DETAILED ASSESSMENT

1. Building frame assessment

1.2. General

In the course of the evaluation and analysis phase it became obvious that a comprehensive assessment was necessary to cover all aspects of energy efficiency. This means that technical, organizational and operational considerations needed to be looked at.
The overall finding is that the potential for reducing energy consumption is very large, estimated at 70-75%. This is the good news. But the other side of the coin is that there is no single measure that can exhaust the saving potential to a significant extent. The reason for this is that the building frames and the heating concept date from an era when energy usage was a minor issue, if any at all.
As mentioned in para. 1.1, considerable renovation works on the church- and the hall/office-complex were carried out in the past, but none or little on the chaplain's house. On the infrastructure side, different small scale improvements and adaptations and at times quick fixes were made over time, but the overall concept remained unchanged and must at this stage be judged as outdated and in certain areas technically flawed.
Today's requirements and standards that allow efficient energy usage have evolved enormously since those days and the understanding of energy consumption in the light of climate change, renewable energies, technological evolution and the developments on energy pricing has changed the entire picture.
Bellow a detailed assessment of the 3 buildings, the infrastructure and operational aspects will be presented.

1.2. Chaplain's house

It was pointed out earlier in this report that no major works were carried out since the chaplain's house was built in 1959/60. Insulation and energy efficiency was no real issue in those days and this shows up more or less in all structural elements. A short assessment of these elements comes to the following conclusions:

- Let's start with the roof. As warm air is lighter then when it is cold, about a quarter of the heat of an uninsulated house is lost through the roof. Our roof was constructed with the sole purpose of keeping the house dry, not for conserving energy. The tiles rest on tile battens which are nailed onto the rafters. The absence of insulation allows large quantities of energy to escape and additionally some uninvited guests like martens found gaps to enter the loft for having their noisy parties. The roof is a particular crucial element

because the roof-pitch also acts as the wall of the rooms on the south- and the north-side of the first floor. Originally the loft floor wasn't insulated either but a few years ago some volunteers laid out 20 centimeters thick slabs of insulation. This was definitely an improvement, but didn't address the vapor penetration issue. The very hot spell in July 2015 offered an opportunity to check out with Father Peter and Shareene what it felt like on the first floor. Both agreed that despite the fact that windows and shutters were kept shut, the temperature reached border line levels.
A detailed examination of the roof condition was not possible at this stage. The visual examination from the ground didn't reveal major damage. A visual sighting from the inside was not possible because the inside of the roof was covered up presumably to keep the martens out. Nevertheless, a 55 year old roof must have developed some open or hidden deficiencies that would need to be attended to, even if this is not visible at first sight.

The outside walls (heated-to-outside) on the east-, south-, and west-side are built with bricks of about 30 centimeters thickness, presumably with air chambers. On the outside a thick plaster with a rough surface was applied. Normally this kind of plaster is about 5 centimetres thick. On the inside, as far as visible, an overpainted thin plaster was applied. To allow reasonable room heights on the first floor towards the roof pitch, side attics were installed. It could not be verified if they were filled with any insulation. The estimated heat transfer coefficient (U-value) is about 0.8-1 W/m^2K. The recommended value is 0.2 W/m^2K. The outside plaster shows in many places signs of corrosion similar to the damage described on the church walls before the renovation in 1998.

1.3 Community Hall/office complex

As mentioned in para. 1 1, this complex went through several expansions and renovations since it was built in 1959/60. Notable from the energy efficiency view-point is the roof renovation in 2006. The layered construction (out- to inside) consist of tiles, 10-15 centimeters air circulation channel, wood panels 2.5 centimeters, approx. 20 centimeters of blow-in cellulose insulation, vapor retarder or vapor stopper, wood paneling. The estimated U-Value is 2 W/m^2K. The recommended value would be 2.5. The walls on the south and north side of the upper- and lower-hall and the office level are adjacent to heated rooms (chaplain's house and church), thus irrelevant from the insulation point of view. The east- and west-side of the 2 halls consist mainly of windows. Expressed in figures, 73% of the wall surface in the upper hall consists of windows. In the lower hall it's 67%.
It comes as no surprise that the window quality does not conform with today's standards. The upper hall windows are of the making of the 1960/70s, meaning wooden window frame with single glazing, no sealing along the window frames. The estimated U-value is 3 W/m^2K. The windows of the lower hall must have been produced in 1993, when the hall was built. The wooden window frames

