Approaching Near Zero Energy In Historic Buildings

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CONTENTS: **PAGE**

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DEMONSTRATOR NO. 1: Teg's Church, Umeå, Sweden

Background

Teg's Church (Tegsskyrkan), is a church located in Umeå in north Sweden. The construction of this modernist church was started in 1964 and was inaugurated on 1969. Largely unaltered, the church has been designated as a cultural heritage by listing it in the Buildings Register of the Swedish National Heritage Board. The church can accommodate up to 500 persons.

Its architecture which is unique in Sweden for a church building and it also has a special method of construction and the building space is a combination of multiple interconnected cubes (Figure 1). The church is almost square-shaped and has a choir oriented towards the courtyard to the south. It is a protected building and requires permission from Länstrylessen for alteration. Nevertheless, it is allowed to may be possible to make some changes. A few alterations were made in the building during early 1970s. There were some acoustic problems and some coatings in the ceiling were made to address the problem. The inner facade was were not "yellow enough" and was painted to have yellow colour. Further, a few windows were replaced.

Figure 1: Teg's church

The management do not have any plan to make alteration to the building in the near future. An energy audit of the building was done in 2012 and the building does not have any major problems such as dampness or mold.

Building Envelope

The building is made of concrete. The highest ceiling in the church is above the altar with 20 m, while the height of the main hall is 16 m. The total window area is 133.5 m^2, and the window to wall ratio of the building is 8.4%. Table 2 provides a summary of envelope materials.

Table 1: Envelope materials

Material and thickness (mm)	Average U-value [W/(m²·K)]	Total area (m²)
Wall (concrete 100 mm+ mineral wool 150 mm+ concrete 250 mm)	0.22	1673
Floor (floor coating 5 mm+ concrete 50 mm+ light insulation 100 mm+ concrete 150 mm)	0.29	688
Roof (light insulation 150 mm+ concrete 150 mm)	0.23	688
Window (double-glazed)	2.9	141

The church main building has three doors: I large door in the west and one each in north and south. No information is available o the air tightness of the buildings.

Ventilation and heating

To meet the fresh-air requirements, the church also has a warm air system with an air supply at floor level and return on opposite sides on the floor. The church is heated by electricity floor heating (RFH), while district heating is used to heat the annex buildings. The district heating was incorporated later. The average measured annual electricity of the church is 1.240×10^5 kWh. In recent years, the church is only heated by the RFH with the three exhaust fans in operation. The warm air system for fresh air has not been used since 2010. The RFH is controlled manually by the operational staff and is based on the data from the air temperature sensor in the church. The set point temperature of the church is 20 Deg C throughout the heating season. There is no CO2 control for existing ventilation unit, there are demand control temperature set point. However, it is not used when the data collection was made. The building manager reported high HVAC energy use and dissatisfaction with the thermal comfort.

Lighting

Electricity use of lighting is recorded in a separate meter, Church use predominantly LED bulbs (200 numbers of 12 Watts). On a normal day, the lighting is turned on at 08:00 in the morning, if there is no event in the evening they are turned off at 16:00, On Thursday when there is a sermon the lights are switched off at 20:00 hrs and on Sundays lights are switched on from 09:00-15:00. There are no automatic controls for the lights and they are switched on/off manually.

Energy efficiency

The energy use of the church is not regularly monitored. Nevertheless, energy use can be accessed from the energy provider-Umeå energy who can offer it as an extra service at a price. The building manager informed that as Teg's church is a protected building it is not possible for them to do whatever they want in the building to reduce the energy cost. It would be more expensive to do the energy efficiency improvement. As per the building manger the church does not consider that their investment on energy efficiency from a short payback period perspective. If there is a good plan then central administration usually approves it.

DEMONSTRATOR NO. 2: Bayview (Formerly Harbour Master's House)

Background

Overlooking the harbour of Pierowall, the largest settlement on the island of Westray, Bayview is a traditionally constructed house of two storeys. Probably built in the late 19th century, the building was the house of the harbour master, before being used as a hotel. The building is an important part of the aesthetic of the pier. The building is not statutorily designated as cultural heritage.The building is based on a local pattern, matching the building adjacent. It is likely that the exterior would need to continue to match this pattern.

