Diocese of London
Environmental Challenge

Generic Building Solutions

Options, Challenges, Solutions, Limitations

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2 Introduction

Generic Building Solutions is a project of the Diocese of London in partnership with the Carbon Trust, with Arup as Consulting Engineers.

The final report by Arup, now published, surveys a range of building interventions and technologies to reduce the carbon footprint of London churches by at least 80% by 2050.
These may be carried out individually or in combination with others, depending on circumstances – as freestanding projects or as part of repairs, reordering or redevelopments undertaken for other reasons.

In appraising these options, churches may need to evaluate them in combination with other building technologies or systems, and with more traditional means of heating and lighting a church or other premises.

In cases where one or another 'new' technology is not feasible or viable, resort may be had to more 'traditional' approaches.

It will still be necessary to find the most efficient solution, with the least carbon footprint, that is feasible and affordable; as well as comparing this with less beneficial alternatives, and with what exists and is to be replaced.

Like-for-like replacement may not often be the preferred solution, it should not be adopted by default, a PCC needs to be able to compare.

This guidance paper therefore contains an overall survey of a large range of options, from the point of view of the environment, energy use and carbon emissions. Their merits are in very general terms indicated in red, amber or green.

It is the balance of factors bearing upon the whole option which is so classified – even if a poor choice might have some limited merits, and a good one may present some challenges.

Few options are to be discounted (though there are some); none may be recommended in any or all circumstances – but are to be evaluated on a case-by-case basis, having regard to the report by Arup and each church's needs.

Note that works to buildings continue to require a faculty, preceded by consultation with the Diocesan Advisory Committee (DAC) and, where required by the Faculty Jurisdiction Rules, statutory consultees including English Heritage and others. See also companion paper 'Needs, Signficance, Impacts and Mitigation'.

Table: **Technologies, systems; General remarks and description; Applications and benefits; Disadvantages, challenges, limitations**
(next page and following)

Technologies, systems	**General remarks and description**	**Applications and benefits**	**Disadvantages, challenges, limitations**
Building fabric			
Cement and concrete	Among the most versatile of building materials.	Used in a host of mainly structural applications.	The manufacture of traditional Portland cement materials for mortar or concrete contributes significantly to greenhouse gas emissions which add to global warming (5-10% of global emissions, of which 60% comes from the limestone base material and 40% from energy used to heat the kiln).
Lime mortar	Any mortar mix where lime is used either as a substitute for cement, or in addition to cement as an admixture with sand.	To be encouraged for some traditional buildings. The introduction of lime as part of the mix in addition to cement and sand may reduce the proportion of Portland cement, as well as making appropriate allowance for building movement. Fully lime-based mortars can result in much reduced carbon emissions.	May not be able to meet engineering codes in structural applications where cement based mortar or concrete would otherwise be employed.
Carbon neutral/negative 'cement'	Low-carbon or even allegedly carbon negative non-Portland cement substitutes have been on the market since the early 2000s at latest.	Applicable to new building work, especially housing.	This remains a new technology, controversial within the building industry and not likely to be familiar to all architects. The poor track record of previous Portland cement alternatives such as high-alumina cement may encourage concern of a risk of unintended and unpredictable consequences, leading to the 'precautionary principle' being applied.
Brickwork and ceramics	A very wide range of traditional clay-based building materials and products.	Very versatile use eg for walls, roofs, internal and external finishes.	The process of kiln firing consumes fossil fuel energy and generates carbon emissions.
Natural stone and slate	A wide range of natural materials especially for walls and roofing.	Natural and renewable (but only by re-cycling).	Primary supplies of some UK stones, eg natural slate, are close to being exhausted. Old material should be reclaimed wherever possible. Importation costs dear in terms of energy and emissions. Bear in mind the vulnerability to extreme weather, especially of sandstone and soft limestones.
Rammed earth	Also known as adobe, a traditional construction in central America.	Can be seen in the new WISE building at the Centre for Alternative Technology, Machynlleth in Wales. Formed in shuttering like concrete.	Limitations on scale, lack of tensile strength.
Structural timber –	Timber is increasingly being seen in new buildings of many types.	There is no shortage of softwood of structural grades for construction. It is hard to judge whether the persistence of concrete use is mainly the result of cost, convenience, ease of engineering calculation, mere inertia and entrenched habit – or some combination of these things.	Timber should be of the correct grade, as is available in softwood from Scandinavia (formerly the Baltic), Canada etc. Timber imported other than from European sources should if possible be avoided to minimise emissions from transport.
non-structural hardwood and softwood	A range of softwoods and hardwoods may still be used for second fix or finishing applications.	There is little intrinsic reason why naturally grown timber should not be used in any construction. The carbon content of the wood is thereby sequestrated in the building fabric for decades or centuries. The most reliable way of ensuring that a species is permitted for use is its certification by the FSC (Forestry Stewardship Council). All timber should be obtained from FSC certificated sources. UK-sourced timber is especially to be encouraged. Although this may be more expensive than imported wood, the difference may be offset at least partly by the reduction in transport costs and emissions.	But limited by availability and the sustainability of sources, in particular to ensure that it originates from managed forests continually replaced in the same species, The use of prohibited species is (by definition) illegal.

