HEATING REPORT

at

ST. WILFRID'S CE CHURCH,
CHURCH LANE,
MOBBERLEY,
CHESHIRE.
WA16 7RD.

Prepared by;

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SECTION 1

PURPOSE OF REPORT

The purpose of this report is to act on the instruction given by the PCC of St. Wilfrid's CE Church, Mobberley as per the e-mail confirmation from the Church Warden – John Hennerley, dated 3rd October 2024 for this report to provide the following Consultancy advice in relation to the Heating Services serving & within that Church.

Services to be provided:-

Mechanical Services;

(i) Assess the heating & energy characteristics of the building

(ii) Examine the condition, performance & capability of the present heating system in relation to the heating requirements of the building.

(iii) Make appropriate recommendations in relation to the proposed replacement heating scheme

SECTION 2

BASIS OF REPORT

The basis of this report is as follows:-

(i) Survey of the building and heating services by John Book on 15/10/2024

(ii) Issue of drawing from the Parish's Architect – Mark Pearce

SECTION 3

HEATING SERVICES

The Church is currently heated by a low pressure hot water heating system from a gas fired heating plant located within the existing basement boiler room, located below the Toilet area, ie. ex. Organ loft at the North East corner of the Church. It should be noted that the pipework from the boilers leaves the boiler-room into the floor voids within the Church itself.

The boiler plant contains 1No. boiler to serve the Church space, and that this is a Broag Remeha Qunita 85 units having a rated output of 84.2kW. The boiler-plant is served from an internal gas supply pipe and internal meter located below the wash-basin within the Vicar's Vestry.

Heat is distributed from the boiler via a circulation pump system. The pipework distribution system has been installed on the design basis of what is known as a two-pipe flow & return system.

There exists a set of flow & return pipework systems which runs from the boiler location into the floor void below the Church floor itself from where circuits travel across and down the length of the Church in floor ducts below the cast-iron floor grilles, and which then rise to above ground floor level on the North & South walls of the Nave to serve exposed 4" cast-iron pipe banks and pipe coils, whilst within the aisle areas where there are cast-iron floor gratings, with 2 x 4" cast iron pipe loops exist below them.

The boiler plant appears to have been installed at least some 16 years ago and is certainly currently within the normal 20/25 year life expectancy for this type of boiler. Whilst this boiler has had intermittent failure issues, relating to the flue seals on these boilers, and within the flue system itself, it is felt that the actual life of this particular boiler may well be limited. The existing heating circulating pump appears to be operating satisfactorily along with the existing feed & expansion tank system, which appears to have replaced a previous pressurisation unit, which is really not recommended on old cast-iron pipework systems.

The boiler plant is flued conventionally through via a flue system which rises to above ground floor level internally but then exits the North wall of the access down into the boiler-room.

It is worth noting that, other than the boiler, this is the original heating system and which would have initially been served with a coke fired boiler which would have been allowed to run for 24 hours per day, 7 days per week all though the heating system with a view to providing a constant temperature of 12degC.

Control of the heating system is made by a conventional programmable control thermostat arrangement.

Energy characteristics of the existing system;
The heat loss from the Church building is currently assessed as being 55kW.

The heat emission surface from the cast-iron pipe loops and pipe bank radiators within the Church is calculated as being able to produce 30kW.

It can therefore be seen that the existing boiler which has a total rated output of 84.2kW is over-sized for maintaining the full heat output required from the installed heat emitters within the Church, and indeed the actual required heat loss of the Church. which leads to large standing losses and poor operating efficiency. Furthermore the use of large bore cast-iron pipework systems within a Church like St.Wilfrid's also requires a large amount of energy to heat the water content within the system, even before any heat is given out from the pipe emitters, which again gives poor operating efficiency. I think it can be seen from the above figures, that this will be why the heating system itself is still only capable of providing the expected temperatures from this system.

Whilst it can be seen that the output from the existing heating system serving the Church itself is only 55% of the calculated heat loss it should be pointed out that the calculated heat loss is based on a room temperature of 18ºC (65ºF) at an external ambient of 0ºC (32ºF). It should therefore be appreciated that the output from the system would have only been designed based on what the original heating system consisted of, which was only to be capable of providing an internal temperature of 12ºC (54ºF) at an external ambient of 0ºC (32º).

