 Key dimensions

Roof orientation	-45° (south-east)
Roof tilt	19°
Heated floor area (m^2)	201.5
Facade area (m^2)	229
Glazed area (m^2)	59
Roof area (m^2)	172
Average floor height (m)	3
Gross total volume (m^3)	610

The ZEB-OM ambition has been important when planning and constructing the building. For example, when planning the positions of the windows and choosing construction materials, the focus has been on reducing the overall energy need.

Compared to a traditional house, the building has a large glazing area, which equals about 29% of the heated floor area. The house also has a relatively high surface-area-to-volume ratio due to the special shape of the house. The surface area to volume (A/V) ratio indicates the compactness of the building and has an influence on the overall energy need (Centre de Recherches Isolation de Rantigny 2015). An external surface area of 602.5 m^2 and volume of 610 m^3, gives a surface area to volume (A/V) ratio of 0.99. According to Passivhaus BRE, a favourable compactness ratio is considered to be one where the A/V ratio $\leq 0.7 m^2/m^3$ (McLeod, Mead et al. 2015).

The location of the building is shown in Figure 1.3 and Figure 2.2. The garage is located north of the main building, while store rooms and a swimming pool are located south-west of the building.

The ground floor consists of an entrance, a bathroom, a multi-media room, an office, a living room, and a kitchen. The first floor accommodates a bathroom, a hall, and three bedrooms.

Figure 2.3 to Figure 2.5 show the floor plans of the main building, as well as the carport, store rooms, and swimming pool.

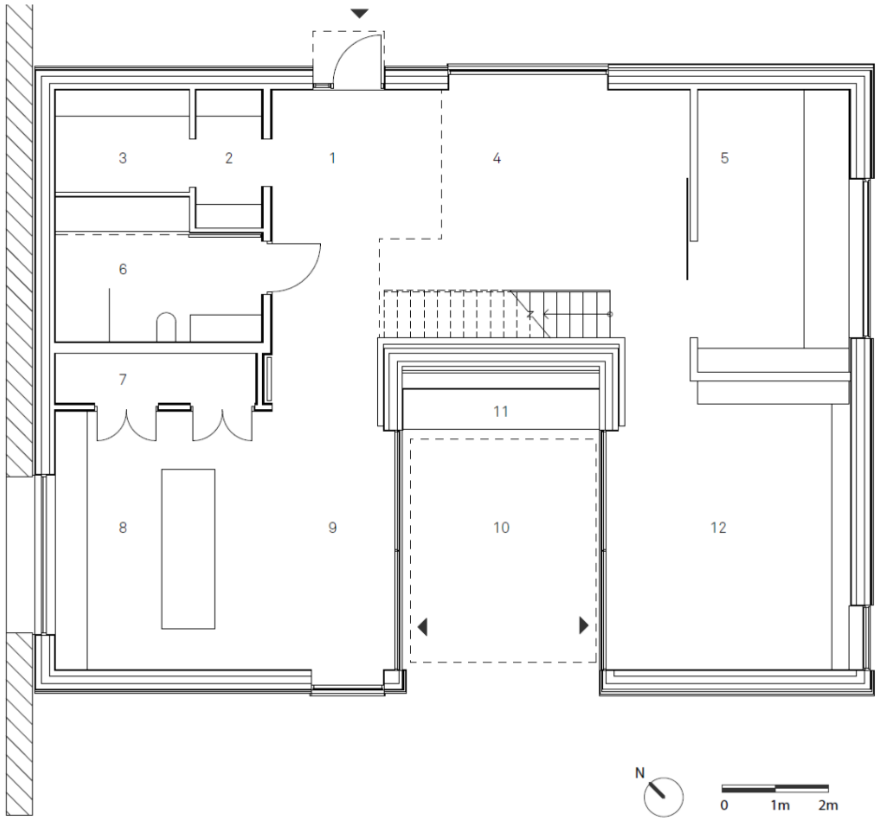


Figure 2.3 Ground floor plan, with entrance (nr. 1), wardrobe (nr. 2), store (nr. 3), multi-media room (nr. 4), office (nr. 5), bathroom (nr. 6), technical room (nr. 7), kitchen (nr. 8), dining room (nr. 9), atrium (nr. 10), fire shelf (nr. 11), lounge (nr. 12). Source: Snøhetta.

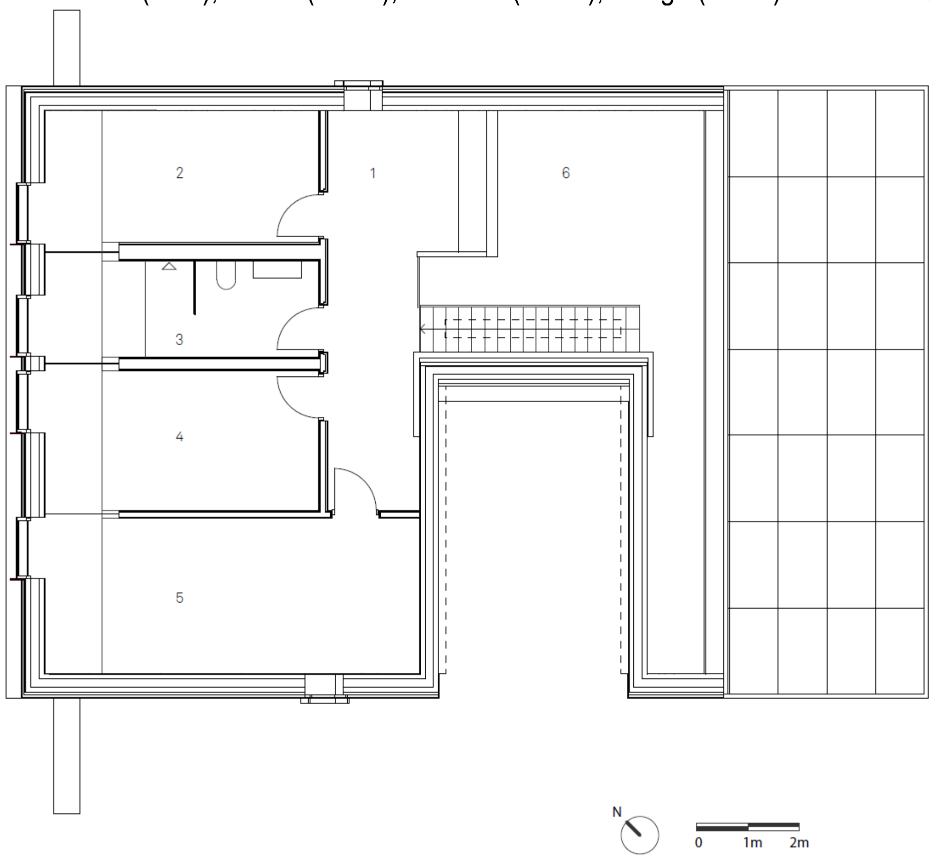


Figure 2.4 First floor plan, with "gallery" (nr. 1), bedrooms (nr. 2, 3, 4), bathroom (nr. 3) and hall / air space (nr. 6). Source: Snøhetta.

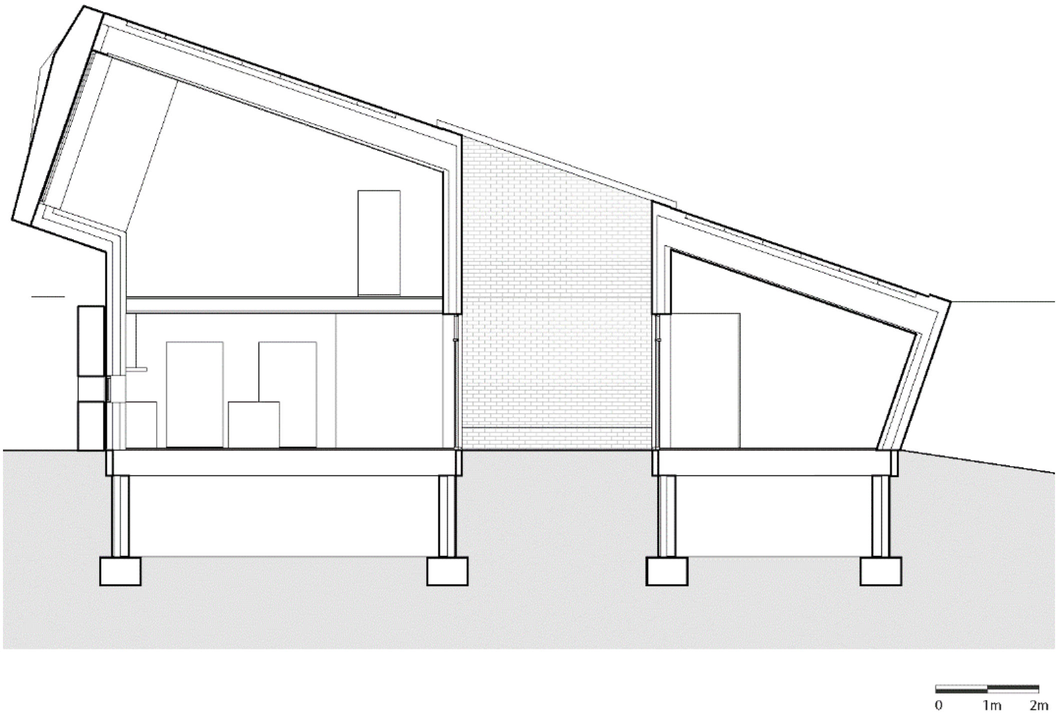


Figure 2.5 Cross section of the ZEB pilot house Larvik. Source: Snøhetta.

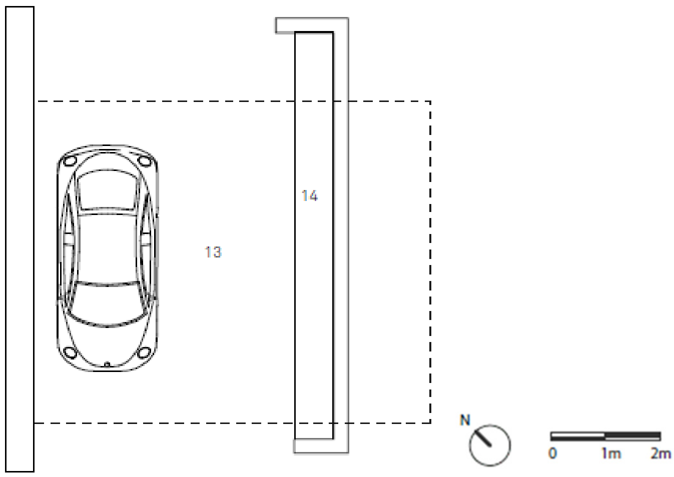


Figure 2.6 Carport with battery bank (nr. 14). Source: Snøhetta.

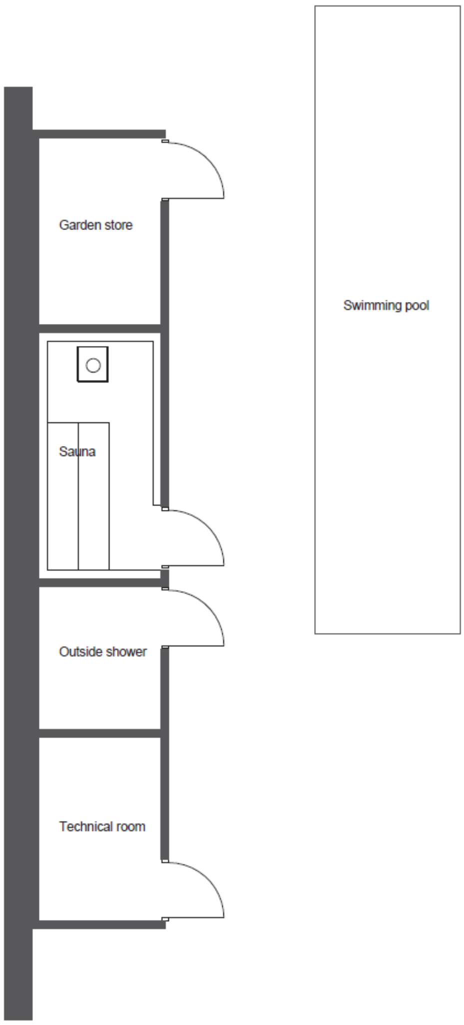


Figure 2.7 The store rooms and a swimming pool. Source: Snøhetta.

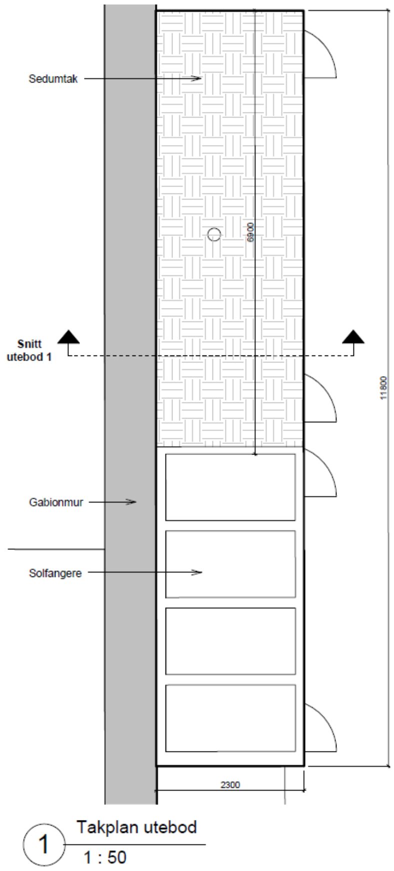


Figure 2.8 The roof of the store rooms with sedum roof and solar collectors. Source: Snøhetta

2.1.2 Building envelope

Research was made to minimize the emissions from construction materials, as well as to investigate their ability to contribute to a good indoor climate.

The building envelope is well insulated and airtight, to reduce the need for heating. The house is designed to avoid the need for energy for cooling. There is solar protection on the bedroom windows, while other windows are placed shaded from the sun.

Figure 2.9 Solar protection on the bedroom windows. Photo: SINTEF Byggforsk.

The material choices of the building envelope are summarized in Table 2.2 to Table 2.5.

Norwegian glue-laminated beams are used in the load bearing structure. The height of the house varies between one and two storeys. There are in total 9 different wall structures (Rosochacki 2014). Reused bricks are used in a centrally located interior wall, giving the wall a thermal mass effect. Stacks of natural stone and timber are used in the exterior facades. The foundation slab is based on a timber and fibre plate construction. A strip foundation was used to minimize the amounts of concrete. In addition, low carbon concrete was used. Low carbon concrete is based on low carbon cement, which is partly based on fly ash substitution for clinker (Norbetong 2012). The light weight frames of the outer walls have timber based load bearing. The exterior walls are well insulated with 350mm of glass wool insulation.

The air leakage number was measured to be 0.60 air changes per hour. The measurements were performed by the company Termograferingsteknikk AS in April 2015, according to NS-EN 13829 (blower door test). The requirement for residential Passive Houses in the Norwegian standard NS 3700 is 0.60 air changes per hour measured at 50 pa under- and overpressure. However, the goal for the project was 0.30 air changes per hour, which is very low.

Different combinations of reflective films were tested on the ground, under the insulated floor. The background for the measurements was that the air in the crawl space under the floor is relatively stable as long as there is a higher temperature in the house than under the building. The heat transfer will be limited and dominated by radiation from the underside of the floor structure to the ground. This heat transfer can be reduced using one or more reflective films mounted horizontally in the crawl space, parallel to the floor surface.

SINTEF has done field measurements to verify the performance of the insulation materials. Different combinations of reflective films were tested on the ground, under the insulated floor. The field measurements support the hypothesis that there is an increased thermal resistance in crawl spaces with reflective foils. A description of the crawl spaces and the test plan is available in a ZEB memo (Uvsløkk 2016).

Figure 2.10 Crawl space with reflective foils and sensors mounted under the floor. Photo: SINTEF

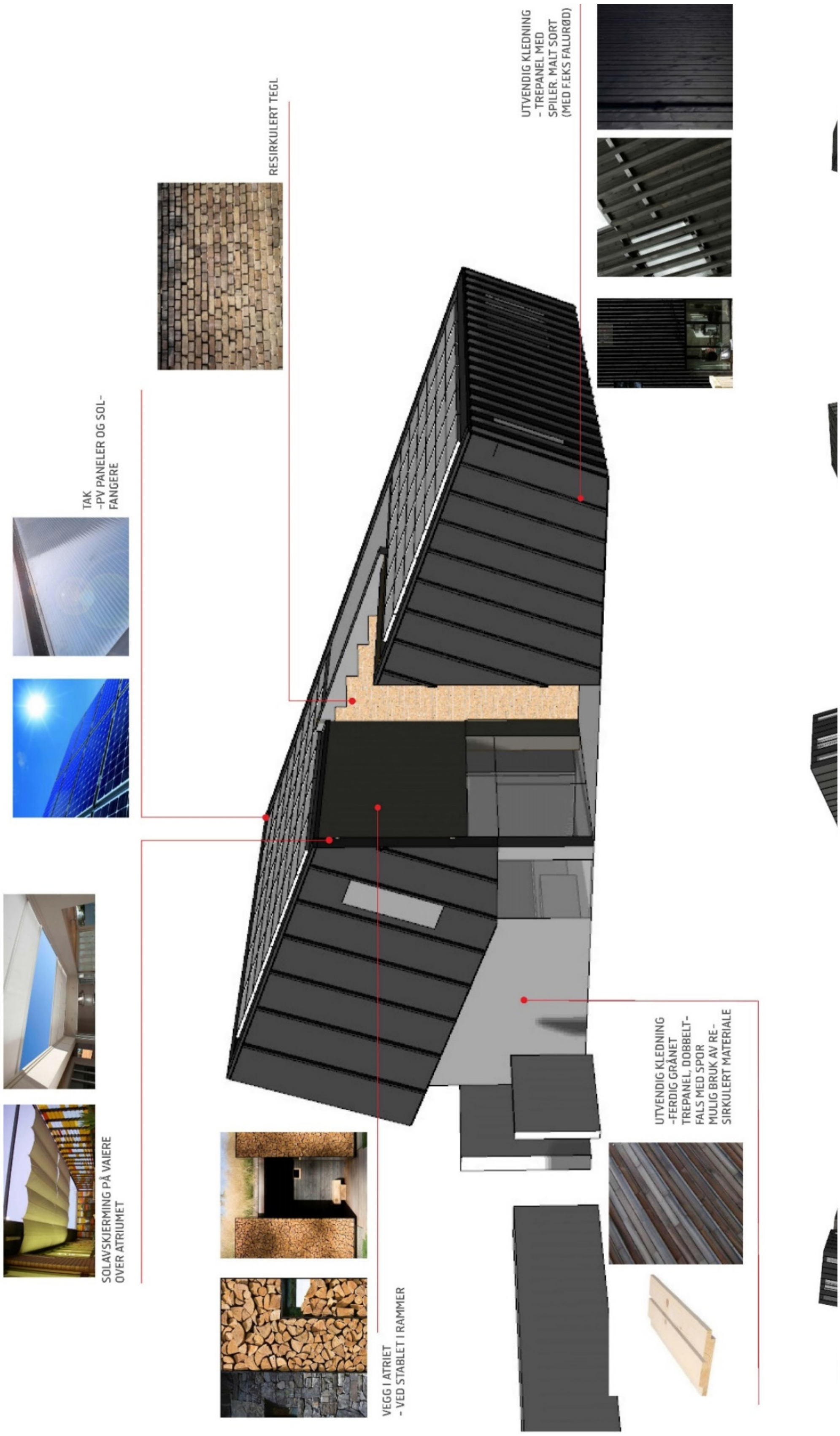


Figure 2.11 Materials in the building envelope. Source: Snøhetta.

Table 2.2 Construction materials for the envelope

Floor towards the free / crawl space U-value 0.080 W / m²K	• 10 mm Boen Prestige parquet. Fully adhered. • 48 x 500 mm beams S-beam from Moelven (glulam) • 500 mm Glava X33 mineral • 25 mm thermo chipboard from Forrestia as underfloor heating • 6 mm rehab plasterboard • Sheathing Tyvek towards the crawl space • Bath room: Tiled floor ("flytsparklet") with underfloor heating (incl. membrane, glue, etc.
Roof (The roof seen from outside) U-value 0.084 W / m²K	• Asphalt sheet (roof covering), Isola Mestertekk • 19 mm rough panels • 2 x 48 mm wood cross battens • Tyvek sheathing • 48 x 500 mm S-beams from Moelven (glulam) • 500 mm Glava X 33 mineral wool • Vapour barrier 0.15 mm • 30 x 48 mm wood battens • Interior lining
Exterior Wall (Wall seen from outside) U-value 0.111 W / m²K	• Wall with double timber frame and cavities • 19 mm cladding of Painted Spruce panel cladding • 23mm horizontal battens and 36mm vertical battens • 9 mm Glass Rock Storm sheathing • 36 x 098 mm timber frame • 150 mm cavity • Vapour barrier 0.15 mm • 48 x 98 mm timber frame supporting wall • 100 + 150 + 100 mm Glava X 33 mineral wool • Interior lining • Sliding doors from Natre with exterior aluminium, maintenance friendly • Windows from Natre, maintenance free with exterior aluminium • For avoiding radon mitigation, a robust radon membrane from Isola was used. The membrane is made of reinforced polymer bitumen with adhesive overlaps. A concern for the sealing solution was that it should be possible to move the house later, if needed (Young (ISOLA) 2016).

Table 2.3 Material choices in the interior

- Acoustics is an important element in the ZEB pilot house Larvik. In the sloped ceiling there are Gyptone acoustic panels from Gyproc. The area chosen is based on acoustic calculations done by Gyproc.
- Ceiling in spruce from Top Acoustics in Switzerland. The product is chosen due to its aesthetic and acoustic properties.
- The partition walls between the bedrooms and the hallway walls are built as soundproofed walls to limit propagation between rooms. The walls are built with 98 mm bottom wall plate, 73 mm staggered stud partition, 100 mm mineral wool and two board layer on each side. Acoustic rating 50 dB.
- Birch Plywood is selected as cladding on several walls. The product is treated with Osmo pigmented wax.
- Heat Treated Ash (Thermoask) in the bathroom. It was treated with Osmo 3034 wax to facilitate cleaning and maintenance. Thermoask was replaced with tiles in the shower zone.
- Parquet 10mm Prestige oak from Boen. The parquet is fully adhered to the substrate and works well in combination with underfloor heating.
- Reused brick wall on one wall, located by the stairs, going through both floors (inside of atrium wall). It was decided to use bricks to add some thermal mass. Reused bricks minimize CO_2 emissions compared to using new bricks.
- On the 2nd floor, untreated aspen was used as part of the wall cladding. Aspen can store moisture and stabilize the interior relative humidity.
- Kitchen from Aubo with painted fronts and worktops 29mm Solid Color. Integrated cooling drawers, wine cooler, dishwasher and stove. Kitchen hood with hob guard from Røroshetta.
- Doors to the technical room are from Jeld-Wen and sound proof.

Table 2.4 Carport materials

• Carport is built with beams of Siberian Larch. Larch contains a large proportion of resin, which works as impregnation. • Sedum on the roof. Sedum roofs consist of flowering plants in the family Crassulaceae, members of which are commonly known as stonecrops. It has a low overall height, retains rain water, and binds CO_2 and dust. • Storage space for technical equipment is built as a traditional insulated exterior wall clad with spruce cladding from Moelven. • Railway Sleepers as façade and sculpture to show how materials can be reused. • To cover the platform, Railway Sleepers are added in sections. • Gabions (rocks in metal net) are used as walls and cladding of the facade. This is an ancient and solid building technique that has become popular in Europe and Norway. A gabion is constructed by hand stacked stone and selected as an alternative to a singular stone piece.

Table 2.5 Outdoor area, store rooms and pool

• Patio Cover with heat treated Ash (termoask) 26x130 mm. (Moelven) boards have grooves and are fastened with clips. • Beams in Siberian Larch and Kebony are placed in ballast. • Sauna and storage rooms are built on beams in Kebony. Kebony is a maintenance-free, environmentally friendly and sustainable material. It is as durable as Cu impregnated materials, but without the drawbacks. • Sedum on the roof. • The building is otherwise built with pine timber frame and cladding is painted. • The wood fired sauna is built in wood and the fittings in aspen are supplied from Tylö. • Retaining walls in reused railroad sleepers of jarrah wood. • In the atrium, reused bricks and built wood boxes are used, creating a bonfire site / meeting point. • The floor is coated with recycled railway sleepers. • The house is covered with spruce panelling from Moelven. 19x148 mm DF barn panel on the upper part and 19 x 148 mm DF with extra tracks on the lower part. • The pool is made by a standard second-hand 40 feet shipping container. The walls of the steel container are strengthened with welded beams and painted with epoxy paint. Part of the steel container was used to build the technical room.

The U-values and other envelope specific input data for the energy performance simulation of the building are summarized in Table 2.6.

Table 2.6 U-values and other envelope specific input data used for the energy performance simulation of the ZEB pilot house Larvik

Description	**Value**
U-value roof	0.084 [W/(m^2K)]
U-value ground floor	0.080 [W/(m^2K)]
U-value windows and doors	0.75 [W/(m^2K)] (average)
U-value exterior walls	0.111 [W/(m^2K)]
Normalised thermal bridge value *	0.03 [W/m^2/K]
Total solar energy transmittance of windows	0.5
Sum of glass and door area related to heated floor area	29.2 %

* The total of all thermal bridge values in a building, related to its heated floor area

2.1.3 Building details

This chapter describes the building details that are considered the most important for ensuring excellent thermal protection of the building envelope. There are also some additional illustrations with building details in Appendix 1.

Figure 2.12 to Figure 2.15 show the transition from the different wall elements to the roof. PV panels are integrated in the roof.

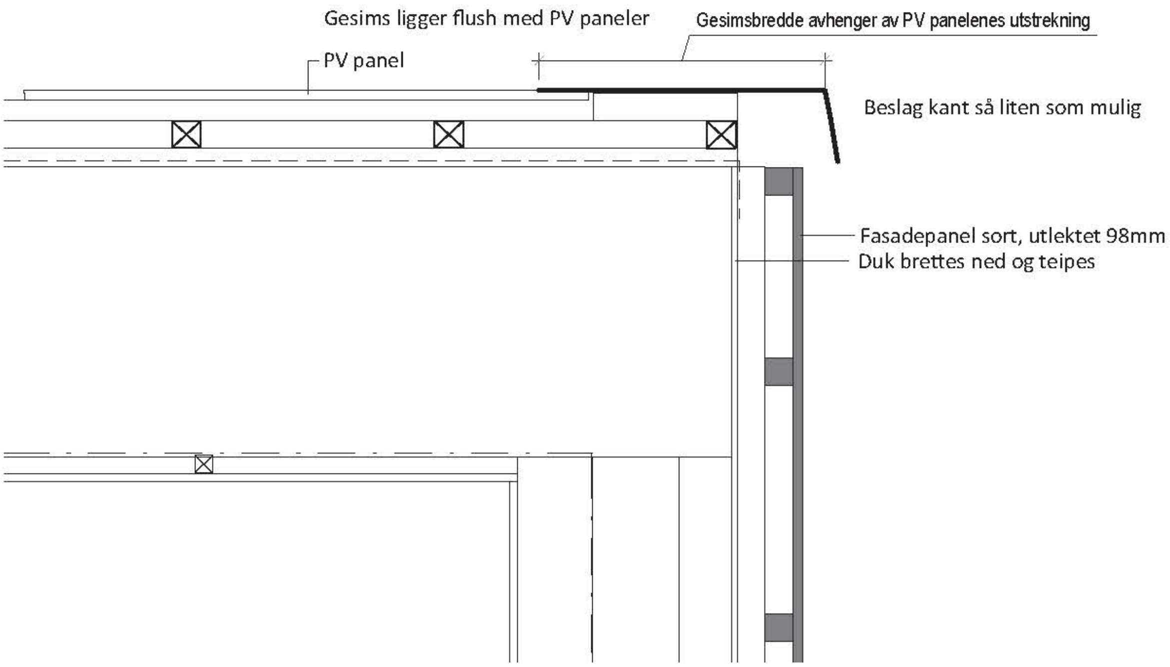


Figure 2.12 The transition from the upright wall elements to the roof (verge). Source: Snøhetta.

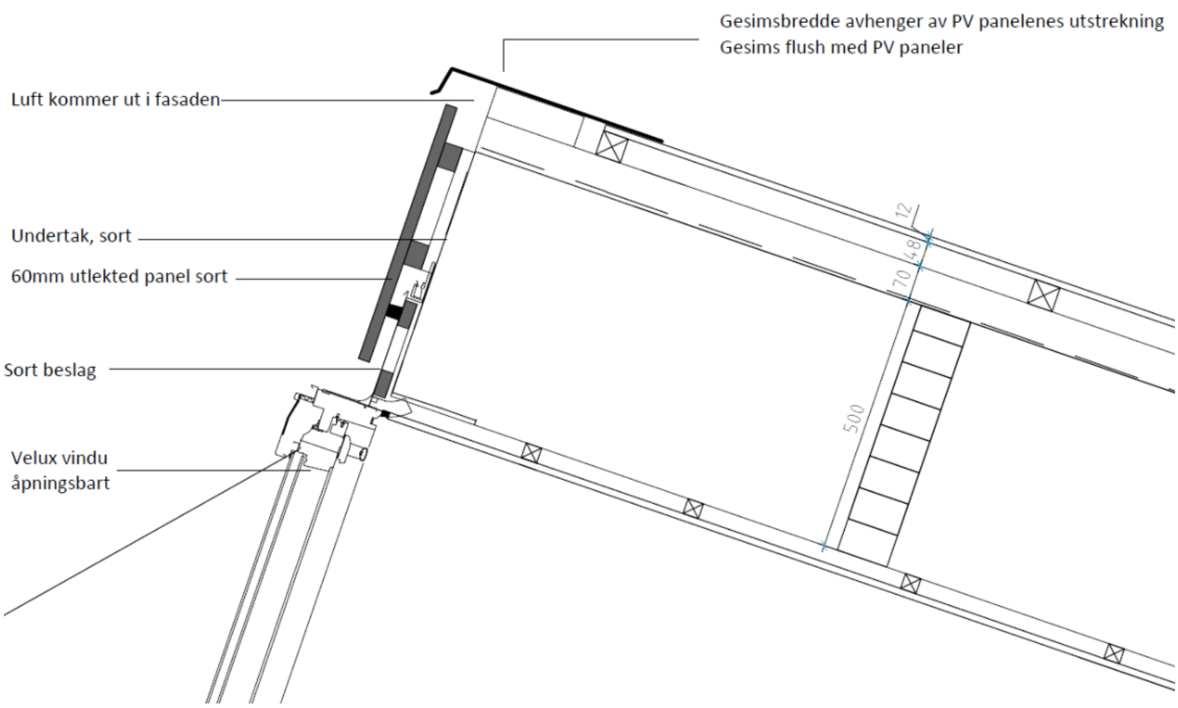


Figure 2.13 The transition from the tilted wall elements to the roof (window / top of the monopitch roof). Source: Snøhetta.

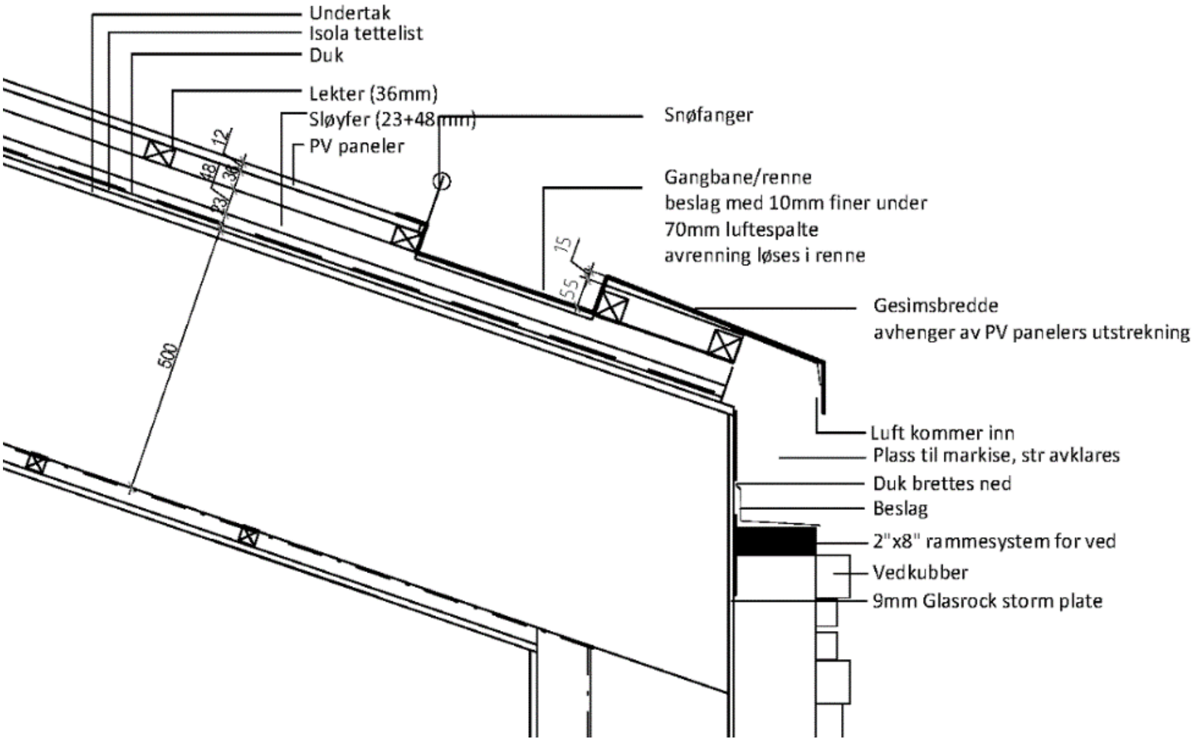


Figure 2.14 The transition from the atrium wall to the roof (eaves). Source: Snøhetta.