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Structural steel	Structural frames and other beams and joists and first fix applications.	High tensile and compressive strength.	A significant but r educing contributor to greenhouse gas emissions.
Aluminium products	Secondary fittings, window frames etc – and for example wind turbines and solar panels.	Aluminium is a versatile, lightweight material, available in moulded, rolled and extruded forms. It is low in cost compared, for example, to cast iron eg for replacement gutters and downpipes. In many cases it may be preferred to plastics such as uPVC. The carbon intensity of aluminium has been much improved in the manufacturing process, and can be further mitigated eg by recycling – but claims for a carbon-negative potential should be viewed with scepticism.	Unfortunately, aluminium manufacture makes a significant contribution to greenhouse gas emissions – the total production process accounts for about 1% of world emissions. Claims that use in solar panels 'offset' emissions from aluminium manufacture appear specious. It would be more valid to say that the emissions from manufacture of solar panels compromise their benefits (though only partly).
Plastics	The range of materials, products and applications is too vast even to summarise.	Very cheap and versatile, much improved in visual appearance and strength eg for double glazing.	Most plastics are petroleum by-products, depending on fossil fuel production for their availability and economy. Extremely harmful when discharged into marine environments. Likely to prove even harder to exorcise from our lives than coal or concrete.
Insulation –	A layer of material, introduced especially within roofs and walls, sometimes floors, specified to reduce transmission of heat (or sound). A wide range of materials is available, eg polystyrene boards and fibrous quilts which have been used in the building industry for many years. More recently, re-used materials such as recycled glass bottles have been employed as high-performing insulation.	Insulating of a roof void where present is the easiest and cheapest to carry out as well as of greatest benefit. Insulation may also be included as part of the build-up of a new roof covering (so long as any parapet or eaves are able accommodate it). Or insulation may sometimes be incorporated beneath the underside of boarding between the rafters of an open-roofed interior. Some modern churches may be able to accommodate insulation in walls, eg where there is a cavity. Insulation is specified in terms of its performance, measured as its U value for which minimum and increasingly stringent standards are required by Part L of the building regulations; lower U value means a lower rate of transmission of heat, therefore higher performance.	A number of consequences of installing insulation need to be considered, as part of the design process for new buildings, and to the fabric of existing buildings. Condensation needs to be avoided, as well as any direct path for damp, eg where cavity walls are infilled with insulation. The effect on a building or space needs to be considered as a whole, even though – perhaps especially where – only one building element is to be insulated, since the behaviour of other parts may be indirectly affected. Church buildings have so far remained exempt from Part L of the Building Regulations. But no good reason is seen to claim exemption for any new church building or extension.
structural insulation	Insulation may be built into pre-fabricated building components.	Such as composite panels eg for ease of assembly in volume housebuilding, combining insulation with loadbearing capacity. Carbon neutrality may be claimed, but this will only be verifiable in the context of building design and specification as a whole.	The range of design options in terms of architectural appearance may be limited by the constraints of any proprietory building system. This may also militate against comparing like-for-like between tenderers for a design-and-build contract.
insulating render and plaster	A range of insulating products are available for internal and external walls.	Limit the build-up of wall thickness due to applied insulation. Base materials include combinations of lime, glass, sand, clay and straw.	May be about 40mm thick, but this is still less than conventional plaster plus applied wall board.
straw bale construction	A traditional form of construction in some overseas locations, attracting increasing interest in the UK.	A range of benefits are claimed in terms of sustainability, reduced carbon emissions from production and transport (assuming local sourcing and manufacture), built in insulation etc.	Experience is lacking in the UK to date, but should be taken into consideration as it develops.
lambswool insulation	The use of lambswool for insulation has been widely advocated by conservation agencies and professionals.	Natural, organic, renewable and 'green' (especially if the wool-bearing animal is regularly sheared and not slaughtered). Can be made eg frpm recycled carpets, in loose, roll or rigid board form.	Lambswool attracts moths. It is as yet unclear that methods of treatment such as 'Borax' are effectual in dealing with this. Wool -based products are diversifying. Still insufficient favourable evidence to recommend its use in construction.
Green roofs	Flat and low-pitched roof constructions, mainly for new buildings and extensions, incorporating planting on a layer of topsoil. Frequently described as 'sedum' roofs, sedum being a varied genus of low-growing perennial plants with a wide variety of colours and textures.	In addition to the aesthetic benefits, green roofs reduce rainwater run-off and therefore flooding. They can also provide thermal and sound insulation as well as encouraging bird and insect life and therefore local biodiversity.	Species of plants for green roofs are to an extent self-maintaining, but roof access is still required. Sedum is a diverse genus of small plants, but still represents essentially a mono-culture; a greater range of planting is to be encouraged, though this may have implications for the design of a structure and maintenance.