A further consideration of the above outputs is that these are based on the normal operating temperature from a low pressure hot water heating system, ie. 82ºC (180ºF) flow and 71ºC (160ºF) return, and hence it is more likely that the temperature within the Church from the current installed system would not exceed 14ºC (57ºF) at an external ambient of 0ºC (32º).

Condition of the existing system;
The condition of the existing heating system is considered to be very poor, as at the time of the visit a leak on the below cast-iron pipework system had just occurred, although there is evidence that various pipework leaks have previously occurred to some of the existing cast-iron pipe runs, which have had quite expensive repairs having to take place.

It should be pointed out that no inspection of the pipework below floor level was possible, other than by lifting some of the cast-iron floor grilles and looking at the top cast iron-pipe in the duct below.

The life expectancy for the boiler plant is likely to be in the order of 20/25 years from the date of installation, but as the boiler has already had to have some work done on the flue seals, and bearing in mind that the boiler is already 16 years old then it is felt that this boiler may need to be replaced sooner rather than later.

Requirements for a Church heating system;

A Church heating system must be capable of not only providing 'warmth' to the congregation but must also be able to be used to assist in the condition maintenance of the Church fabric & fitments. The assistance towards condition maintenance of the Church fabric & fitments is made by trying to ensure that the internal surface temperature of the structure is slightly higher than the external surface temperature. This helps to prevent interstitial condensation within the fabric construction and hence damp and stale/moisture laden air within the space. It is thought that the use of the existing controller will adequately provide for good control of the heating system by ensuring that the Church is currently not allowed to become too cold by maintaining the internal space at a temperature not less than 12degC.

Existing System Considerations;

From the survey & report perspective the following points should be worth noting:-

(i) It should be recognised that the heating system is only capable of providing 'warmth' conditions rather than true comfort levels, however it is felt that due to the age and construction of the building it is felt that these lower temperatures do provide some benefit to the maintenance of the Church both in terms of fabric condition and in making the space reasonably comfortable to worship in, although with it just being advised that the leak to the cast-iron pipework system which I viewed on my visit, cannot now be repaired then it appears that a completely new heating system will be required.

(ii) System operating efficiency & conditions provided within the Church are paramount for consideration and perhaps it would be worthwhile to again point out that in addition to the current boiler being over-rated for the installed heating system, plus the fact that the existing system is not capable of providing recognised comfort temperatures within the Church, then the overall efficiency of the existing heating system is very low.

(iii) It should be noted that the existing incoming electrical supply is a 1-phase supply with this appearing to be fused at 80amps.

(iv) For reference purposes, please see the apportionment of the heat loss from the various elements of the building as follows;

Air heat loss	-	24%
Heat loss through windows	-	13%
Heat loss through walls	-	27%
Heat loss through roof	-	25%
Heat loss through floor	-	11%

Heat Source options available to consider;

The following 2-stage considerations are being proposed but the recommendations are being made on an eventual complete replacement heating system basis due to the current inefficient boiler system and the existing large-bore one-pipe heating system. Clearly for the consideration for replacing the existing heating boiler we need to consider what options are available to us, as follows;

a) Direct gas fired boiler replacement – normal life expectancy 20/25 yrs

b) Electric boiler replacement – normal life expectancy 15/20 yrs

c) Biomass boiler – normal life expectancy 20/25 yrs

d) Air source heat pump – normal life expectancy 15/20 yrs

e) Ground source heat pump – normal life expectancy 15/20 yrs

f) Hybrid System combining Boiler & direct electric radiant system 20/25 yrs

g) Hybrid System combining both ASHP & Boiler System 20/25 yrs

Direct Gas Fired Boiler Replacement:-

This option would certainly be the most economical one of the options for a conventional boiler replacement to be carried out by utilising a modulating form of 'Hydrogen Ready' gas boilers, which would modulate to meet the actual heat output temperatures at varying times and at varying outside ambient temperatures. The use of these types of gas boiler system is likely to show a small improvement in running costs to that what is currently being experienced, in the order of 10%, even though the new boiler plant operation is likely to show a 30% increase in efficiency from the existing boiler. Clearly these savings on running costs would only be further improved if a new low water content system was to be provided. For the avoidance of doubt the existing gas boiler is only likely to be 60% efficient, whereas a new boiler would have an efficiency of 90%, therefore would reduce the current carbon generation by one third. A further point to consider is that as we are currently being advised that a 20% hydrogen gas mix should be available within the next 5 / 6 years, then this will further reduce the carbon being generated, when this may be introduced into the National Grid system

A budget cost indication for this work would be in the order of £21,000.