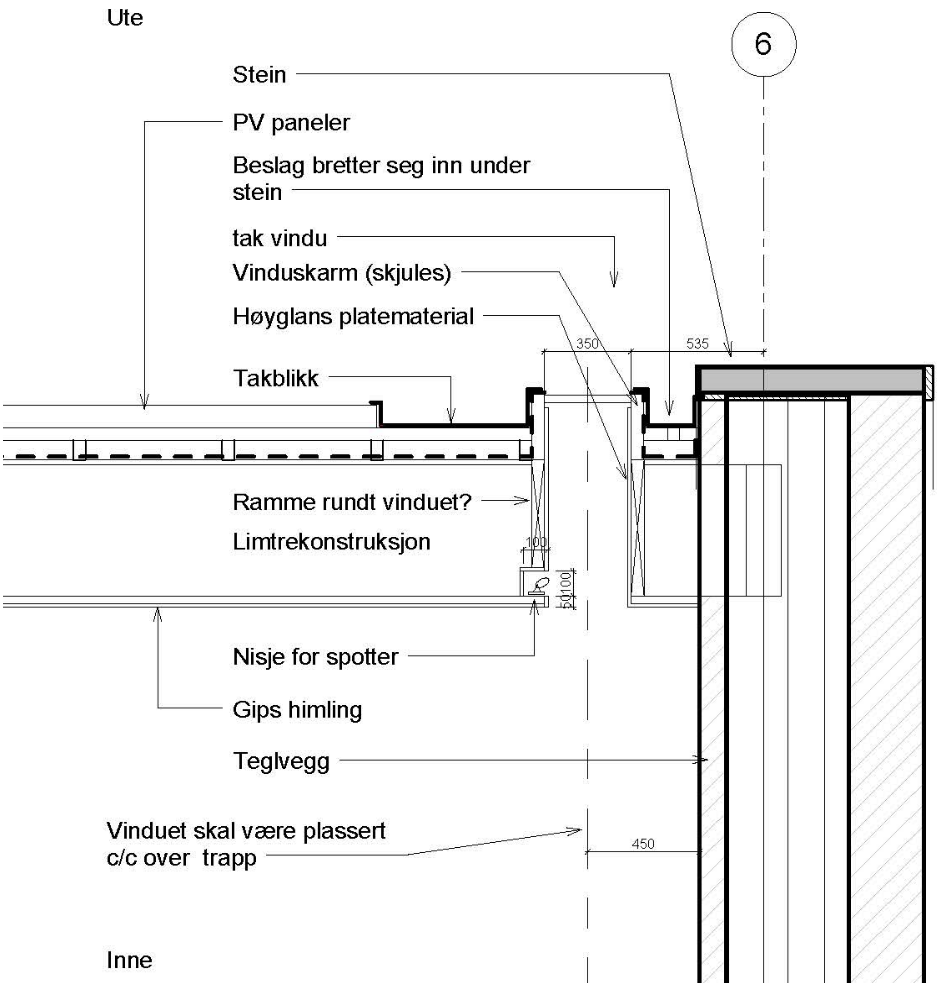


Figure 2.15 The transition from the brick faced atrium wall / roof elements to the roof window (verge). Source: Snøhetta.

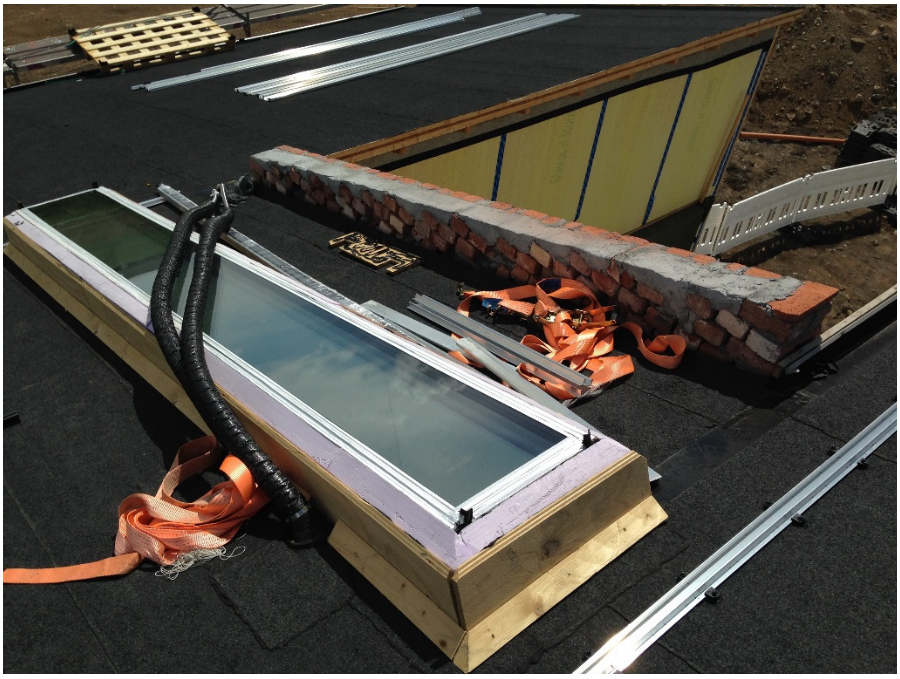


Figure 2.16 Photo of the realized construction of skylight. Source: Snøhetta.

Figure 2.17 and Figure 2.18 show the transition from the wall and floor elements to the ground. Further building details are described in Figure 2.19 to Figure 2.22.

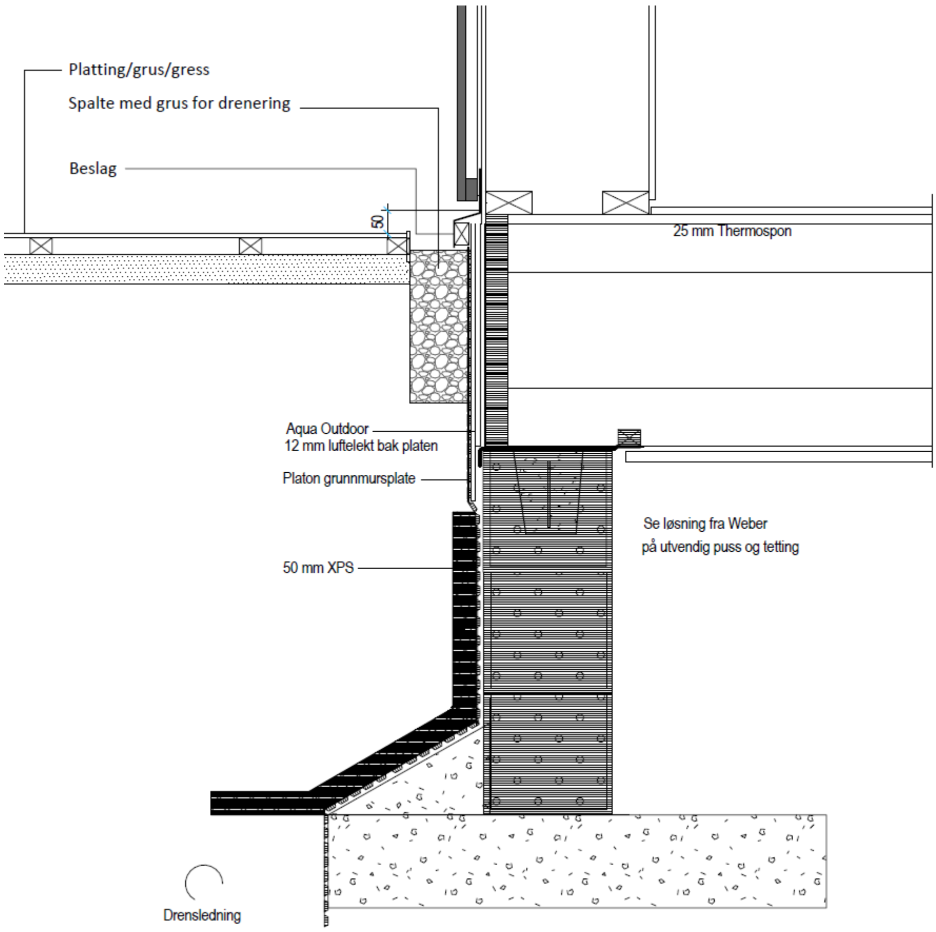


Figure 2.17 The transition from the wall and floor elements to the ground. Source: Snøhetta.

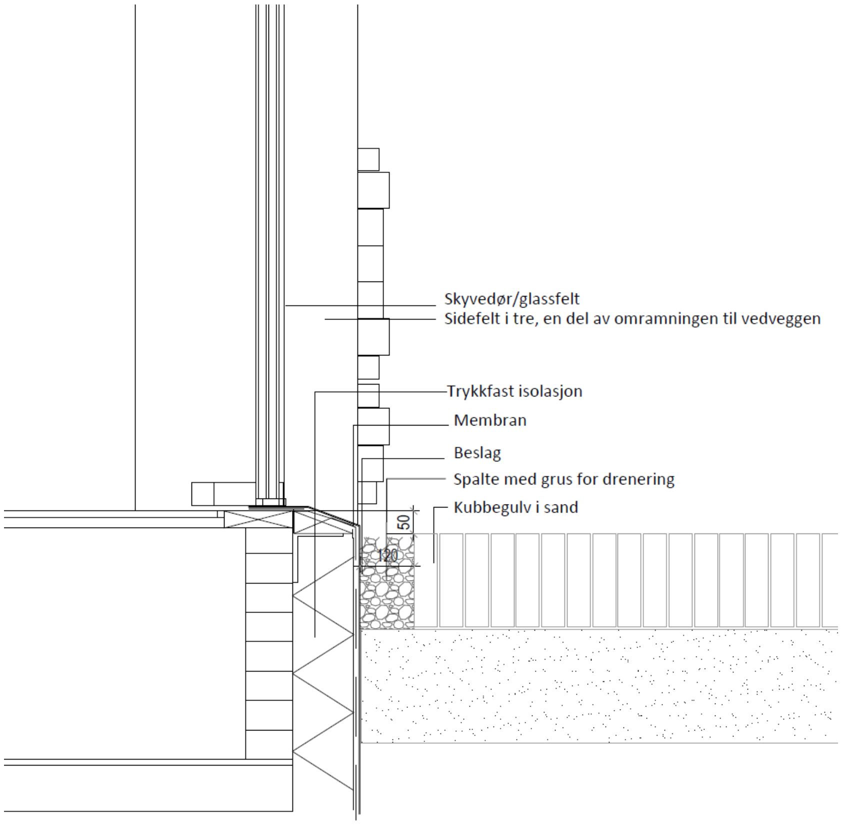


Figure 2.18 The transition from the wall and floor elements to the ground in the atrium. Source: Snøhetta.

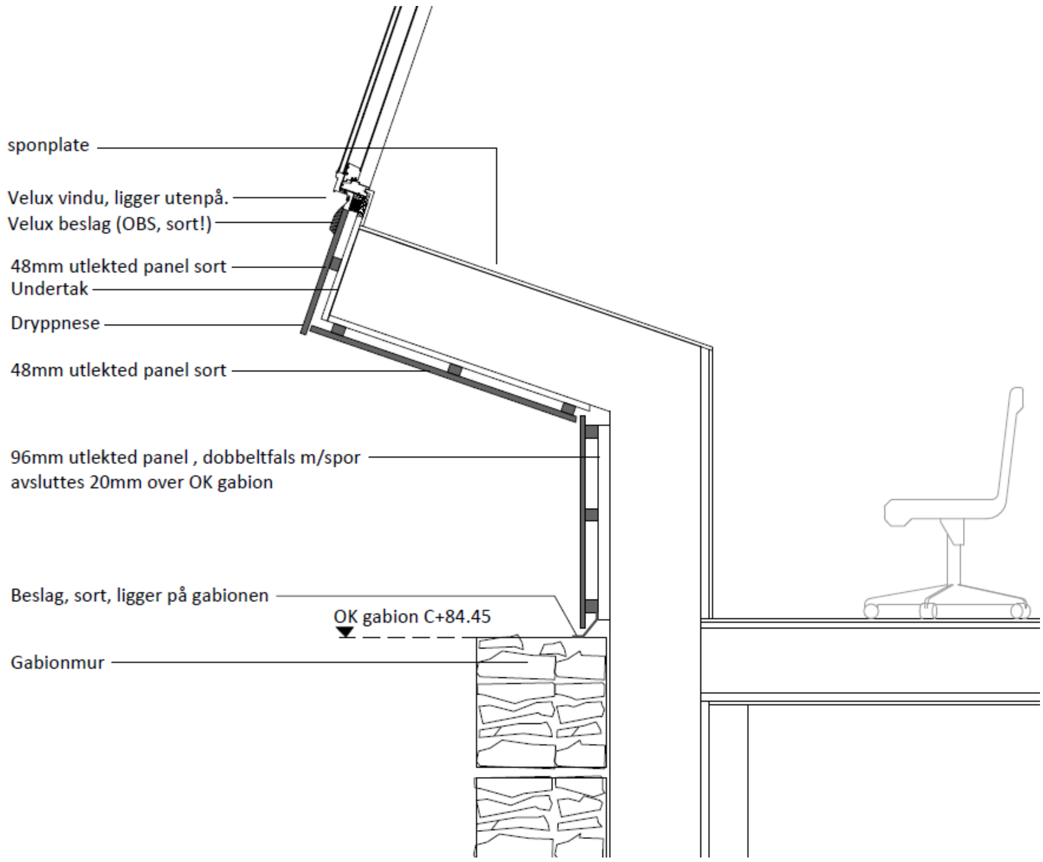


Figure 2.19 The transition from the upright wall elements to the windows in the north-west facing tilted wall. Source: Snøhetta.

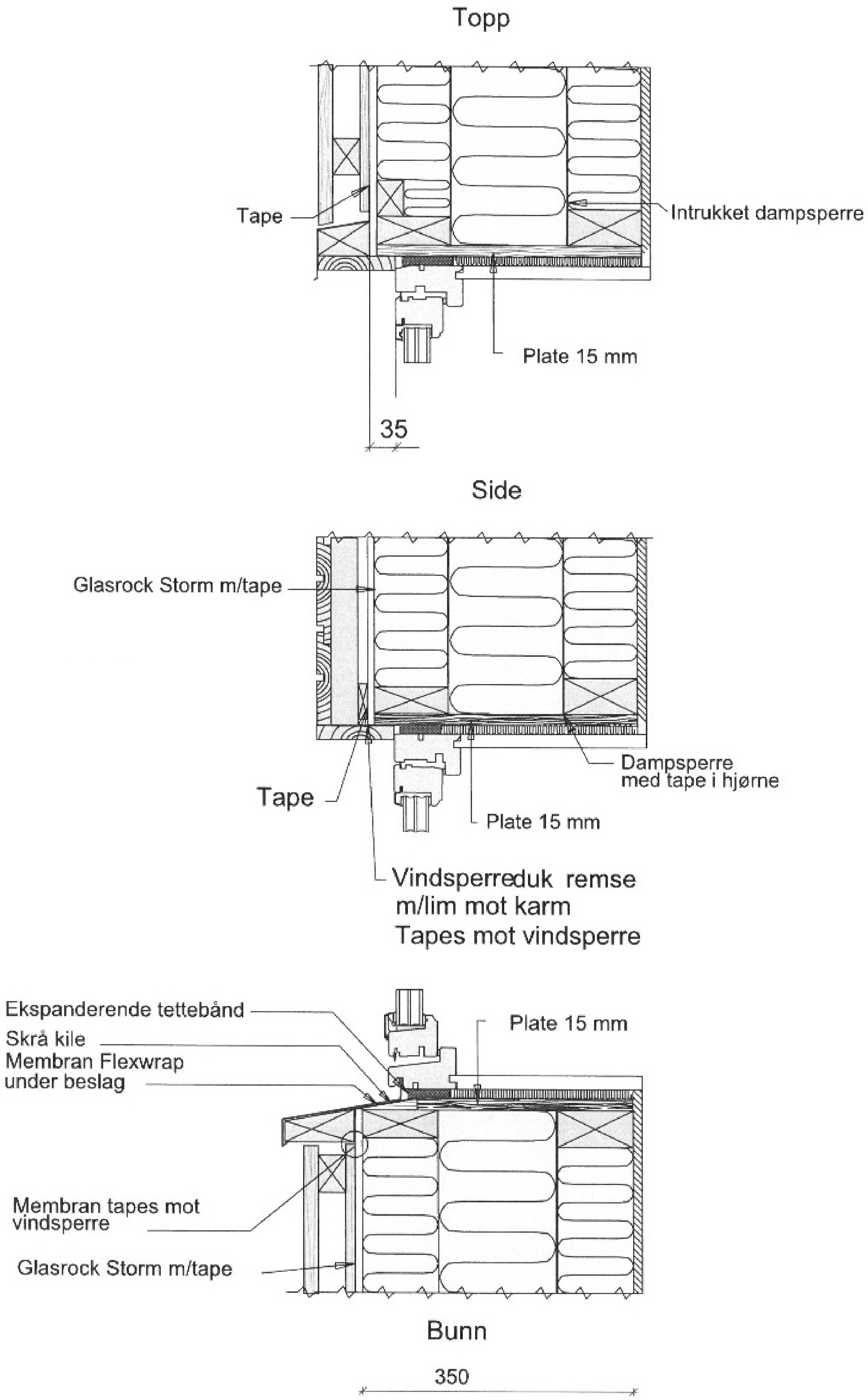


Figure 2.20 Details around the windows. Source: Optimera.

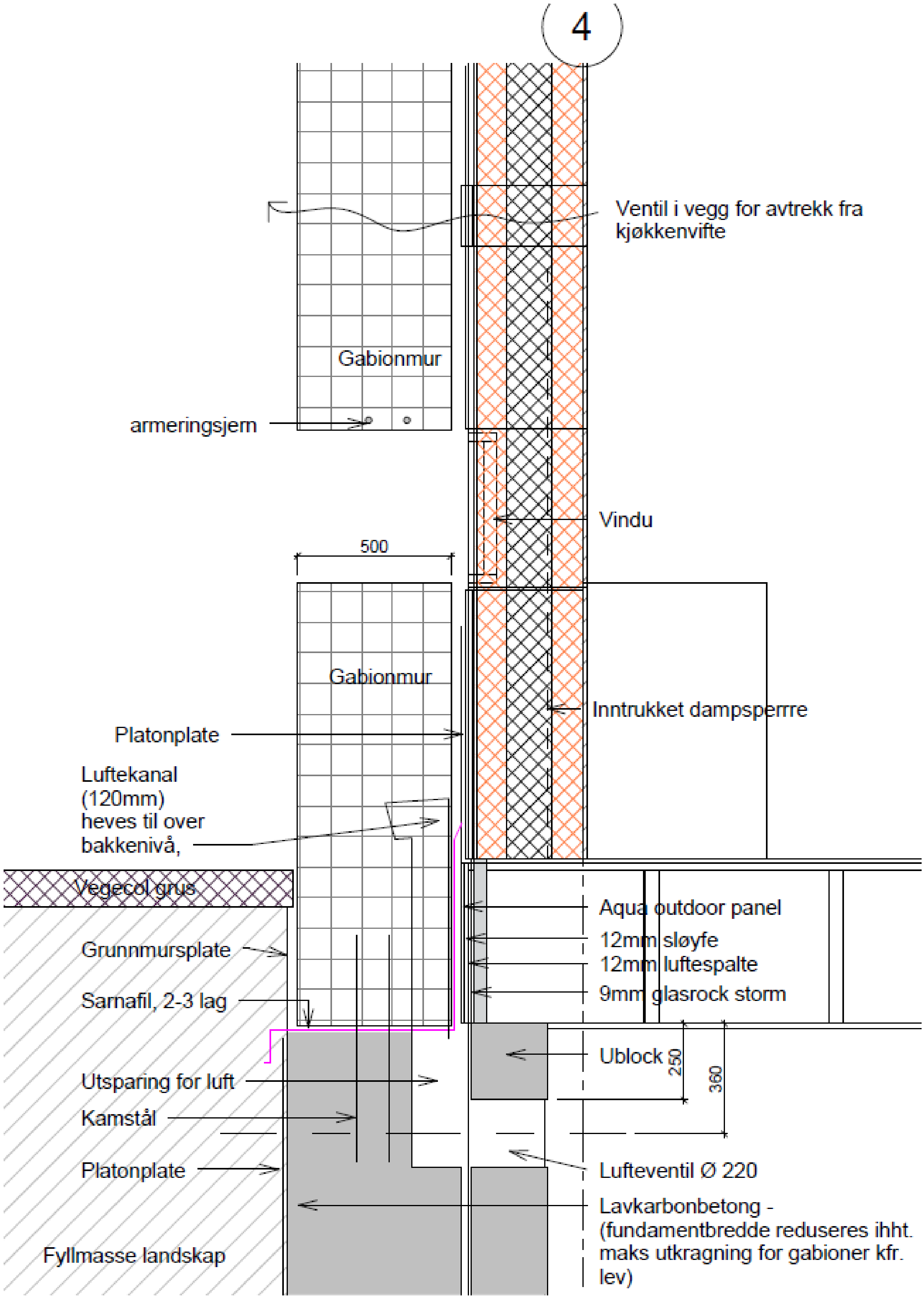


Figure 2.21 The transition from the gabion wall elements to the cinder aggregate blocks. Source: Snøhetta.

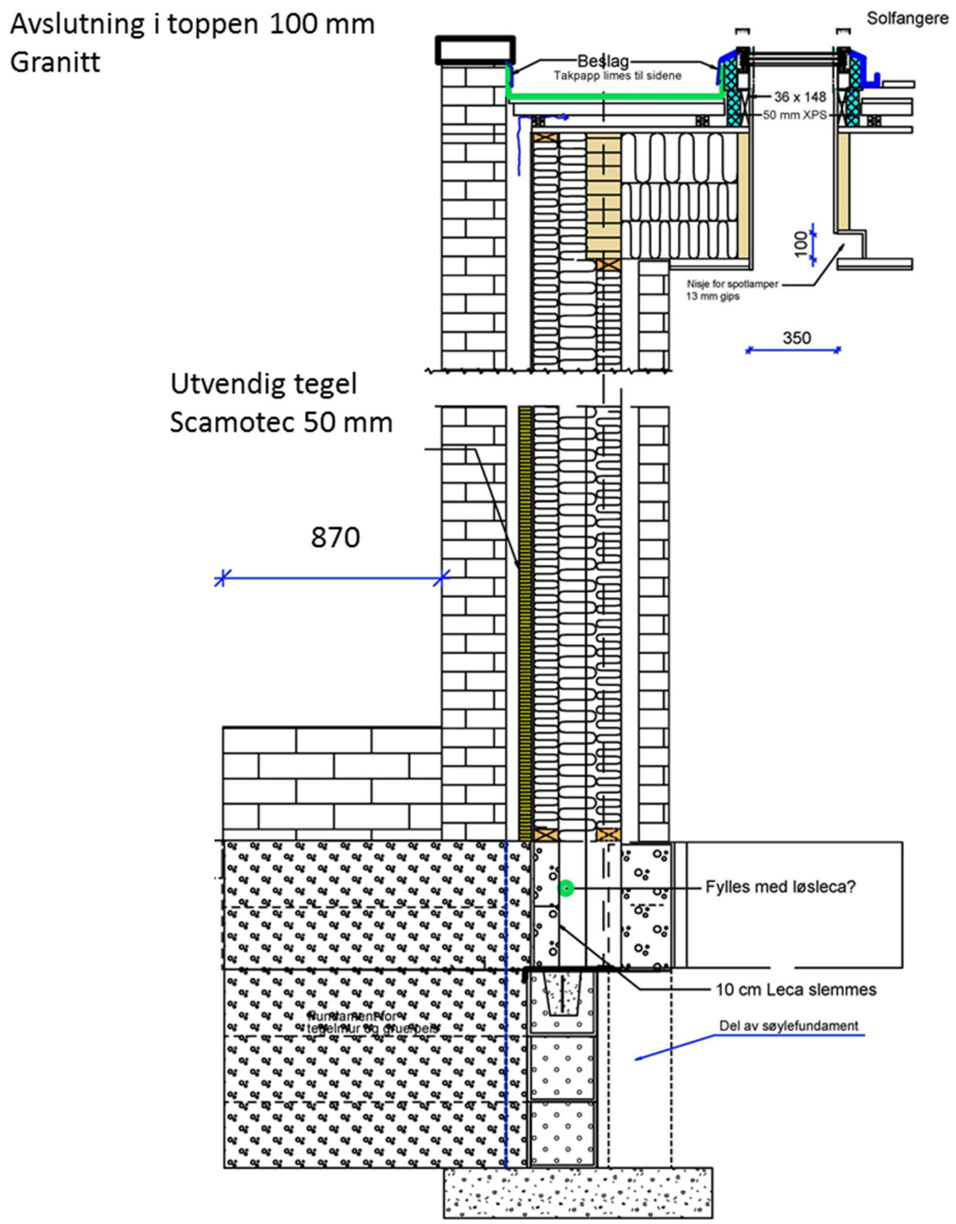


Figure 2.22 Brick faced atrium wall (confer Figure 2.15). Source: Optimera.

2.2 Design choices

The building design was influenced by the aim to develop a single-family house that generates more energy than it consumes. To achieve this, the house has a large roof for solar PV and thermal panels. In addition, great efforts have been made to combine high aesthetic quality with comfort and energy efficiency. Materials used are off the shelf, choosing low carbon products where possible, to reduce the GHG emissions. It was an important principle in this project to reuse materials to limit GHG emissions from material use.

2.2.1 Design choices based on emission drivers

Two main emission drivers were identified based on previous studies (Wiberg, Georges et al. 2014); the photovoltaic modules and the traditional concrete slab (Kristjansdottir, Andresen et al. 2016).With respect to building parts, it was identified that external walls with windows, insulation, and other structural parts had the highest emissions (Rosochacki 2014).

To reduce emissions, the ground floor plate was based on a timber and fibre plate construction. Underneath the timber slab is a strip foundation of low carbon concrete. Low carbon concrete is based on low carbon cement, which is partly based on fly ash substitution for clinker (Norbetong 2012). Reused bricks from a nearby construction site were used as a wall inside to increase the thermal mass for the building. Façade materials include painted Norwegian timber, stacks of fire wood, natural stone, and reused bricks. Photovoltaic modules from Innotech Solar (ITS) were chosen due to their low embodied carbon emissions (De Wild-Scholten 2013, Innotech Solar 2013). The building has timber based load bearing, with Norwegian glue-laminated beams. Timber was used also as one of the main materials for surface coverings inside the building. (Kristjansdottir, Andresen et al. 2015)

Also other reused materials were used in the project, such as the steel container which was transformed into a swimming pool and recycled railroad sleepers cut into shape for the exterior sitting area and carport wall material (Rosochacki 2014).

2.2.2 Energy efficiency concept

The space heating need of the house was minimized by designing a well insulated and air tight building envelope (ref. Chapter 2.1.2) and a ventilation system with high efficiency heat recovery (ref Chapter 3.1). The energy performance calculations were done according to the Norwegian standard NS 3031:2007 (Standard Norway 2007). The lighting system was designed to be based on LED and good daylight utilization. Documentation of the energy use was done by performing simulations with the Norwegian simulation tool SIMIEN (Programbyggerne 2012), (Kristjansdottir, Andresen et al. 2015).

2.2.3 Energy generation concept

To achieve the ZEB-OM, ambition level of the building, on-site renewable energy generation was applied to compensate for the operational energy use and for the embodied emissions from the materials and technical installations. In addition, the building should supply enough energy for an electric car.

The energy generation was based on roof mounted photovoltaic modules for electricity and a combination of different heat sources for thermal energy. The photovoltaic system was designed to be connected to the local electricity grid and a local battery bank (Amundsen 2014). A geothermal heat pump (3kW) was planned to provide 80 % of the space heating, and the remaining heat would come from the solar thermal panels. The heat is distributed through an underfloor heating system. Grey water heat recovery systems were also installed. It was estimated that the heat recovery rate from the grey water heat exchangers would be 50 %. The estimated energy output of the photovoltaic modules was simulated in PVsyst (PVSYST SA 2011). The design phase PV area was approximately 122 m^2, but the final PV area was 150 m^2. This increase in PV area was possible after concluding that the area initially reserved for maintenance access was not necessary and therefore available for PV. The design phase energy yield from the solar thermal panels (8 m^2) was simulated using PolySun (Velasolaris 2012). The final solar thermal panel area was approximately 16 m^2 (Kristjansdottir, Andresen et al. 2015).

They energy system is described in more detail in chapter 4.

3. Building Services

This Chapter describes the ventilation system, the lighting, and the water system of the ZEB pilot house Larvik.

3.1 Ventilation

The ventilation system is a balanced, mechanical ventilation system with constant air flows. The ventilation system is connected to a heat exchanger (87% efficiency) and an exhaust air heat pump (Nilan Compact P). The heat pump can supply both heating and cooling to the ventilation inlet and is also used to heat domestic hot water. Table 3.1 provides the key design data for the ventilation system.

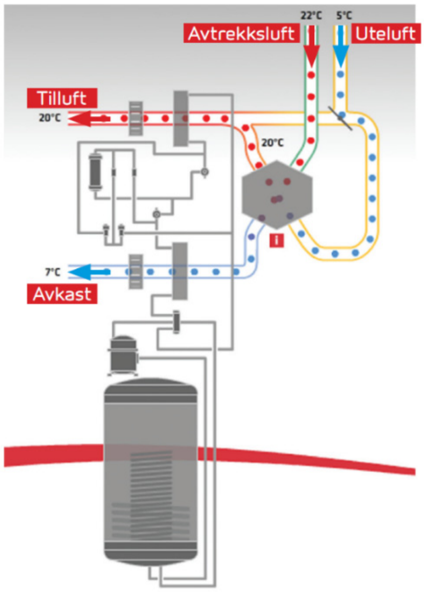


Figure 3.1 The Nilan Compact P ventilation system (Nilan)

Table 3.1 Key design data for the ventilation system

Description	Value
System	Nilan Compact P
Type	Mechanical ventilation
Design volume flow rate	242 m^3/h
Ventilation air volume (mean value)	1.2 m^3/hm^2
Ventilation heat recovery efficiency	87 %
Specific Fan Power, SFP	1.3 kW/m^3 per s
Air tightness at 50 Pa	0.30 designed, 0.60 measured

In addition, a heating and cooling battery is installed which uses energy directly from the boreholes. The battery has two functions; It provides heating during wintertime for protecting the heat exchanger from freezing, and cooling during summertime, if needed (Amundsen 2014).

An air distribution system called NilAIR is used. NilAIR consists of corrugated and bendable plastic tubes, which are smooth inside.

Figure 3.2 Ventilation grilles in the house (photo: SINTEF)

During warm periods, the ventilation concept relies on natural ventilation and all main rooms have at least one window that can be opened.

3.2 Lighting

The building is constructed to maximize natural daylight as well as to minimize the need for external sunscreens. These factors have been important when deciding the location and dimensions of the windows (NAL 2016). A DIVA for Rhino Model was used for daylight analysis in dimensioning calculations performed by Snøhetta.

A daylight simulation was performed by Saint Gobain (SAINT-GOBAIN 2013). Daylight Autonomy (DA) is the amount of time that you can expect to reach a certain light level through the use of just daylight, without switching on lights. The Daylight Autonomy for the building was calculated for the given climate between 8 AM and 6 PM and for an illuminance level of 300 lux. The main rooms of the building were included: the kitchen, living room and bedrooms, as shown in Figure 3.3. The criteria set was that the calculated daylight autonomy should be above 60 %.

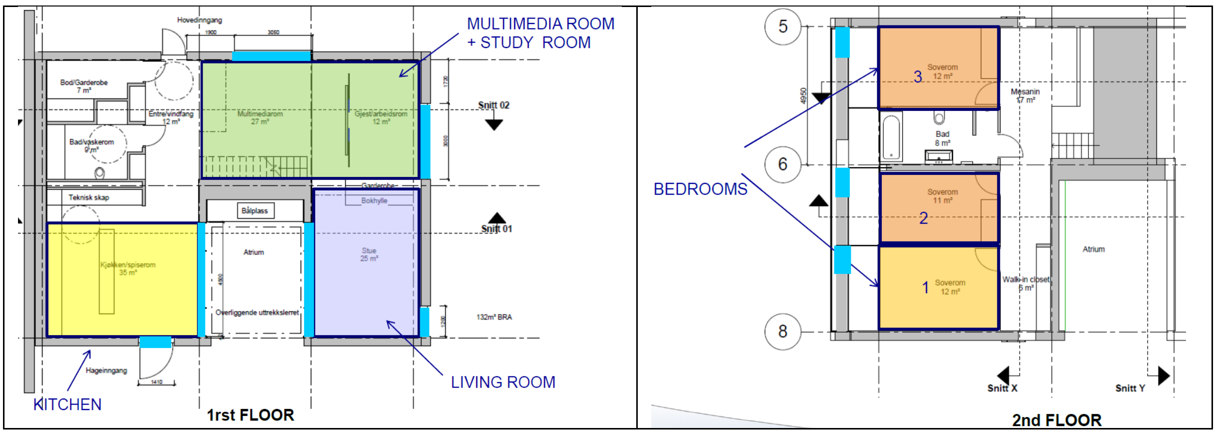


Figure 3.3 The rooms included in the daylight calculation (SAINT-GOBAIN 2013)

The calculated result was that the ZEB pilot house Larvik complies with the set criteria on daylighting, as shown in Table 3.2. SAINT-GOBAIN (2013) describes the results in more detail.

Table 3.2 Daylight calculation result for ZEB pilot house Larvik (SAINT-GOBAIN 2013)

	Room	Number of windows		Window-to-floor ratio (%)	Average DA (%)
		Vertical	Velux		
1st floor	Kitchen	2 (SW, SE)	-	55 %	60 %
	Living room	2 (NW, SE)	-	57 %	62 %
	Multimedia + study room	2 (NE, SE)	-	27 %	59 %
2nd floor	Bedroom 1	-	1 (NW)	25 %	62 %
	Bedroom 2	-	1 (NW)	28 %	65 %
	Bedroom 3	-	1 (NW)	25 %	62 %

LED-lighting is installed in the rooms of the building.