are fitted with double glazing. The heat transfer coefficient is similar to one in the upper hall.
Another issue is that so far the heating was on for both halls during 24 hours a day and 5040 hours during a 7 months heating period. During this time the halls were only occupied 826 hours (upper hall, resp. 927 hours (lower hall). The controller, presumably installed to regulate the temperature in the halls, does not work because its configuration is flawed. The Danfoss regulator valves installed on the radiators of the upper and lower halls did help controlling the temperature but can't solve the round the clock heating issue. Additionally, some are not working properly or are defect.
It was also observed that the radiator piping for upper and the lower halls is interconnected to one single heating circuit. This impacts the heating control in the sense that it is not possible to control the halls separately. This however would be essential because during the heating period (7 months) out of the 1753 hour that both halls are occupied only 497 hours are overlapping. In other words, both halls are hated up during 759 hours when only one is occupied.

1.4. Church complex

Major renovations were carried out in 1998:

- Renewal of the plaster (Kalkschlämme) on the outside walls
- Overall renovation of the roof (Replacement of wooden structures and broken
  tiles, adding an under-roof with some insulation, but uncertain if vapor retarder and air circulation was built-in.
- Installation of lightning rod
- Glassing-in of the church entrance

With regard to the roof, the visual inspection as seen from the church ground reveals no damage or degradation of any kind. From the technical point of view, there are no details available from the 1998 renovation. The roof thickness is by visual estimation approx. 15 centimetres, which is an indication that only minimal insulation was installed. No air circulation ducts are visible, neither vapour retarder. Measures of the inside surface temperature of walls and roof, conducted during the hottest days in July 2015 revealed that roof and windows are, thermally speaking, weakest elements of the complex.

The church walls on the east and west side toward the outside (heated-to-outside) are of solid construction with an overall thickness of approx. 42 centimetres. Visually it appears to be built with some kind of brick, unknown if solid or with air chambers. The outside structure consists of a with a rough surfaced thick plaster, about 5 centimetres thick and a white "Kalkschwämme" cover. The inside is covered with a thin plaster, overpainted. The thickness of the north wall is about 50 centimetres. Further details are unknown. These solid walls provide a decent insulation and also act as a big energy sink, but presumably are the cause draughts that were frequently the reason for complaints.

Natural lighting is provided through 6 double windows on the west- and east-side wall and 1 window on the northern wall, 5.5 meters above the inside floor. The size of the side windows is 1.2 x 2.3 meters (2.8 square meters) and the one on the north wall 1.8 x 3 meters (5.4 square meters). The outside windows consist of a metal frame assembled with antique single pane glass. The construction of the inside windows consists of an approx. 3 centimetres thick wooden frame fitted with single pane glass with structural surface. No insulation band is fitted in any of the window frames. The estimated heat transfer coefficient (U-value) is 3 W/m^2K, at best.

2. *Heating system assessment*

The heating system infrastructure consists of the following components:

- Central oil burner and boiler system in the main heating room (chaplains house)
- Energy distributer over 3 heating circuits
- Heat exchanger for the church
- Radiator heaters for the chaplains house, upper and lower halls, church and office
- Temperature control systems

Generally speaking, the entire heating system is in good and reliable working condition and at this stage there are no known issues that need immediate attention. However, temperature control in general is unsatisfactory. One issue concerns the controller in the church. Its details are discussed bellow. The shortcomings can to some extend be overcome by manual intervention, nevertheless, every so often it is the cause of complaints from the congregation. The main problem is that a number of people manually intervene, often uncoordinated, and according to subjective criteria
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Temperature control in the church halls and the chaplain's house is another problem area. Some 10-15 years ago, the exact installation date is not known, 2 temperature controllers were installed in the main heating room. These addressed the temperature control in the 2 heating circuits for the chaplain's house and the church halls. These VARIO Set controllers works with 3 temperature sensors, one located outside, one in the forward path of the heating circuit and the 3rd one inside the controller box. The idea was to install these boxes in the room where the temperature was to be regulated. However, for some unknown reasons, both boxes were installed in the main heating room, with the result that temperature control in the targeted rooms never really worked correctly. Additionally it was discovered that 2 sensors were out of order (one was repaired in the meantime) and that the programming interface in both boxes works erratically. At this stage, the chaplain's house controller is out of order. The church hall controller could be reinitiated, but the fact that it operates without a room sensor allows an operation only under tight supervision. .