Electric Boiler Replacement:-

Whilst this option currently exists to replace the gas boilers with electric boilers which would reduce the carbon footprint if a renewable electrical supply was being purchased, the fact that these currently only operate at 100% efficiency, ie. meaning that for every kW of heat produced you would use 1kW of electricity, this therefore means that as electricity is currently more expensive than gas, then this would be an expensive option to run.

A budget cost indication for this work is not being considered as a boiler plant of this nature would be unaffordable to run, plus the existing incoming electrical supply which is 80amp 1-phase, and which would have a capacity of approx., 15kW, then this does not have the capacity to run this type of electric boiler system.

Biomass Boiler System:-

A biomass boiler installation to replace the existing boiler system would be a possibility to consider but would entail high initial capital costs, and whilst the Government's Renewable Heat Incentive (RHI) Scheme closed in March 2021, then there is no incentive other than carbon reductions to consider looking at this option. However there are a couple of issues with considering biomass for you (i) it is unlikely that you would be able to provide the space for fuel storage, and (ii) fuel delivery would be a problem

A budget cost indication for this work is not being considered as a boiler plant of this nature would not be possible to be provided for.

Air Source Heat Pump System (ASHP):-

An air source heat pump (ASHP) system utilises some externally located 'condensers' which you are likely to have seen previously serving an air-conditioning system. These units simply utilise an electrical supply and the type of ASHP we would be looking at using is known as a Air to Water heat pump, which extracts heat from the air and injects this into the water based heating system. The difference between an air to water heat pump and a boiler is that an air source unit will not get the heating water at as high a temperature as a boiler, which would mean that ASHP's are more suited to underfloor heating or a type of heat emitter which can operate with lower water temperatures. However a range of higher temperature heat pumps is now being made available, although the existing electrical supply would still not be adequate enough to support a total ASHP system delivering some 55kW of heat

A budget cost indication for this work would be in the order of £56,000 (includes external condenser units and internal heat packs, but **excludes** a possible electrical supply upgrade required to source a full ASHP system)

Ground Source Heat Pump system (GSHP):-

This type of system (GSHP) is almost identical to what as been described above for an ASHP, the only difference being that ground loops or boreholes would have to be installed in the adjacent land and the performance from a GSHP is more reliable than an ASHP as ground temperatures do not vary as much as air temperatures do, although we would share the concerns of this type of plant on the existing system, as indicated for the ASHP, along with the existing running periods required.

A budget cost indication for this work is not being considered as the costs required for either boreholes or an extensive amount of land would not be affordable.

Hybrid System combining both ASHP & Boiler System:-

This type of system as an option is currently being utilised in some Churches whereby a ASHP system would only be used for supplying heating to achieve the background temperature level of 10/12degC within the Church, but has the capacity from gas supplies to support a boiler source which can be used to top-up the heating temperatures required upto say 16 / 18degC.

With regards to St. Wilfrid's Church, it is clear that the existing electrical supply would only be capable of supplying a partial ASHP heat output system and therefore the top-up boiler would be a hydrogen ready one. **However in order to establish whether even a small size ASHP could be provided, extensive negotiations would have to take place with SPEN, to try and establish whether it would be possible to utilise a 2nd 1-phase 80amp fuse block on the existing incoming cable termination, as it is thought that the possibility of increasing the existing supply cable to a 3-phase supply would not only be remote but would be likely to be at a similar cost to what St. Wilfrid's – Grappenhall had experienced at £97,000.**

A budget cost indication for this work would be in the order of £35,000, assuming the use of the 2nd single phase fuse-block.

Hybrid System combining direct electric heating & Boiler System:-

This type of system as an option is currently being utilised in some Churches whereby a boiler system would only be used for supplying heating to achieve the background temperature level of 10/12degC within the Church, but then a system of electric direct radiant form of heating could be used to provide direct warmth to the congregation when required for the Worship Service times in different areas at any time.

With regards to St. Wilfrid's Church, it is clear that the existing electrical supply would only be capable of supplying a limited form of direct electric heating, possibly within the side aisles and Chancel areas, with the remaining wet system being served by a hydrogen ready gas boiler. The same comments would apply here as that detailed under the previous ASHP hybrid system.