3.3 Water system

Rainwater from the roof is harvested, mechanically cleaned, and stored in a 6000 litre tank. The rainwater is reused in toilets and for watering the garden. The water system is dimensioned to cover the annual need for water in the toilets. If the rainwater tank is empty, municipal water is provided automatically to the system through a valve.

4. Energy Supply Systems

The house has a water-based underfloor heating system connected to a ground source heat pump and solar thermal collectors. As already described, the energy concept also includes the balanced ventilation system with heat recovery and an exhaust air heat pump, a waste water heat recovery system, and LED lighting. Photovoltaic panels for electricity production cover the roof to provide electricity and to compensate for emissions.

Only the energy supply system on/in the main building is described in this Chapter. There are also solar collectors on the roof of the store rooms, but these are not included within the system boundary.

4.1 Energy need and delivered energy

The simulations of operational energy performance were done using the dynamic energy simulation tool SIMIEN (Programbyggerne 2012) and in accordance with the Norwegian Standard NS 3031:2007+A1:2011 (Standard Norway 2007). Energy need for lighting and equipment was set according to expected use for a normalized operation period.

The calculations showed a net energy need for the building of 14,136 kWh per year. The calculated annual specific energy need for the building is 70.2 kWh/m^2 per year. Table 4.1 presents the energy need budget of the building, using terms from prEN 15603 (European committee for standardization 2013).

Table 4.1 Energy budget: Calculated energy need for the ZEB pilot house Larvik

Energy budget	Energy need (kWh/year)	Specific energy need (kWh/m^2/year)
Room heating	4,799	23.8
Ventilation heating	418	2.1
Domestic hot water	3,212 (6,424)*	15.9 (31.8)*
Fans	765	3.8
Lighting	1,765	8.8
Technical equipment	3,177	15.8
Total net energy need	**14,136 (17,348)***	**70.2 (86.1)***

** Due to the assumption that 50% of the energy in the grey water would be recovered with the heat recovery system, only half of the energy need for domestic hot water is included.*

The energy need for domestic hot water is based on the default value in NS 3031 (29.8 kWh/m^2 = 6020 kWh/year), added to the calculated hot water need for the washing machine and dishwasher, based on information from the suppliers of the appliances. Then, the calculated energy need of 6,414 kWh/year was reduced by 50%, due to the assumption that 50% of the energy in the grey water would be recovered with the heat recovery system.

Compared to the design-study calculation of the energy need (Kristjansdottir, Andresen et al. 2015), Table 4.2 shows the changes in the revised calculations. The changes are marked in bold. The main change is the air leakage rate, which is changed to 0.6 air changes per hour based on the measurements. There is also an increase in the solar energy transmittance of windows, from 0.4 to 0.5.

Further details of the SIMIEN-calculations are available in Appendix 11.

Table 4.2 Description and values for different energy performance simulations in the design phase and As-built.

	Kristjansdottir et.al. 2015	As-built report 2016
Description	Value	Value
Heated volume (m^3)	610	610
Heated floor area (m^2)	**197**	**202**
Roof area (m^2)	**174**	**172**
Normalized thermal bridge value (Wm^2/K)	0.03	0.03
Total solar energy transmittance of windows	**0.4**	**0.5**
Air leakage rate (n50) (1/h)	**0.3**	**0.6**
Inside air temperature (set point) (°C)	20.3	20.3
Ventilation air volume (mean value) (m^3/hm^2)	1.2	1.2
Ventilation heat recovery efficiency	87 %	87 %
Specific Fan Power, SFP (kW/m^3 per s)	1.3	1.3
Average power for lighting (LED) (W/m^2)	1.0	1.0
Window and outer door area (m^2)	**57**	**59**
U-value roof ($W/(m^2K)$)	0.08	0.08
U-value ground floor ($W/(m^2K)$)	0.08	0.08
U-value windows and doors ($W/(m^2K)$) (average)	**0.73**	**0.75**
U-value exterior walls ($W/(m^2K)$)	**0.10**	**0.11**
System efficiency, heating system	**6.52**	**6.16**
System efficiency, cooling system	**3**	**2.75**
Power need, domestic hot water	**1.80**	**1.82**
Energy need in total (kWh)	14,045	14,136
Delivered energy (kWh)	7,045	7,142
	Simien (MKH_140401.smi)	Simien (MKH_As_built_160408 - ÅLS 160520)

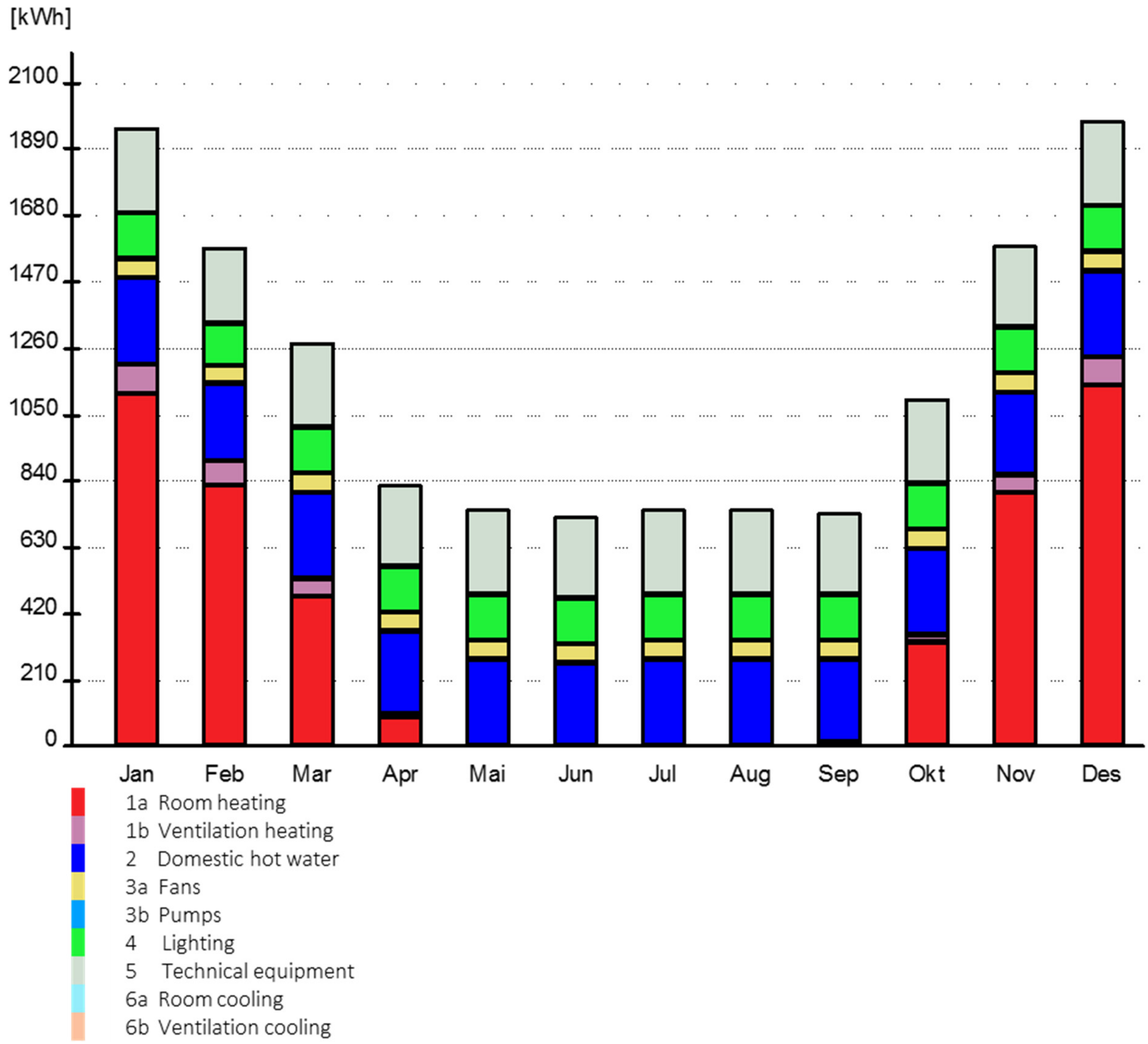


Figure 4.1 Monthly energy need in the ZEB pilot house Larvik, based on "As built-simulation" described in Table 4.2.

Including the ground-source-to-water heat pump, the air-to-water heat pump in the exhaust of the ventilation shaft, and the thermal solar collector system, the demand for *delivered* energy (electricity) was calculated to be 7,142 kWh per year, or 35.4 kWh/m^2 per year.

Table 4.3 Energy budget: Delivered energy

Energy budget	**Delivered energy (kWh/year)**	**Specific delivered energy (kWh/m²/year)**
Direct electricity	5,707	28.3
Electricity heat pump (ground-source HP)	1,014	5.0
Electricity solar energy	144	0.7
Other energy sources (HP in ventilation)	276	1.4
Total delivered energy	**7,142**	**35.4**

The monthly heating balance is shown in Figure 4.2.

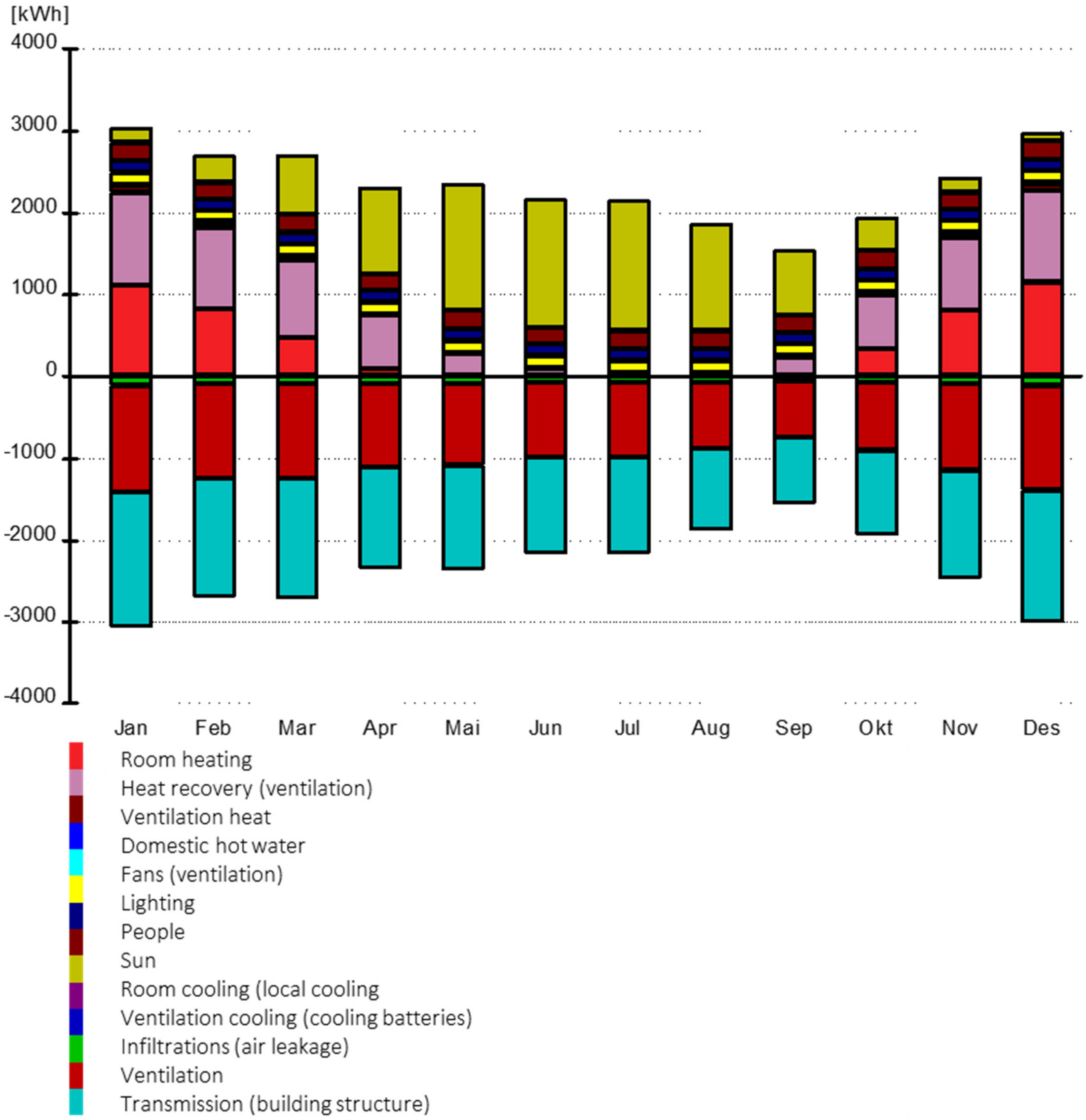


Figure 4.2 Monthly heating balance in the ZEB pilot house Larvik, based on "As built-simulation" described in Table 4.2.

The total energy balance, including delivered electricity, delivered heat from ground-source HP, exhaust air HP, and solar collectors as well as recovered heat from the grey water system is shown in Table 4.4.

Table 4.4 Total energy balance for the ZEB pilot house Larvik, based on "As built-simulation".

Energy balance (kWh/year)	**Energy need**	**Delivered energy**		
		Electricity	Heat from ground-source HP, exhaust air HP and solar collectors	Heat from grey water system
Space heating and ventilation	5 217	1 025	4 192	
Domestic hot water	6 424	409	2 803	3212
Fans, lighting, technical equipment	5 707	5 707		
		7 142	6 995	3 212
Total	**17 348**			**17 348**

Annual electricity yield from the 22.75 kW_p PV system was calculated by the software PVsyst (PVsyst SA, 2011), to 19,200 kWh per year. The estimated monthly division is shown in Figure 4.3.

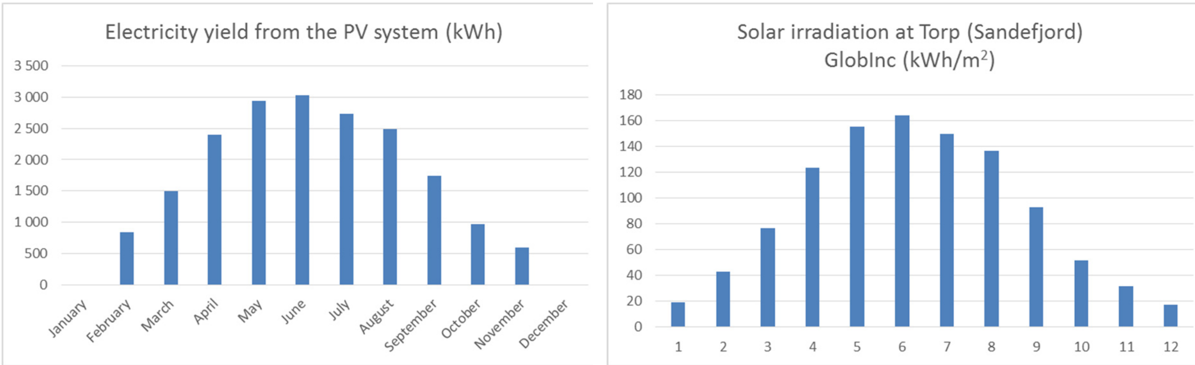


Figure 4.3 Calculated monthly electricity yield from the PV-plant and solar irradiation in collector plane

Site-specific Meteonorm data (Meteotest, 2009) have been used, for location Torp (Sandefjord) which is 15 km away from the building. The estimated annual horizontal solar radiation for the location is 945 kWh/m^2. The tilt of the panels are 19 degrees, and the roof orientation is -45 (south-east). The global incident radiation on the collector plane is 1061 kWh/m^2, while the effective global radiation corrected for IAM and shading is 1018 kWh/m^2. This gives a specific yield power of 845 kWh/kW_p and specific yield area of 128 kWh/m^2 PV.

When calculating the electricity production, it was assumed that the modules are 100% snow-covered during December and January and 20% snow covered during November and February. Internal energy consumption of the inverters was considered to be negligible. The system is not optimally oriented for its location, which would be a tilt angle of 40-45° from the horizontal and south facing (annual optimisation). The losses in available irradiation, due to non-optimal orientation (not including shading losses) is around 12 %. The lifetime of 30 years has been used, regardless of product warranties, due to recommended guidelines for life cycle assessments (Fthenakis 2011). There is no significant shading.

The PV system and the energy production calculation is further described in the report "Greenhouse gas emissions from PV systems in residential Zero Emission Buildings -pilot cases from Norway" (Kristjansdottir, Andresen et al. 2015).

The EU energy label of the building is a green A (Amundsen (Brødrene Dahl) 2016).

4.2 Heating system

The heating system consists of a ground-source-to-water heat pump which is designed to cover 80% of the heating load, and a solar thermal collector system which is designed to cover 20% of the heating load. Hot water is collected in a 400 liter tank by Oso.

The energy supply system is shown in Figure 4.4. The whole system could be divided into six parts, including the solar collector subsystem, the domestic hot water (DHW) supply subsystem, the closed loop ground-source subsystem, the ventilation system, the ground source heat pump (GSHP) subsystem, and the space heating subsystem.

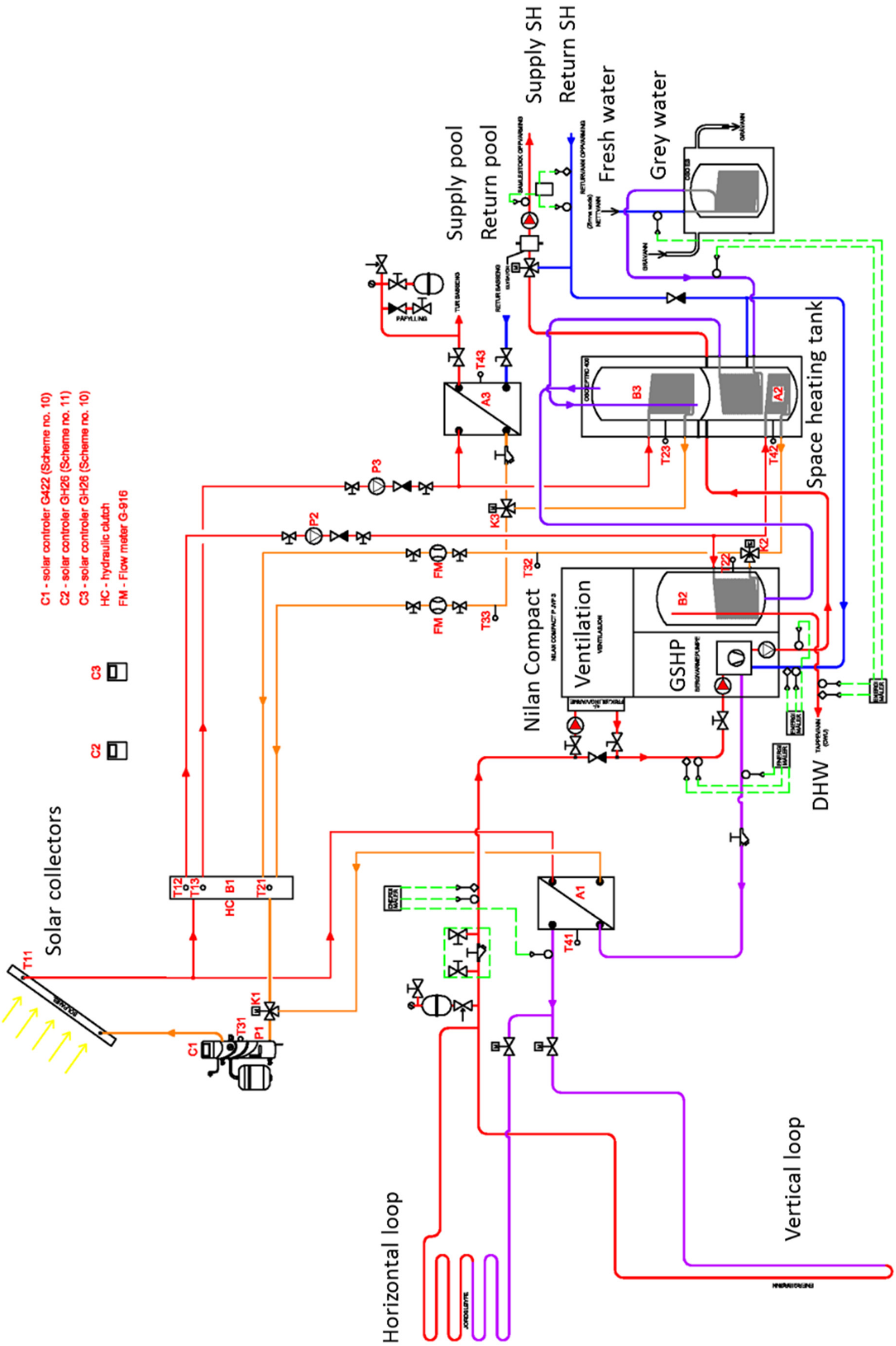


Figure 4.4 Energy supply system for heating. Source: Brødrene Dahl.

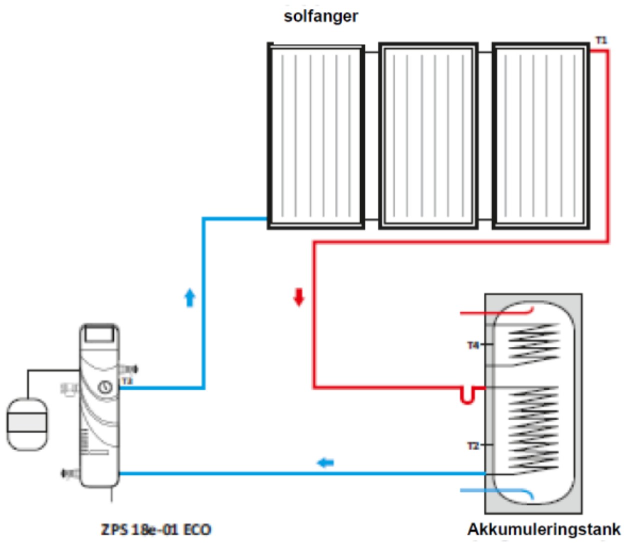
The ground-source-to-water heat pump
The heating system includes a Nilan Compact P Geo 3 with an integrated 3 kW ground source heat pump. The heat pump can retrieve energy from either an energy well of 100m or an earth circuit at 150m. This system is designed to cover 80% of the energy need for space heating. According to the test conducted by the Danish Technological Institute in accordance with EN 14825: 2012, the heat pump has a SCOP of 5.17 (Amundsen 2014). The ventilation air is heated directly from the ground-source heat exchanger.

Figure 4.5 The technical room (photo SINTEF)

The solar collectors
The remaining 20% of the space heating comes from 16.8 m² of solar collectors from Hewalex, mounted on the roof. The flat plate solar collectors have a tilt angle of 19°, facing south-east. The heat transfer fluid is a 33% mixture of glycol and water.

The excess solar heat is utilized to recharge the borehole.

Figure 4.6 The solar collectors (photo Brødrene Dahl/Paal-André Schwital)



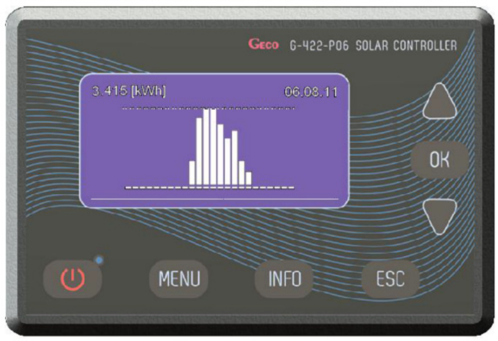


Figure 4.7 General illustration of control system for solar collectors (from Hewalex)

A pump- and control system from Hewalex is installed (ZPS18e-01 ECO and controller G-422-P06). There are three separate controllers (numbers refer to Figure 4.4):

- Controller C1 has first priority for heating the tank HC (B1). The controller regulates based on the difference in temperature between T21 and T11, with set point 6 degrees temperature difference. If the criterion for delivering heat to the tank HC (B1) is not fulfilled, the second priority is to provide heating for the heat exchanger A1 (the loops). The set point for operation is 20 degrees difference between T11 and T41. Maximum temperature is 30 degrees.
- Controller C2 has first priority for heating the tank for domestic hot water (B2). The controller regulates based on the difference in temperature between T22 and T12, with set point 5 degrees. If the criterion for delivering heat to the tank (B2) is not fulfilled, the second priority is to provide heating for the space heating tank (A2). The set point for operation is 4 degrees difference between T12 and T42.
- Controller C3 has first priority for heating the space heating tank (B3). The controller regulates based on the difference in temperature between T23 and T13, with set point 5 degrees. If the criterion for delivering heat to the space heating tank (B3) is not fulfilled, the second priority is to provide heating for the heat exchanger for the pool (A3). The set point for operation is 20 degrees difference between T13 and T43. Maximum temperature is 32 degrees.

There are an additional 4 solar collectors placed on the roof of the store rooms, but since these collectors do not deliver heat to the energy system of the main building, only to the pool and the shower in connection to the sauna, they are not included in the energy balance of the house.

Heat accumulation and distribution
The heat is accumulated in a 400 l tank from OSO (OSO EPTRC 400), and distributed in the house with underfloor heating from Uponor throughout the 1st floor and in the bathroom on the 2nd floor. The floor heating is a low-temperature system, where temperatures of the supply and return water are based on the outdoor temperature. For the outdoor design temperature, the temperatures of the heat distribution system are 35/30 °C. The temperature levels are lower when it is warmer outside.

Figure 4.8 Heat distribution to the underfloor heating (photo SINTEF)


Figure 4.9 Radiator on the ground floor (photo SINTEF)


Figure 4.10 Radiator on the first floor (photo SINTEF)

Domestic hot water
For domestic hot water, several different technologies are applied. Heat from waste water (sink, shower, dishwasher, washing machine) preheats the water in the water tank. Two different grey water heat recovery systems are installed; one simple system in the drain of the shower and one system including an accumulator tank from OSO. In addition, domestic hot water is provided by the solar collectors, by an air-to-water heat pump in the exhaust of the ventilation shaft, and by the ground-source-to-water heat pump. Appliances use hot water directly (no electricity for water heating needed). Excess heat from the solar panels is used for heating the water of the swimming pool and the seasonal energy storage in the borehole.

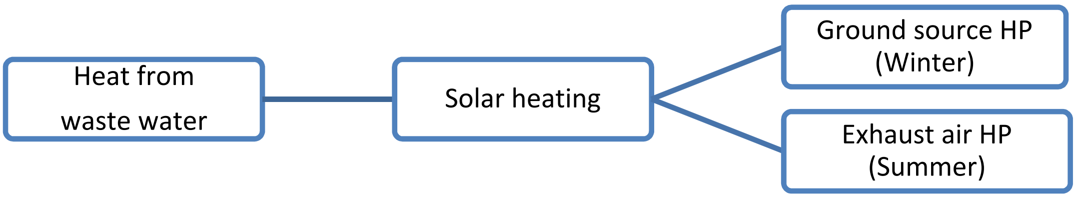


Figure 4.11 Priority for heating domestic hot water

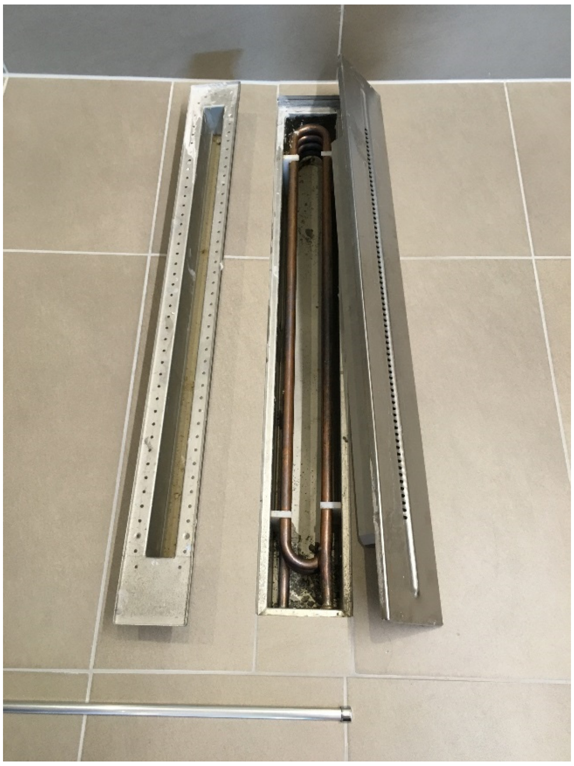


Figure 4.12 Grey water heat recovery system in the drain of the shower (photo SINTEF)

Figure 4.13 Grey water heat recovery system outside, including an accumulator tank (photo SINTEF)

Table 4.5 summarises basic system design parameters for the heating system. Technical specifications for the ground source heat pump, solar collectors, and heating tank is available in Appendix 2 to 4.

Table 4.5 Basic system design parameters (based on Nord, Qvistgaard et al. (2015))

Parameters	**Value**
Indoor / outdoor winter design temperatures	21 °C / -17 °C
Borehole number	1
Borehole depth	100 m
Brine/water ground source heat pump (GSHP)	
COP	5.17
Heating capacity	3 kW
Solar collector	
Number of collectors	8
Collector area	Gross (inkl frames) 16.76 m^2 Net (collectors only) 14.54 m^2
Exhaust air heat pump (EAHP)	
COP air/air	4.6
Heating capacity air/air	2 kW
COP air/water	3.9
Heating capacity air/water	1.2 kW
Storage tank for space heating and DHW	
Volume DHW in Nilan tank	180 l
Volume DHW in Oso EPTRC Volume space heating in Oso EPTRC	210 l 190 l
Electrical supply	3 kW
Heat loss coefficient	2 kWh/day

4.3 Photovoltaic System

Annual electricity yield from the PV system was calculated in the design phase to be 19,200 kWh per year. The PV system is connected to the utility grid. The solar PV system also has a battery energy storage, with the aim to increase the economic output of the PV system.

The solar PV system consists of 91 installed modules from Innotech Solar (ITS). The photovoltaic modules have a rated efficiency of 15.5% and their peak power is 250 W_p, giving a total power output of 22.75 kW_p. The area of the installation is 150 m^2.

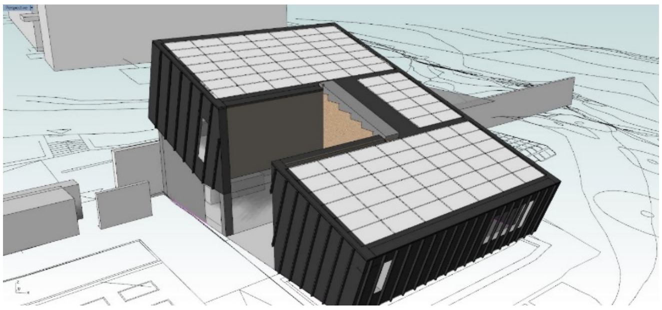


Figure 4.14 The PV system (Snøhetta)

As shown in the diagram of the PV installation in Figure 4.16, the PV modules are divided into four blocks. For each block there is an overvoltage protection (Schneider Electric iPRD40r-1000). There is also a circuit breaker (Schneider Electric iPRD40r-1000), for the protection of photovoltaic modules from fire in case of short-circuits. Since the PV system has a battery bank, charge controllers are installed. There are four MPPT 80 600 Solar Charge Controllers, one for each block. The direct current is then delivered to a battery bank (48V at 600Ah). After the battery bank, direct current DC is transferred to AC in three 6 kW inverters from Schneider Electric. There is a System control panel SCP from Schneider Electric monitoring the process.

Figure 4.15 The Solar Charge Controllers in the garage (photo: SINTEF Byggforsk)

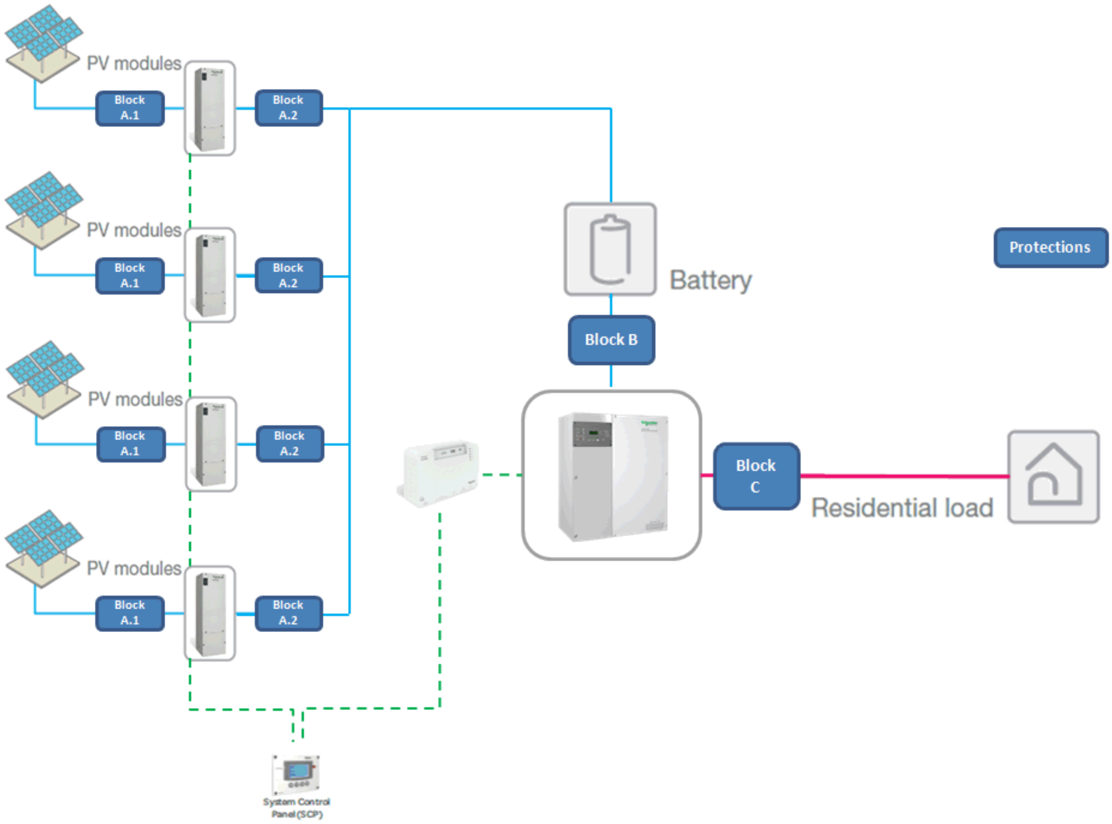


Figure 4.16 Diagram of the solar PV system. Source: Schneider Electric.