2.1 Church heating

The heating of the church nave and altar section consists of the combination of a warm air blower and normal hot water radiators, complemented with electric radiators. The latter, though inefficient, are used only under exceptional circumstances. The warm air heater provides warm air through a duct that enters the nave through 2 grids located on the floor of the church front on the right and the left side. The return air flows back through an air duct (2 grids) positioned in the centre aisle of the church. None of the 2 ducts have insulation or noise attenuation. The radiators are installed mainly on the east- and west-wall of the church. Controlled by a Siemens REV 24 room temperature controller, the church is heated up only when it is used. The yearly occupation in 2014/15 was 969 hours, though 573 hours during the 7 months when the heating was running and 396 hours during the 5 months when heating was off. Generally speaking, the heating system in the church works satisfactory except for two aspects that impact the comfort for the congregation and the efficiency of the energy usage. The comfort issue was mentioned already in CC-protocols before the 1998 renovation. The reasons for the complaints were the uneven temperature distribution and drafts during the service when the warm air heater got manually turned down. At that time the opinion prevailed that the bad condition of the roof was the reason. But the problem did not disappear after the roof was renovated and remained on the agenda. A more recent issue is the heating control system which doesn’t allow the regulation of the temperature in a satisfactory way. Both of these issues will be dealt with here after.

Comfort for the congregation:

The temperature profile and draught problems are the combined result of a conceptual issue of the warm air heater and the unsatisfactory temperature regulation.

Issues of the warm air heater*:*

- The first problem concerns the way warm air is channelled into the church nave. The positioning of the air-inlet and -return grids do not allow to channel the warm air directly to the area were the people are seated. The problem is that the main warm air thrust is directed towards the ceiling, with the effect that the temperature in the upper level of the nave is 3-5 degree warmer than in the seating area. (pls. refer to annex IV). We are here at the source why we have an uneven temperature pattern, and why the back of the church remains colder than other areas. The reason is that the warm air is not directed to the areas where it matters.
- A second problem concerns the flow of the warm air through the air ducts which causes noise that disturbs the service when it runs on level 2. To keep the noise level down, the blower needs to be manually switched to the

lower level, which reduces inflow of heating energy by approx. 65%. To correct this, noise attenuation blades would have to be installed in the ducts.

- Also concerning the air flow is the fact that on the one hand the air ducts are not equipped with insulation panels, and on the other hand that the return air from the church is channelled into the open space of the storage room instead of directly into the warm air heat exchanger. Both of these deficiencies are the source of non-negligible energy loss.
- A further very basic issue is the concept of heating systems which deploy air as an energy transport media. By nature they are heavy energy consumers and inefficient compared to other technologies. The reason for this is the very low heat capacity of air, which necessitates the forced circulation of large volumes of air by running an electrical fan. This burns up a lot of energy that is not directly related to the room heating process.

Radiator heater issue

The hot water pipes that feed the radiators are not dimensioned to feed sufficient energy to the installed radiator surface.

Temperature control issues

- The currently deployed Siemens room temperature controller allows controlling 1 heating circuit. As we operate 2 heating circuits (warm air heater and radiators) the controller is configured to regulate both simultaneously. The result is that both circuits are turned off once the programmed target temperature is reached, normally at 18^0 C. Once the heating is tuned off, the thick church walls that represent a massif heat sink causes a rapid temperature drop along the walls. Subsequently the cold air flows downwards along the wall and is ultimately the source of the feeling of a draft.
- The currently operated Siemens controller does not allow to turn the warm air heater off and at the same time keep the radiators running, which could to some extend counteract the effect of the down-flow of cold air.

2.2 Chaplain's house heating

Normal radiator heaters. Except for the fact that there is no temperature control, no knowns issue

2.3 Halls + kitchen heating

Normal radiator heaters fitted with Danfoss valves. No known technical issues except for the fact that there is no temperature control.

2.4 Existing central oil heating system

Oil burner and boiler date from the late 1980s and were installed in 1989. A new oil burner was installed in 2003 and is still in service today. The technology unsurprisingly is technically outdated and compared to new solutions inefficient. Additionally it is largely over dimensioned. Outdated are also the 4 water pumps that circulate the heating water. Modern day pumps run about at 15% of the energy. The system is in good condition and works reliably. There is at this stage no technical reason for a short term replacement.

3. Appliances

Most of the appliances are not classed in the top 3 energy efficiency category, but are in good condition and work reliably. However, the hot water boiler for the chaplain's house, installed in the main heating room, gives reason for a critical view. It is with a capacity of 500 liter largely oversized. To sustain an adequate house water temperature for 500 liters uses up a lot of unnecessary energy. The recommended boiler capacity for a house of this size would be 250-300 liters. .