# GEOTHERMAL ENERGY IN NORWAY

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**ABSTRACT**

In this paper we discuss the recent developments of geothermal energy in Norway. Emphasis will be given on deployment of geothermal heat pump technology which is used widely in Norway in residential and commercial facilities. This will be illustrated on several examples.

**Keywords**: heat pumps, zero energy building

## 1. INTRODUCTION

Norway has become an important energy nation. Abundant offshore hydrocarbon resources (which have brought Norway huge economic revenues) and extensive access to cheap and clean hydropower (which provides most of Norway's electricity) have enabled Norway to enjoy a high level of security of supply of energy and one of the highest standards of living in the world. Despite its successes, Norway is facing important energy policy challenges. Since1990, the growth in on-shore energy consumption has not been matched by an increase of on-shore energy production despite the increased efficiency/transmission capacity and increased flexibility in general. The construction of gas-fired power stations has been stopped due to concerns about $CO_2$ emissions, and the construction of additional hydropower stations and on-shore wind farms has also been delayed by environmental concerns. Off-shore wind, tidal and solar energies are in a research stage, however there is some growth in local and regional capacity in biomass- and waste based district heating. Norway has no programme for nuclear energy. The domestic power production comes mainly from hydro (170 TWh), wind (2 TWh) , natural gas (3 TWh). The energy production and energy consumption in Norway is summarised in Figure1.

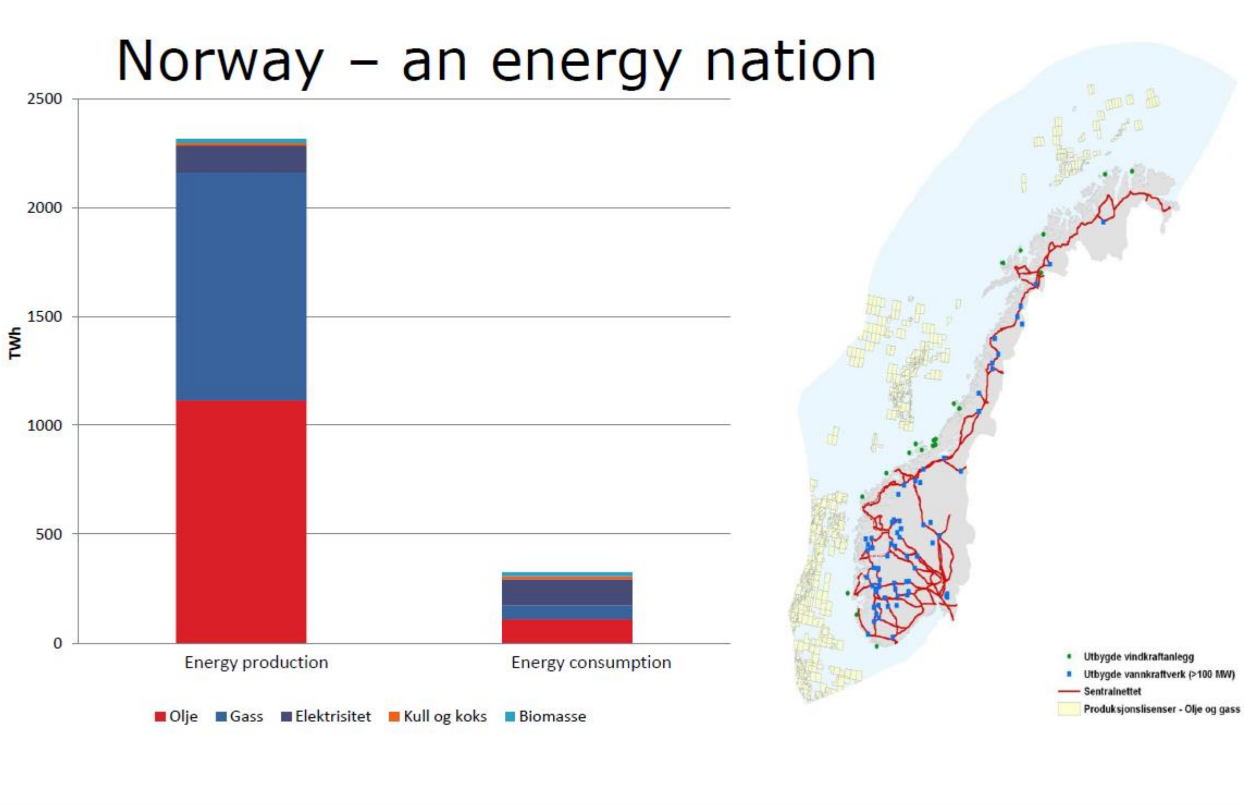


Fig. 1 Summary of energy production and energy consumption in Norway. The green dots on the Norwegian map (right side) show existing windmill farms and blue spots show existing hydropower stations.