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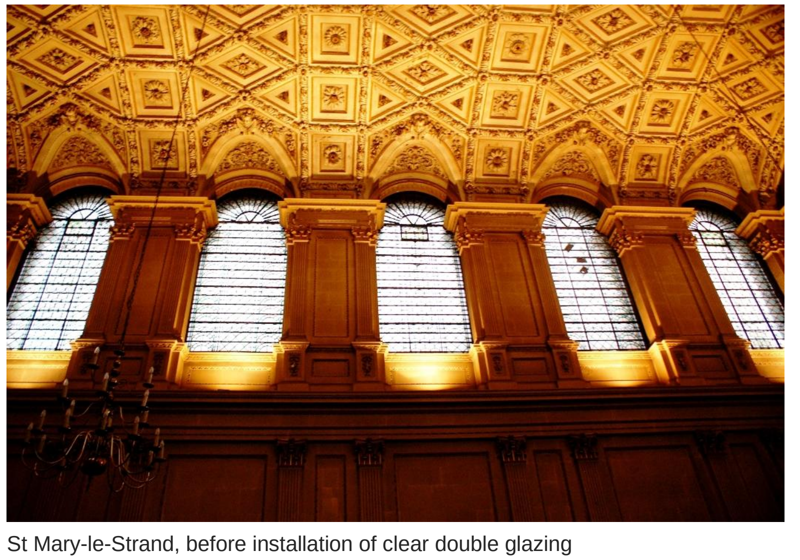
Draught proofing –	In principle, draught stripping to reduce external air infiltration and heat loss is to be advised in itself. This may take the form of rubber or metal strips with brush seals for opening elements. Proprietory injected gap-filling sealants are also available, allowing better adaptation around irregular profiles. But bear in mind that draughts may not be caused by air gaps at all, but commonly by convective air movement, known as down-draughts, eg inside windows.	Where feasible, draught stripping may be applied as a stand-alone measure, or in conjunction with other measures to conserve heat such as secondary glazing (next page). With insulation, internal air temperatures will rise for the same heat input, accelerating heat loss through openings and perforations; an alternative solution than draught sealing may be to turn down the heating so that the temperature remains the same, perhaps more evenly distributed, and with reduced heat loss – or some combination of partial measures.	Draught proofing is not a cure-all in a traditional building, such as many churches. It is not advisable to hermetically seal 'natural' or 'traditional' building materials which need to be able to sweat and breathe, inhaling and exhaling moisture as weather conditions fluctuate. Also it is impractical in many cases to draught proof existing doors and windows, which may have become irregular in profile, or may have complex arched openings and tracery. Visual and heritage considerations should also be taken account of in any alterations to architectural elements such as doors and windows.
'Quattroseal'	A proprietary gap-filling draught-proofing sealer – www.quattroseal.com/	Particularly designed for 'heritage buildings', approved by English Heritage.	Probably not the cheapest, but with a creditable track record.
Improved glazing –	Modification to existing glazing or frames may be feasible and appropriate especially if replacing glazing anyway, eg a 20th c building with steel window frames. The replacement of wooden windows especially to domestic buildings with uPVC is very familiar.	Aluminium frames with built in thermal breaks may provide considerable improvement in energy terms. Replacing wood with wood (hardwood) is to be preferred though more expensive – but only if from sustainable sources (see comments on timber above).	Churches replacing original windows have encountered a range of challenges with manufacture and supply of profiles, and the possibility of a change of appearance requiring planning permission. This is likely to be the case even if attempting a like-for-like replacement – an exact match is hardly ever viable to manufacture – so the best likeness which delivers current performance standards is generally preferable.
new double glazing	Most commonly uPVC (plastic) frames, especially for domestic buildings, made to measure in existing structural openings. Other materials such as aluminium may be necessary and/or feasible in general for churches and/or for reasons of preserving architectural character and appearance. Double glazing should be sealed with argon-filled voids.  St Mary-le-Strand, before installation of clear double glazing	A wide variety of types and performances are available, banded A to G by the GGF (Glass and Glazing Federation). It is important closely to examine both the type and the installer before commitment. Companies are very competitive with each other. New double glazing is currently being installed in parsonages in the Diocese of London, but only where they are replacing windows which would have had to be replaced anyway as part of the normal maintenance cycle.	See previous comments on plastics and aluminium. The appearance of uPVC frames becomes less acceptable as the energy efficiency improves and frames are therefore thicker. They may not be granted planning permission in listed buildings and/or conservation areas – for visual reasons including the appearance of multiple glass layers, as well as the frames. Listed building consent may also be needed (except in the case of a church – but uPVC windows are unlikely to be granted faculty permission for most churches except in ancillary areas and out of sight). As a compromise, especially for a domestic property, it may be possible to install double glazing on the rear elevation and secondary glazing (see next page) at the front, so as to preserve the appearance of the street elevation.