The PV modules are not integrated in the roof, but mounted on top of a bitumen felt, in a landscape orientation. Both the PV modules and the mounting structures can be removed without any impact on the physical functions of the roof. The roof mounting system is named K2 systems (K2-systems 2015).

A section of the roof construction of the ZEB pilot house Larvik is shown in Figure 4.17 A), and site pictures of the installation and battery bank are shown in B) and C).

Table 4.6 summarises key data of the solar PV system. Technical specifications for the batteries, charge controller, inverter, solar cells, and mounting system is available in Appendix 5 to 9.

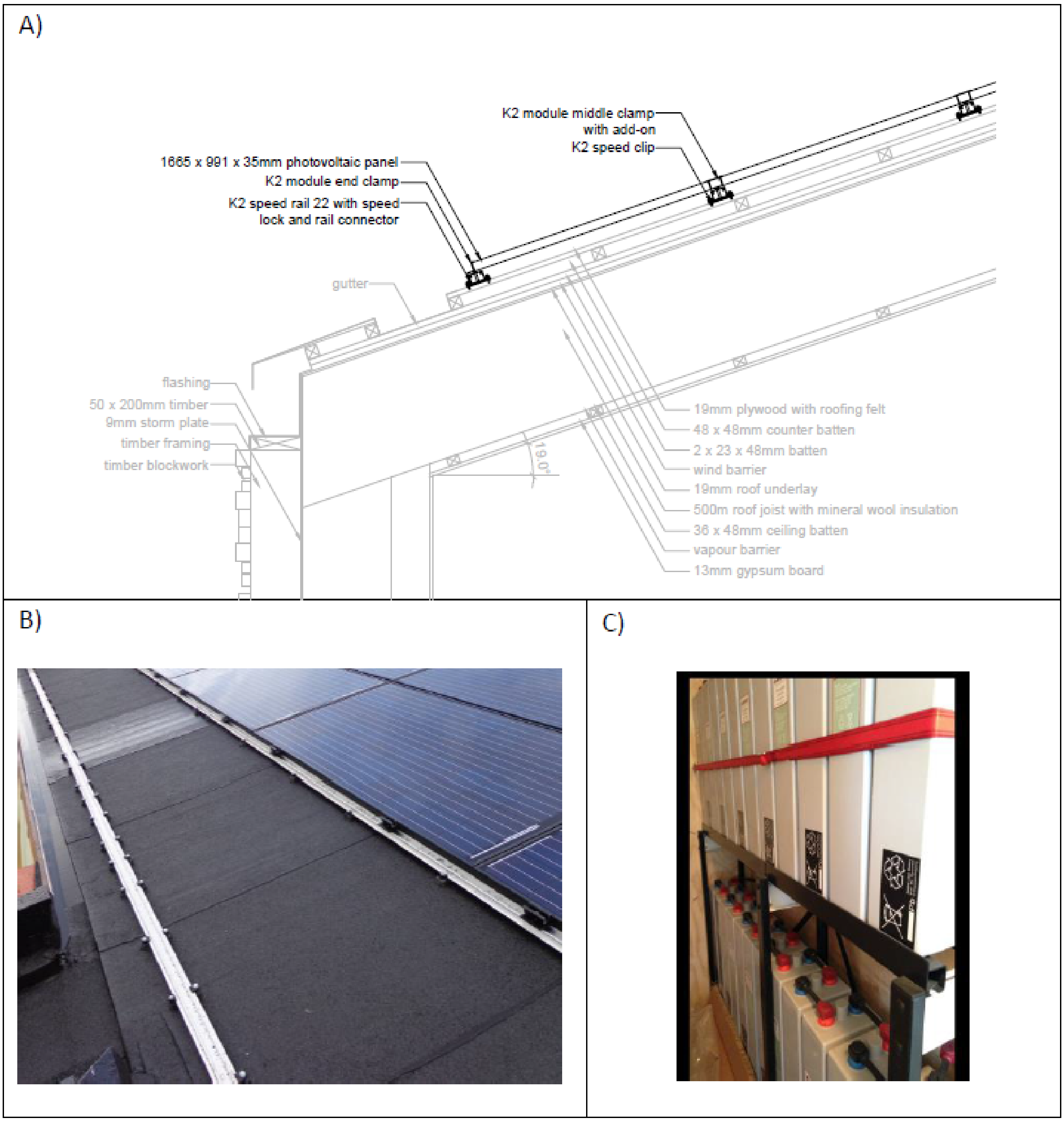


Figure 4.17 A) Section of the roof construction, B) Picture of the roof installation, C) Battery bank (Kristjansdottir, Good et al. 2016)

Table 4.6 Key data of the solar PV system

Description	Unit	
Solar panels		
Manufacturer	-	Innotech Solar (ITS)
Type of module	-	EcoPlus, Design Black 250
Country of PV module production		Sweden (modules) and Germany (cells)
Cell technology	-	Poly-Si
Rated power per module	W_p	250
Efficiency at STC*	%	15.5
Module size	m^2	1.65 (1.665 x 0.991)
Weight	kg	19
Number of modules	-	91
Total module area	m^2	150
Total rated power	kW_p	22.75
Product warranty	years	12
Performance, warranty, initial degradation		At least 97% of initial power after the first year
Performance, warranty, annual degradation		No more than 0.7% at least 80.2% after 25 years
Inverter		
Manufacturer		Schneider Electric
Inverter type		Conext XW6048-230-50
Number of inverters		3
Output power (continuous) at 40°C, per inverter		6 kVA
Efficiency		95.4%
Mounting system		
Type of mounting system		BAPV
Mounting system manufacturer		K2 Systems
Place of mounting frame production		Leonberg, Germany
Charge controller		
Type		Conext XW MPPT80-600
Monitoring system		Conext™ ComBox
		Conext Solar System Control Panel
Battery storage		
Type of batterier		Norbat, CFPV 2V 600Ah, OpzV GEL
Weight	kg	42.3
Number of batterier	-	24
Total storage capacity		48V at 600Ah
Country of battery production		China

4.4 Control system

An intelligent building control system (KNX from Schneider) controls heating and lighting. The energy system is connected to meters that are controllable via a web connection (described in Chapter 5.1). The control system can be managed by phones and tablets. The battery bank is located in the carport, and its charging status is controllable by the same system.

5. Operational Energy Performance

5.1 Energy measurements

Simulated energy use values may differ from actual energy use based on aspects such as occupant behaviour and technical performance of the components installed. Also, due to the lack of time and appropriate tools, simplified assumptions often have to be made in the design phase. One such simplification in the design of the ZEB pilot house Larvik was to assume that 50% of the energy in the grey water would be recovered with the heat recovery system. In addition, the energy simulations included a number of assumptions with respect to the envelope air tightness, efficiency of ventilation system, efficiency of heating system, behaviour of occupants, and climatic conditions. All these assumptions can only be validated by detailed measurements of the building in operation. (Kristjansdottir, Andresen et al. 2015)

The pilot house has energy metering on all electrical consumption, thermal energy production, and consumption of heating and hot water. Since this is a pilot house for demonstration purposes, there is no-one living in the building. Part of the energy consumption is therefore lower than in an occupied building, such as use of domestic water. Still, there will be useful information from the energy metering, such as the energy produced from the solar cells. Also the measurements of solar heating production will be useful, since all the heat is either delivered to the house or to the pool. The measurements therefore provide information about the total heat production from the solar collectors. Available measurements of the energy yield from solar collectors is shown in Figure 5.1. Measurements were not available for the whole period, and some days show no energy yield from the solar collectors even though energy was delivered. In Figure 5.1, June 2015 is shown in more detail, since this is a month where most measurements data were available. An example of a sunny day is June 12th 2015, where 60 kWh heat was delivered from the solar collectors.

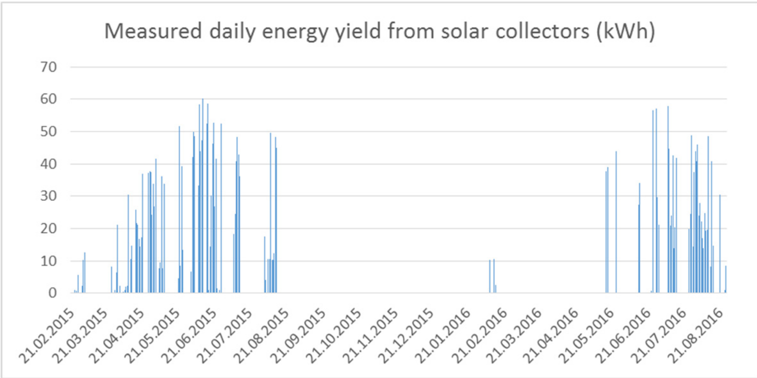
The installed energy meters in the building are:

Electric circuits with energy measurement per circuit:
Heat pump
Compact P / ventilation
Technical demand
Pool
Lighting
Electrical plugs
Charge for electric car in carport

Energy measurements for heating:
Solar collector (Measurements are divided on needs (tap water, pool, etc))
Energibrønn / sløyfe (Measurements are divided on needs)
Heating
Domestic hot water
Grey water heat recovery

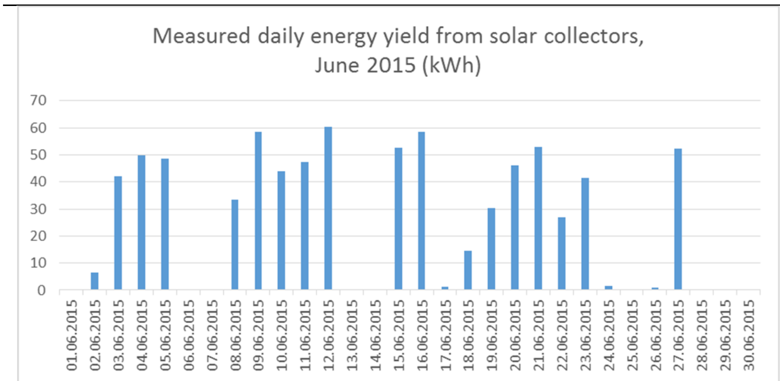
In addition, the outside temperature is measured in a weather station. Also the supply air temperature for the ventilation is measured.

The grid operator Skagerak Nett has also initiated electricity measurements to study the quality of the electricity from the solar cells delivered to the grid.

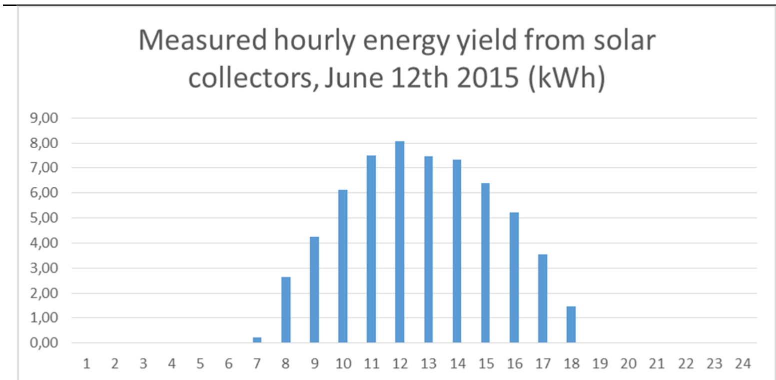


Measured daily energy yield from the solar collectors (kWh).

Measurements are not available for the whole period, so some of the days show zero energy generated even though the solar collector delivered heat this day.



Measured daily energy yield from the solar collectors in June 2015 (kWh).



Measured energy yield from the solar collectors June 12th 2015 (kWh).

Figure 5.1 Measured energy yield from solar collectors

5.2 Detailed analysis of the operational energy performance

Nord, Qvistgaard et al. (2015) and Qvistgaard (2014) have done a detailed analysis of the heating system of the ZEB pilot house Larvik. In order to investigate the system performance and total energy use, the dynamic simulation tool IDA-ICE (EQUA Simulation AB) was used. IDA-ICE performs a whole-year detailed and dynamic multi-zone simulation, which enables analysis of the thermal indoor climate and the energy consumption of the entire building. IDA-ICE is able to simulate complex energy supply systems more detailed than SIMIEN, which was used for simulating the energy performance in the design phase, as described in Chapter 4.1.

The study found that 85% of the total heating need of the building was covered by renewable energy. The results showed that the solar energy generated by the system could cover 85-92% of the domestic hot water need in summer and 12-70% of the need in winter. In addition, the solar energy may cover 2.5-100% of the space heating need, in winter and summer respectively. The results showed that the supply air volume, the supply air and zone set point temperatures, the auxiliary electrical volume, the volume of the DHW tank, the orientation and tilt angle and the collector area were the parameters that had the most significant impact on the total energy use.

Figure 5.2 shows the total delivered energy of the energy system (Nord, Qvistgaard et al. 2015). The “Electrical heating” column represents the electrical energy utilized by the electrical boilers and the compressors in the ground source heat pump (GSHP) and the exhaust air heat pump (EAHP). HVAC Aux covers the electricity use of the fans and pumps in the system. The annual total specific delivered energy for the building was calculated to 35.5 kWh/m^2 in the study. This is similar to the SIMIEN-calculation of 35.4 kWh/m^2.

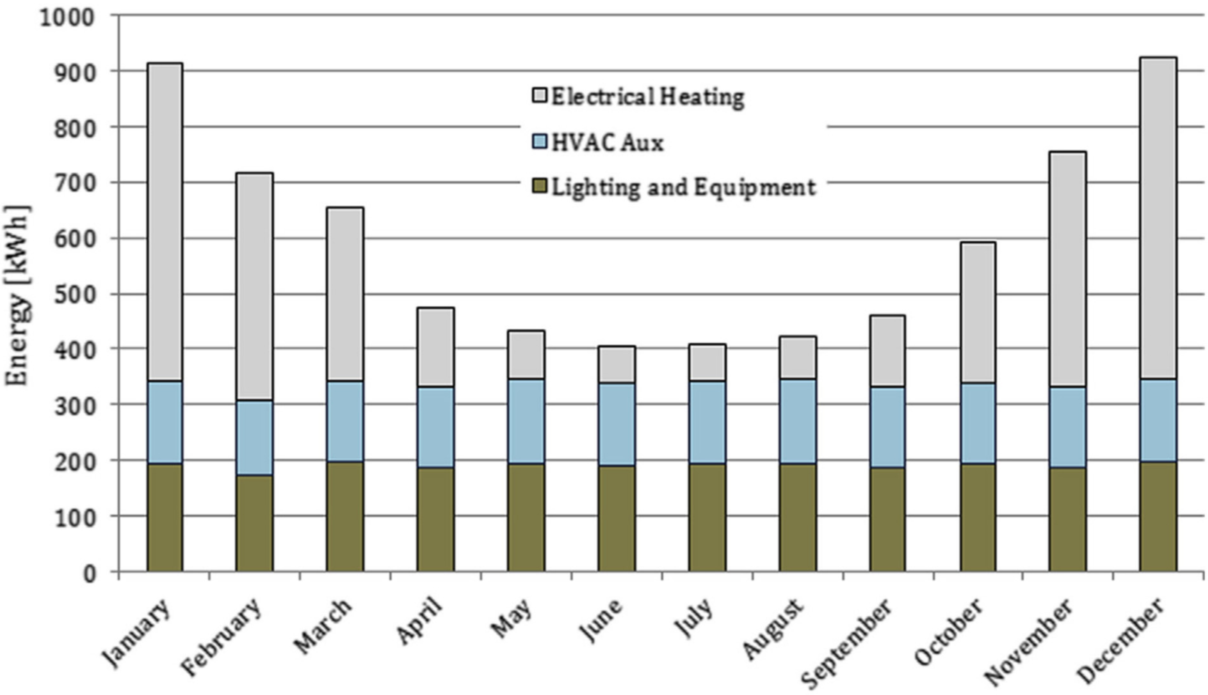


Figure 5.2 Calculated monthly delivered energy (not including the PV system), source: (Nord, Qvistgaard et al. 2015).

Figure 5.3 shows the monthly energy balance between the energy need and the amount of utilized renewable energy. Both the Space heating (SH) need and the Domestic hot water (DHW) need were included in the “Energy need” columns. The monthly solar fractions obtained are represented by the orange line, and the solar fraction was calculated to be 100% from May to August. This indicates that excess solar heat is produced. The system's total annual solar fraction for the simulated year was 35.9%. The specific heating need for the building was 27.1 kWh/m^2 per year, which is higher than the required 17.6 kWh/m^2 stated in NS 3700.

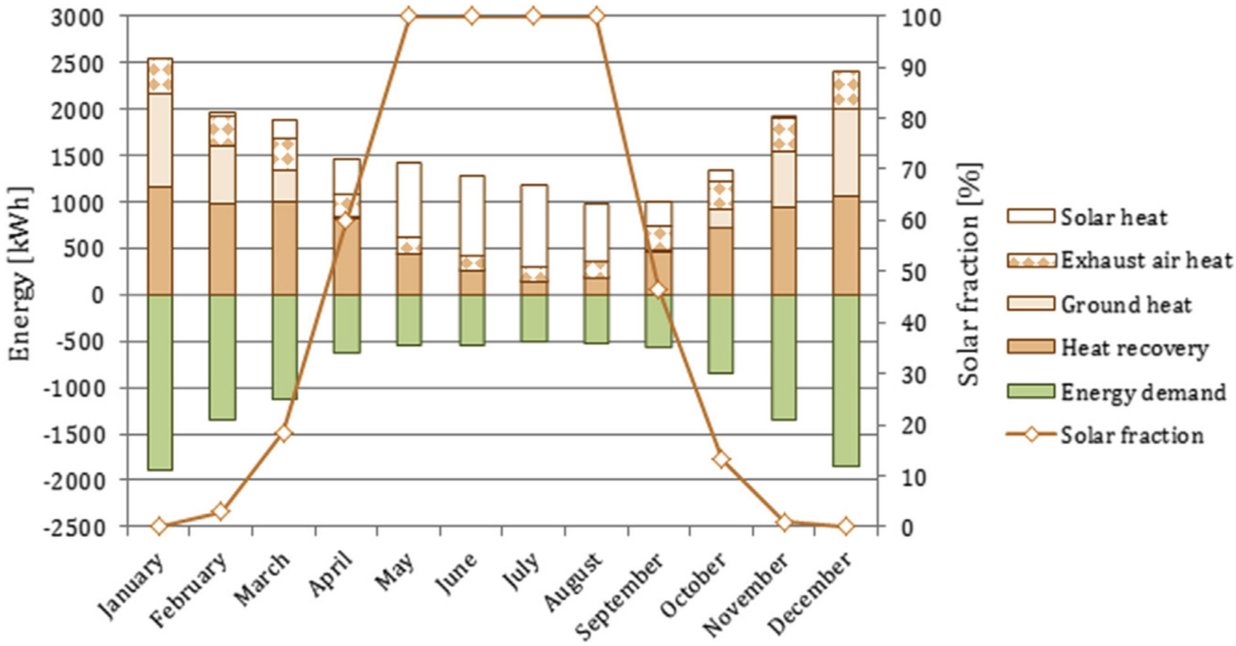


Figure 5.3 Energy need, utilized energy, and solar fraction, source: (Nord, Qvistgaard et al. 2015).

5.3 Tests of the energy performance in the ZEB pilot building Larvik

Saint-Gobain has developed two methods for evaluating the thermal performance of buildings, named the QUB method and the QUB/E method. Researchers from Saint-Gobain has compared the CUB method successfully to other experimental reference measurements in several cases (Centre de Recherches Isolation de Rantigny 2015). Table 5.1 gives a brief description of the QUB and QUB/E methods. Saint-Gobain has used the methods to evaluate the thermal performance of the pilot building in Larvik.

The results from the QUB test are described below. The development of the QUB/E method is still in the early stage and is therefore not included.

Table 5.1 Description of the QUB and QUB/E methods from Saint-Gobain

Building Envelope performance control ➔ QUB (Quick U-Bat)	Building Envelope diagnosis ➔ QUB/Element
• Measurement of the whole envelope performance • Comparison with values calculated in a thermal study (a "reference", which supposes perfect construction) • Better adapted for new buildings (reference = thermal study) • Started in 2010 → close to industrialization phase at Centre de Recherches Isolation de Rantigny	• QUB + identification of local losses for possible improvements • Measurement of global and local losses (walls, windows, roof, ceiling…) • Suitable for renovation projects (also possible at reception of new or renovated building) • Technical solution identified in 2014 → R&D at Saint-Gobain

Experimentally, the QUB method requires the house to be heated for a few hours, and then cooled for the same duration during the night, in an empty building in order to reduce the unknown heat gains. For the pilot building Larvik, each phase lasted 6 hours. Losses are calculated by first measuring the thermal power through the envelope (in W), the internal and external temperature differences (in K), and the slopes of the internal temperature evolution during each phase (K/s), and then by applying a QUB equation to obtain the value of the heat loss coefficient (or HLC), expressed in W/K. The HLC is the envelope thermal transmittance, also called the inverse of its thermal resistance, and can be understood as the average U-Value of the house (W/m^2K) multiplied by its heat exchange area (m^2).

In this case, the QUB method enables the measurement of the envelope losses and their comparison to the values calculated with a thermal study, which supposes perfect construction and does not include any infiltration losses. A calculated value lower than the measured one, should thus be expected. The thermal study predicted a HLC of 110 W/K, whereas the experimental QUB method gave a result of 126 W/K, or 15% higher. For a house of such insulation, Saint-Gobain evaluates a 15 % difference as very low and considers this a very good result.

6. Material Emissions

6.1 Methods and Tools

A simplified life cycle emission balance over the estimated service lifetime is visualized in Figure 6.1. The emissions from production of materials (initial and estimates for replacement) as well as the emissions from energy use and energy production in the operational phase are included. The construction and demolition phases are excluded. The building itself is the physical boundary for the analysis; exteriors like the garage and the terrace are not included.

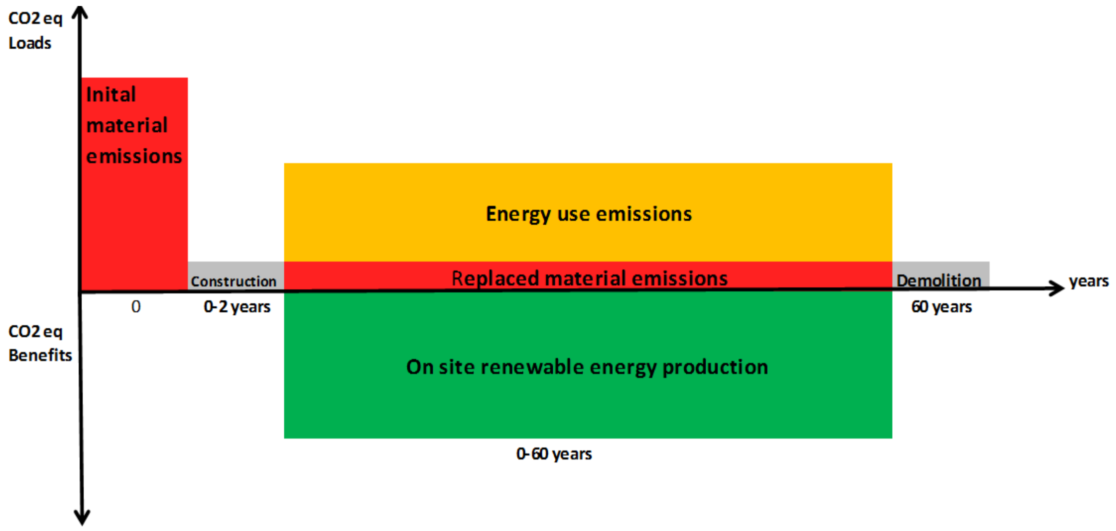


Figure 6.1 Zero emission life cycle balance for a building, the green area represents renewable energy production that compensates for emission loads (Kristjansdottir, Andresen et al. 2015).

For a building with ZEB-OM ambitions, Figure 6.2 shows which emission elements to include.

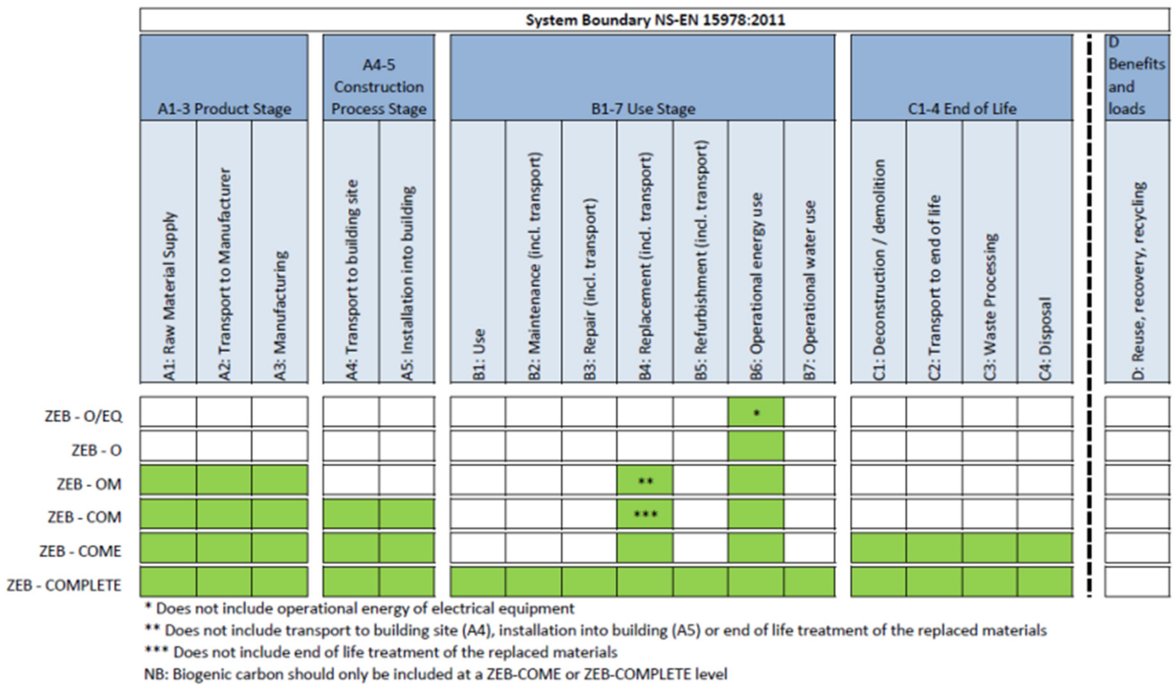


Figure 6.2 ZEB balance elements, according to the life cycle phases as defined in NS-EN 15978 (Fufa, Schlanbusch et al. 2016).

Kristjansdottir, Andresen et al. (2015) presents the *design phase* calculation of greenhouse gas emissions for the pilot house in Larvik. Measures that could reduce GHG emissions (kg $CO_{2\,eq}$) were identified, and input to the ZEB balance calculations was provided. The presentation below is based on the design phase calculations, with some updates.

Building materials quantities are based on material take offs from the Building Information Model (BIM) made by the architects. The life cycle analysis tool SimaPro version 7.3 is used for the material emission calculations. Quantities of materials for technical installations and concrete and steel in the foundation were based on communication with relevant professionals. Material emission data used was from relevant Environmental Product Declarations (EPDs), from the Ecoinvent database v2.2 (Ecoinvent 2010), and from the specific information from Innotech for the PV modules and Norbetong for the concrete. For the reused bricks, no emission loads were accounted for. Also, on- site losses of materials were not accounted for.

The limited amount of time in the design phase and the limited information available on quantities and types of materials to be used resulted in quite rough estimates for material emissions. This is further described in Chapter 9.1, The Design Process.

According to the emissions data for the ITS PV modules, the emissions are around 60 kg CO_2/m^2 module. 20 kg CO_2/m^2 was added as an estimate for the aluminium frame. The production of the ITS modules are partially based on secondary materials and hydropower (Innotech Solar 2015), and in order to keep the embodied emissions low, these modules were chosen. Module emissions were multiplied by 1.2 to include a scenario for the balance of system emissions (inverter, cabling etc.). This was based on the relative contributions of to the carbon footprint between the balance-of-system and modules, as analysed by (Fthenakis 2011).

Assumed service lifetimes are listed in Table 6.1.

Table 6.1 Service lifetime scenarios (from Kristjansdottir, Andresen et al. (2015), except batteries (Coromatic 2016))

Component	Service lifetime [years]	Component	Service lifetime [years]
Photovoltaic panels	30	Floor material	15
Heat pump	20	Interior wall surface	30
Ventilation ducts	60	Insulation	60
Solar thermal system	30	Steel	60
Concrete	60	Windows/ doors	30
Batteries	20		

6.2 Embodied GHG Emissions

Figure 6.3 shows the calculated emissions for different construction parts. As described, this analysis is based on the design phase calculation (Kristjansdottir, Andresen et al. 2015). Even though the design phase calculation is rather rough, it gives an overview of the main factors when it comes to embodied GHG emissions.

In the design phase, the emissions from the product phase were calculated to be 3.6 kg CO_2 eq/m^2 per year and the material replacement scenario 2.2 kg CO_2 eq/m^2 per year. In total, material emissions were 5.8 kg CO_2 eq/m^2. The results from the design phase calculation are shown in Figure 6.3.

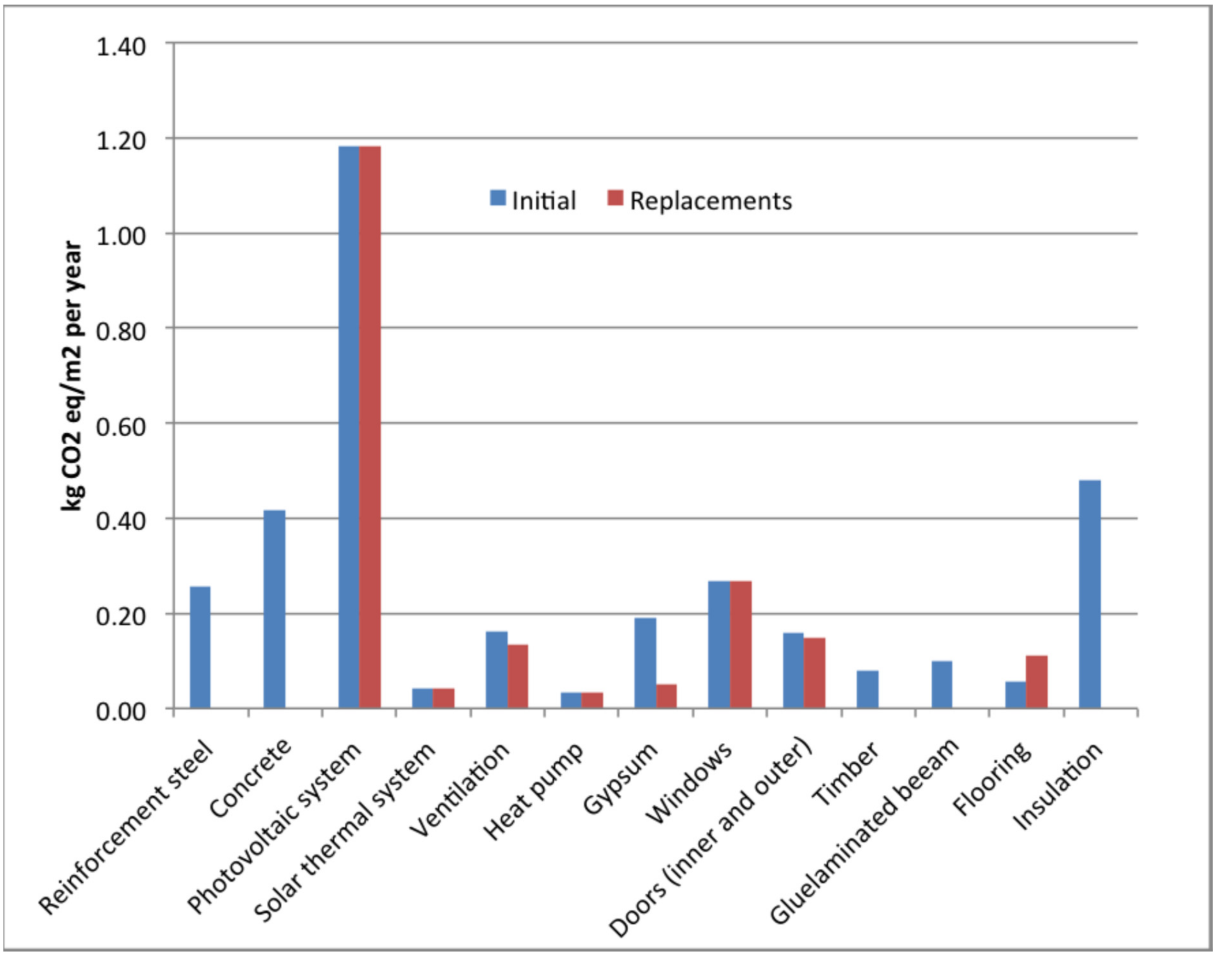


Figure 6.3 Design phase calculation (Kristjansdottir, Andresen et al. 2015).