Norway’s energy use per capita is similar to that of other countries with a similar climate. However, it differs completely in its structure because of the high share of cheap hydro-generated electricity which contributes with 99% of the domestic electricity production. The result is that Norway together with Iceland consumes the highest amount of electricity per capita in the world, approx. 17 MWh. This has created a high demand for electricity for heating purposes in private, public and commercial buildings, a demand normally met by oil, gas or district heating systems in other countries. The main goal of the government energy policy is to reduce the dependence on hydropower by restricting demand and increasing diversity. In 2001 the state-owned enterprise Enova SF was established to achieve the energy targets. Enova provides investment grants of 230 million Euro per annum. The funding comes from a levy on the electricity distribution tariffs. A new national collective R&D strategy for the energy sector, “Energi 21”, was launched in 2008 where geothermal energy is included though not with the highest priority. The vision of the strategy is for Norway to be Europe’s leading energy and environment conscious nation.

Norway is part of the Fennoscandian Shield. The bedrock consists of Precambrian rocks with a belt of Caledonian rocks extending from SW to N Norway. Permian volcanic and intrusive rocks are found in the Oslo region. The porosity of the crystalline bedrock is low. The lithosphere is cool and thick and characterized by low heat flow density below continental average. There is lack of heat flow data from Norway and the country is still marked as a white spot without available temperature data below 1000 m in the Atlas of Geothermal Resources in Europe. A recently heat flow study with new data from deep onshore boreholes shows higher heat flow values and a higher geothermal potential than previous expected. The palaeoclimatically and topographically corrected surface heat flow varies between 50 and 60 mW/m2 in south and central Norway.