The change from the Harbour Masters house to a hotel included changes in the internal walls, as well as the addition of a conservatory. Unoccupied since 2018, the Westray Development Trust has purchased the building with the aim to redevelop it into four flats, as the trust had identified a shortage of affordable rental accommodation on the island.

Figure 2: Bayview

Building envelope

The house is a 2 ½ storey building with sandstone walls, with a render finish, and a slated timber roof. The windows have been replaced and are double glazed. The total floor area is 151m^2. Much of the interior has been built from timber. The only insulation in the building is 150mm roof insulation.

The building has two layers on external wall: layer 1 of 15 mm Harl and layer 2 has 600 mm sandstone which has U-value of approximately 1.2 W/m^2 K. There 21 double pane windows in total and the U-value of windows and window area is not available. The building airtightness is not available.

Ventilation and heating

The building has natural ventilation. Heating is provided by an oil boiler and distributed through radiators. The hot water also comes from the main system.

Energy efficiency

The energy could not be measured accurately, as the building has remained empty since 2018. The SAP simulated assessment of the house has given a primary energy indicator of 305kWh/m^2/year. Calculated against the total floor area, this is 46,055kWh/year, or £1687 per year. The building owners are reliant on the knowledge of the quantity Surveyor, architect and contractor to guide them through legislation/standards and what is technically feasible for the property. For anything above and beyond the normal standards, that the architect or quantity surveyor or contractor would be accustomed to, technical support/advisors are needed. For example, the building manager mentioned that they had hoped to utilize the waste energy from the freezers of a neighbouring factory. The factory is planning renovation works which halted these plans but before that Bay View were having difficulty locating a company able to undertake this work on a small scale, in the remote island location. Financial support is always important. Particularly as there can be gaps in funding, for example, there may be grant funding available for insulation but no funding available for the preparatory work needed at the property in order for the insulation to be installed. In Orkney, there are also issues with grid capacity which means that securing a grid connection for a small turbine, for example, can be problematic. Many large turbines in the region are heavily curtailed. Planning may also be an issue.

DEMONSTRATOR NO. 3: Lighthouse Keeper's Cottages, Orkney Islands, Scotland

Background

Built in 1852, the complex of a lighthouse with two houses for the lighthouse keepers and a separate fog horn is located prominently at the north-eastern edge of the island of North Ronaldsay. At 42.3 metres, the North Ronaldsay is Britain's tallest land-based lighthouse. The complex is statutorily designated as cultural heritage through listing at Category B, Scotland's second highest listing category (reference: LB5892). The purpose of the cottages was to provide dwellings for the lighthouse keepers next to the lighthouse. This has changed, as the lighthouse is now unmanned. Currently, the south eastern block is used as holiday lets. The western block contains a café, visitor centre as well as a commercial unit used as a mill. The complex is owned by the North Ronaldsay Trust, and the keeper's cottages are important evidence about the working life of this building.

The holiday lets have been upgraded, but retain the domestic function. The western block has had minor changes to accommodate the current function. The space heating will be reassessed. One of the blocks will go back to domestic setting, possibly being turned into a caretaker flat. The alterations needed are yet to be determined.

Figure 3 Lighthouse Keeper's Cottages, Exterior

Building envelope

Standing on a rectangular plan, the symmetrical keepers' accommodation blocks are single storey stone structures of eight bays and with a platform roof. The building has two layers on external wall: layer 1 of 15 mm Harl and layer 2 has 900 mm sandstone which has U-value of approximately 1.1 W/m^2 K. There 28 single pane windows in total and the approximate U-value of windows is 5.5 W/m^2 K. The approximate area of windows as percentage of wall area is 15%. The building has 4 external doors (2 doors per block) which are 2-leaf boarded door with small pane fanlight. The building airtightness is not available.

Ventilation and heating

Ventilation for the building is provided by natural means.

- Yarn Mill: Ventilation very good, insulation poor, concrete ceiling no insulation. No hot water to the radiators, heating via gas heaters.
- Café: Ventilation Good, insulation moderate, concrete roof some fibre-glass insulation, hot water via immersion, heating via wind generator with electric back up.
- Cottages: Ventilation good, insulation moderate, concrete roof some fibre-glass insulation, hot water via immersion, heating via wind generator with coal fire.