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secondary glazing –	Secondary glazing is to be encouraged for consideration in many churches and church halls and other buildings, as a heat-saving measure. The secondary glazing itself may (rarely) be double-glazed.	Secondary glazing may be more straightforward to manufacture and fit in a rectangular rather than arched or traceried opening, and in more modern buildings where a group of windows may be similar in size and regular in shape.	Secondary glazing is much more of a standard product with a limited range of higher performance specifications, therefore it is unlikely to achieve equal energy savings to total window replacement. Avoidance or draining of any condensation within the space between inner and outer windows needs to be designed into the frames and fittings of secondary glazing. Make sure that there is sufficient depth within the wall thickness and window sills.
internal	Secondary glazing is normally retrofitted internally within the space.	May be less visually detrimental than total window replacement, or external double or secondary glazing.	Make sure that glazing bars coordinate with the outside windows, and that inside and outside can both still be opened and closed securely, allowing for the positioning of handles and stays.
external	External secondary glazing may be feasible in limited cases.	The use of acrylic as an exterior secondary glazing material may serve a dual purpose, for security as well as reducing heat loss and improving air tightness. Arup's *Generic Building Solutions* report contains an analysis for 3mm acrylic with a 12 mm air gap, showing that the benefit is dependent on the proportion of window to wall.	More problematic in terms of integrating with the existing building in a visually satisfactory manner. Unlikely in many cases to gain planning permission and/or faculty permission. The architectural appearance of external plastic sheet may be its chief drawback, though preferable to polycarbonate, possibly less obtrusive than wire guards. The change in appearance and any visual detriment will be least in the case of plain untraceried windows in modern buildings.
Curtains	Curtains or hangings inside doors and windows, or eg adjoining a stairway, may contribute to energy-saving.	Appropriate eg in church halls and domestic buildings. Sometimes in a church, eg as part of a draught lobby (see below).	Dirt, wear and tear need to be borne in mind.
Draught lobbies	Formation of a lobby inside the main entrance of a church not only provides a means to control draughts; but also it is a popular means of maintaining security, whilst offering visibility into the church through glazed inner doors while the body of the church remains locked – and not having to replace the external doors or change the outside appearance when the building is closed at night.	This may be achieved as part of reordering and subdivision to provide for additional uses.	As with any alterations to a church, a faculty is needed and the Diocesan Advisory Committee (DAC) should be consulted. The DAC will for example discuss with the church the functional and pastoral implications of security and visibility. Beware of covering a heating radiator with a full-length curtain.
Volume reduction	A range of means might be devised to reduce the volume requiring to be heated within a large internal space such as a church or hall, as part of a reordering or as a freestanding project.	Many reordering projects included subdivision of large spaces to insert a range of smaller rooms. Together with zoning of heating (see later in this guidance), this may greatly assist in reducing energy intensity, and even gross energy use in some cases. The insertion of additional floors, for example, can reduce the loss of heat into roof spaces. Among more radical options, experimentation with a clear PTFE membrane has been conducted by Aardvark EM. Potentially an insulating blanket might even be feasible in rare cases, such as an internal tent structure made of ETFA, with its own built-in insulating characteristics.	Major alterations to the interior especially of a church present significant challenges, in terms of architectural appearance and the effect on existing or historic fittings and furnishings – to be resolved as with any alterations to a church in discussion with the Diocesan Advisory Committee (DAC) and others.