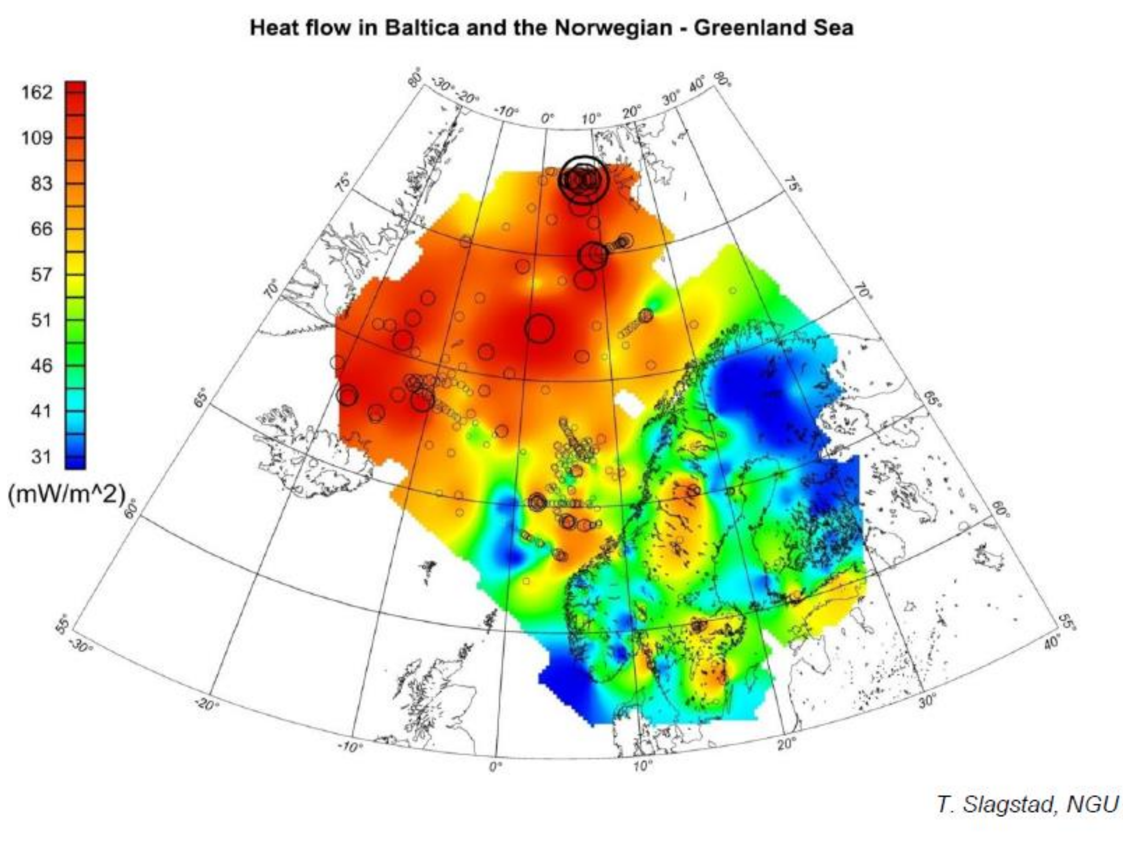


Fig. 2 Heat flow in Baltica and the Norwegian-Greenland Sea.

## 2. GEOTHERMAL ENERGY- OVERVIEW

Norway is a young nation when it comes to the utilisation of geothermal energy. Geothermal energy use is dominated by the relatively widespread deployment of geothermal heat pumps. There is no electricity production from geothermal resources and there are no deep geothermal energy installations in operation. Preliminary planning for utilizing deep geothermal energy in a district heating system in mainland Norway has commenced and geothermal energy use is being investigated for Ny Ålesund, Svalbard, a remote settlement in the Artic, where geothermal is considered to partly replace fossil fuels.

To date all geothermal installations in Norway are geothermal heat pumps (GHP). Statistics from the Norwegian heat pump organization (NOVAP) identifies a peak of 3600 GHP installations in 2011 (Figure 3). For 2014, 3000 GHPs were installed, and during 2015 about 2600. NOVAPs statistics cover approximately 90% of the Norwegian heat pump market.

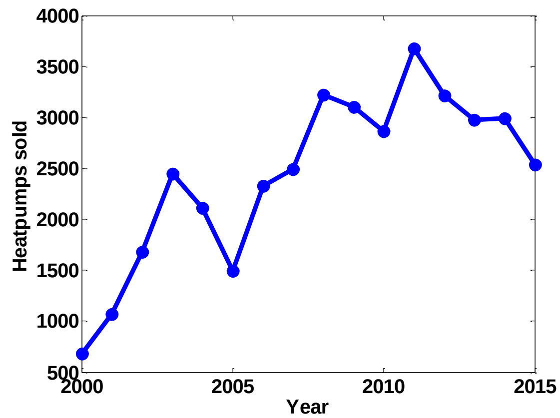


Fig. 3 Heat pump sales statistics for Norway from 2010 to 2015. Source: NOVAP

The majority of the GHP systems in Norway are vertical closed loop systems extracting heat and/or cold from crystalline rocks through borehole heat exchangers (BHE). The Geological Survey of Norway (NGU) collects statistics on GHP boreholes in the GRANADA database (http://www.grunnvanninorge.no/databaser_ngu.php). The data base is incomplete because of delayed reporting by drillers and not all boreholes drilled are registered. GRANADA borehole statistics show a similar trend to the NOVAP data, with maximum installations in 2011 and a decrease from 2011 to 2015.

A typical Norwegian GHP is based on one or more boreholes drilled to between 50 and 300 meters. A trend towards deeper boreholes has been observed in the last 5 to10 years, partly due to reduced drilling costs for deeper boreholes. The average borehole depth in fields with 4 or more boreholes increased to more than 200 meters in 2009 and to about 230 meters in 2014 and 2015 (Figure 4).