Compared to the design phase, some changes are introduced in the following calculations:

1. In the design phase calculation, it was assumed that there were no changes in emissions from the replaced components and materials. E.g. PV module emissions are simply multiplied with two (30 years*2=60 years). This assumption is conservative as it is likely that photovoltaic modules produced in 2045 will have a higher efficiency and be produced more efficiently with an increased amount of renewable energy. If the replaced solar cells after 30 years have 50 % less emissions than the initial solar cells, this will reduce the emissions with approximately 0.6 kg CO_2 eq /m^2 per year. (-0.6 kg CO_2 eq/m^2 per year)
2. In the design phase calculation, CO_2 emissions from the battery production were not included. Calculated emissions from the battery pack of 24 batteries is 3341 kg CO_2 in total, giving initial emissions of approximately 0.27 kg CO_2 eq/m^2 per year. If assuming that the emissions are reduced with 30 % when being replaced after 20 years, and another 30 % after 40 years, the replacement emissions are 0.33 kg CO_2 eq /m^2 per year. (+0.27 kg CO_2 eq /m^2 per year + 0.33 kg CO_2 eq/m^2 per year)
3. Given that the design phase calculations are rather rough and that experiences show that when detailing the calculations – including all building materials, it is likely that the emissions will increase. Since we have not included a detailed emission calculation in this as built report, 20 % are added to the total calculated emissions as an estimate. (+1.16 kg CO_2 eq/m^2 per year)

4. In total, these changes give total annual material emissions of 6.9 kg CO_2 eq/m^2, divided into initial emissions of 4.6 kg CO_2 eq/m^2 per year and replacement emissions of 2.3 kg CO_2 eq/m^2 per year.

If calculating the embodied GHG emissions in more detail in possible further work, the amount of the different construction parts are needed. As an input to such further calculations, amounts of different construction parts are collected, available in Appendix 12.

7. The ZEB Balance

To fulfil the ZEB-OM ambition for the Pilot house Larvik, on-site renewable energy generation is needed for the operational energy use and for embodied emissions from the materials and technical installations. In addition, the building should supply enough energy for an electric car.

The building is designed as an "all-electric" building, which means that all energy exported or imported to the building is in the form of electricity. The net emission balance (ΔCO_2) over the service lifetime of 60 years for an *all-electric* ZEB-OM can be formulated as in Equation 1:

$$\Delta CO_2 = CO_{2mp} + CO_{2mo} + CO_{2e}(Q_d - Q_e) \qquad (1)$$

where:

- $CO_{2\,mp}$ is the annualised **m**aterial emissions in the **p**roduct phase [kg CO_2 eq/m^2 per year]
- $CO_{2\,mo}$ is the annualised **m**aterial emissions during **o**peration (here product phase replacements only) [kg CO_2 eq/m^2 per year]
- Q_d is the annual electricity **d**elivered to the building [kWh/m^2 per year]
- Q_e is the annual electricity **e**xported to the grid from the building [kWh/m^2 per year]
- $CO_{2\,e}$ is the annually averaged CO_2eq **e**mission factor for **e**lectricity [kg CO_2eq/kWh]

If the net balance, ΔCO_2, is zero or less, a zero-emission balance is achieved.

When calculating the emissions, the same CO_2 equivalent factor was used for the import and export of electricity to and from the building. The emission factor of 0.132 kg CO_2 eq/kWh electricity was used for $CO_{2\,e}$. This yearly averaged factor is based on a future scenario assuming a fully decarbonised European grid by the end of 2055, according to EU policy goals (Fufa, Schlanbusch et al. 2016). The emission results are sensitive to changes in the emission factor. It is more difficult to achieve a ZEB balance with a low emission factor, and easier with a higher factor.

Figure 7.1 shows the emission balance calculated for the ZEB Pilot house Larvik. The emission elements in the table, A1-3, B4, and B6, are explained in Figure 6.2.

For the delivered energy, only the delivered electricity is included in Figure 7.1. The total energy balance is described in Table 4.4.

For the electricity, the emission factor of 0.132 kg CO_2 eq/kWh was used for the delivered energy to the building, including both the grid electricity and the electricity generated by the solar cells. As an alternative, only the exported electricity could be included in Figure 7.1, and not the electricity used directly by the building. This would reduce both columns in Figure 7.1 by 943 kg$CO_{2\,eq}$ / year, corresponding to 7142 kWh.

The embodied emissions are described in Chapter 6. For the electric car, the energy need is estimated to 0.2 kWh/km.

The carbon dioxide emissions are calculated to 2,650 kg$CO_{2\,eq}$ per year over a 60-year lifetime, or approximately 13.2 kg$CO_{2\,eq}$/m^2 per year. It is estimated that 36 % of emissions come from operational energy use (B6), while 52 % of emissions come from building materials and replacements (A1-3+B4). 12 % of emissions are connected to the use of the electric car.

The calculated emission balance gives a close margin on the ZEB-OM ambition for the ZEB-pilot house Larvik, but not when including 12,000 km with the electric car. Reducing the use of the electric car to 7,600 km gives a balance in the calculated emissions, given the described conditions.

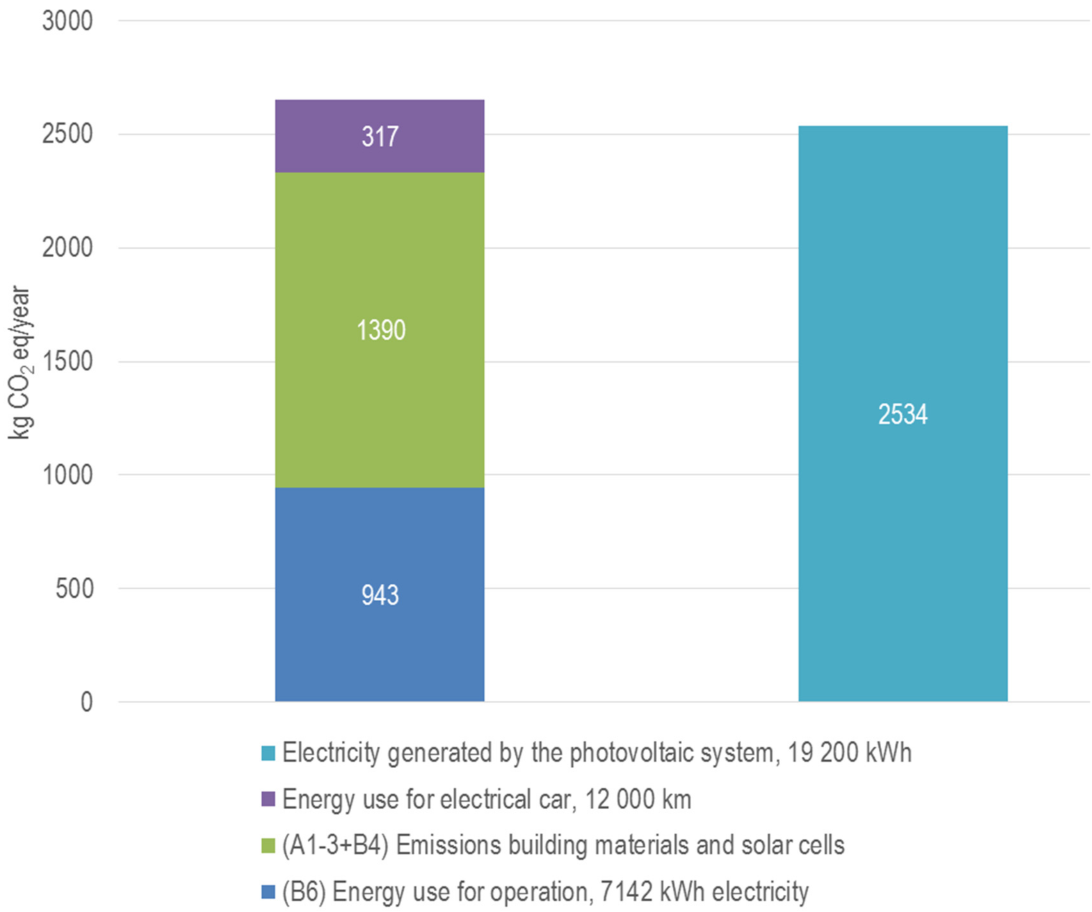


Figure 7.1 The calculated emission balance for ZEB-pilot house Larvik (kg$CO_{2\ eq}$/year)

8. Indoor Climate Performance

The Saint-Gobain's Multikomfort concept has a focus on indoor air quality and daylight, as well as environmental performance. The use of solar gains and natural light is maximized through the building construction and location. The daylighting calculations are described in Chapter 3.2 Lighting. Further, the building's external envelope aims to contribute to aesthetic quality and comfort.

Acoustics is also an important element in the ZEB pilot house Larvik. A requirement of 0.7 sec reverberation time was defined. Acoustics calculations from Gyproc/Gyptone are available in Appendix 13. Acoustic products from Topakustik were later chosen by the architects, who expect the performance to be similar to the calculations in Appendix 13.

The house has a balanced ventilation system with constant air flows. The temperature in the building is currently automatically regulated to 22 degrees during the daytime and 18 degrees during the night.

9. Design and Construction Process

9.1 The Design Process

Figure 9.1 Design phase model of the building. Source: Snøhetta.

The project was initiated during the autumn of 2012. The first design phase team meeting was held in January 2013, and the design phase ended in a workshop in June 2013. The ambitious task of building a ZEB-OM was addressed in a series of interdisciplinary workshops arranged during the design process. Also, thematic working groups (energy, construction, embodied emissions, etc.) were initiated to co-ordinate how it could be possible to achieve such an ambitious objective.

The group working on the embodied emissions included an architect, a construction engineer, an energy engineer, and a GHG accounting expert from ZEB (Kristjansdottir, Andresen et al. 2015).

Several measures to reduce emissions through material choices, energy efficiency, and renewable energy generation were initiated during the design phase. Various digital tools were used by SINTEF and Brødrene Dahl, as described in e.g. Chapter 2.2 (Design choices) and 4 (Energy Supply Systems).

Material choices

The analysis by Dahlstrøm et al. (2012) and Houlihan Wiberg et al. (2014) helped to get an overview of embodied emissions drivers. The team focused on gathering as much environmental information on the suggested materials as possible. Based on previous analyses, two topics received special attention for emissions reductions. This was the choice of photovoltaic modules and the choice of foundation materials and construction. Different choices for PV modules and foundations structures where roughly calculated as inputs to the ZEB balance.

Three different foundation alternatives were evaluated in the design phase: 1) a standard alternative with a normal concrete slab (0.2 m thick) with reinforcement steel, 2) a standard alternative with low carbon concrete, and 3) a timber construction built on a strip foundation of low carbon concrete. The analysis showed that alternative 3 had the lowest emissions, with around 0.5 kg CO_2 eq/m^2 per year.

The other alternatives had emissions of around 2 and 2.5 kg CO_2 eq/m^2 per year. Thus the foundation solution was chosen based on alternative 3.

Also, two types of photovoltaic modules were evaluated: A high-efficiency module from SunPower (efficiency 20.4%) and modules from Innotech Solar (ITS) (efficiency 15.4%). Both modules are based on crystalline silicon solar cells. In the production of the ITS module, defective wafers are repaired and used in the new modules. The high efficient SunPower modules are produced with virgin materials.

Emissions from the modules analysed are given in Table 9.1. Based on the results, the ITS panels were chosen. More information on the design phase evaluation is available in the report "Design phase greenhouse gas emissions for a zero-emission residential pilot building" (Kristjansdottir, Andresen et al. 2015).

Table 9.1 Types of PV panels and emissions (Based on Kristjansdottir, Andresen et al. (2015)).

Type of panel	Rated power [W_p]	Efficiency	PV area needed [m^2 PV]	Embodied emissions [kg CO_2eq/m^2 PV per year]	Embodied emissions [kg CO_2eq/per year]
ITS	250	15.4%	109	5.1	556
SunPower	333	20.4%	92	7.0	644

Embodied emissions challenges

One of the design phase challenges was that producers did not always have information about production-related emissions, or they were reluctant to deliver such information. Thus, making comparisons between materials and products were difficult.

The initial material inventory and embodied emissions analysis were rough, as all the inputs were not yet available (Kristjansdottir, Andresen et al. 2015). By using a simplified inventory, it can be challenging to make credible comparisons of alternatives. Construction phase quantities were received from the construction engineer as the building process progressed (after June 2013). In Table 9.2 the different quantities are given. Increased quantities will obviously increase emissions. There are small differences in the design and construction phase quantities from glass wool insulation, where quantities were taken from the BIM. However, quantities of concrete and reinforcement steel for the foundation are significantly different, as these quantities were based on rough estimates.

Table 9.2 Amounts of materials in the design phase and construction phase

Material	Design phase	Construction phase	Unit
Concrete	18	33	m^3
Reinforcement steel	132	1800	kg
Glass wool insulation	230	242	m^3
EPS insulation	0	7.5	m^3
XPS insulation	0	4	m^3

By using the construction quantities from Table 9.2 there is an increase in material emissions of around 0.5 kg CO_2/m^2 per year, resulting in a total increase in emissions of around 8.5%. These differences are due to rough estimates and lack of information. In the comparison made with the foundation alternatives, a volume of 18 m^3 of concrete for the timber slab alternative was used. However, the concrete volume that was actually used for the construction was 33 m^3. The design phase values show that despite the increase in material use, the reduced use of concrete still seems to pay off compared to the timber construction, but less than was initially estimated. This is further described in (Kristjansdottir, Andresen et al. 2015).

Team work
Participants in the design team describes the building process in interviews (Moum, Hauge et al. 2016 (to be published)). Initially, the ambition of the building was ZEB-O (operating), but the ambition was increased to ZEB-OM (operation and materials) after the building became a ZEB pilot building.

Looking at the design process in general, the team highlights the importance of interdisciplinary work in these kinds of pilot buildings with high environmental ambitions. For such buildings to become a successful reality, architecture and technology must come together and ensure optimization of both comfort and energy use. The engineers designing the technical solution were involved from the beginning of the project.

Being a part of the building project is described as interesting and "driven by curiosity". The expectations to work on such a different project were high, and the group was described as very competent.

There has been a larger focus on using *environmental friendly materials* than in other building projects. The interviewed team members say that the experience from focusing on the material choices has been demanding but at the same time interesting and useful. The researchers from the ZEB-centre have been involved in this process, which was described as important for choosing and fulfilling the high ambitions. Optimera and Brødrene Dahl have been involved in requesting LCA (Life Cycle Assessment) data and EPDs (Environment Product Declarations) from the subcontractors. From this process, they learned which producers and sub-contractors that could deliver such documentation; which the team considered a sign of commitment. An important prerequisite was that the project should be realized by using regular products (NAL 2016). Also the travel distance of the materials has been documented.

Also the ambitions for *design* have been high. The design and placement of windows gained increased focus in such a well insulated house, to avoid overheating but still have a view. The team wanted to make sure that the house facilitated aesthetic quality and comfort – which for example led to the realization of the outdoor fireplace.

9.2 The Construction Process

The project team evaluates the organization of the project as good (Moum, Hauge et al. 2016 (to be published)). A central issue has been the importance of having an interdisciplinary project team from the beginning. The project team has had a project manager from Brødrene Dahl and one from Optimera, as well as a manager for technical engineering from Brødrene Dahl and a manager for construction technology from Optimera. Representatives for the craftsmen were involved from an early phase, within electricity, ventilation, water, and building construction. The architects were also represented in some of the meetings during the construction phase.

The design phase was comprehensive, but there were still details that needed to be designed during the construction process. Since several new solutions are implemented in a demonstration project, some details are not discovered until the construction process. This gives the ones involved in the construction team new challenges and roles. The project development has therefore been a learning process for many of the participants involved in the design and construction.

An example of a challenge in the construction phase has been the construction of the glued wooden beams used as construction elements. The wooden construction was delivered as pre-cut elements and built on site. The work was done in a tent for protection against the weather. Using the tent should secure a low humidity in the materials. However, the tent made the construction work more complicated, and the construction period was therefore longer than planned. Looking back at the process, workers at the construction site conclude that it would have been better to make the glued wooden beams before setting up the tent.

The financial model of the project has been an "interaction model" ("samspillsmodell"). In an interaction model, the team is jointly responsible for the engineering towards an agreed target price. The project manager describes this as a good model for future development projects. Especially when many of the involved partners need to acquire new knowledge, this is evaluated as a valuable project model. In such projects, the design phase is especially important.

Figure 9.2 shows pictures from the construction process.







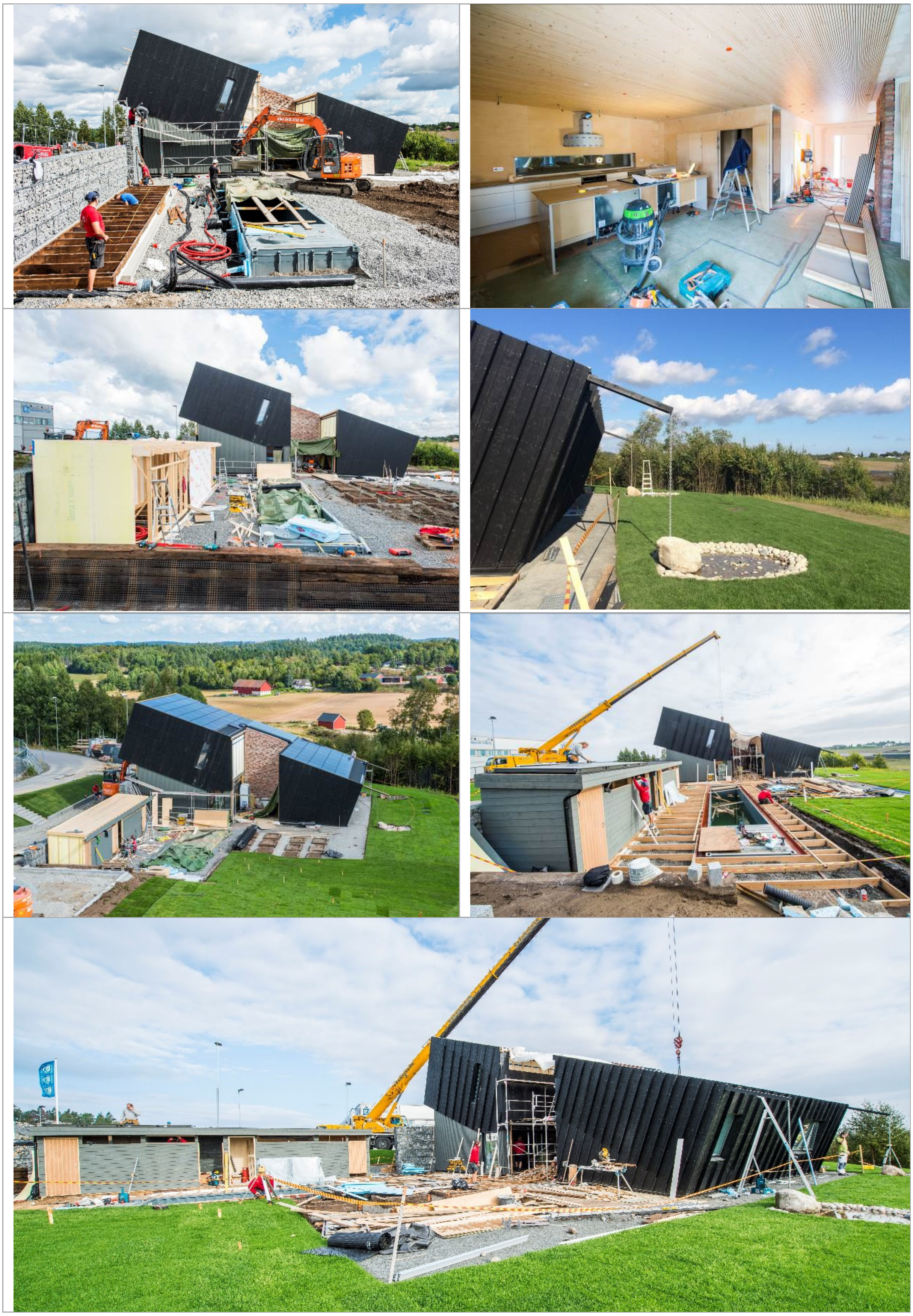



Figure 9.2 Pictures from the construction process (photos: Brødrene Dahl/Paal-André Schwital).

10. Costs

Since this is a pilot building, the design and construction costs were higher than what would be expected in a standard project. Especially the number of working hours in the design and construction phase is longer in a pilot project than in a more streamlined building project. The main focus has not been on reducing costs, but on reducing emissions and on quality of design and architecture.

To estimate the future costs of such buildings, information on actual costs is combined with general cost for Norwegian buildings and components. The industrial partners have calculated that a realistic total cost for such a building in the future will be 5.8 million NOK, inclusive tax. Compared to a building following the TEK10 standard (current building code), the building would be approximately 1 million NOK more expensive. The extra cost is mainly related to energy efficiency measures in the building (app. 40 %), the heating system (app. 20 %), and the PV and battery system (app. 35 %).

When calculating the cost effectiveness, savings due to reduced energy need is taken into account. The energy price for the future 60 years is assumed to be 1 kr/kWh. In the calculations, 100 % self-consumption is assumed, or similar energy price for selling and buying electricity. For the surplus energy, a selling price of 0.5 kr/kWh is assumed.

Table 10.1 shows the input data for the calculation, comparing the building to a building following the TEK10 standard.

For the TEK10 building, the following assumptions are made:

- The building area, building structure, and system boundary does not change. Only the energy savings in the building are therefore included, not the use of the pool.
- The building follows the energy frame method in the national regulations (revised TEK10), where maximum energy need for the building per m² heated floor area is 100 kWh + 1600 kWh/m² heated floor area. For 201.5 m^2, maximum energy need is 108 kWh/m², or 21 750 kWh per year in total.
- The heating source used is direct use of electricity only (no heat pumps, solar collectors, solar cells, or heat recovery).

Table 10.1 Cost efficiency

	A building following the TEK10 standard	A future building similar to the pilot building	Difference
Investment, inclusive tax	4.8 million NOK	5.8 million NOK *	1 million NOK
Delivered energy to building and el. car	21 750 kWh + 2,400 kWh	7,142 kWh + 2,400 kWh	
Annual energy cost, if 1 NOK/kWh	24 150 kr	0 kr **	24,150 NOK/year
Income from plus-energy house, if 0.5 NOK/kWh		4,829 NOK (kWh: 19,200 - (7,142+2,400))	4,829 NOK/year
		Savings during 60 years	1 739 000
		Simple payback time	35 Years

* Ambitious buildings and technology choices may qualify for support from Enova.
Such support varies, and is not included in the cost efficiency calculation.
** Assume 100 % self-consumption or similar energy price for selling and buying electricity.

11. Summary and Conclusions

The ZEB pilot house Larvik is a two-storey single-family residential building situated near Larvik, Norway. The building was designed by Snøhetta, Brødrene Dahl and Optimera for demonstration purposes, to showcase and test energy solutions for energy-efficient and plus-energy buildings. The house has gained a lot of attention. A number of people are visiting the house, e.g. plumbers and builders that want information about possible new solutions.

The ambition level of the building was ZEB-OM. To achieve this ambition level, on-site renewable energy generation is needed for the operational energy use and for embodied emissions from the materials and technical installations. In addition, the building should supply enough energy for an electric car.

An interdisciplinary project team has been involved in the design and construction process. Research was made to reduce the emissions from construction materials, and also their ability to contribute to good indoor climate was taken into account. A number of active and passive energy measures are demonstrated. Lessons learned from the project can be useful for other building projects with ambitious goals.

The energy generation system is based on roof mounted photovoltaic modules for electricity, and a combination of different heat sources for thermal energy: a ground-source-to-water heat pump, an air-to-water heat pump in the exhaust of the ventilation shaft, a solar collector system, and a grey water heat recovery system

The calculations show a net energy need for the building of 17,348 kWh per year, or 86.1 kWh/m^2. The demand for *delivered* energy is reduced due to the different heat sources for thermal energy. The remaining demand for delivered energy was calculated to 7,142 kWh electricity per year, or 35.4 kWh/m^2. The calculated production from the photovoltaic system is in total 19,200 kWh per year.

The carbon dioxide emissions are calculated to 2,650 $kgCO_{2\ eq}$ per year over a 60-year lifetime, or approximately 13.2 $kgCO_{2\ eq}/m^2$ per year. It is estimated that 36 % of emissions come from operational energy use (B6), while 52 % of emissions come from building materials and replacements (A1-3+B4). 12 % of emissions are connected to the use of the electric car.

The calculated emission balance gives a close margin on the ZEB-OM ambition for the ZEB-pilot house Larvik, but barely exceed the target when including 12,000 km with the electric car. Reducing the use of the electric car to 7,600 km gives a balance in the calculated emissions, given the described conditions. The balance is sensitive to the methodology for material emission accounting and the choice of electricity emission factors for the import and export of electricity.

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APPENDICES

A.1 – Illustrations with building details

Chapter 2.1.3 describes the building details that are considered the most important for ensuring excellent thermal protection of the building envelope. In this Annex there are some additional illustrations with building details.

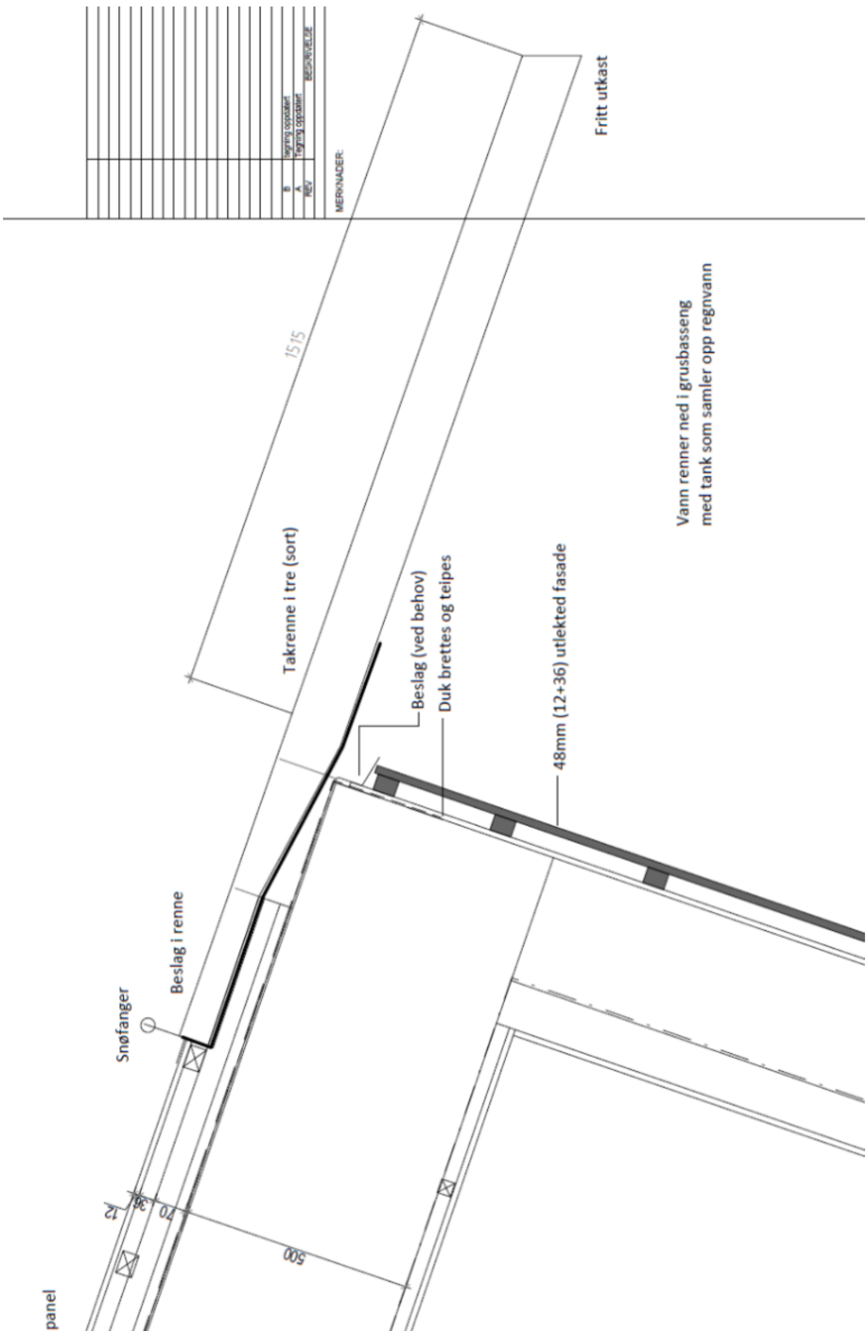


Figure A1.1 The transition from the tilted wall elements to the roof (eaves). Source: Snøhetta.

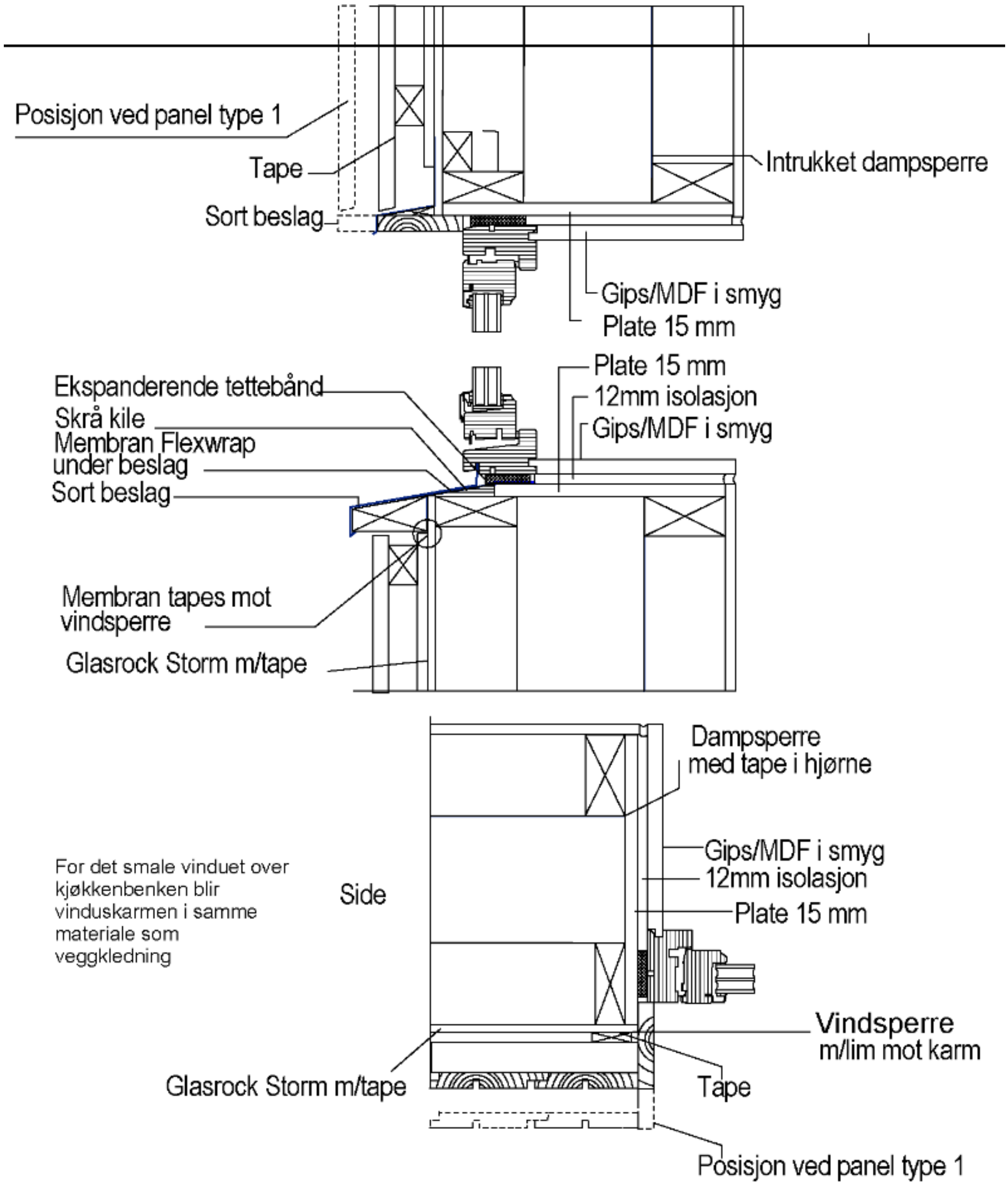


Figure A1.2 Details for the windows. Source: Snøhetta.

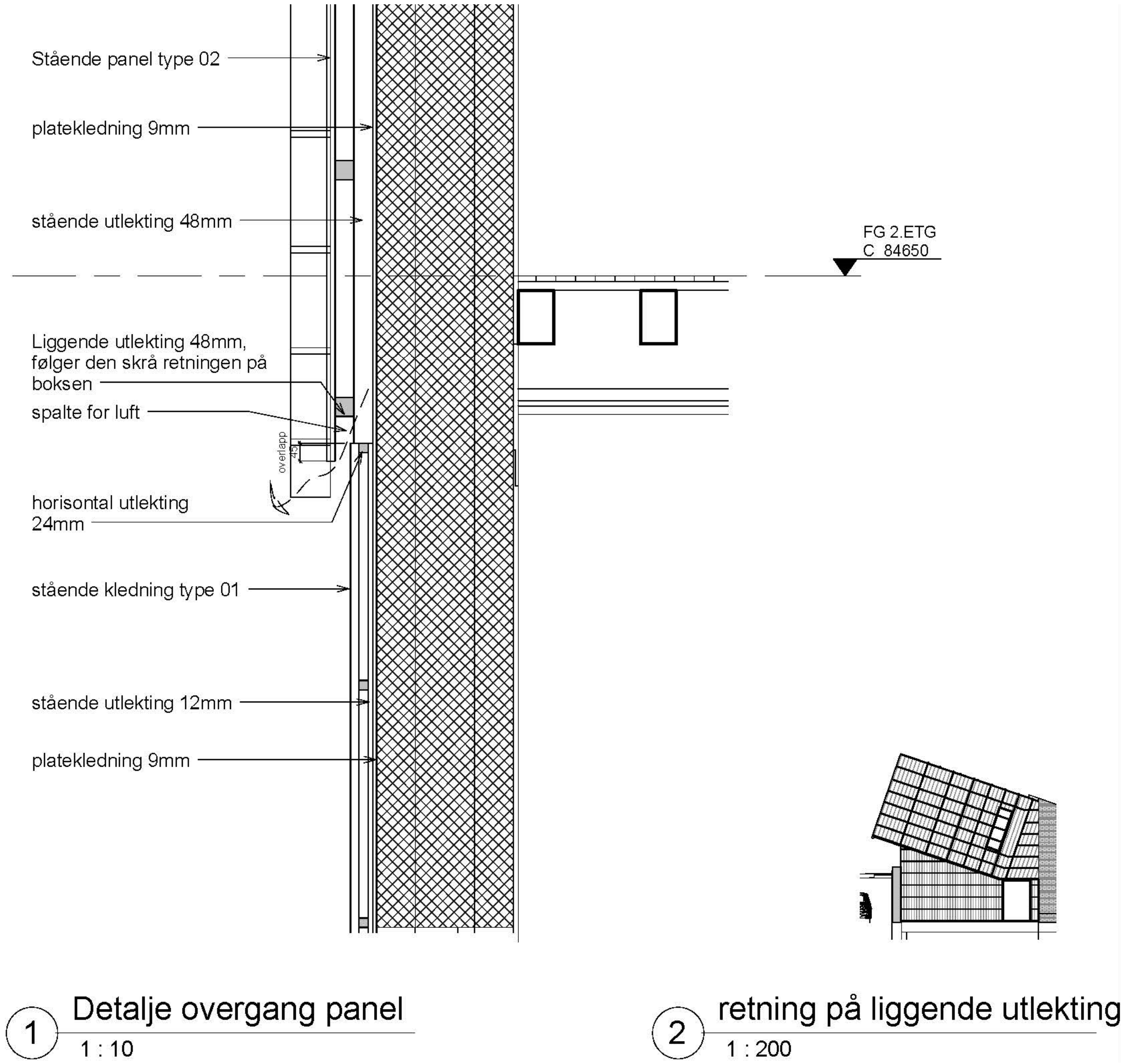


Figure A1.3 Details for the wall. Source: Snøhetta.