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Electrical services			
Energy monitoring	Energy monitoring equipment typically takes the form of smart metering, but enhanced systems are also available eg with web-based remote reporting in real time. This may piggy-back on the electrical intake without having to replace the regional supplier's meter. A system of this kind branded 'Carbon Guerrillas' is being offered by Aardvark EM to participants in the Diocese of London's *Climate Action Programme*.	The simplest method of energy-monitoring a church without need to install any extra hardware is to benchmark consumption eg through the Diocese of London's dedicated *Energy-saving Benchmarking* scheme (www.london.anglican.org/Energy-saving-Benchmarking) , then keep regular meter readings and bills and compare performance annually against benchmarks.	Management discipline is important to the success of any energy-monitoring programme. See the detailed advice in Arup's *Generic Building Solutions* report.
Smart metering	The UK Government has committed itself to 'rolling out' smart metering to all domestic customers by 2020, but this would not include churches – which should therefore consider investing in smart metering. Arup's report advises that multi-channel smart meters are available with inputs from electricity, gas and water meters and also temperature sensor readings.  HM Tower of London, a client of Power Perfector (see under)	Benchmarking is an essential management tool, and the benefits of smart metering are a complement to it, especially where a meter is visible to users who can see the effects of their actions in real time. All advice for the Diocese of London and the national church note the benefits of smart metering. The real-time awareness of consumption which smart metering (with a live data panel) provides is typically shown to save 3-15% (Arup) in electricity use. Monthly or even daily metering is also of benefit. Monthly billing is available from the Utility Warehouse Discount Club, via Charity Funding Solutions, under the Diocese of London's scheme of *Climate Action Plans* (www.london.anglican.org/Shrinking-the-Footprint-Climate-Action-Plans).	Although there will be an initial cost until any national free roll-out, such cost is likely to be paid back within a few years if not months.
Voltage power optimisation –	A system of 'voltage power optimisation' imported from Japan is marketed in the UK by Power Perfector of Paddington – www.powerperfector.com/. The unit is installed at the mains electricity intake and modulates the voltage to services on the premises, so as to maximise efficiency without wasting excess heat.	Case studies by Power Perfector appear to substantiate their claim of 11-14% saving in electricity consumption of premises served by their installations. The voltage at the mains intake may also be 'tapped down' to achieve at least some of the same savings as an alternative to, or further supplemented by a VPO installation by Power Perfector or otherwise.	There have been suggestions that Voltage Power Optimisation may cause malfunction of systems such as lifts. New electrical systems are likely to be already dedicated to available voltage. Engineering advice obtained by the Diocese of London has not been able to substantiate the claims made by and for Power Perfector for the level of savings achievable, but neither has it discredited them.
domestic voltage power optimisation	At least one domestic scale system is now also available.	8-10% savings are claimed.	Same observations as above.