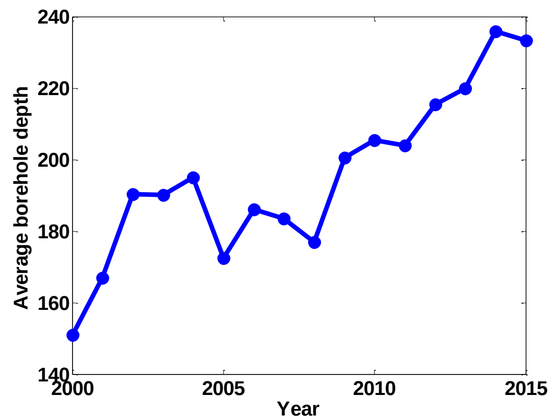


Fig. 4 Average borehole depth for fields with 4 boreholes or more for Norway from 2000 to 2015. Source: GRANADA/NGU

A typical Norwegian GHP system uses a 115 mm diameter borehole with a single 40 mm U tube installed. Some BHEs use alternative collectors, such as coaxial arrangements or collectors with a rougher surface which produce turbulent flow at lower flow rates. The Norwegian drilling industry has historically been dominated by Norwegian companies, but in the last few years some companies from Finland and Sweden have penetrated the Norwegian heat pump market.

European Union guidelines for calculating renewable energy from heat pumps from different heat pump technologies (2013/114/EU) pursuant to Article 5 of Directive 2009/28/EC of the European Parliament are used in calculating the total annual energy use from GHP installations. Europe is divided into three climate zones. Norway is situated in the cold climate zone. The default value for equivalent full load operation hours for GHPs is now 2470 hours. Previously, in calculations for national energy savings from GHPs annual operation in heating mode was 4000 hours. Norway spans over 13 degrees of latitude, some of which is north of the Polar circle, with no sunshine in the coldest season. In addition, there is a large diversity in the climate zones from coastal, high mountains and inland. There are large differences in building heating and cooling demands depending on location, building type and age. It is worth noting that new buildings have lower heating demands than older established buildings.

Table 1 summarises the status of geothermal energy use in Norway in 2014.

| **Electricity** | |
|---|---|
| Total Installed Capacity ($MW_e$) | 0 |
| Contribution to National Capacity (%) | 0 |
| Total Generation (GWh) | 0 |
| Contribution to National Demand (%) | 0% |

| Direct Use (2014 data) | |
|---|---|
| Total Installed Direct Use ($MW_{th}$) | na |
| Total Heat Used TJ/yr | 8260 |
| Total Heat Used TWh/yr | 2,3 |
| Total Installed Capacity for Heat Pumps ($MW_{th}$) | 1300 |

Table **Error! No text of specified style in document.**-Geothermal energy use in Norway for 2015.

(The data is based on gross estimates. na=data not available)

## 3.BUILDING SECTOR (Ground Source Heat Pumps- GSHP)

As mentioned earlier, the building sector in Norway is focused in deploying GSHPs in new buildings. According to the recent law passed by the Norwegian Parliament, heating in both public and private buildings using oil and gas will be forbidden by 2020. Therefore many existing houses and other buildings are converting their heating systems into arrangements based on heat pumps. Figure 5 shows visualization of BHEs in the central Oslo area which resembles slice of "Swiss Cheese" famous for its holes.

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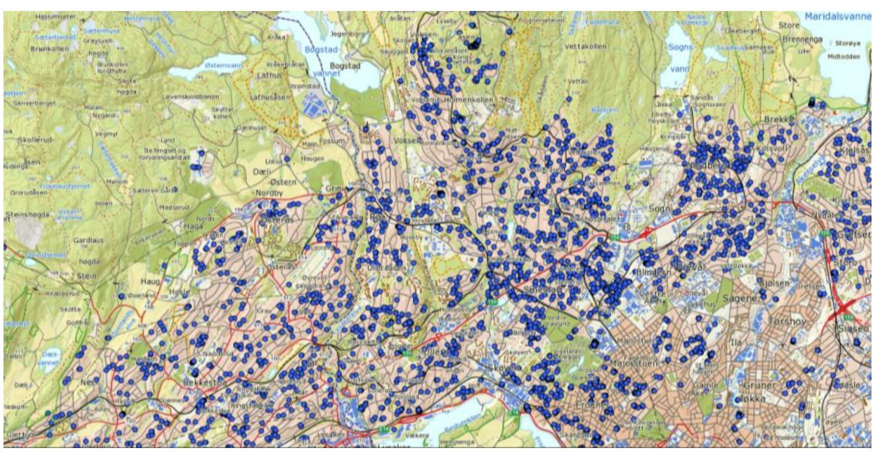

Fig. 5 Visualization of BHEs in the central Oslo area from GRANADA. Source: GRANADA/NGU

A typical example is an illustration of the BTES arrangement at Ljan School in Oslo which has hybrid heating system with integrated solar collectors in the asphalt in the schoolyard.