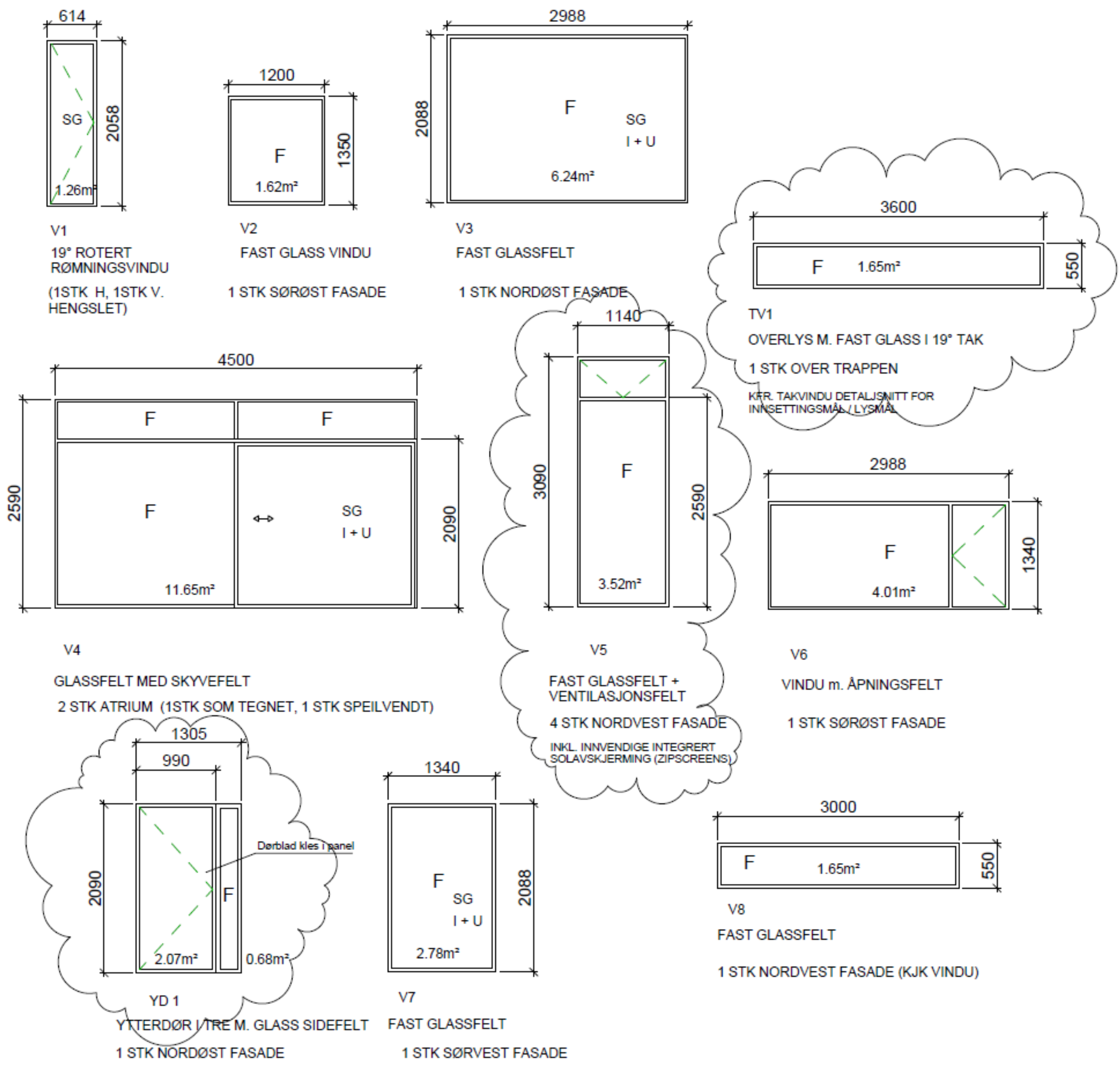


Figure A1.4 Door and window façades. Source: Snøhetta.

A.2 – Technical specifications, Nilan compact P GEO 3

Tekniske spesifikasjoner	GEO 3
Dimensjoner (B x D x H)	Integrert i Compact P 550 x 300 x 1.100 mm
Vekt	55 kg
Styring	CTS 700
Kompressor variabel hastighet	Ja (20-100%)
Oppstillingssted, romtemperatur	5°C → 35°C
Tilførselsspenning og tilslutning	400/230V 2L+N+PE, 50Hz / 230V L+N+PE, 50Hz
Sikringsstørrelse	13A/20A
Startstrøm, I_{max} Start	14A
Standby el-forbruk	2,5 W
El-suppleringsvarme	2 kW
Merkeeffekt brinepumpe (max/min). A-pumpe	87/6 W
Merkestrøm brinepumpe (max/min). A-pumpe	0,7/0,06 A
Kjølemiddel	R410A
Kjølemiddelfylling	1,1 kg
Pressostat lavtrykk (on/off)	2,2/3,4 barG
Pressostat høytrykk (on/off)	42/33 barG
Frostsikringsmiddel	Ethylenglykol/vann Ethanol/vann
Frostsikring, brine	-20°C → -18°C
Designtrykk brine-/sentralvarmeside	4/4 bar
Åpningstrykk sikkerhetsventil brine-/sentralvarmeside	3,5/2,5 bar
Ekspansjonsbeholder brine-/sentralvarmeside	8/8 liter
Fortrykk ekspansjonsbeholdere	0,5 barG
Miljøpressostat brine, lekkasjealarm (on/off)	0,6/1,1 barG
Varmeytelsen P_H med variabel kompressor	0.5-3 kW
Sentralvarme, fremløpstemperatur, driftsområde	25°C → 45°C
Brinetemperatur til fordamper, driftsområde	-5°C → 20°C
Sentralvarme trykktap kondensator	10 kPa/0,14 l/s
Sentralvarme tilslutning	3/4"
Brine trykktap fordamper	10 kPa/0,19 l/s
Brine tilslutning	1"
COP 0/35°C ved max. P_H, iht. EN14511:2012 med brine/vann dT=3/5°C	4,5 (P_H max. 3 kW)
EHPA testet og godkjent	N/A
SCOP testet iht. EN14825:2012**	5,17
Lydeffektnivå L_{WA} ved 100% varmeytelse 0/35°C	≤ 51 dB(A)
Lydeffektnivå L_{WA} ved 50% varmeytelse 0/35°C	≤ 44 dB(A)
Lydtrykknivå L_{pA} i 1 m ved 100% varmeytelse 0/35°C	≤ 40 dB(A)
Lydtrykknivå L_{pA} i 1 m ved 50% varmeytelse 0/35°C	≤ 33 dB(A)

*) Overholder "EHPA Test Regulations vers. 1.4, 2011-02-01" med max. ytelse 3 kW ved 0/35°C iht. EN14511:2012

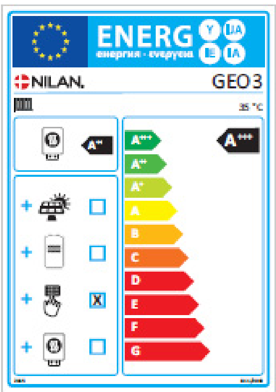
**) SCOP (Sesonal COP) er for "lav temperatur anvendelse, middel (A) klima " bestemt flow"

Lyddata iht. EN12102 og EN ISO 9614-2

TEKNISKE PARAMETRE

GEO 3 Varmepumpeanlegg til romoppvarming

Modell	GEO 3
Luft-vann-varmepumpe	Nej
Vann-vann-varmepumpe	Nej
Brine-vann-varmepumpe	Ja
Lavtemperaturvarmepumpe	Ja
Utstyrt med supplerende forsyningsanlegg	Ja
Varmepumpeanlegg til kombinert rom- og tappevannsoppvarming	Nej
Temperaturstyring:	
Model	CTS 700
Klasse	2
Andel af årsvirkningsgraden	2%



Element	Symbol	Verdi	Enhed
Nominell nytteeffekt (*)	*Prated*	3,44	kW
*Angitt varmeytelse for dellast ved innetemperatur på 20 °C og utetemperatur på T_j			
T_j = -7 °C	*Pdh*	3,04	kW
T_j = +2 °C	*Pdh*	1,88	kW
T_j = +7 °C	*Pdh*	1,26	kW
T_j = +12 °C	*Pdh*	1,02	kW
T_j = bivalenttemperatur	*Pdh*	3,03	kW
T_j = temperaturgrense for drift	*Pdh*	0	kW
For luft-vann-varmepumper Tj = -15 °C (hvis TOL < -20 °C)	*Pdh*		kW
Bivalenttemperatur	T_{biv}	-7	°C
Syklusintervalytelse for oppvarming	*Pcych*		kW
Koefficient for effektivitetstap	*Cdh*	0,97	
Elforbruk i andre tilstander enn aktiv tilstand			
Slukket tilstand	P_{OFF}	0,003	kW
Termostat fra-tilstand	P_{TO}	0,010	kW
Standbytilstand	P_{SB}	0,010	kW
Krumtaphusoppvarmningstilstand	P_{CK}	0,000	kW
Annet			
Ytelsesregulering:	Variabel kompressor Variabel innendørs temperatur regulering		
	FFast innendørs vannflow Fast utendørs vannflow		
Lydeffektnivå, inne	L_{WA}	51	dB
Årlig energiforbruk	Q_{HE}	931	kWh

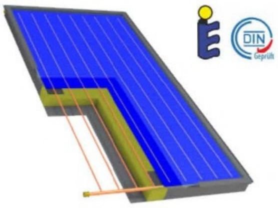
Element	Symbol	Verdi	Enhed
Årsvirkningsgrad ved romoppvarming	η_s	208	%
Angitt effektfaktor eller primærenergi-effektfaktor for dellast ved innetemperatur på 20 °C og utetemperatur på T_j			
T_j = -7 °C	*COPd*	4,66	
T_j = +2 °C	*COPd*	5,29	
T_j = +7 °C	*COPd*	5,63	
T_j = +12 °C	*COPd*	5,82	
T_j = bivalenttemperatur	*COPd*	4,61	
T_j = temperaturgrense for drift	*COPd*	0	
For luft-vann-varmepumper Tj = -15 °C (hvis TOL < -20 °C)	*COPd*		
For luft-vann-varmepumper: Temperaturgrense for drift	*TOL*		°C
Syklusintervalytelse	*COPcyc*		
Temperaturgrense for vannoppvarming	*WTOL*	52	°C
Supplerende forsyningsanlegg			
Nominell nytteeffekt	*Psup*	2	kW
Energiinput type	Elektrisk		
For luft-vann-varmepumper: Nominell luftgjennomstrømning ute			m³/h
For vand- eller brine-vand-varmepumper: Nominel brine- eller vandgennemstrømning, varmeveksler, ude		0,518	m³/h

A.3 – Technical specifications, Solar collectors KS2000 SLP

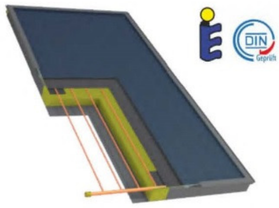
HEWALEX

COMPONENTS OF SOLAR SYSTEMS

FLAT PLATE SOLAR COLLECTORS:



HEWALEX KS2000 TLP



HEWALEX KS2000 SLP

COMPONENTS OF SOLAR SYSTEMS

SOLAR COLLECTOR:	KS2000 TLP (KS2000 TP)	KS2000 SLP (KS2000 SP)	KS2000 TLP AC (KS2000 TP AC)
Article number	14.22.00 (14.21.00)	11.22.00 (11.21.00)	14.41.00 (14.40.00)
Solar Keymark certificate (PN-EN12975-1,2:2007)	011-7S181 F	011-7S180 F	011-7S1693 F
Active (aperture) area, m^2	1,818	1,817	1,827
Gross area (total), m^2	2,095	2,094	2,091
Optical efficiency (with respect to aperture), %	80,2	81,1	79,4
Heat loss coeff. a1 (with respect to aperture), W/m^2K	3,80	4,46	4,36
Heat loss coeff. a2 (with respect to aperture), W/m^2K^2	0,0067	0,0096	0,0049
Glazing: solar glass / structured / tempered	+ / + / +	+ / + / +	+ / + / +
Material of absorber sheet / piping	copper / copper	copper / copper	aluminium/copper
Type of selective coating	BlueTec eta plus	black chrome	BlueTec eta plus
Piping layout of absorber	harp	harp	harp
Number of connections	4x external¾"	4x external¾"	4x external¾"
Joining technique	ultrasonic welding	ultrasonic welding	laser welding
Dimensions, mm	2020 x 1037 x 87	2019 x 1037 x 90	2020 x 1035 x 90
Housing[2)]	aluminium	aluminium	aluminium
Weight (when empty), kg	40	39	38
Liquid capacity, litres	1,1	1,1	1,1
Maximum operating pressure, bar	6	6	6
Warranty, years	10	10	10

[1)] This Collector is not sold in solar sets.
[2)] Letter "L" in the name of the collector denotes that aluminium housing and frames of the collector are powder-painted in RAL7022 (umbra grey). The lack of "L" letter denotes that only collector frames are powder-painted.

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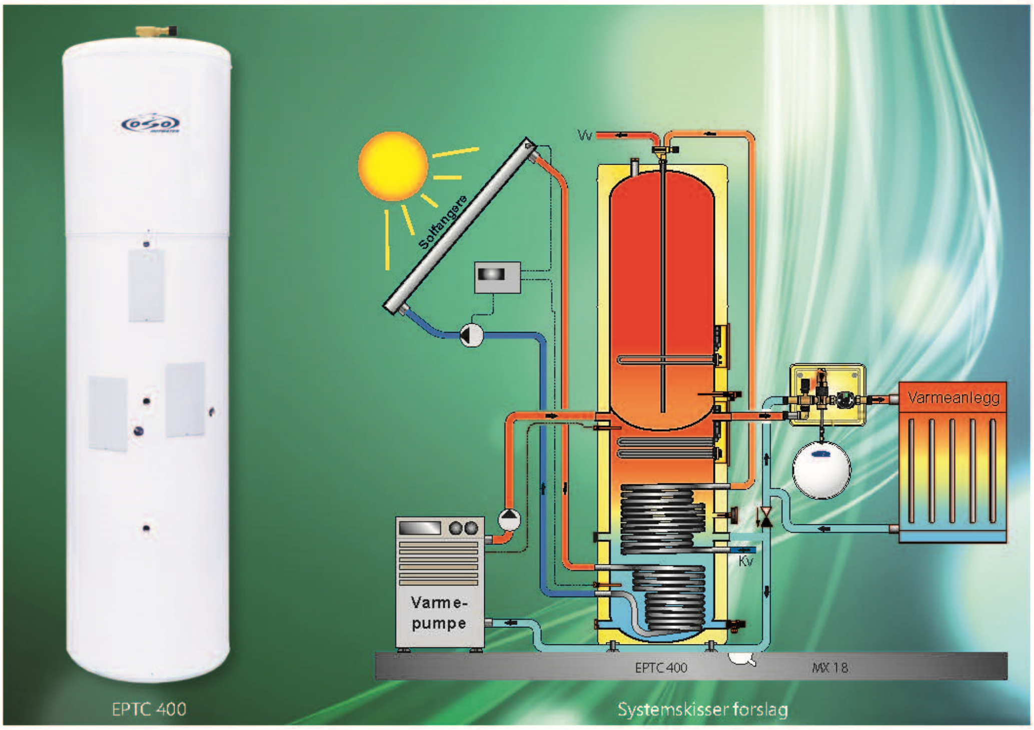
A.4 – Technical specifications, Heating tank EPTC400

EPTC

Optima Twin Coil - EPTC - gir varme og varmtvann



Spesielt utviklet for varmepumpe og solfanger

Markedets mest avanserte varmesentraler, med optimale enøkfordeler. EPTC støtter bruk av solfangere i kombinasjon med varmepumpen. De alternative energikildene utnyttes optimalt, og tanken har større varmtvannskapasitet enn andre dobbeltmantlede beredere. Optima-serien har minimalt varmetap takket være OSO ECO Foam, og produktserien er de eneste skumisolerte varmesentralene på markedet.

EPTC 400 (pat.s.) passer for varme og tappevannsbehov i boliger 100-400m². Optimal varmepumpetype er uten mulighet for tappevannsprioritering inntil 18 kW, i kombinasjon med solfangere 8-12 m². Elektrisk backup er standard, med modulerbar el. effekt fra 2,5 – 15 kW. El. ettervarmer i øvre magasin er 3kW 230V 1-fas. Forvarmet kaldtvann kan ettervarmes med el. Tappevannsvolumet til EPTC 400 passer for familier på inntil 7 personer.

Den ideelle montasjesentralen Fix – PV 12 sikrer korrekt og rask installasjon - se s. 34.

FORDELER

- Unik fleksibilitet for alternative varmekilder
- Dobler tappevannsproduksjonen
- El backup rett på varmeanlegget

PRODUKTFAKTA

Garanti	Tank 10 ar - deler 2 ar
Isolasjon	ECO Foam - vannbasert
Sertifisering	CE / NEMKO
El-element	5/4" rørgjenge
Termostat	60-90°C (preset 75°C)
Blandeventil	45-80°C (preset 55°C)
Sikkerhetsventil	9 bar + 3 bar - fabr. m.

Tekniske data

Best. nr. Volum - kW+coil	Dia x H mm	Ansl. kv/vv - t/r	Ansl. coil	Volum l.	Vekt kg	M^3	NRF nr.	Veil. pris
EPTC 400 - 3+15+coil 0,8+0,7 m²	ø 580 x 2250 H	½"-ø15 - 6 x 1"	3/4"	210/190	95	0,80	800.0279	31 750

NB: Priser i tabellen er veil. og gyldige fra 1. januar 2015. Inkl. mva

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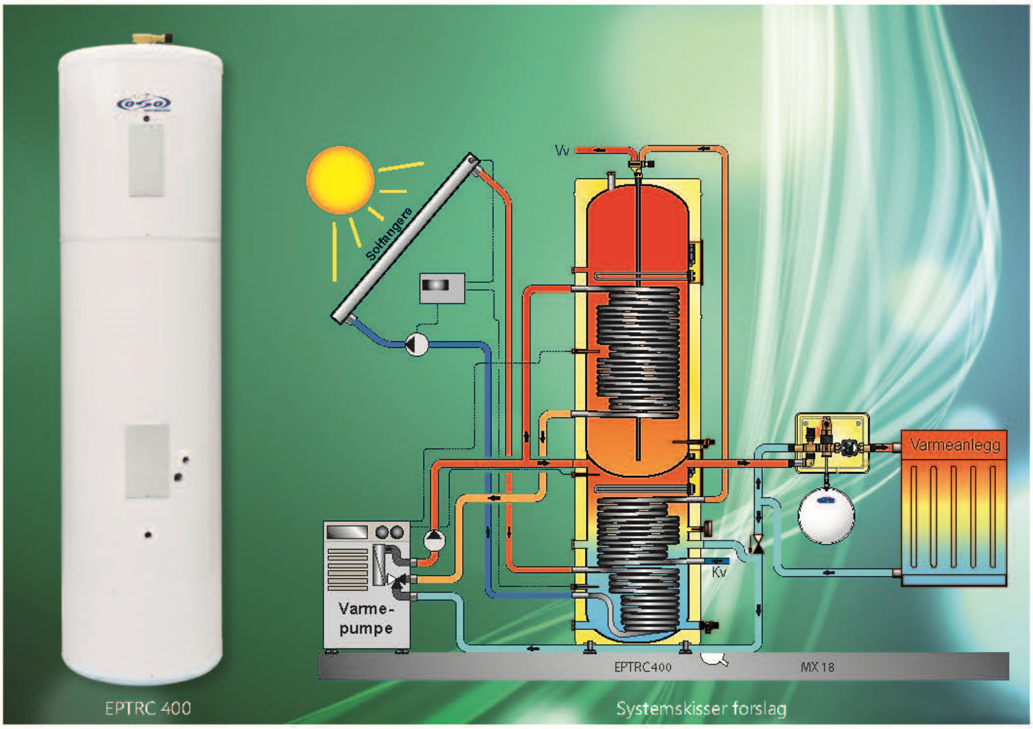
Forandringer forbeholdes

EPTRC

Optima Triple Coil - EPTRC - gir varme og varmtvann



Utviklet for VP, solfanger og biobrensel

Markedets mest avanserte varmesentraler, med optimale enøkfordeler. EPTRC støtter bruk av solfangere i kombinasjon med varmepumpen, samt en tredje alternativ varmekilde som f.eks. bio/pelletskjel. De alternative energikildene utnyttes optimalt, og tanken har større varmtvannskapasitet enn andre dobbeltmantlede beredere. Optima-serien har minimalt varmetap takket være OSO ECO Foam, og produktserien er de eneste skumisolerte varmesentralene på markedet.

EPTRC 400 (pat.s.) har alle fordelene til EPTC, men er spesielt utviklet for varmepumpe med mulighet for tappevannsprioritering / vekselventil. Den store coilen på 1,8m² i indre magasin støtter optimal drift for varmepumper inntil 12kW. Solfangerareal som støttes er 8-12 m². Tappevannsvolumet til EPTRC 400 passer for familier på inntil 5 personer.

Den ideelle montasjesentralen Fix – PV 12 sikrer korrekt og rask installasjon - se s. 34.

FORDELER

- Unik fleksibilitet for alternative varmekilder
- Dobler tappevannsproduksjonen
- El backup rett på varmeanlegget

PRODUKTFAKTA

Garanti	Tank 10 ar - deler 2 ar
Isolasjon	ECO Foam - vannbasert
Sertifisering	CE / NEMKO
El-element	5/4" rørgjenge
Termostat	60-90°C (preset 75°C)
Blandeventil	45-80°C (preset 55°C)
Sikkerhetsventil	9 bar + 3 bar - fabr. m.

Tekniske data

Best. nr. Volum - kW+coil	Dia x H mm	Ansl. kv/vv - t/r	Ansl. coil	Volum l.	Vekt kg	M^3	NRF nr.	Veil. pris
EPTRC 400 - 3+9+coil 1,8+0,8+0,7 m²	ø 580 x 2250 H	½"-ø15 - 6 x 1"	3/4"	240/160	106	0,80	800.0281	35 400

NB: Priser i tabellen er veil. og gyldige fra 1. januar 2015. Inkl. mva

Forandringer forbeholdes

A.5 – Technical specifications, Batteries

Metric
part of Coromatic Group

NorBat OPzV-serien enkeltceller
GEL - CFPV2600 T10 - 2 V 600 Ah

Bilde er av 300Ah modellen

Nominell spenning		2 V
Kapasitet (10 timer, 25°C)		600 Ah
Design life		20 års
Tiltrekningsmoment		12 Nm
Dimensjon	Lengde	206±2 mm
	Bredde	145±1 mm
	Høyde	646±2 mm
	Total høyde	681±2 mm
Ca. vekt		42.3 kg (±5 %)

Indre motstand (Fullt ladet 25 °C)		Ca. 0.45 mΩ
Kapasitet influert av temperatur (10 timer)	40 °C	102 %
	25 °C	100 %
	0 °C	85 %
	-15 °C	65 %
Selvutladning (25 °C)	3 måneder	Restkapasitet: 93 %
	6 måneder	Restkapasitet: 85 %
	12 måneder	Restkapasitet: 72 %
Nominell driftstemperatur		25 °C ±3 °C
Driftstemperatur intervall		-20 °C - +50 °C
Ladespenning (float)		2.25 til 2.30 V
Ladespenning (cyklisk)		2.30 til 2.35 V
Maks ladestrøm		120 A
Terminalmaterialet		kobber
Maks utladestrøm		2 400 A (5 sek.)

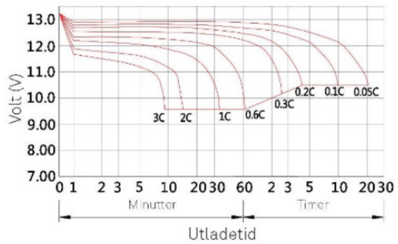
Utladekarakteristikk (A, 25 °C):

F.V/TID	30 min	60 min	2 t	3 t	4 t	5 t	6 t	8 t	10 t	20 t	24 t	48 t
1.60 V	510	342	207	159	129	110	94.2	74.1	61.1	32.4	27.9	14.8
1.65 V	500	337	206	158	128	109	93.7	73.8	61.0	32.3	27.8	14.8
1.70 V	435	328	204	157	127	108	93.0	73.1	60.8	32.2	27.8	14.7
1.75 V	473	322	201	156	126	107	92.4	72.8	60.4	32.0	27.8	14.8
1.80 V	455	312	196	151	122	104	89.6	70.4	60.0	31.8	27.5	14.5

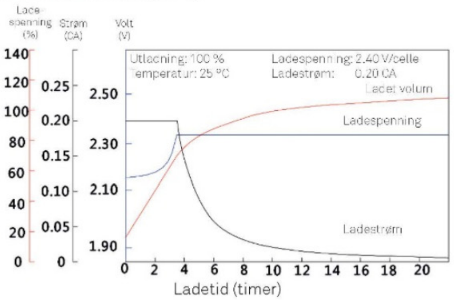
Utladekarakteristikk (Watt, 25 °C):

F.V/TID	30 min	60 min	2 t	3 t	4 t	5 t	6 t	8 t	10 t	20 t	24 t	48 t
1.60 V	854	650	400	312	252	216	188	147	122	64.7	56.1	29.9
1.65 V	835	640	397	310	250	215	185	146	121	64.6	56.0	29.8
1.70 V	806	624	394	308	249	213	183	145	121	64.4	55.8	29.7
1.75 V	884	611	388	306	247	212	182	144	120	64.0	55.5	29.5
1.80 V	852	593	378	297	240	206	177	139	119	63.6	55.2	29.3

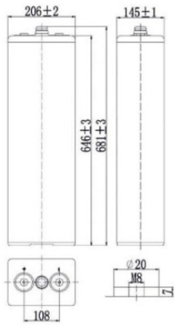
Utladekarakteristikk (25 °C)



Ladekarakteristikk (25 °C)



Dimensjon (mm):



T10
Terminal

A.6 – Technical specifications, Charge controller

MPPT 80 600
Solar Charge Controller

> Install for less, Harvest more energy

The MPPT 80 600 Solar Charge Controller offers an industry-first set of integration features and top performance that allows for large PV array systems to be easily installed and connected to the battery bank at the lowest overall cost. Installing one MPPT 80 600 is faster than installing multiple smaller charge controllers and lowers overall costs further by utilizing fewer PV strings, smaller wiring and conduit, and by eliminating the need for PV combiner boxes and DC circuit breakers. Longer distances from array site to battery bank are also easier to accommodate than with smaller charge controllers. Advanced Fast Sweep™ MPPT charging technology helps harvest the most energy available from the PV array, even in partial shade conditions. 80 A of battery charge current allows for the connection of PV arrays rated up to 600 V STC (2560 W for 24 V systems, 4800 W for 48 V systems).

Product Features

Easy to **Install**

- Fewer string wires
- Smaller AWG Wire
- No need for combiner box or GFI circuit breaker

Flexible

- Available remote monitoring and configuration
- Compatible with any brand of PV Module, any grounding method
- Stand-alone application or full integration with Conext XW Inverter charger system

Higher Return on **Investment**

- Installs faster with fewer costly components
- Improve battery life with selectable multi-stage temperature compensated charging
- Harvest more energy with Shade Tolerant Fast Sweep MPPT Algorithm

Product Applications


Residential, Backup Power and Grid-tie


Small Commercial, Backup Power and Grid-tie


Off-grid Solar


Community Electrification

www.schneider-electric.com

Schneider Electric

MPPT 80 600 Solar Charge Controller

DS20121129_MPPT80600

Device short name	MPPT 80 600
Electrical specifications	
Nominal battery voltage	24 and 48 V (Default is 48 V)
Max. PV array voltage (operating)	195 to 550 V
Max. PV array open circuit voltage	600 V including temperature correction factor
Battery Voltage Operating Range	16 to 67 VDC
Array short-circuit current	35 A (28 A @ STC)
Max. charge current	80 A
Max. and min. wire size in conduit	#6 AWG to #14 AWG (13.5 to 2.5 mm^2)
Maximum output power	2560 W (nominal 24 V), 4800 W (nominal 48 V)
Charger regulation method:	Three-stage (bulk, absorption, float) plus manual equalization Two-stage (bulk, absorption) plus manual equalization
Supported Battery Types	Flooded, GEL, AGM, Custom
Efficiency	
Maximum power conversion efficiency	94% (nominal 24V), 96% (nominal 48V)
General specifications	
Power consumption, night time	< 1 W
Battery temperature sensor	Included
Auxiliary output	Dry contact switching up to 60VDC, 30VAC, 8A
Enclosure material	Indoor, ventilated, aluminum sheet metal chassis with 22.22 mm and 27.76 mm (7/8 in and 1 in) knockouts and aluminum heat sink
IP degree of protection	IP20
Product weight	13.5 kg (29.8 lb)
Shipping weight	17.4 kg (38.3 lb)
Product dimensions (H x W x D)	76.0 × 22.0 × 22.0 cm (30.0 × 8.6 × 8.6 in)
Shipping dimensions (H x W x D)	87.0 × 33.0 × 27.0 cm (34.3 × 13.0 × 10.6 in)
Device mounting	Vertical wall mount
Ambient air temperature for operation	-20°C to 65°C (-4°F to 149°F), power derating above 45°C
Storage temperature range	-40°C to 85°C (-40°F to 185°F)
Operating altitude	Sea level to 2000 m (6562 ft)
System network and remote monitoring	Available
Warranty	Five-year standard
Part number	865-1032
Regulatory approval	
Safety	CSA Certified (UL1741, CSA 107.1) and CE Marked for the Low Voltage Directive (EN50178)
EMC	FCC and Industry Canada (Class B), CE Marked for the EMC Directive (EN61000-6-1, -6-3), C-Tick compliant

Specifications are subject to change without notice.

MPPT 80 600 Solar Charge Controller works with the following Schneider Electric products

Conext XW Inverter / Charger
(230 V/50 Hz)
XW 4024 Product No. 865-1045-61
XW 6048 Product No. 865-1035-61
(120/240 V/60 Hz)
XW 4024 Product No. 865-1010
XW 6048 Product No. 865-1000-01

Conext SW Inverter / Charger
SW 2524 120 Product No. 865-2024
SW 4024 120 Product No. 865-3524
SW 2524 230 Product No. 865-2524-61
SW 4024 230 Product No. 865-3524-61

System Control Panel (SCP)
Product No. 865-1050

Automatic Generator Start (AGS)
Product No. 865-1060

Conext ComBox
Communication Device
Product No. 865-1058

A.7 – Technical specifications, Inverter

Conext™ XW inverter/charger (230 V / 50 Hz)

One solution for global power

Conext XW is an adaptable pure sine wave, single-phase and three-phase inverter/charger system with global grid-tie functionality and dual AC power inputs. Available solar charge controllers, monitoring, and automated generator control modules enable further adaptability. From single Conext XW unit to multiple clusters of units, up to 36 kW each, the Conext XW is a scalable system that allows for the integration of solar capacity as required.

Adaptable and scalable, the Schneider Electric™ Conext XW system is the one solution for global grid-interactive and off-grid, residential and commercial, solar and backup power applications.

Why choose Conext XW (230 V / 50 Hz)?