Technologies, systems	**General remarks and description**	**Applications and benefits**	**Disadvantages, challenges, limitations**
Lighting			
Natural or artificial light? –	Lighting of churches up to the early 20th c was primarily based on the exploitation of natural daylight, to enhance the appearance of internal spaces, their architectural form and detail. For example, for an east-west orientated church, in the morning the Sanctuary would be back-lit, and in the evening might be illuminated by a shaft of sunlight through the west window.	Natural daylight is always to be preferred where available. Artificial light was at first primarily a supplement to natural light, in order to provide for particular functional needs, or to enhance the aesthetic appearance of an interior.	Of course, direct sunshine is not always present, and no natural light at all except during hours of daylight. Some Victorian architects made a virtue out of necessity, in designing church interiors which purposely restricted the area of glazing so as to limit natural light and create a sense of the numinous.
lay lights and light pipes	Where there is an enclosed inner room with a void above the ceiling, lay lights may be used to bring in borrowed light from any clerestorey or roof light. Or if the roof is flat, a light pipe can conduct light down through the ceiling.	Lay lights tend to collect dirt, which damages their appearance inside the room. Light pipe covers may readily be removed for cleaning.	Of limited application, but very useful when there is the opportunity.
window blinds	Roller or slatted blinds (vertical 'louverdrape' or horizontal 'Venetian' type) for sunscreening.	Applicable more to meeting rooms than a worship area or hall.	Need to be installed and used mindfully. It is not uncommon to see blinds down in broad daylight while lights are on – unnecessary except to protect from direct sun.
Wax candles	To begin with, artificial lighting would have taken the form of oil lamps or wax candles.	Candles may still be used for special occasions such as carol services.	Bear in mind the fire risk from hot candle wax. It is also not necessarily 'zero-carbon' – it is hydro-carbon based, mainly obtained as a by-product of oil (albeit the oil is being produced anyway), not only from beeswax which is much more expensive.
New lighting	Wholesale replacement of lighting is a 'lifetime' project, justified when an existing system has become unsafe or failing – or very substantially falling below adequate performance or efficiency. Examples of 'scene setting' for different worship contexts are given in Arup's report.	The lighting of a church should as a rule endeavour to optimise the use of daylight at the same time, and not over-light the interior or over-rely on artificial light to provide illuminance or special effects. A very wide range of lighting systems and applications are available. Typically, whatever new lighting technology is adopted it should incorporate lighting control, zoning for multi-functional use, with lower levels of general background lighting.	Electrical lighting draws the principal electrical load in a church. It typically accounts for 15-35% of a church's total energy use and carbon emissions – the second highest contribution after heating, therefore a high priority for improving performance.
Low energy lighting –	Low energy lighting relies fundamentally on discharge technology – typically reducing energy consumption to one-sixth of its value for the same illuminance from an incandescent lamp such as the traditional tungsten-filament type (aka 'GLS' – General Lighting Service).	Compact fluorescent lamps (CFLs) are not the only alternative to conventional lamps, though in many ranges on the market they may be the only alternative to justify the 'low energy' label. Types and performances of different lamp types are tabulated in Arup's report, indicating the advantages of fluorescent and metal halide types. Types should be chosen carefully. For suggestions on sourcing and specification, see diocesan website, or contact the Head of Environmental Challenge.	Unfortunately, CFLs were introduced to the market and strongly pushed as an alternative to GLS tungsten bulbs, before the technology was mature – arguably as a panic response to the inefficiency of this traditional light source, which was out of proportion to the actual contribution to domestic energy consumption of tungsten bulbs. Though of undoubted environmental benefit, CFLs have suffered from a range of other well-known shortcomings. The significant warm-up time of discharge-type lamps should be borne in mind.
low energy lamp replacements	Churches including Holy Trinity Prince Consort Road and St Mary Islington have achieved savings of at least 70% in electricity use by installation of low-energy lamps in existing fittings. Lamp replacement also delivers extended lamp life, cutting the considerable costs and disruption due to access for replacement.	Compact fluorescents are available as direct replacements in a range of situations, such as with integrated control gear as a substitute for GLS (tungsten filament) bulbs, or candle lamps for chandeliers. These are also available with a colour temperature similar to tungsten lamps. Older existing fluorescents and/or their ballasts may also benefit from replacement, achieving significant energy savings.	Optimal savings may not be achievable by replacjng lamps for existing systems in all churches; this will depend on the types and ages of light fittings already installed, and/or the requirement for dimming.