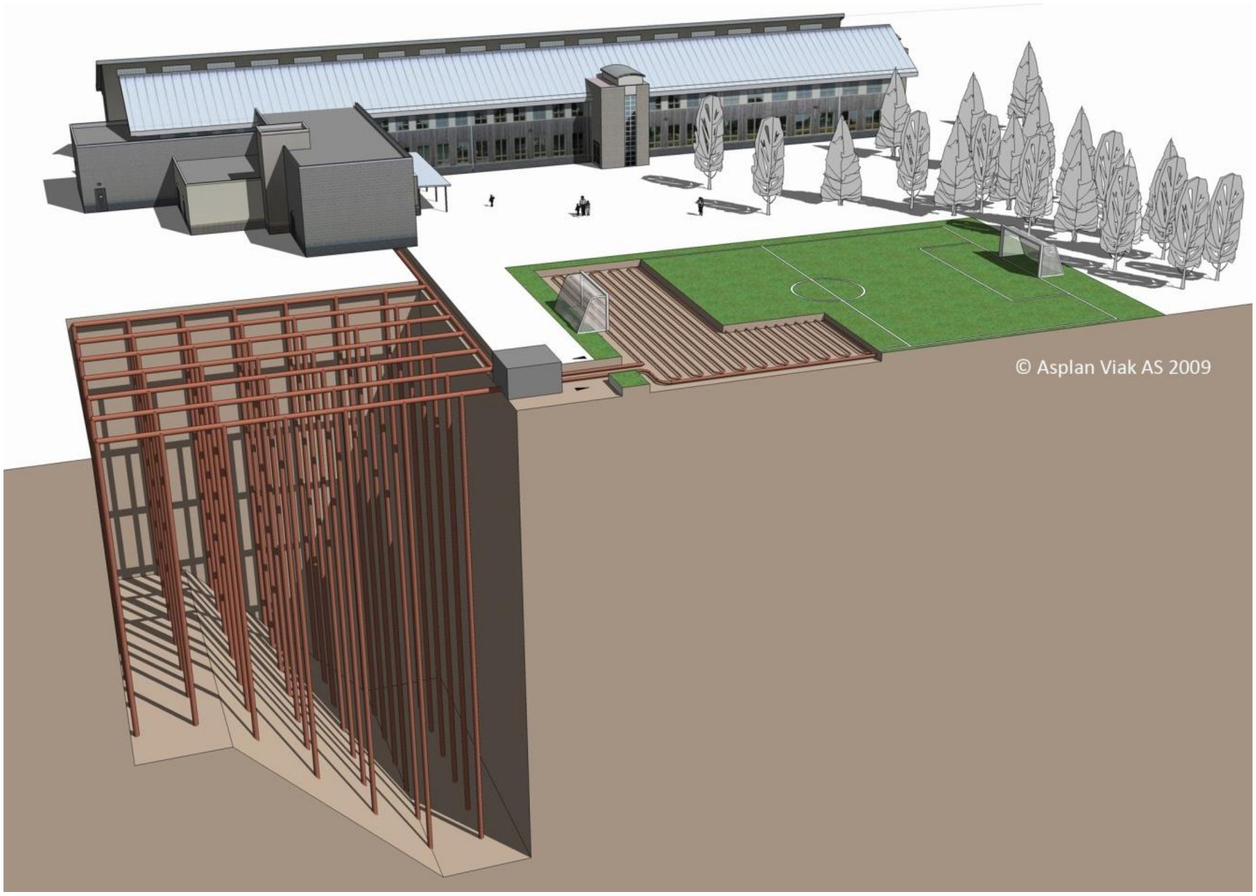


Fig. 6 Illustration of the BTES system at Ljan School in Oslo with integrated solar collectors in the asphalt in the schoolyard

**Passive buildings and plus energy buildings**

A Norwegian building code is the main legal instrument for improving energy efficiency in Norway. It was revised in 2007 in accordance with the EU Directive on the Energy Performance of Buildings (2002/91 EC). New and renovated buildings are subject to stricter energy performance requirements. The requirement, denoted TEK-10, came fully into force on 1 August 2009. A new building code was planned for 2015, but the introduction of the new building code has been delayed until 2017 (TEK-17) based on strong feedback from the industry. The target level for TEK-17 is the passive house standard or active houses producing energy. Zero Emission/Energy Buildings (ZEB) and Plus Energy Buildings belong to this category.