A budget cost indication for this work would be in the order of £42,000, assuming the use of the 2nd single phase fuse-block.

HEAT EMITTER OPTIONS AVAILABLE TO CONSIDER;

There is no doubt that the best method of heating a Church is by the use of a radiant form of heating, and again whilst the best form of radiant heating is the use of an underfloor heating system, these are only affordable if works are already being contemplated to the floor itself, such as the removal of pews, plinths, etc., and the lifting of the whole floor for replacement with some new level deck floor construction which can incorporate the underfloor heating pipework and insulation required. Whilst the cost of the underfloor heating installation would be no different to that indicated below for the radiator installation, if no works were being considered to the floor then you would need to at least double, if not treble the radiator cost to be able to considered providing an underfloor heating system. Incidentally underfloor heating systems are ideally suited to the use of heat pump systems, both ASHP & GSHP types.

Hence the only other real recommendation which I would make, which is common to all of the foregoing heat source options would be to try and reduce the water content of the heating system by replacing the existing large bore pipework system. As can be seen from the predicted heat output from the existing heating system with the poor operating efficiencies being identified it would be necessary to install a new smaller bore steel pipework system with new high-efficiency heat emitters to be able to achieve full efficiency in operation and more acceptable comfort conditions. It is likely that the new system would comprise of new high efficiency radiators and steel finned element pipework to be provided in identical locations to what currently exist, ie. on the North & South walls, and below the floor gratings within the Aisles. The budget figure indication for a replacement heating system on this nature, in addition to the heat source costs would be in the order of £38,500.

If the option was to have a gas boiler providing the background heat via a new system of radiators, but with the use of electric direct radiant heaters within the Side Aisles & Chancel, then the budget estimate for the radiator installations would be £35,000 and the cost of the electric heaters would be in the order of £14,000, thereby giving a similar overall cost consideration of £49,000.

Running costs are likely to be reduced by some 10% with a new heating system but at least the temperatures being provided would be more comfortable than those at present, whilst the reduction in carbon being generated from the use of these systems would be a valuable step to be taken in assisting carbon reduction in line with the Church of England's aspirations in becoming carbon neutral by 2030.

Note !
The figures make no allowance for dealing with any asbestos material related matters and it has been assumed that the Church has already been provided with an asbestos certificate showing that it would be safe to work in all areas of the Church particularly the floor voids and boiler-room. Professional Fees and VAT need to be added to all costs indicated, and therefore for assessment purposes 15% & 20% respectively will need to be added to the above figures, although the 20% VAT will be able to be reclaimed through the Listed Places of Worship scheme.

Considerations for the provision of Solar PV panels;
Clearly one of the common points for Church buildings is that generally one aspect of the roof is usually South facing, and hence ideal for locating Solar PV panels on, providing that the roof structure is suitable for such an installation to take place. Solar PV panels generate electricity an can assist in reducing electricity taken from the grid supply. However as this electricity will be generated at times when the Church is not in use, then the benefit in use of these systems would have being taken from the export of electricity with the Feed-in-Tariff, but unfortunately that scheme is no longer in place and monies paid for such export by electrical suppliers is minimal and does not really contribute towards the installation costs. Furthermore the actual suitability of the mains electrical supply into the building is crucial to be able to connect such PV systems into, and whilst unfortunately the electrical supply into St. Wilfrid's Church is only of a single phase capacity which will only accept a limited number of PV panels, a budget cost consideration of £14,000 can be indicated for the provision of a 12No. roof PV panel system that would have the facility to generate 3.86kW, which would of course be very useful if an ASHP 'hybrid' system option was to be used as part of a hybrid system.

It should however be pointed out that full Planning and Building considerations would need to be carried out regarding the suitability of the roof construction prior to trying to gain Approval for the installation of such panels on the roof of this Church, and this would have to be undertaken by the Church Architect / Building Surveyors.