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Energy-saving lamps	A term for reduced energy lamps which are not true low-energy lamps (ie not compact fluorescents or CFLs).	Eg halogen fittings may be acceptable in some circumstances (see previous page and column to far right). Look for the ratio of 'voltage' to 'equivalent voltage' (as low as 15% for CFLs, more for each halogen lamps). When replacing fittings as well as lamps, look for types with in-built reflectors.	Whether 'low-energy' or 'energy-saving' lamps are adopted, or some combination according to situation, attention is needed to achieving compatible colour-rendering.
LEDs (light-emitting diodes) –	Very low energy, low carbon and potentially versatile alternative to conventional lighting.	Currently suitable mainly for task and accent lighting. They can be used to replace tungsten halogen spotlights.	LEDs are envisaged as the next generation of ultra-low energy lighting for the market. Currently they remain unable to provide substitutes in a wide range of lighting types and situations, in particular where high illuminance or wide coverage are required – including for the principal background lighting of interior spaces in churches. LEDs are generally not as powerful as tungsten halogen equivalents, but the latter are often over-specified for the situation.
organic LEDs	One of a range of 'clean technologies' being developed for the market-place.	Likely to be very low or even zero carbon.	Not yet available to verify performance.
Lighting controls –	By correlating lighting use with functional requirements, well specified and used programmable lighting controls can deliver large savings in energy and carbon emissions.	Should be carefully considered with a church's lighting designer, so as to optimise both performance and energy efficiency.	Not all lamps are dimmable (eg not CFLs).
zoning	Subdivision of premises into zones with separate lighting systems and/or combinations options.	The option to turn lights down or switch them off independently may yield savings of a similar order to the wholesale substitution of bulbs where these are not dimmable.	Needs management discipline.
switchboards, dimmers	In support of the above.	Very versatile configurations are feasible. Considerable savings in energy wastage due to users not switching off lights manually.	But avoid over-elaboration, and specification of excessive numbers of fittings.
daylight & occupancy sensors	Wall-mounted substitutes for on-off switching, delivering power to the lights when BOTH movement is detected AND ambient light is below pre-set level.	Suitable for little-used ancillary areas such as back staircases. (Escape stairs will require emergency lighting in any event). Cheap and simple to install and use.	Can be slow to activate when a person is moving quickly and may already be descending a staircase in low light – a potential safety hazard.
External floodlighting –	For architectural enhancement and/or security.	Whilst these functions are often seen as distinct (architectural lighting on a main elevation, security lights down a side passage), opportunities should be taken to consider their mutual needs and benefits and design them together. Timers (solar clocks to take advantage of daylight saving) and photocell controls should be specified to achieve these ends which are not necessarily incompatible.	In neither case should they be allowed to waste energy. Architectural lighting should be limited to reasonable evening hours and/or special occasions, security lighting should activate only when persons are present. Light pollution should also be avoided. Appropriate cowls should be provided to avoid overspill.
fibre optics	Fibre optics are a reduced carbon technology which can be employed with advantage in floodlighting.	As at All Souls Langham Place for example – www.paigroup.com/LTP/LTP-All-Souls-Church.html.	Needs sensitive architectural handling.

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Small power			
Portable heaters	The highest demand for small power in a church is usually attributable to portable electrical heating appliances.	See under 'Heating', below.	There is a risk of more than cancelling savings by turning down central heating, then heating small rooms locally by electric heaters, especially during cold weather. To be avoided if at all possible, as a major cause of electrical demand. Far preferable to zone the central heating, so it can be turned up locally (or use thermostatic radiator valves, see further down this guidance).
Computer equipment –	Ubiquitous in every home, school and business, and most church offices.	The benefits of IT, email and the internet are well enough known. It tends to be assumed that to replace paper use with IT is an improvement in 'greenness' – but this is not necessarily so. Best to use each for what they do most efficiently in energy terms.	IT use is thought to contribute about 2% of greenhouse gas emissions worldwide – a similar proportion to aviation, and growing at a similar rate. Schools and offices are notorious for their tendency to leave IT switched on all night. Particular efforts should be made to avoid contributing to the demand for off-site storage in data centres, eg for back-up facilities, where a significant proportion of worldwide energy consumption is concentrated.
computer monitors	LCD flat screens have now superseded cathode ray tubes (CRTs).	Flat screens consume about half the power of CRTs (size for size). Replacement will therefore save electricity. As with many replacement decisions, a cost-benefit analysis may be needed to compare the benefit of replacement compared to the expected life of existing equipment.	Beware malfunction of routers, copiers etc if switched off in a manner not in accordance with the manufacturer's instructions. Also some older monitors are designed to switch off only when the computer itself is off. (The same is true for hi-fi amplifiers, DVD players etc which abhor cold or humidity.)
IT power management	The simplest and cheapest method of IT power management is to switch off as often as possible – monitors and other peripherals for short periods, at the mains for longer periods of absence or non-use.	Installed hardware for IT power management is mainly only applicable to larger commercial premises – might also be helpful in a school.	Consider losses through friction and heat which increase power demand.
Motors and drives	For heating and ventilating fans and pumps. Occasionally, for lifts.	Advice is included in Arup's report on replacement with higher efficiency motors.	The electrical load on fans and pumps substantially adds to the energy use and emissions from heating systems primarily driven by gas.
New catering equipment	Cookers, fridges, washing machines, dishwashers etc.	The highest available efficiency (A++ or A+ where available, always A or B minimum) should be obtained when equipment needs to be replaced. Dramatic energy savings can be made when older equipment is replaced.	Make sure to dispose in a safe and environmentally friendly manner. Enquire of the supplier of the replacement appliance.
Mains power saving accessories	A variety of patented devices are on the market for domestic use, including the type famously demonstrated on 'Dragons' Den'. This is understood to use an infrared receptor on the power bar to sense the turn-off signal from the remote and reduce power to the appliances (TV etc.). A double press may be needed to switch on again. There is also a USB device.	Domestic scale eg parsonages, or for ancillary areas such as vestries and church offices. Available over the counter in major supermarket chains.	Stand-by power use is generally lower than the claims sometimes made; while not all types of power saver may in fact save as much as they claim to. See also publications by the Energy-Saving Trust on the selection and use of domestic appliances: www.energysavingtrust.org.uk/resources.