Zero Emission/Energy Buildings (ZEB) and Plus Energy Buildings are given significant attention in Norway. In order to achieve Zero Emission/Energy Buildings (ZEB) or Plus Energy Buildings, a combination of energy sources is required. Geothermal energy may be part of such an energy system, typically in combination with Photovoltaic (PV) and / or Solar Thermal (ST) energy harvesting. ST-energy is stored in the geothermal bore field and batteries store the PV energy. There are currently three Norwegian ZEB-projects where geothermal energy is included or planned, two smaller projects in the South-East of Norway, and one large project in Western Norway.

The multi-comfort project “Plus House Larvik” (Figure 7) is a pilot 200 $m^2$ family house in Larvik. The house in the garden has a characteristic tilt towards southeast and a sloping roof surface clad with solar panels and collectors. These elements, together with geothermal energy, serve the energy needs of the house and generate enough to power an electric car year-round. The well-known Norwegian architectural company Snøhetta (which designed amongst others the Oslo Opera House, and the cultural building on the World Trade Centre 9/11 Memorial site) has designed the Plus House Larvik (http://snohetta.com) with the financial support of Research Council of Norway.

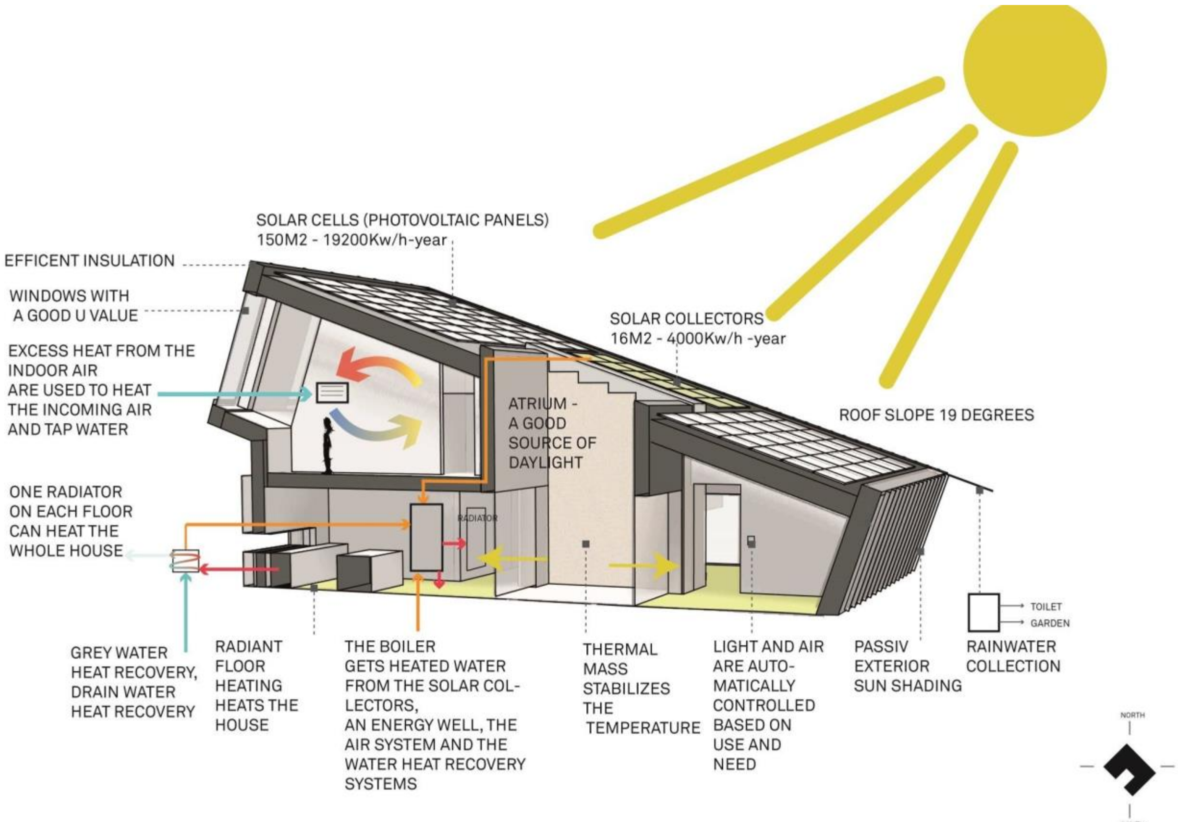

Fig 7 Plus House Larvik

Another example of Passive House project is the planned HOLMEN indoors swimming pool with 15 energy wells and 650 square meters of solar panels (Figure 8).

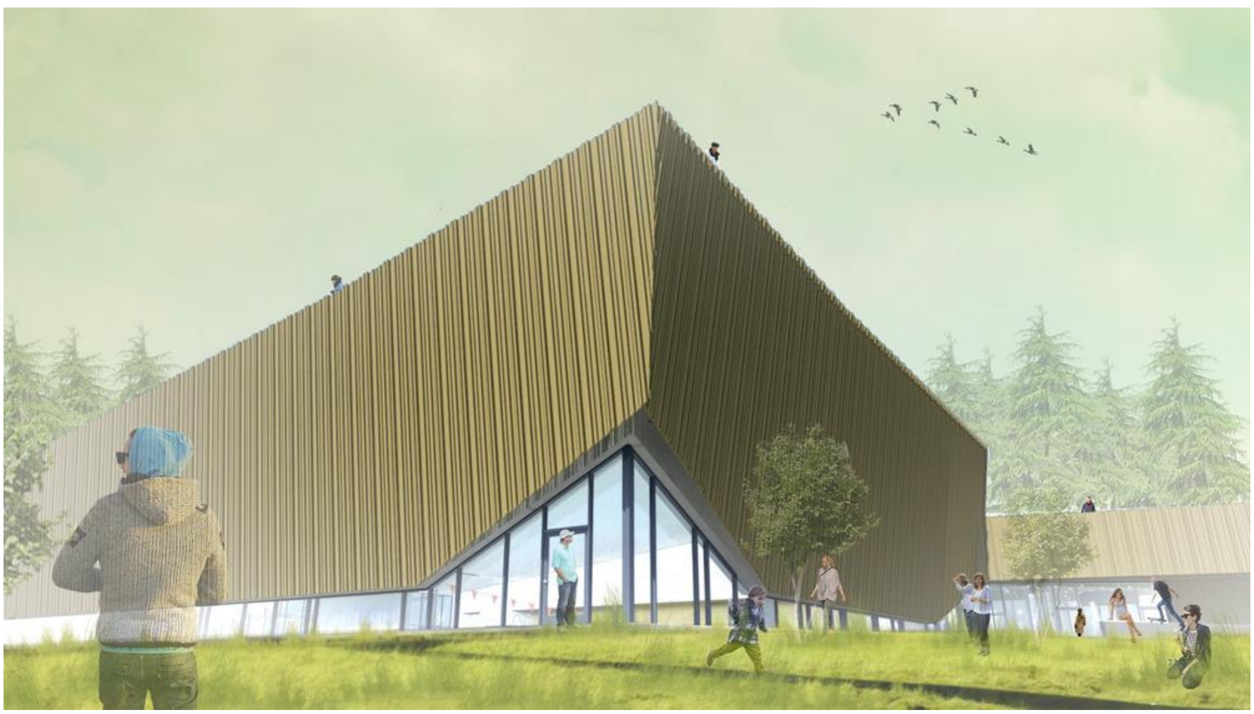

Fig 8 HOLMEN indoors swimming pool

## 4.CONCLUSIONS

Ground Source Heat Pumps (GSHP) are regarded both economically and technically as one of the best alternatives for energy efficient heating and cooling of new large and medium sized buildings in Norway, and these applications are in reaching national energy targets. Norway has no deep geothermal installations in operation, but Norwegian industry and research institutes are involved in international EGS and deep geothermal projects in particular those financed by European Union (EU) and Research Council of Norway with emphasis on innovative drilling, high temperature and pressure corrosion and scale, and high temperature and pressure tracer technology.

## 5.REFERENCES

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