True bankability

- Warranty from a trusted partner with over 177 years of experience
- World leader in industrial power drives, UPS and electrical distribution
- Strong service infrastructure worldwide to support your global needs

Higher return on investment

- Harness the continuously declining production cost of solar power
- Hybrid integration of generator reduces diesel fuel costs

Designed for reliability

- Robust design through rigorous reliability testing (HALT)
- Proven field performance: 7 years with high reliability, globally in multiple applications and environments

Flexible

- Adapts to single and three-phase systems
- Scales to 36 kW for commercial or large electrification installations
- Supports DC coupled and AC coupled solutions

Easy to service

- Remote monitoring and configuration
- Replaceable boards and components
- Global support

Easy to install

- Devices configure quickly into a stylish wall mounted system
- Inverters connect both grid and generator power with dual AC input

Product applications

Residential, backup power and grid-tie

Off-grid solar

Community electrification

Small commercial, backup power and grid-tie

www.schneider-electric.com/solar

Schneider Electric

Conext XW series (230 V / 50 Hz)

Device short name	XW4024 230 50	XW4548 230 50	XW6048 230 50
Electrical specifications			
Output power (continuous) at 40°C	4.0 kVA	4.5 kVA	6.0 kVA
Output power (surge) at 40°C	8.0 kVA (20 sec)	9.0 kVA (15 sec)	12.0 kVA (15 sec)
Output current	17.4 A	19.6 A	26.1 A
Peak output current (rms)	35 A	40 A	53 A
Input current at rated power	178 A	96 A	131 A
Type of signal	True sine wave	True sine wave	True sine wave
Automatic transfer relay	56 A	56 A	56 A
Typical transfer time	8 ms	8 ms	8 ms
DC input voltage (nominal)	25.2 V	50.4 V	50.4 V
Input voltage limits	20 to 32 V	40 to 64 V	40 to 64 V
Charging current	150 A	85 A	100 A
Power factor corrected charging	0.98	0.98	0.98
Auxiliary relay output	0 to 12 V, maximum 250 mA DC	0 to 12 V, maximum 250 mA DC	0 to 12 V, maximum 250 mA DC
Power consumption (search mode)	< 7 W	< 7 W	< 7 W
AC input voltage (nominal)	230 V +/- 3%	230 V +/- 3%	230 V +/- 3%
Input voltage limits (bypass/charge mode)	165 to 280 V (230 V nominal)	165 to 280 V (230 V nominal)	165 to 280 V (230 V nominal)
Frequency	50 Hz +/- 0.1 Hz	50 Hz +/- 0.1 Hz	50 Hz +/- 0.1 Hz
AC input frequency range (bypass/charge mode)	40 to 68 Hz (50 Hz nominal)	40 to 68 Hz (50 Hz nominal)	40 to 68 Hz (50 Hz nominal)
Total harmonic distortion (THD)	< 5% at rated power	< 5% at rated power	< 5% at rated power
AC connections	AC1 (Grid), AC2 (Generator)	AC1 (Grid), AC2 (Generator)	AC1 (Grid), AC2 (Generator)
AC input breaker	60 A single-pole	60 A single-pole	60 A single-pole
Efficiency			
Peak	94.0%	95.6%	95.4%
General specifications			
IP degree of protection	IP20 (sensitive electric components sealed inside enclosure)		
Product weight	52.5 kg (116.0 lb)	53.5 kg (118.0 lb)	55.2 kg (121.7 lb)
Shipping weight	74.0 kg (163.0 lb)	75.0 kg (165.0 lb)	76.7 kg (169.0 lb)
Product dimensions (H x W x D)	58 x 41 x 23 cm (23 x 16 x 9 in)	58 x 41 x 23 cm (23 x 16 x 9 in)	58 x 41 x 23 cm (23 x 16 x 9 in)
Shipping dimensions (H x W x D)	71.1 x 57.2 x 39.4 cm (28.0 x 22.5 x 15.5 in)	71.1 x 57.2 x 39.4 cm (28.0 x 22.5 x 15.5 in)	71.1 x 57.2 x 39.4 cm (28.0 x 22.5 x 15.5 in)
Device mounting	Wall mount (backplate included)	Wall mount (backplate included)	Wall mount (backplate included)
Ambient air temperature for operation	-25°C to 70°C (-13°F to 158°F) (power derated above 45°C (113°F)		
System network and remote monitoring	Available	Available	Available
Warranty (Depending on the country of installation)	2 or 5 years	2 or 5 years	2 or 5 years
Part number	865-1045-61	865-1040-61	865-1035-61
Features and options			
Display type	Status LEDs indicate AC In status, faults/warnings, equalize mode, On/Off and equalize button battery level. Three-character display indicates output power or charge current		
Supported battery types	Flooded (default), Gel, AGM, custom	Flooded (default), Gel, AGM, custom	Flooded (default), Gel, AGM, custom
Battery bank size	100 to 2000 Ah (scaled to PV array size)		
Battery temperature sensor	Included	Included	
Non volatile memory	Yes	Yes	
Multiple unit configurations	Single-phase: up to four parallel units. Three-phase: two units per phase		
Regulatory approval			
CE marked according to the following EU directives and standards:			
EMC directive	EN61000-6-1, EN61000-6-3, EN61000-3-2, EN61000-3-3		
Low voltage directive	EN50178		
RCM marked and compliant	AS 4777.2, AS 4777.3, AS/NZS 3100		

Specifications are subject to change without notice.

Conext XW works with the following Schneider Electric products

XW Power Distribution Panel
Product no. 865-1015

XW Conection Kit
Product no. 865-1020

System Control Panel
Product no. 865-1050

Automatic Generator Start
Product no. 865-1060

MPPT 60 150 solar charge controller
Product no. 865-1030-1

MPPT 80 600 solar charge controller
Product no. 865-1032

XW Configuration Tool
Product no. 865-1155

Conext Combox Communication device
Product no. 865-1058

DS20130815_ConextXW50Hz

A.8 – Technical specifications, Solar cells

DesignBlack – Mono

STC*

Pmax	Wp	240	250	260
Vmpp	V	29.7	30.1	30.8
Impp	A	8.25	8.44	8.60
Uoc	V	37.0	37.2	37.6
Isc	A	8.90	9.05	9.19
IR****	A	20	20	20
η	%	14.6 – 15.2	15.2 – 15.8	15.8 – 16.4

NOCT**

Pmax	W	176	182	189
Vmpp	V	26.7	27.2	27.8
Uoc	V	29.3	29.8	30.3
Isc	A	7.13	7.25	7.40

Temperature Coefficients

Pn	-0.43 %/K
Uoc	-0.32 %/K
Isc	0.04 %/K

DesignBlack – Poly

STC*

Pmax	Wp	240	250	260
Vmpp	V	30.2	31.0	31.2
Impp	A	8.11	8.22	8.49
Uoc	V	37.1	37.6	37.8
Isc	A	8.66	8.79	8.98
IR****	A	20	20	20
η	%	14.6 – 15.2	15.2 – 15.8	15.8 – 16.4

NOCT**

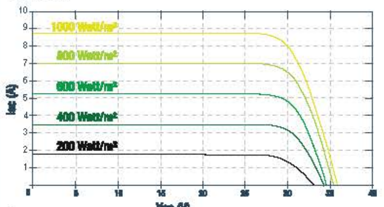
Pmax	W	176	182	186
Vmpp	V	27.3	27.8	28.3
Uoc	V	33.9	34.2	34.5
Isc	A	6.90	7.00	7.10

Temperature Coefficients

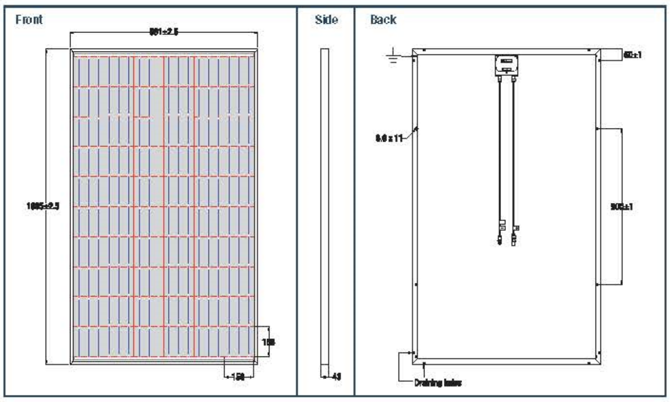
Pn	-0.38 %/K
Uoc	-0.32 %/K
Isc	0.077 %/K

NOCT**	49.2°C
Module efficiency reduction at 200 W/m²***	-0.6 (± 0.3)% abs.
Max. System Voltage	1000 V
IP protection level	IP 65
Module Design	Glass-foil (black)
Frame	Al black
Glass	Solar glass with anti-reflection surface treatment, 3.2 mm
No. and Type of Solar Cells	60 crystalline solar cells, 156 x 156 mm, 180 µm ± 30 µm
Cables	Junction box with MC4 (pluggable) connectors, cable: 2 x 1 m / 4 mm²
Bypass-Diodes	3 pcs.
Dimensions (l x w x h)	1665 x 991 x 43 mm
Weight	19 kg
Operating Temperature Range	-40 ... +80°C
Ambient Temperature Range	-40 ... +45°C
Mechanical ratings	Suction pressure of 2400 Pa approved (Wind speed 130 km/h with safety factor 3), load of 5400 Pa approved
Certification	IEC 61215 : 2005 IEC 61730 -1 / -2 : 2004 IEC 61701 : 1995 (salt mist resistant) MCS DLG Focus Test (ammonia resistant) UL 1703 : 2002 R5.12 CEC/CSI listing
Positive sorting	-0 Wp / +10 Wp
Pallet dimensions	1720 x 1045 x 180 mm
Product warranty	12 years
Performance warranty	25 years linear performance warranty according to the Warranty Conditions of Innotech Solar

I/V Curve¹



¹poly 240 Wp



* STC – Standard Test Conditions, measurement conditions: intensity irradiation 1000 W/m², spectral distribution AM 1.5, temperature 25 ± 2°C, according to standard EN 60904-3
** NOCT – Normal Operation Cell Temperature, measurement conditions: irradiation intensity 800 W/m², AM 1.5, temperature 20°C, wind speed 1 m/s.
*** Reduced effiency with the decrease in the intensity of irradiation of 1000 W/m² and 200 W/m², temperature 25°C according EN 60904-1
**** Reverse current power rating: operation of the modules with an external power source is only permitted with a string fuse with a release current of < 2 x Isc @ STC*
Measuring tolerances of Pmax @ STC ± 3%, of reference module ± 2%, all other electric parameters ± 10%
This datasheet conforms to EN 50380. Innotech Solar reserves the right to change specifications without notice.

Revision 09-2013

A.9 – Technical specifications, Mounting system

Mounting systems for solar technology

INFORMATION

PROJECT DATA

Project Name: design house Norway

CUSTOMER

Customer: FuSen
Contact Person: Thor Christian Tuv

Address: Address

Telephone: Telephone
Telefax: Telefax
Email: Email

BUILDING DATA

LOCATION

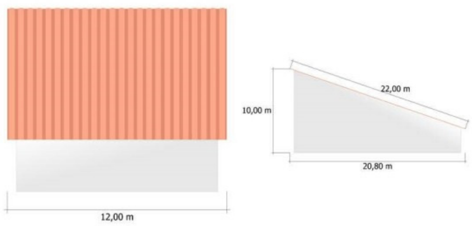
Ground level: 50 m
Country: Norway

BUILDING TYPE

Roof Type: Pitch Roof
Building Length: 12,00 m
Building Width: 20,80 m
Building Height: 10,00 m

BUILDING DIMENSIONS

Roof Covering: Trapezoidal Sheet (Steel)
Thickness: 0,63 mm
Tensile Strength: 360 N/mm²
Roof Slope: 19 °
Crimp Distance: 0,500 m



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Mounting systems for solar technology

LOADS

SNOW LOAD

Snow Load Relating To Roof Area: d_i = 0,946
Environment: Normal area
Shape Coefficient Relating To Snow: μ_i = 0,800
Snow Load On Ground: s_k = 3,500 kN/m²
Snow Load: s_i = 2,647 kN/m²

WIND LOAD

Wind Velocity: v_b = 22,0 m/s
Terrain Category: IV: Urban area
Gust Velocity Pressure: q_p = 0,356 kN/m²

ROOF AREAS

Area	maxCpe	minCpe	Wind Pressure [kN/m]	Wind Suction [kN/m]
Field area	0,253	-1,145	0,089	-0,404
Eaves	0,333	-1,33	0,118	-0,469
Corner Region (Eaves)	0,333	-2,125	0,118	-0,749
Gableboard	0,253	-2,242	0,089	-0,790
Corner Region (Ridge)	0,253	-2,774	0,089	-0,978
Ridge	0,253	-1,714	0,089	-0,604

DEAD WEIGHT

Modul Area: A_M = 1,65 m²
Module Weight: G_M = 19,00 kg
Dead Weight: g_M = 0,113 kN/m²

LOAD COMBINATION

Partial Safety Coefficient Permanent: γ_G = 1,35
Partial Safety Coefficient First Variable: γ_{Q1} = 1,50
Partial Safety Coefficient N Variables: γ_{Qi} = 1,50
Partial Safety Coefficient Exceptional: γ_A = 1,00
Combination Coefficient Relating To Wind: $\psi_{0,W}$ = 0,60
Combination Coefficient Relating To Snow: $\psi_{0,S}$ = 0,50
Combination Coefficient Relating To Snow 1000 M Above Sea Level: $\psi_{0,S}$ = 0,70

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Mounting systems for solar technology

Lk1: $E_d = 1,35 * G_k + 1,50 * S_k$
Lk2: $E_d = 1,35 * G_k + 1,50 * W_{k,Pressure}$
Lk3: $E_d = 1,35 * G_k + 1,50 * (W_{k,Pressure} + 0,5 * S_k)$
Lk4: $E_d = 1,35 * G_k + 1,50 * (S_k + 0,6 * W_{k,Pressure})$
Lk5: $E_d = G_k + A_d + 0,2 * W_{k,Pressure}$
Lk6: $E_d = G_k + 1,50 * W_{k,Suction}$

MAXIMUM IMPACT

Area	Confirmation Of Structural Safety [kN/m]				Confirmation Of Serviceability [kN/m]				Distance Fastener
	Pressure Perpendicular	Pressure Parallel	Suction Perpendicular	Suction Parallel	Pressure Perpendicular	Pressure Parallel	Suction Perpendicular	Suction Parallel	
Field area	3,944	1,330	-0,500	0,036	2,640	0,891	-0,298	0,036	1 Crimp
Eaves	3,970	1,330	-0,598	0,036	2,657	0,891	-0,363	0,036	1 Crimp
Corner Region (Eaves)	3,970	1,330	-1,018	0,036	2,657	0,891	-0,643	0,036	1 Crimp
Gableboard	3,944	1,330	-1,080	0,036	2,640	0,891	-0,685	0,036	1 Crimp
Corner Region (Ridge)	3,944	1,330	-1,361	0,036	2,640	0,891	-0,872	0,036	1 Crimp
Ridge	3,944	1,330	-0,801	0,036	2,640	0,891	-0,499	0,036	1 Crimp

ROOF STRUCTURE

Modules: 103
Module Arrangement: Horizontal
Rail Orientation: Horizontal
Module Length: 1665 mm
Module Width: 991 mm
Module Height: 35 mm
Module Weight: 19,00 kg

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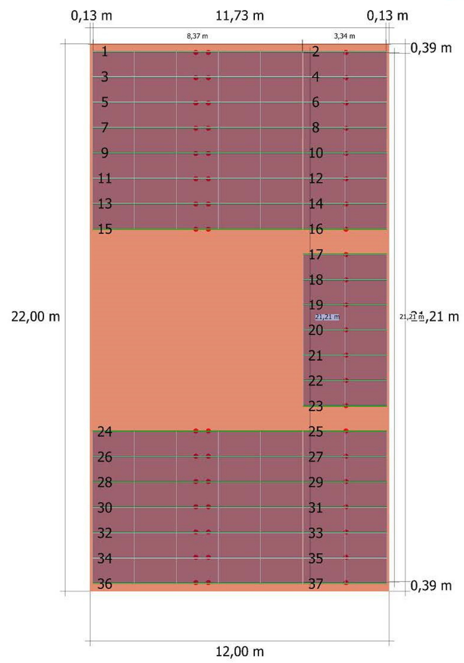
Mounting systems for solar technology



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CONFIGURATION

FASTENER

Description: K2 SpeedClip
Acceptable Vertical Pressure: 2,50 kN
Acceptable Vertical Tension: -2,50 kN
Acceptable Parallel Pressure: 2,00 kN
Screw: Self-tapping screw with mounted neopren
Acceptable Vertical Tension: -1,20 kN
Acceptable Parallel Pressure: 1,19 kN

RAIL

Description: K2 SpeedRail 22
Moment Of Inertia Iy: 7,74 cm4
Moment Of Inertia Iz: 1,53 cm4
Section Modulus Wy: 2,46 cm³
Section Modulus Wz: 1,09 cm³

Mounting systems for solar technology

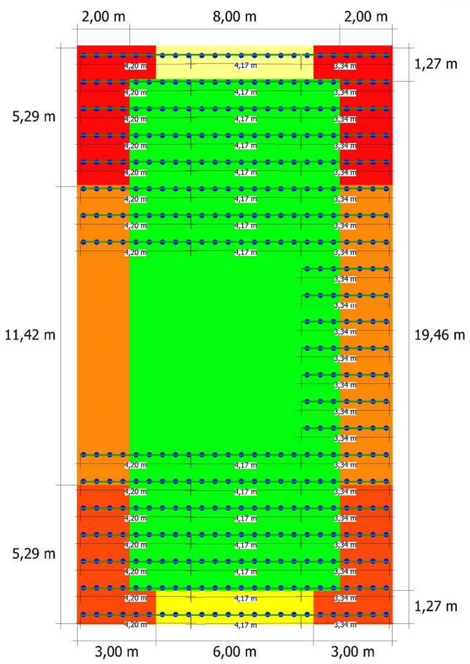
LAYOUT

DESIGN GUIDE

Rail 1: 1x 4,20 m; 1x 4,20 m (Cut To 4,17 m)
Rail 2: 1x 4,20 m (Cut To 3,34 m)
Rail 3: 1x 4,20 m; 1x 4,20 m (Cut To 4,17 m)
Rail 4: 1x 4,20 m (Cut To 3,34 m)
Rail 5: 1x 4,20 m; 1x 4,20 m (Cut To 4,17 m)
Rail 6: 1x 4,20 m (Cut To 3,34 m)
Rail 7: 1x 4,20 m; 1x 4,20 m (Cut To 4,17 m)
Rail 8: 1x 4,20 m (Cut To 3,34 m)
Rail 9: 1x 4,20 m; 1x 4,20 m (Cut To 4,17 m)
Rail 10: 1x 4,20 m (Cut To 3,34 m)
Rail 11: 1x 4,20 m; 1x 4,20 m (Cut To 4,17 m)
Rail 12: 1x 4,20 m (Cut To 3,34 m)
Rail 13: 1x 4,20 m; 1x 4,20 m (Cut To 4,17 m)
Rail 14: 1x 4,20 m (Cut To 3,34 m)
Rail 15: 1x 4,20 m; 1x 4,20 m (Cut To 4,17 m)
Rail 16 - 23: 1x 4,20 m (Cut To 3,34 m)
Rail 24: 1x 4,20 m; 1x 4,20 m (Cut To 4,17 m)
Rail 25: 1x 4,20 m (Cut To 3,34 m)
Rail 26: 1x 4,20 m; 1x 4,20 m (Cut To 4,17 m)
Rail 27: 1x 4,20 m (Cut To 3,34 m)
Rail 28: 1x 4,20 m; 1x 4,20 m (Cut To 4,17 m)
Rail 29: 1x 4,20 m (Cut To 3,34 m)
Rail 30: 1x 4,20 m; 1x 4,20 m (Cut To 4,17 m)
Rail 31: 1x 4,20 m (Cut To 3,34 m)
Rail 32: 1x 4,20 m; 1x 4,20 m (Cut To 4,17 m)
Rail 33: 1x 4,20 m (Cut To 3,34 m)
Rail 34: 1x 4,20 m; 1x 4,20 m (Cut To 4,17 m)
Rail 35: 1x 4,20 m (Cut To 3,34 m)
Rail 36: 1x 4,20 m; 1x 4,20 m (Cut To 4,17 m)
Rail 37: 1x 4,20 m (Cut To 3,34 m)

Distance Of Fastener:
Rail 1, 3, 5, 7, 9, 11, 13, 15, 24, 26, 28, 30, 32, 34, 36: 16 x 0,50 m
Rail 2, 4, 6, 8, 10, 12, 14, 16 - 23, 25, 27, 29, 31, 33, 35, 37: 6 x 0,50 m

Mounting systems for solar technology



Mounting systems for solar technology

MAXIMUM UTILIZATION

Rail	Rail		Cantilever		oad Carrying Capacity	oad Carrying Capacity
Area	Tension [%]	Deflection [%]	Length [m]	Deflection [%]	Fastener [%]	Screw [%]
Field area	45,5	17,9	0,223	4,3	94,7	67,2
Eaves	45,7	17,9	0,223	4,3	95,3	67,2
rner Region (Eave	45,7	17,9	0,118	55,9	95,3	67,2
Gableboard	45,5	17,9	0,118	55,8	94,7	67,2
rner Region (Ridg	45,5	17,9	0,118	55,8	94,7	67,9
Ridge	45,5	17,9	0,223	4,3	94,7	67,2

THE SYSTEM HAS BEEN CALCULATED SUCCESSFULLY.

CALCULATION NOTICE

¬ The analysis is only made for the substructure. The rails are considered as multi span beams with a cantilever using evenly distributed loads.

¬ The design rules comply with the EURO CODE EN 1990 - Basis of structural design.

¬ The determination of wind loads is based on EN 1991-1-4 - wind loads. The different sections have been combined for clarity.

¬ The determination of the snow load is based on EN 1991-1-3 - Snow loads. Any snow bag possibility has to be considered by a higher snow load.

¬ The values of the material load capacity are taken from the manufacturer's technical handbook.

BILL OF MATERIAL

Position	Number	Article	Quantity	Weight
1	1001164	K2 SpeedClip	409	9,240 kg
2	1001622	Self-tapping screw with mounted neoprene supported washer	818	5,900 kg
3	1003379	K2 SpeedRail 22; 4,20m	52	139,800 kg
4	1003558	K2 Set Speedlock for SpeedRail 22	52	3,000 kg
5	1003571	K2 Set Rail connector for K2 SpeedRail	15	0,980 kg
6	1004555	K2 End Clamp 34-36mm, black anodized	64	1,984 kg
7	1005131	K2 Middle Clamp Standard, 20mm, M8	174	6,664 kg
8	1000087	Hexagonal socket head cap screw DIN 912/EN ISO 4762, M8x35, A2-70	238	7,000 kg
9	1001643	M K2 Slot nut with clip, Stainless steel	238	4,200 kg
10	1000473	Locking washer S8, A2	238	0,200 kg
11		AddOn	238	0,000 kg
Sum				**178,94 kg**

A.10 – Measurement, air tightness

TERMOGRAFERINGS-TEKNIKK AS
VARMESØKENDE KAMERA

INFRARØD TEKNOLOGI

Tetthetsbevis

Utført dato: 16.04.2015

Hustype: "Enebolig" IMSUSS. Multikomforthus-Ringdal

Anleggets adresse: Ringdalskogen

Krav til tetthet: (m^3/m^3h) I byggteknisk forskrift og i NS 3700 Kriterier for passive og lavenergi hus

Bygningstype	Frittliggende småhus	Rekkehus i inntil to etasjer	Andre bygninger
TEK 97	4	3	1,5
TEK 2007 / 2010	2,5	1,5	1,5
Lavenergi klasse 1-NS 3700	1	1	1
Lavenergi klasse 2-NS 3700	3	3	3
Passivehus – NS 3700	0,6	0,6	0,6

Denne boenheten er definert til: Frittliggende enebolig

Det maksimale totale lekkasjetall får være etter deres krav:
n_{50} = 0,3. Omsetninger ved 50Pa trykkforskjell mellom ute og inne

Målt lekkasjetall:
Det er brukt 765m^3 i beregningen

n_{50} = 0,6 Omsetninger ved 50 Pa trykkforskjell mellom ute og inne.
Lekkasjemåling er foretat. etter innvendig dampsjiktsperre og alle gjennomføringer er utført

Byggeforskriftene etter byggherres krav til total tetthet er da: ikke helt oppfylt!
Det er i dette tilfellet kun kjørt overtrykk, grunnet problemer med trykkendringer, se vedlegg

For at kontrollen av lufttetthet skal fungere etter hensikten må den gjennomføres etter at både utvendig vindsperre og innvendig dampsperresjikt er montert, og når arbeid med gjennomføringer i tak og yttervegg er ferdig.

Tetthetstesten er utført etter NS-EN 13829 "Bestemmelser av bygningers luftlekkasje". Punkt 5.2.1 metode B. Det blir foretatt både undertrykk og overtrykk målinger med Blower Door. Luftvekslingstallet som er grunnlaget for å avgjøre om leiligheten / huset holder kravet gitt i NS-EN 13829 og er basert på gjennomsnittet av disse to målinger, pluss, minus 10% målenøyaktighet.

Tetthetsmåling utført av
Termograferings Teknikk AS
Sverre Selvig
Org.nr. 980 907 031

TERMOGRAFERINGSTEKNIKK AS Pb 544 Nanset 3252 Larvik	Web: www.tgt.no Mobiltelefon: 907 35 583	E-post: Bankgiro: Org.nr.:	tselvig@online.no 1594 29 56891 980 907 031

A.11 – Simien calculations

SIMIEN

Resultater årssimulering

Simuleringsnavn: Årssimulering
Tid/dato simulering: 12:13 20/5-2016
Programversjon: 5.504
Simuleringsansvarlig: Harald Amundsen / Åse Lekang Sørensen
Firma: SINTEF
Inndatafil: U:\...\MKH_As_built_160408 - ÅLS 160520.smi
Prosjekt: Multikomforthus Larvik - ZEB
Sone: Alle soner

Energibudsjett		
Energipost	Energibehov	Spesifikt energibehov
1a Romoppvarming	4799 kWh	23,8 kWh/m²
1b Ventilasjonsvarme (varmebatterier)	418 kWh	2,1 kWh/m²
2 Varmtvann (tappevann)	3212 kWh	15,9 kWh/m²
3a Vifter	765 kWh	3,8 kWh/m²
3b Pumper	0 kWh	0,0 kWh/m²
4 Belysning	1765 kWh	8,8 kWh/m²
5 Teknisk utstyr	3177 kWh	15,8 kWh/m²
6a Romkjøling	0 kWh	0,0 kWh/m²
6b Ventilasjonskjøling (kjølebatterier)	0 kWh	0,0 kWh/m²
Totalt netto energibehov, sum 1-6	14136 kWh	70,2 kWh/m²

Levert energi til bygningen (beregnet)		
Energivare	Levert energi	Spesifikk levert energi
1a Direkte el.	5707 kWh	28,3 kWh/m²
1b El. Varmepumpe	1014 kWh	5,0 kWh/m²
1c El. solenergi	144 kWh	0,7 kWh/m²
2 Olje	0 kWh	0,0 kWh/m²
3 Gass	0 kWh	0,0 kWh/m²
4 Fjernvarme	0 kWh	0,0 kWh/m²
5 Biobrensel	0 kWh	0,0 kWh/m²
Annen energikilde	276 kWh	1,4 kWh/m²
Totalt levert energi, sum 1-6	7142 kWh	35,4 kWh/m²

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SIMIEN

Resultater årssimulering

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Prosjekt: Multikomforthus Larvik - ZEB
Sone: Alle soner

Dekning av energibudsjett fordelt på energikilder						
Energikilder	Romoppv.	Varmebatterier	Varmtvann	Kjølebatterier	Romkjøling	El. spesifikt
El.	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	28,3 kWh/m²
Olje	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Gass	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Fjernvarme	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Biobrensel	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Varmepumpe	19,1 kWh/m²	0,0 kWh/m²	3,2 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Sol	4,8 kWh/m²	0,0 kWh/m²	9,6 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Annen	0,0 kWh/m²	2,1 kWh/m²	3,2 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Sum	23,8 kWh/m²	2,1 kWh/m²	15,9 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	28,3 kWh/m²

Årlige utslipp av CO2		
Energivare	Utslipp	Spesifikt utslipp
1a Direkte el.	742 kg	3,7 kg/m²
1b El. Varmepumpe	132 kg	0,7 kg/m²
1c El. solenergi	19 kg	0,1 kg/m²
2 Olje	0 kg	0,0 kg/m²
3 Gass	0 kg	0,0 kg/m²
4 Fjernvarme	0 kg	0,0 kg/m²
5 Biobrensel	0 kg	0,0 kg/m²
Annen energikilde	36 kg	0,2 kg/m²
Totalt utslipp, sum 1-6	928 kg	4,6 kg/m²

SIMIEN
Resultater årssimulering

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Prosjekt: Multikomforthus Larvik - ZEB
Sone: Alle soner

Kostnad kjøpt energi		
Energivare	Energikostnad	Spesifikk energikostnad
1a Direkte el.	4566 kr	22,7 kr/m²
1b El. Varmepumpe	811 kr	4,0 kr/m²
1c El. solenergi	115 kr	0,6 kr/m²
2 Olje	0 kr	0,0 kr/m²
3 Gass	0 kr	0,0 kr/m²
4 Fjernvarme	0 kr	0,0 kr/m²
5 Biobrensel	0 kr	0,0 kr/m²
Annen energikilde	221 kr	1,1 kr/m²
Årlige energikostnader, sum 1-6	5713 kr	28,4 kr/m²

SIMIEN

Resultater årssimulering

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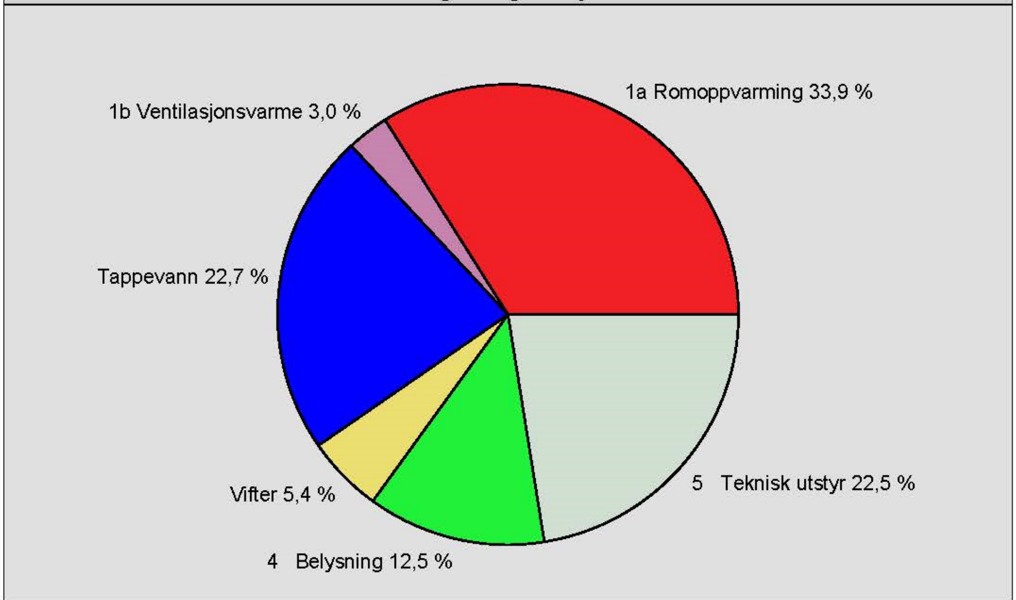
Inndatafil: U:\...\MKH_As_built_160408 - ÅLS 160520.smi
Prosjekt: Multikomforthus Larvik - ZEB
Sone: Alle soner

Årlig energibudsjett



1a Romoppvarming	4799 kWh
1b Ventilasjonsvarme (varmebatterier)	418 kWh
2 Varmtvann (tappevann)	3212 kWh
3a Vifter	765 kWh
3b Pumper	0 kWh
4 Belysning	1765 kWh
5 Teknisk utstyr	3177 kWh
6a Romkjøling	0 kWh
6b Ventilasjonskjøling (kjølebatterier)	0 kWh
Totalt netto energibehov, sum 1-6	14136 kWh

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Resultater årssimulering

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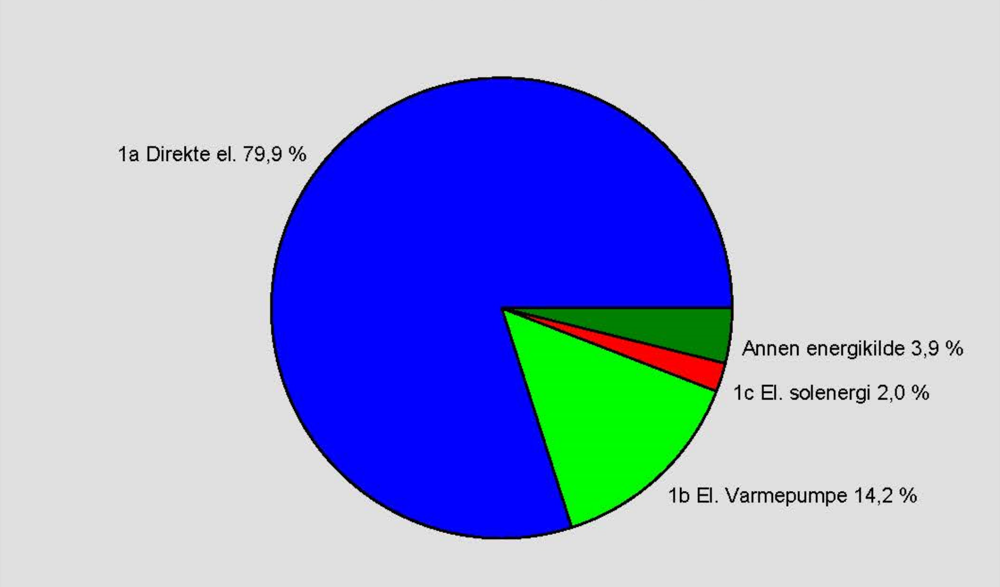
Inndatafil: U:\...\MKH_As_built_160408 - ÅLS 160520.smi
Prosjekt: Multikomforthus Larvik - ZEB
Sone: Alle soner

Levert energi til bygningen (beregnet)



1a Direkte el.	5707 kWh
1b El. Varmepumpe	1014 kWh
1c El. solenergi	144 kWh
2 Olje	0 kWh
3 Gass	0 kWh
4 Fjernvarme	0 kWh
5 Biobrensel	0 kWh
Annen energikilde	276 kWh
Totalt levert energi, sum 1-6	7142 kWh