The energy of the building is supplied by an oil-fired boiler installed in 2005 and distributed through radiators. Secondary heating is available in the holiday cottages in the form of stoves. Wind turbines are installed as part of the complex, which supply some of the energy of the complex. The heating is currently not sufficient for the area.

Energy efficiency

4 x 6 kW wind generators reduce electric consumption, and excess electricity is put into heat storage. FIT meters and electric meter readings are checked regularly. Individual aspects of energy usage not monitored. The barriers for energy efficiency improvement are availability of funds, expert advice and installers availability. If these barriers can be addressed then it is possible to improve the energy efficiency of the buildings. The remote location of North Ronaldsay, is also an issue to adopt energy efficiency measures.

DEMONSTRATOR NO. 4: The Vicarage, Viðareiði, Faroe Islands

Background

The Vicarage of Viðareiði, which is the northernmost of the 20 Vicarages of the Faroe Islands, has been on this site for around 500 years. This particular building was built in 1854 and is an excellent example of Faroese build, which had developed as a craftsman tradition through centuries. The building has significant cultural and emotional significance for the local area, both as the office and residence for the local priest with family. It is also used as gathering place for various social activities. The church council meeting is also held in this building 1-2 times/year.

Figure 4: Vicarage of Viðareiði

The construction, inner timber wall limits the thickness of insulation to 100mm stone wool, as well does the construction of the roof. The building has two floors and the total heated area is 243 m2. The ground floor is 218 cm. high, the smoke room is open to the ridge is around 450cm high, while the attic and jamb wall has height of 205 cm and 150 cm, respectively.

The vicarage was originally a farmhouse and had two entrances, one for the workmen in the farm and one for the priest. The entrances were located at each end. Later this was changed to a common entrance in the middle of the building. All of the farm's original buildings, such as stables, cowsheds, warehouses, grain mills, etc., have been demolished over time. In the 60s, a bathroom/toilet was arranged and the ceiling was made for accommodation. Stairs led up to the attic and to three bedrooms and a bathroom. Electricity came to Viðareiði and the vicarage in 1956 and a central heating system was installed in the building. Small interior changes have been made over the life of the building.

Plans for alteration:

- A new thermal heating system including floor heating on the ground floor and radiators in the attic and the former cowshed.
- The electricity supply will be renewed

The ground floor will be insulated, the windows and front doors will be changed, the building will be made more windproof.

Building envelope

The main building is a timber construction on a stone foundation. External walls have 1" vertical boarding and batten cladding, 1" battens, 12mm plywood, 100mm rockwool, 5x5" posts, inner vertical boards in note. In 1992 the external wall was renovated and main building and smoke room was insulated.

The building has 26 windows (6 windows on the roof). The windows are double glass and have wood frames. The windows in the roof are also double glass wooden velux. The approximate area of windows as ratio to wall area are 15%, 2% and 2% for the main building, smoke room and cow shelter, respectively. The windows are located in all four sides of the building and also facing sky. 98% of the windows were replaced in 1992. Hinges and corner braces of the windows are in a bad condition and the wood frame is partially rotten. The building has five wooden door and they are in bad condition and are not air tight. The roof is made of 6 - 7" turf, synthetic climate screen, 21mm plywood. A 100 mm thick rockwool is used as insulation in the attic of the main building.

Ventilation and heating

There is no mechanical ventilation in the building. Mechanical ventilation would ruin the image of a classical Faroese farmhouse, since there is no way we can hide the pipes and other components. The ventilation is provided by manual opening of windows and doors. Oil fired boiler is used for heating the building. The original heating until 1956 was turf and coal in ovens placed around 4 chimneys. The building is heated on demand. The main building is kept around 22 degrees Celsius, the Smoke room is heated occasionally, while the cow shelter and basement are not heated. Some minor problems have already emerged, such as difficulty in maintaining the desired temperature of 22 Deg C in two rooms when the wind is blowing from a particular direction.

Energy efficiency

The main energy efficiency improvement in the building during the last 40 years was the insulation in wall and roof. No major energy efficiency measures are implemented in the building. The energy use is not monitored. It is planned to have a monitoring system on the energy use of the ground heating system, and on the rest of the electrical system. This will be monitored from the office of the Diocesan Authorities, and can show the daily energy use. The financial constraint is a barrier to undertake energy efficiency measures. Further, it is not possible to insulate the walls more than they already are, due to the historical and cultural value of the building. If solar panels are to be used then they should be as small as possible, so that they don't disturb the historical environment.