Status of St. Wilfrid and space usage;

It is important to recognise that the Church of St.Wilfrid's is a **Grade 1 Listed building**, and has regular, almost daily uses and therefore the heating is 'on' each day. **The purpose of the heating is therefore both for conservation reasons as well as comfort reasons.**

SECTION 4

RECOMMENDATIONS;

The basis of these recommendations has changed somewhat, because of the recent complete failure of the existing 4" cast-iron pipework system below the cast-iron floor grille in the cross aisle between the North door into the Nave and the South Porch door. It should be pointed out that this last leak which only arose in the past week or so, was yet another cast-iron pipework failure which has occurred within this system over recent years, and despite the fact that this last leak is not possible to repair, would not have really changed my recommendation that in my opinion this existing cast-iron pipework system needs replacing in it's entirety.

The Church is now having to be provided with some temporary form of electric heating, which will be essential in order for the Parish to be able to not only maintain it's Services, but also to try and maintain some reasonable conditions within the space to prevent building deterioration over the coming Winter period. Timing is now becoming a major issue with it now being required for a completely new heating system to be designed, specified, tendered and applied for a Full Faculty.

The real issue is the incoming electrical supply into St. Wilfrid's, which as indicated earlier is only a low capacity single phase supply, although there does exist a 2nd single phase fuse-block, which if SPEN allowed the use of this then we could establish a 2nd single phase supply to possibly serve an ASHP system, although this would only be able to provide 32kW maximum of heat and would therefore need to be part of a hybrid system with a hydrogen ready gas boiler acting as the top-up heat provided. Unfortunately this would require a formal application to be made to SPEN, and which could take 2 – 3 months before a final decision is given, after they have completed their infrastructure cabling assessment. It is however again important to stress that it is highly unlikely that it would not be possible to replace this incoming 1-phase supply cable with a 3-phase supply, without an infrastructure upgrade which could lead to similar costs which SPEN had already identified at St. Wilfrid's – Grappenhall at £97,000.

I feel that my recommendation in order to be able to progress a complete replacement heating system at this Church would yes by all means make a formal application to SPEN, but commence the design based on a hybrid system, initially solely a hydrogen ready gas boiler, but with valved connections in which a ASHP system could be connected into. The budget cost for this work would be in the order of £21,000 +fees, +VAT. It should be pointed out that whilst new replacement boilers are likely to reduce the carbon generated by approx., 30%, that if a new system was to be eventually provided then these boilers could remain as part of a new 'hybrid' system with ASHP's, which would then further reduce the carbon generated.

In terms of the consideration for the location for any external ASHP unit, I can confirm having looked within the Bell Tower which is fully louvred on all 4 sides, and which these external ASHP units would have operated satisfactorily within, however it can be seen that as there is no access hatch provided in the floors below the bells, and as the location of the bells themselves practically covers the whole floor area within that space, then unfortunately this option would not be possible, and therefore this type of plant would have to be mounted externally at ground level, with the only real space option being the North East corner externally to the East window in the Clergy Vestry. However as this is a Grade 1 Listed building full Listed building consent and Planning permission would have to be applied for which could take many months to obtain, if indeed this was granted at all.

It would therefore be my recommendation to consider running with the gas boiler system option at a budget cost of £21,000, with the provision for the future connection of an ASHP system, plus a new radiator and steel finned element pipework system at a budget cost of £38,500, which would currently indicate a total budget figure for a new heating system at £59,500 +fees, +vat.

The above costs make no allowance for carrying out an asbestos R & D survey, if one isn't already in place, or any possible remedial works that may be found to be necessary, certainly within the boiler room and the below floor ducts.

I think that it also worth indicating the basis of the selection of this type of system, bearing in mind running costs as well as carbon reduction as the current gas rate is at only 3.19p/kW, whilst the electricity cost is 17.38p/kW.

It is therefore important to recognise that this Church has a limited electrical supply capacity, and currently has no heating available from the existing system and whilst the Parish are mindful of the wishes in becoming carbon neutral by 2030, they are also mindful that in order to maintain the congregation not only attending the Church as they currently do, but in also hoping to grow the Church usage that it will be important to provide a heating system sooner rather than later.

Clarification note regarding fees;

As an indication for fees based on the initial likely option to be taken, ie. the replacement of the existing gas boiler with a hydrogen ready gas boiler system, plus a completely new heat emitter system, it can be seen that as the indicated budget costs for this would be £59,500, then based on the 15% fee requirement then this would indicate a fee of £8,925.00p +vat.