SIMIEN

Resultater årssimulering

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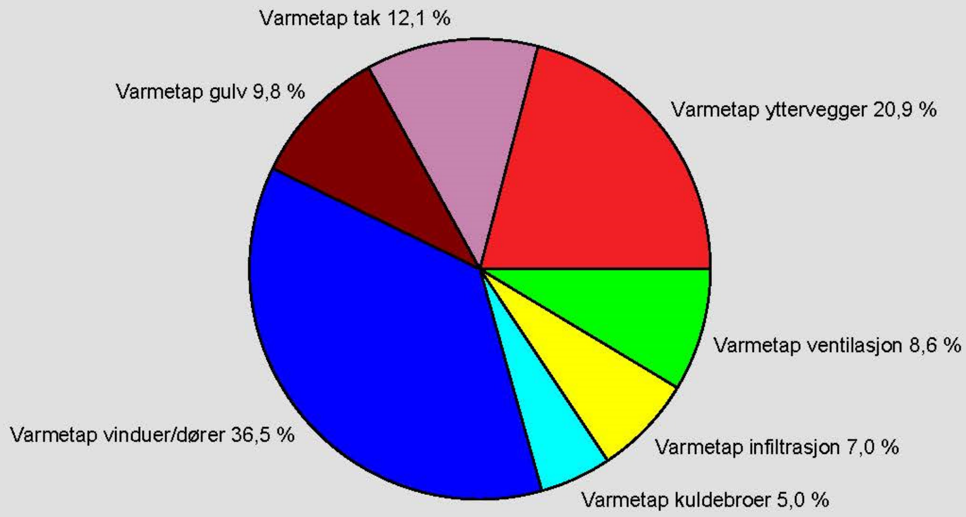
Programversjon: 5.504
Simuleringsansvarlig: Harald Amundsen / Åse Lekang Sørensen
Firma: SINTEF
Inndatafil: U:\...\MKH_As_built_160408 - ÅLS 160520.smi
Prosjekt: Multikomforthus Larvik - ZEB
Sone: Alle soner

Varmetapsbudsjett (varmetapstall)



Varmetapstall yttervegger	0,13 W/m²K
Varmetapstall tak	0,07 W/m²K
Varmetapstall gulv på grunn/mot det fri	0,06 W/m²K
Varmetapstall glass/vinduer/dører	0,22 W/m²K
Varmetapstall kuldebroer	0,03 W/m²K
Varmetapstall infiltrasjon	0,04 W/m²K
Varmetapstall ventilasjon	0,05 W/m²K
Totalt varmetapstall	0,60 W/m²K

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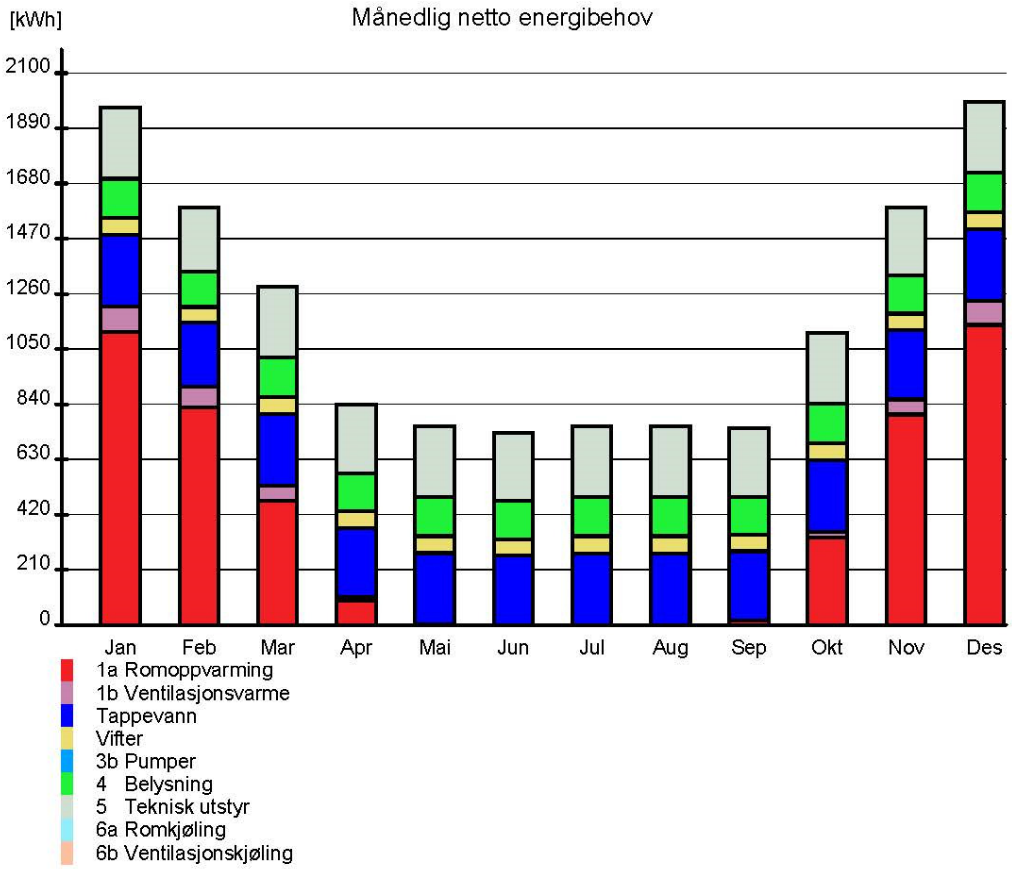

SIMIEN

Resultater årssimulering

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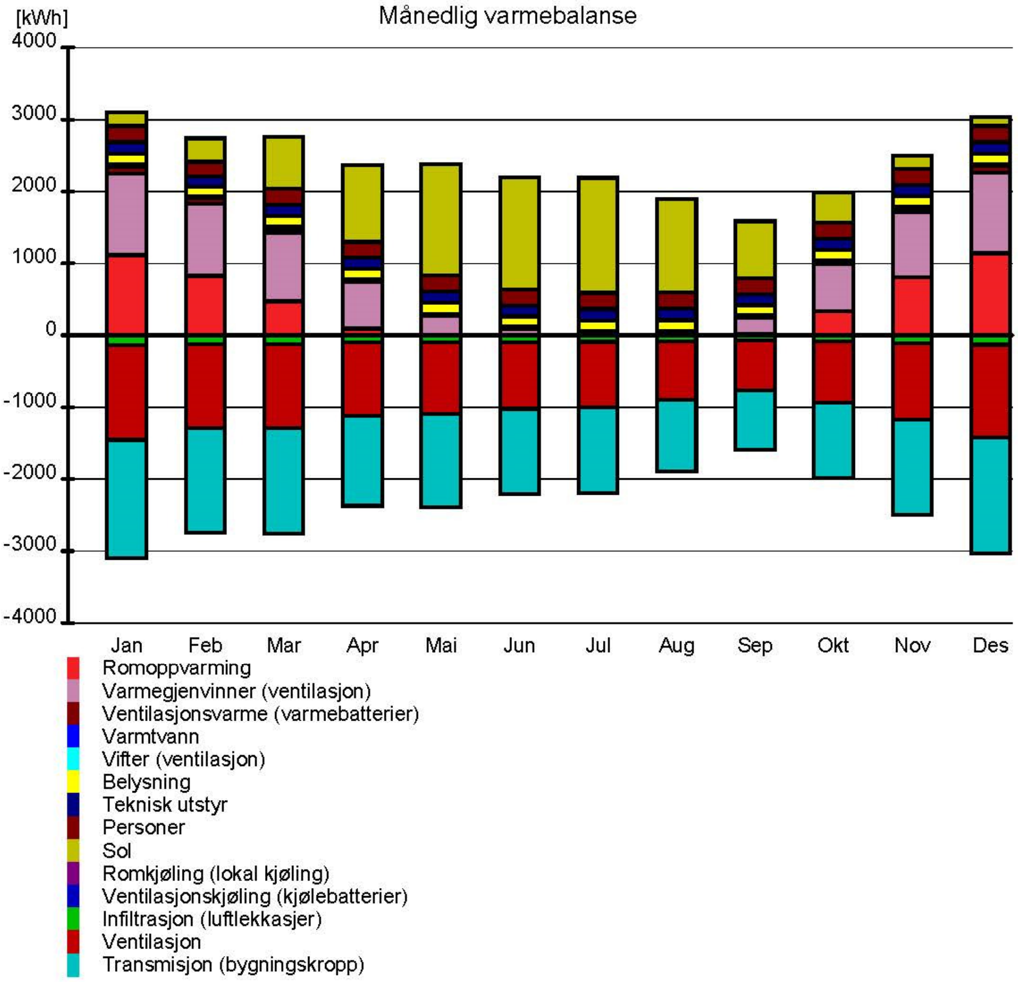

SIMIEN

Resultater årssimulering

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Månedlige temperaturdata (lufttemperatur)					
Måned	Midlere ute	Maks. ute	Min. ute	Maks. sone	Min. sone
Jan	-1,2 °C	7,4 °C	-15,5 °C	23,3 °C (Ringdalskogen 1,etg)	19,0 °C (Ringdalskogen 1,etg)
Feb	-0,7 °C	9,2 °C	-13,2 °C	24,6 °C (Ringdalskogen 1,etg)	19,0 °C (Ringdalskogen 1,etg)
Mar	1,9 °C	12,5 °C	-7,8 °C	26,5 °C (Ringdalskogen 1,etg)	19,0 °C (Ringdalskogen 1,etg)
Apr	5,9 °C	16,4 °C	-2,1 °C	31,1 °C (Ringdalskogen 2,etg)	19,0 °C (Ringdalskogen 1,etg)
Mai	11,6 °C	21,3 °C	1,7 °C	39,2 °C (Ringdalskogen 2,etg)	19,3 °C (Ringdalskogen 2,etg)
Jun	15,0 °C	22,2 °C	7,9 °C	43,0 °C (Ringdalskogen 2,etg)	22,8 °C (Ringdalskogen 2,etg)
Jul	17,7 °C	27,1 °C	10,4 °C	44,3 °C (Ringdalskogen 2,etg)	23,7 °C (Ringdalskogen 2,etg)
Aug	17,9 °C	26,3 °C	10,1 °C	42,9 °C (Ringdalskogen 2,etg)	23,9 °C (Ringdalskogen 1,etg)
Sep	12,9 °C	20,7 °C	4,8 °C	37,0 °C (Ringdalskogen 2,etg)	19,1 °C (Ringdalskogen 2,etg)
Okt	7,3 °C	15,6 °C	-1,2 °C	26,0 °C (Ringdalskogen 1,etg)	19,0 °C (Ringdalskogen 1,etg)
Nov	2,5 °C	11,5 °C	-5,8 °C	24,1 °C (Ringdalskogen 1,etg)	19,0 °C (Ringdalskogen 1,etg)
Des	-0,8 °C	8,3 °C	-12,8 °C	23,0 °C (Ringdalskogen 1,etg)	19,0 °C (Ringdalskogen 1,etg)

SIMIEN

Resultater årssimulering

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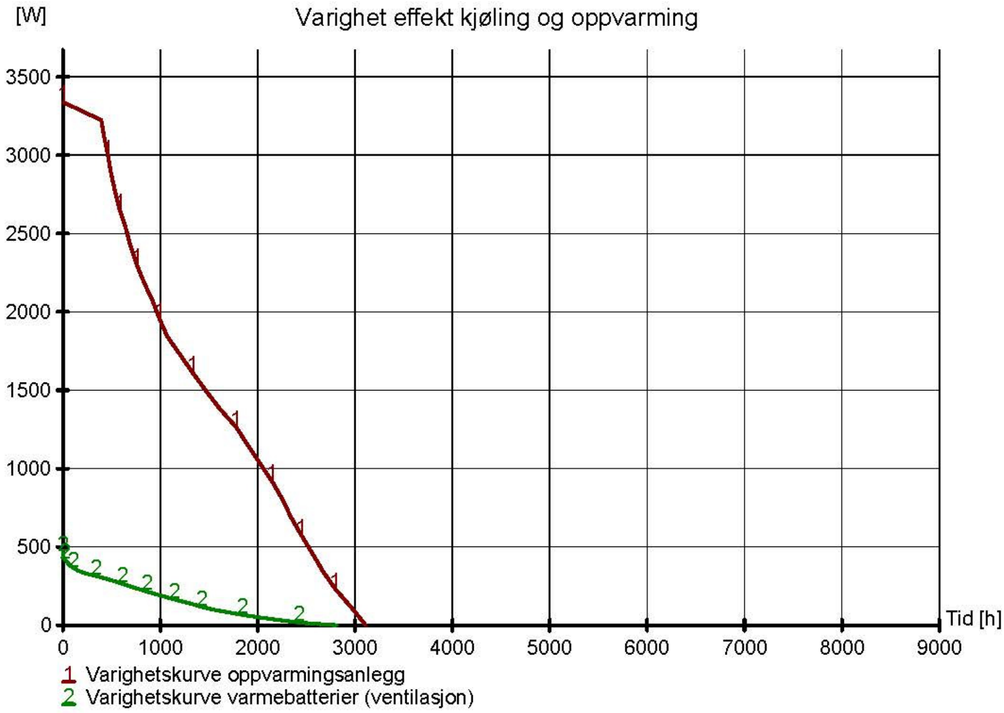
Sone: Alle soner



SIMIEN
Resultater årssimulering

Simuleringsnavn: Årssimulering
Tid/dato simulering: 12:13 20/5-2016
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Prosjekt: Multikomforthus Larvik - ZEB
Sone: Alle soner

Dekningsgrad effekt/energi oppvarming	
Effekt (dekning)	Dekningsgrad energibruk
3,3 kW (90 %)	99 %
2,9 kW (80 %)	96 %
2,5 kW (70 %)	92 %
2,2 kW (60 %)	86 %
1,8 kW (50 %)	79 %
1,5 kW (40 %)	70 %
1,1 kW (30 %)	57 %
0,7 kW (20 %)	41 %
0,4 kW (10 %)	23 %
Nødvendig effekt til oppvarming av tappevann er ikke inkludert	-

Dokumentasjon av sentrale inndata (1)		
Beskrivelse	Verdi	Dokumentasjon
Areal yttervegger [m²]:	229	<dokumentasjonstekst>
Areal tak [m²]:	172	<dokumentasjonstekst>
Areal gulv [m²]:	140	<dokumentasjonstekst>
Areal vinduer og ytterdører [m²]:	59	<dokumentasjonstekst>
Oppvarmet bruksareal (BRA) [m²]:	202	<dokumentasjonstekst>
Oppvarmet luftvolum [m³]:	610	<dokumentasjonstekst>
U-verdi yttervegger [W/m²K]	0,11	<dokumentasjonstekst>
U-verdi tak [W/m²K]	0,08	<dokumentasjonstekst>
U-verdi gulv [W/m²K]	0,08	<dokumentasjonstekst>
U-verdi vinduer og ytterdører [W/m²K]	0,75	<dokumentasjonstekst>
Areal vinduer og dører delt på bruksareal [%]	29,2	<dokumentasjonstekst>
Normalisert kuldebroverdi [W/m²K]:	0,03	<dokumentasjonstekst>
Normalisert varmekapasitet [Wh/m²K]	24	<dokumentasjonstekst>
Lekkasjetall (n50) [1/h]:	0,60	<dokumentasjonstekst>
Temperaturvirkningsgr. varmegjenvinner [%]:	87	<dokumentasjonstekst>

SIMIEN
Resultater årssimulering

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Prosjekt: Multikomforthus Larvik - ZEB
Sone: Alle soner

Dokumentasjon av sentrale inndata (2)		
Beskrivelse	Verdi	Dokumentasjon
Estimert virkningsgrad gjenvinner justert for frostsikring [%]:	87,0	<dokumentasjonstekst>
Spesifikk vifteeffekt (SFP) [kW/m³/s]:	1,30	<dokumentasjonstekst>
Luftmengde i driftstiden [m³/hm²]	1,20	<dokumentasjonstekst>
Luftmengde utenfor driftstiden [m³/hm²]	0,00	<dokumentasjonstekst>
Systemvirkningsgrad oppvarmingsanlegg:	6,16	<dokumentasjonstekst>
Installert effekt romoppv. og varmebatt. [W/m²]:	18	<dokumentasjonstekst>
Settpunkttemperatur for romoppvarming [°C]	20,3	<dokumentasjonstekst>
Systemeffektfaktor kjøling:	2,75	<dokumentasjonstekst>
Settpunkttemperatur for romkjøling [°C]	0,0	<dokumentasjonstekst>
Installert effekt romkjøling og kjølebatt. [W/m²]:	0	<dokumentasjonstekst>
Spesifikk pumpeeffekt romoppvarming [kW/(l/s)]:	0,00	
Spesifikk pumpeeffekt romkjøling [kW/(l/s)]:	0,00	
Spesifikk pumpeeffekt varmebatteri [kW/(l/s)]:	0,00	
Spesifikk pumpeeffekt kjølebatteri [kW/(l/s)]:	0,00	<dokumentasjonstekst>
Driftstid oppvarming (timer)	16,0	<dokumentasjonstekst>

Dokumentasjon av sentrale inndata (3)		
Beskrivelse	Verdi	Dokumentasjon
Driftstid kjøling (timer)	0,0	<dokumentasjonstekst>
Driftstid ventilasjon (timer)	24,0	<dokumentasjonstekst>
Driftstid belysning (timer)	24,0	<dokumentasjonstekst>
Driftstid utstyr (timer)	24,0	<dokumentasjonstekst>
Oppholdstid personer (timer)	24,0	<dokumentasjonstekst>
Effektbehov belysning i driftstiden [W/m²]	1,00	<dokumentasjonstekst>
Varmetilskudd belysning i driftstiden [W/m²]	1,00	<dokumentasjonstekst>
Effektbehov utstyr i driftstiden [W/m²]	1,80	<dokumentasjonstekst>
Varmetilskudd utstyr i driftstiden [W/m²]	1,08	<dokumentasjonstekst>
Effektbehov varmtvann på driftsdager [W/m²]	1,82	<dokumentasjonstekst>
Varmetilskudd varmtvann i driftstiden [W/m²]	0,00	<dokumentasjonstekst>
Varmetilskudd personer i oppholdstiden [W/m²]	1,50	<dokumentasjonstekst>
Total solfaktor for vindu og solskjerming:	0,50	<dokumentasjonstekst>
Gjennomsnittlig karmfaktor vinduer:	0,19	<dokumentasjonstekst>
Solskjermingsfaktor horisont/utspring (N/Ø/S/V):	0,55/1,00/0,61/1,00	<dokumentasjonstekst>

SIMIEN

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Sone: Alle soner

Inndata bygning	
Beskrivelse	Verdi
Bygningskategori	Småhus
Simuleringsansvarlig	Harald Amundsen / Åse Lekang Sørensen
Kommentar	

Inndata klima	
Beskrivelse	Verdi
Klimasted	Sandefjord (Torp)
Breddegrad	59° 12'
Lengdegrad	10° 15'
Tidssone	GMT + 1
Årsmiddeltemperatur	7,6 °C
Midlere solstråling horisontal flate	111 W/m²
Midlere vindhastighet	3,6 m/s

SIMIEN

Resultater årssimulering

Simuleringsnavn: Årssimulering
Tid/dato simulering: 12:13 20/5-2016
Programversjon: 5.504
Simuleringsansvarlig: Harald Amundsen / Åse Lekang Sørensen
Firma: SINTEF
Inndatafil: U:\...\MKH_As_built_160408 - ÅLS 160520.smi
Prosjekt: Multikomforthus Larvik - ZEB
Sone: Alle soner

Inndata energiforsyning

Beskrivelse	Verdi
1a Direkte el.	Systemvirkningsgrad romoppv,: 0,98 Systemvirkningsgrad varmtvann: 0,98 Systemvirkningsgrad varmebatterier: 0,98 Kjølefaktor romkjøling: 3,00 Kjølefaktor kjølebatterier: 3,00 Energipris: 0,80 kr/kWh CO2-utslipp: 130 g/kWh Andel romoppvarming: 0,0% Andel oppv, tappevann: 0,0% Andel varmebatteri: 0,0 % Andel kjølebatteri: 0,0 % Andel romkjøling: 100,0 % Andel el, spesifikt: 100,0 %
1b El. Varmepumpe	Systemvirkningsgrad romoppv,: 4,42 Systemvirkningsgrad varmtvann: 4,42 Systemvirkningsgrad varmebatterier: 4,42 Kjølefaktor romkjøling: 3,00 Kjølefaktor kjølebatterier: 3,00 Energipris: 0,80 kr/kWh CO2-utslipp: 130 g/kWh Andel romoppvarming: 80,0% Andel oppv, tappevann: 20,0% Andel varmebatteri: 0,0 % Andel kjølebatteri: 0,0 % Andel romkjøling: 0,0 % Andel el, spesifikt: 0,0 %
1c El. solenergi	Systemvirkningsgrad romoppv,: 20,00 Systemvirkningsgrad varmtvann: 20,00 Systemvirkningsgrad varmebatterier: 20,00 Kjølefaktor romkjøling: 2,50 Kjølefaktor kjølebatterier: 2,50 Energipris: 0,80 kr/kWh CO2-utslipp: 130 g/kWh Andel romoppvarming: 20,0% Andel oppv, tappevann: 60,0% Andel varmebatteri: 0,0 % Andel kjølebatteri: 0,0 % Andel romkjøling: 0,0 % Andel el, spesifikt: 0,0 %
Annen energikilde	Systemvirkningsgrad romoppv,: 3,84 Systemvirkningsgrad varmtvann: 3,84 Systemvirkningsgrad varmebatterier: 3,84 Kjølefaktor romkjøling: 2,50 Kjølefaktor kjølebatterier: 2,50 Energipris: 0,80 kr/kWh CO2-utslipp: 130 g/kWh Andel romoppvarming: 0,0% Andel oppv, tappevann: 20,0% Andel varmebatteri: 100,0 % Andel kjølebatteri: 100,0 % Andel romkjøling: 0,0 %

Andel el, spesifikt: 0,0 %

SIMIEN

Resultater årssimulering

Simuleringsnavn: Årssimulering
Tid/dato simulering: 12:13 20/5-2016
Programversjon: 5.504
Simuleringsansvarlig: Harald Amundsen / Åse Lekang Sørensen
Firma: SINTEF
Inndatafil: U:\...\MKH_As_built_160408 - ÅLS 160520.smi
Prosjekt: Multikomforthus Larvik - ZEB
Sone: Alle soner

Inndata ekspertverdier	
Beskrivelse	Verdi
Konvektiv andel varmetilskudd belysning	0,30
Konvektiv andel varmetilsk. teknisk utstyr	0,50
Konvektiv andel varmetilsikudd personer	0,50
Konvektiv andel varmetilsikudd sol	0,50
Konvektiv varmoverføringskoeff. vegger	2,50
Konvektiv varmoverføringskoeff. himling	2,00
Konvektiv varmoverføringskoeff. gulv	3,00
Bypassfaktor kjølebatteri	0,25
Innv. varmemotstand på vinduruter	0,13
Midlere lufthastighet romluft	0,15
Turbulensintensitet romluft	25,00
Avstand fra vindu	0,60
Termisk konduktivitet akk. sjikt [W/m²K]:	20,00

A.12 – Amount of different construction parts

If calculating the embodied GHG Emissions in more detail later, the amount of the different construction parts are needed. As an input to such later calculations, amounts of different construction parts are collected, as described in this table.

Construction Parts (according to NS 3451:2009)		
2 Building		
21 Groundwork and Foundations	33 m3	Concrete (Norbetong)
22 Superstructure	28,14 m3 7,2 m3 373 kg	Wood (Moelven) Wood (Treindustrien) Metals (Outokumpu Oyj)
23 Outer walls	332,10 m^2 352,72 m^2 285,47 m^2 3527,20 m^2 255,05 m^2 19,77 m^3 1,00 pc 30,17 pc	Coverings (Saint Gobain Gyproc) Plastics (Tommen Gram) Coverings (Saint Gobain Gyproc) Insulation (Glava) Wood (Treindustrien) Wood (Treindustrien) Doors (Nordic Door) Windows (Lian Trevarefabrikk)
24 Inner walls	289,05 m^2 2,70 m^2 39,24 m^2 119,80 m^2 311,40 m^2 1,90 m^3 40,86 m^2 89,59 pc 31,12	Coverings (Saint Gobain Gyproc) Glass (Bauglass Industri) Ceramics (Industrieverband) Paints (Dulux) Insulation (Glava) Wood (Treindustrien) Plastics (Icopal) Wood (Fibo-Trespo) Doors (Nordic Door)
25 Floor Structure	2,52 m^3 71,00 m^2 1,56 m^3 71,00 m^2 2,90 m^3 132,00 m^2 3,89 m^3 330,00 m 197,37 m^2 132,00 m^2 180,00 m^2 6,00 m^2 3,20 m^2 117,65 m^2	Wood (Treindustrien) Insulation (Glava) Wood Coverings (Saint Gobain Gyproc) Wood Plastics (Baca Plastindustri) Wood (Treindustrien) Wood (Masonite Beams) Insulation (EPS Gruppen) Coverings (Saint Gobain Gyproc) Flooring (EGGER) Flooring (Desso) Ceramics (Industrieverband) Insulation (Jackofoam)
26 Outer Roof	1,43 m^3 152,00 m^2 152,00 m^2 304,00 m^2	Wood (Treindustrien) Insulation (Glava) Plastics (Icopal) Coverings (Saint Gobain Gyproc)
28 Stairs and Balconies	0,60 m^3 6,41 m^2 20,00 kg	Wood (Treindustrien) Glass (Bauglass Industri) Metals (Outokumpu Oyj)
3 Heating, Ventilation and Sanitation		
36 Ventilation and Air Conditioning	110,00 m 100,00 m 1,00 kg	Ventilation (NILAIR slange) Ventilation equipments (Skjøtemuffe, Spiro, Skjøtenippel, Skjøtemuffe, Bend, Fordeler, Boks for rist, Rist, Ytterveggkrappe, Air Handlling Unit) Sealing (Sealing Tape) Electronics

4 Electric Power		
43 Low Voltage Power		Electronics: Schneider Electrics, Exxact, KNX, etc
49 Photovoltaic, panel	122 m^2	Replacement of PV-panels after 30 y.
Batteries	1015 kg	batteries
6 Other Installations		
69 Other	16,00 m^2 1,00 pc 1,00 pc 1,00 pc 200,00 kg	Flat Plate Solar Collector Hot Water Tank, 600l Expansion vessel 25l Pump 40W Polyethylene, low density
TOTAL		

[1]Represents the main emissions due to all the materials that go into the building in year 0.
[2]Represents the emission scenario from materials that are replaced during the 60 years lifetime.

A.13 – Acoustic calculations

vers. 2.4e

Gyptone® **Beregning av etterklangstid**

Sak Multikomfort hus

Vedlegg 2

Sak nr. **Dato** 09-12-2013 **Beregnet av** JF

Forutsetninger

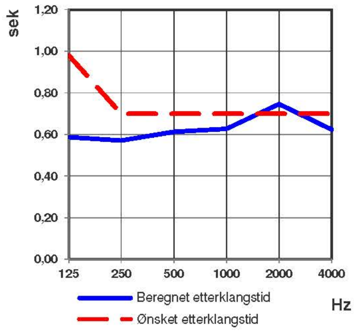
Emne	Stue	**Frekvens intervall**	125 - 4000 Hz
Lydklasse	C	**Ønsket etterklangstid**	0,7 sek
Kategori	Andet	**Tillatt avvik ved 125 Hz**	40 %
Romtype	Beboelses rum	**Volum**	75,1 m³

Konstruksjon	**Areal**	**Materialer**
Luftvolum		*Luftabsorpsjon*
Inventar	12 m²	Møbler
Gulv	22 m²	Parkett på oppforet
Vegge	11,3 m²	2x13 mm gips på stålbindingsverk, 50 mm mineralull, malt overflate
Vegge	32 m²	Blank mur med glatte fuger, malt
Vinduer	14,8 m²	Vinduer med termoglass
Døre	2,6 m²	Massiv tredør
Himling	20 m²	BIG Sixto 63 - 45x45 mm underlag, cc 300 mm, 45 mm mineralull
Glat friese	6 m²	Base 31 - 45x45 mm underlag cc 300 mm, 50 mm mineralull

Beregningsresultat

Kalkulerte absorpsjonsarealer og etterklangstider

Frekvens	**125**	**250**	**500**	**1000**	**2000**	**4000**	**Hz**
Absorpsjonsareal	20,46	21,05	19,61	19,14	16,10	19,26	m²
Ønsket etterklangstid	0,98	0,70	0,70	0,70	0,70	0,70	sek
Beregnet Etterklangstid	0,59	0,57	0,61	0,63	0,75	0,62	sek
Gjennomsnittlig etterklangstid	0,63						sek



Note

Vårt program for beregning av etterklangstid er basert på grunnleggende akustisk teori (Sabine), som under visse omstendigheter kan resultere i akustisk avvik fra kalkulert verdi. Resultater skal betraktes som antydende og presenteres uten ansvar for Gyproc AS.

Stue

vers. 2.4e

Gyptone®

Beregning av etterklangstid

Sak Multikomfort hus

Vedlegg 3

Sak nr. Dato 09-12-2013 Beregnet av JF

Forutsetninger

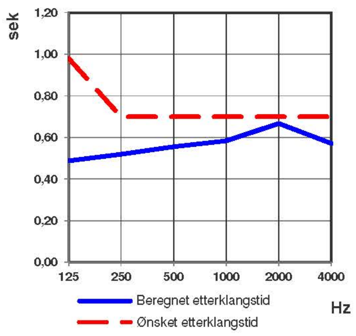
Emne	Soverom K202	**Frekvens intervall**	125 - 4000 Hz
Lydklasse	C	**Ønsket etterklangstid**	0,7 sek
Kategori	Andet	**Tillatt avvik ved 125 Hz**	40 %
Romtype	Beboelses rum	**Volum**	72 m³

Konstruksjon	Areal	Materialer
Luftvolum		*Luftabsorpsjon*
Inventar	10 m²	Møbler
Gulv	19 m²	Parkett på oppforet
Vegge	41,3 m²	2x13 mm gips på stålbindingsverk, 50 mm mineralull, malt overflate
Vegge	20,7 m²	22 mm sponplate, 50 mm hulrom med mineralull
Vinduer	8,3 m²	Vinduer med termoglass
Døre	2 m²	Massiv tredør
Himling	20,1 m²	BIG Sixto 63 - 45x45 mm underlag, cc 300 mm, 45 mm mineralull
Glat friese	0 m²	Base 31 - 45x45 mm underlag cc 300 mm, 50 mm mineralull

Beregningsresultat

Kalkulerte absorpsjonsarealer og etterklangstider

Frekvens	125	250	500	1000	2000	4000	Hz
Absorpsjonsareal	23,63	22,15	20,73	19,73	17,28	20,15	m²
Ønsket etterklangstid	0,98	0,70	0,70	0,70	0,70	0,70	sek
Beregnet Etterklangstid	0,49	0,52	0,56	0,58	0,67	0,57	sek
Gjennomsnittlig etterklangstid	0,56						sek



Note

Vårt program for beregning av etterklangstid er basert på grunnleggende akustisk teori (Sabine), som under visse omstendigheter kan resultere i akustisk avvik fra kalkulert verdi. Resultater skal betraktes som antydende og presenteres uten ansvar for Gyproc AS.

Soverom K202

vers. 2.4e

Gyptone®

Beregning av etterklangstid

Sak	Multikomfort hus			Vedlegg	1
Sak nr.		Dato	09-12-2013	Beregnet av	JF

Forutsetninger

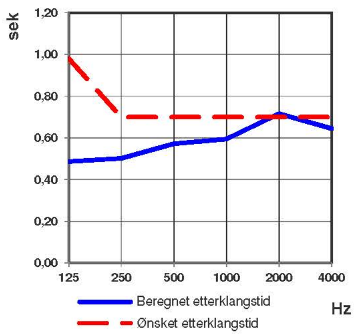
Emne	Kjøkken/spiserom	**Frekvens intervall**	125 - 4000 Hz
Lydklasse	C	**Ønsket etterklangstid**	0,7 sek
Kategori	Andet	**Tillatt avvik ved 125 Hz**	40 %
Romtype	Beboelses rum	**Volum**	93,6 m³

Konstruksjon	Areal	Materialer
Luftvolum		*Luftabsorpsjon*
Inventar	20 m²	Møbler
Gulv	36 m²	Parkett på oppforet
Vegge	13 m²	2x13 mm gips på stålbindingsverk, 50 mm mineralull, malt overflate
Vegge	24,2 m²	Blank mur med glatte fuger, malt
Vinduer	17,9 m²	Vinduer med termoglass
Åpning mod Entre	5,2 m²	Åpning
Himling	22 m²	BIG Sixto 63 - 45x45 mm underlag, cc 300 mm, 45 mm mineralull
Glat friese	14 m²	Base 31 - 45x45 mm underlag cc 300 mm, 50 mm mineralull

Beregningsresultat

Kalkulerte absorpsjonsarealer og etterklangstider

Frekvens	125	250	500	1000	2000	4000	Hz
Absorpsjonsareal	30,78	29,80	26,16	25,20	20,90	23,24	m²
Ønsket etterklangstid	0,98	0,70	0,70	0,70	0,70	0,70	sek
Beregnet Etterklangstid	0,49	0,50	0,57	0,59	0,72	0,64	sek
Gjennomsnittlig etterklangstid	0,59						sek



Note

Vårt program for beregning av etterklangstid er basert på grunnleggende akustisk teori (Sabine), som under visse omstendigheter kan resultere i akustisk avvik fra kalkulert verdi. Resultater skal betraktes som antydende og presenteres uten ansvar for Gyproc AS.

Kjøkken-spiserum

The Research Centre on Zero emission Buildings (ZEB)

The main objective of ZEB is to develop competitive products and solutions for existing and new buildings that will lead to market penetration of buildings that have zero emissions of greenhouse gases related to their production, operation and demolition. The Centre will encompass both residential and commercial buildings, as well as public buildings.

NTNU – Trondheim
Norwegian University of
Science and Technology

SINTEF

The Research Centre on
Zero Emission Buildings

Partners

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Byggenæringens Landsforening
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Direktoratet for byggkvalitet
www.dibk.no

DuPont
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NorDan AS
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Enova
www.enova.no

SAPA Building system
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Sør-Trøndelag fylkeskommune
www.stfk.no

Entra Eiendom AS
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