ENERGY PATHFINDER

DEMONSTRATOR NO. 5: The Cathedral of St Mary & St Anne (North Cathedral), Cork, Ireland

Background

The construction of Cathedral of St. Mary & St. Anne (North Cathedral) started in 1799 and was dedicated in 1808. It is the seat of the Bishop of Cork and Ross and the mother church of the Roman Catholic Dioceses of Cork and Ross. The building is a combination of sandstone with limestone dressings and is of early Neo- Gothic Revivalist style. The Cathedral is on the National Inventory of Architectural Heritage under the category ‘National’. Church hosts daily mass Monday-Friday from 10.15-10.45 am, and during the weekend there are 5 Masses.

Figure 5:. The Cathedral of St Mary & St Anne, Cork, Ireland

Windows have historical features and cannot be altered. Cost is the biggest barrier for alteration of the building. The flat roof membranes had deteriorated in several locations and had served beyond their life time. There were some leaks in the roof and presumably heat was also escaping at a quicker rate due to the reduced thermal resistance. In summer 2021 it is planned to install a combination of blown cellulose and rolled mineral wool insulation over the main nave of the church. It is proposed to install an energy monitoring system in Autumn 2021.

Building envelope

The building has 109 single glazed windows. Internal Glazing has been installed in a few windows in the visitors centre in the basement. The External doors of the Cathedral are made of wood and the average U-value of the doors are 2.5 W/m^2 K. The majority of the walls in the church have 50mm to 60mm cavity. Airtightness of the building is unknown.

Ventilation and heating

The building has only natural ventilation. There are some vents in the attic space which were installed when the original insulation was installed in the attic. The building does not require mechanical ventilation as there is currently sufficient levels of ventilation. There are some statues in the Cathedral with grills behind them that provide ventilation between the Cathedral and the main nave of the attic. Gas boilers are the primary source of heating and air-to-air heat pump is the secondary heating source in the Cathedral. There was an underfloor heating in the Cathedral which was changed in 1996 to a fan system. There are radiators in the rest of the building. The cathedral is heated intermittently depending on demand and activities. Temperate & humidity sensors to be installed.

Energy efficiency

In 2016 the cathedral Church began installing sustainable energy measures which included an LED lighting upgrade and the installation of photo voltaic panels (4.68 kW_p) to generate electricity. The following measures are installed and/or plans for installation

- In 2018 an Air to Air heat pump was installed as a secondary heating source and 2 electric vehicle Chargers which the community can use free of charge.
- 2020 - flat roof membranes were replaced as well as repairs to upstands, flashings, parapet render, and some minor repointing
- 2021 - Attic insulation will be installed over the main body of the Cathedral

The cathedral does not have energy monitoring system and has plan to install a meter to monitor electricity. Investment cost is a major barrier to implement energy efficiency measures. Further, cost for technical advices on energy efficiency measures is also reported to be very high. For example, it costed approximately € 3570 for hygrothermal analysis to determine what attic insulation should be used. The Cathedral church needs financial incentives to install energy saving measures.

DEMONSTRATOR NO. 6: Myross Wood HOUSE, CORK, IRELAND

Background

The Georgian-styled Myross Wood House was likely to be built between 1752 – 1785. The house was purchased by the Irish Missionaries' Society in 1946 and was used as a study house for young religious. The south wing was totally rebuilt in 1959 and the interior of the house has been adapted to the needs of the community over the years. The west wing was reconstructed and refurbished in 1987. But, apart from these relatively small modifications, the house remains as it was built by the Rev. Arthur Herbert in the 18th century and extended by the Earl of Kingston in the early 19th century. It is a two-storey building with a floor area of approximately 2205m^2. The north and south wing has the largest heated floor area of 650 m^2 and 630 m^2, respectively.