I can confirm that I have already indicated that the fees being paid for this report at £840 would be considered for being offset against any further fees incurred, and also no 20% vat needs adding to my fees as my Private Practice through which I do all my Church works through. Hence whilst I would be prepared to offset the total £840 off a complete boiler & new system scheme, which would reduce that fee down to £8,085, I would also offer a further reduction on that fee down to a fixed sum of £7,350, which would be split at £5,250 upto the design & tender stage and £2,100 on completion of the works. These fees would remain fixed and would not change in-line with the eventual tendered costs.

I can also confirm that this fee would include for the application required to SPEN regarding the incoming electrical supply.

I have not indicated any further fee considerations for the possible ASHP system or the possible solar PV scheme, as that would not seem to be appropriate at this time.

I would clarify the purpose of paying a fee is to not only prepare a specification and any drawings required for DAC / Faculty considerations, but also to obtain competitive tenders from 3 or 4 recognised Church Heating Contractors, and hence the costs of the fees is normally recovered against savings made from this competitive tendering.

Furthermore if you are looking at approaching any grant funding bodies to assist in the financing of these works, then it would be a requirement that they would also require sight of at least 3 tenders plus the specification and design drawings prior to considering such funding, hence it should be pointed out that your initial fee expenditure commitments for a total heating plant & system replacement would be the £5,250 fee upto tender stage for this, plus of course the current £840 fee payable for this report.

I think it is again important to recognise and point out that the heating system required for this Church does need to satisfy both the Conservation requirements and Comfort level requirements, which in my opinion can only reasonable be provided by a wet system of heating previously detailed, and initially supplied via boiler plant, but hopefully with then an ASHP being added.

CHURCH of ENGLAND'S GUIDANCE NOTES

Hydrogen (extract from - ChurchCare Advice and guidance for church buildings)

The Faculty Jurisdiction (Amendment) Rules 2022 require churches to obtain permission for any gas-for-gas or oil-for-oil boiler replacement; hydrogen and Hydrotreated Vegetable Oils (HVO) have been cited as an alternative to gas and oil for like boiler replacement.

The obvious appeal of hydrogen is that it does not release CO_2 when burnt and that it can be made from water, an almost limitless resource.

Hydrogen is produced commercially by separating the hydrogen from water in a process called electrolysis. For hydrogen to be considered "green", electricity from renewable sources has to be used to electrolyse the water. There are three forms of hydrogen commercially available; only **one** is green, and most of the world's hydrogen is currently manufactured using fossil fuels.

Generating electricity from wind or solar, converting it into hydrogen and then burning the hydrogen at home uses more energy than just using the electricity to directly heat a home, with a heat pump.

"Heating homes in the UK with green hydrogen would use approximately six times more renewable electricity than heat pumps. We do not have the time or resources to waste further investigating hydrogen's role in home heating, especially when the well-known laws of thermodynamics determine the answer." Second National Infrastructure Assessment

It seems likely that any future use of hydrogen will be limited rather than universal. It is likely best suited to applications or places that are hard to electrify – in the main, transport-related. This limited—rather than universal—use of hydrogen should inform our decisions.

The Church Buildings Council concludes that hydrogen **is not** likely to be practically and economically viable for use in the short and medium term for heating churches.

Hydrogen as a potential future fuel has **limited rather than universal uses**. It is highly unlikely that hydrogen will play a role in achieving the Church's Net Zero Carbon goal by 2030. Distribution and storing hydrogen presents significant safety challenges making it more suitable for use in regulated commercial settings.

The limited, rather than universal, use of hydrogen should inform design choices for heating systems. A new replacement boiler being hydrogen-ready will not make a meaningful contribution towards a shift to net zero.

Hybrid boiler systems (advice from theEnvironmental & Sustainablity Office – Cathedral and Church Buildings Department).

The main message is, **consider hybrid or bivalent solutions where there is no one technology suitable**. Sample of one passages below.

Hybrid boilers are now marketed by heat pump manufacturers, they combine an air source heat pump with a conventional gas boiler. This approach can be achieved without the need for a manufacturers solution if designed and installed correctly. Here the heat pump is designed to operate efficiently and is adequately sized to meet the energy demands for most days of the year, with the "top up boiler" typically a gas boiler providing top up energy (heat) on days when there is a high demand for heat, i.e. very cold winter days. **Hybrid solutions are not a zero-carbon solution because they still use some natural gas or oil so they should be considered as a *transitional* approach**.