The east wing in mostly original condition and is on National Inventory of Heritage. The house is considered historic but not protected. It has 52 bedrooms most of which are for single occupancy. More recently the residence used as seminary and for religious gatherings. The building has found to have increase dampness

Figure 6: Myross Wood House is overlooking an inlet from the Celtic Sea

Building envelope

The construction is masonry (part cavity - 1959) with artificial slate roofs over attic voids. A typical layer of the external wall has cement render at the outside, followed by masonry, lime plaster and finally some thin polystyrene lining. The ground floor is part solid and part suspended. The building has a total 97 windows of which the newly built (1959) south wing has 66 windows. The windows are generally double-glazed and has UPVC as frame material. The average U-value of the windows is 1.8 W/m^2.K. The approximate area of windows as a ratio of wall area is 18-20%. Windows were replaced in 2000 and the conidition of windows are considered reasonable. The south wing has 4 external doors while the east wing has 2 external doors. The total door area is 21 m^2 and are made of wood. The approximate U-value of the door is 2.5 $W/m^2.K$. The external doors in the east wing are in poor state while that in the south wing are considered to be reasonable condition. The roofs are made of timber rafters and battens. The attic has insulated with 100 mm of mineral wool. The airtightness of the building is unknown.

Ventilation and heating

The building has natural ventilation. Heating is provided to all wings of the building by an oil boiler and distributed through radiators. The hot water also comes from the main system. The boiler rating is 401 KW. The annual oil consumption for heating purpose is 7800 litres and the annual heating cost is €18,250. Approximate annual electricity uses of the building range from 36250 -44 000 KWh and the electricity cost range from €5800 -7050 (for the last 2 full years)

Energy efficiency

The building does not have an energy monitoring system and the annual energy use is estimated from the billing data. The following thermal improvement has been implemented in the building as outlined in the report by Carrig Conservation.

Walls: Thin (approx. 10mm thick) insulation installed on the internal face of the external walls in the Community Room and Dining Room

Roof: Loose-fill mineral wool insulation (approx. 100 mm) on the flat over the 1959 wing and rolled mineral wool insulation (approx. 100 mm) on the flat over the oldest wing of the building. Both attics were insulated around 2011 and both need to be topped up and checked for condition. Non-breathable roofing felt membranes installed on underside of the roofs and above rafters of both wings.

Windows: Most of the original windows have been replaced at various stages with metal-framed or uPVC double glazed windows. A few single-glazed timber-framed windows remain. (Carrig, 2020, p. 9)

DEMONSTRATOR NO. 7: Rector's house, Raahe, Finland

Background

The headmistresses' residence and office was constructed in 1900. Originally it consisted of two residences. The total floor area and heated area of the building is 553m² and 503 m², respectively. The building has 2 floors and a basement and the height of the first floor, second floor and basement is 3.4 m, 2.4 m and 2.2 m, respectively. The headmistresses' residence has gone through several renovations throughout the years. The first major changes were made in the 1950s, and a renovation and modernization was made in 1991. It is a protected building under S2 category; the exterior of the building is protected.

The decorative work in the facades is impressive and its preservation is a requirement of the building's protection decision. A condition assessment of the building was carried out. It is planned to recommission the building as an international artists' residency. According to the space plan of the Artists' residency, the rooms layout will be changed to correspond to the new use. The floors, walls and ceiling surfaces of the first and second floors will be renovated as necessary.

Figure 7: Entrance of the building

Building envelope

The building external wall has plaster board, gallows and wooden panel cladding. There are 40 windows which are double-pane windows and most have venetian blinds. Windows orientation are Northwest, Northeast, Southwest and Southeast. The original windows frames are generally in fair condition but would require immediate painting, puttying and sealing repair. Replacing existing glazing with modern energy efficient glazing could alter the building's exterior appearance and affect the aesthetics. The building has four external doors. The decorative wooden doors at the entrance are thick and there is no need to replace them for energy efficiency, However, the doors could be sealed. There was considerable deterioration of the paint on the façade on the south end of the building. The whole building façade requires repainting. The attic has insulation with 350 mm wool.

Ventilation and heating

The building has mechanical ventilation, the details are unknown. The building was originally heated by ceramic stoves found in all the living quarters. The building is now heated by district heating

Energy use

As per energy calculations the current annual heating energy use of the building is 122 135 KWh. After the renovation the heating energy use of the building is expected to come down to 49 319 KWh/year, which is a reduction of approximately 60%. The major energy use reduction is through reducing air leakage of the building and improvement in air ventilation system. The renovation of the building may significantly reduce the building's carbon foot print, from 20.3 tons/ year to 11.7 tons/year