Technologies, systems	General remarks and description	Applications and benefits	Disadvantages, challenges, limitations
Micro-generation			
Combined heat and power (CHP) –	A 'prime mover' (a generating engine, often a Stirling engine) generates electricity, and the heat created as a by-product is used to supply heat and hot water.	Where applicable and viable (described as 'good CHP') this may deliver CO_2 savings greater than biomass (see below) and at a lower cost. A supplementary gas boiler is needed for heat when there is no call for electricity.	It is essential that the engine should be able to modulate to a variable electricity and/or heat demand. At other times there may be a surplus of heat for which some storage medium may be needed (see Thermal Energy Storage, below) to avoid wastage and diseconomy.
mini-CHP	The scale of unit likely to be applicable to some churches.	Tight urban sites with a range of other buildings and uses either on site or adjoining, with which heat and/or electricity can be shared.	Unlikely to be viable when the heat demand is for less than 4,000 hours in a year. NB – this is the heat the church would have required anyway; if the heat is used just because it is there, at times and in conditions when a heating system would normally be switched off or at a lower setting, the economy is a bogus one.
micro-CHP	Domestic scale, eg the award-winning system by Baxi.	Combines a gas boiler with CHP system in a single unit.	It remains to be seen whether this really delivers on its prospectus.
CCHP	CHP is also available as CCHP (combined cooling heat and power).	As with heat pump technologies (see further down this guidance), more viable with cooling as well as heating.	Of very limited application to churches.
biomass C(C)HP	C(C)HP system driven by a wood-burning engine.	If and when they become available, this may potentially even deliver carbon negative status, ie effecting a net removal of greenhouse gases from the atmosphere.	No known systems available yet.
Photovoltaic solar panels	Photovoltaics is a technology to convert sunlight into electricity. Panels comprise a glass substrate with silicon cells engraved with a conducting material. Each panel has multiple cells and the panels are connected into strings. The panels are mounted at an angle to the horizontal. Mono-crystalline panels are preferable to the poly-crystalline type. A thin film type is also available. Photovoltaic panels have been chosen by the Diocese of London as the priority for the first phase of micro-generation technology to be rolled out to churches and parsonage houses. For fuller analysis, see Arup's report and separate illustrated guidance paper.	PV panels should be applied to roofs that are orientated south, or nearly so – as is indeed common for churches. They should be mounted either on flat areas behind a parapet (but raised at an angle) or on pitched roof slopes – in turn either mounted on the roof or integrated with it. Churches with roof parapets behind which solar panels can be hidden may be preferable for planning/ listed building/ faculty reasons, though this limits the useable area. There is no overriding prohibition on solar panels being visible; whether this is acceptable or not depends on siting and design in individual cases. See separate strategy and guidance papers.	Shading from trees or surrounding buildings on a panel or string may reduce or negate the electricity generated by that string, or even render it net negative in some cases. This may be calculated by use of a hand-held device with bespoke software. On the other hand, trees may protect views without reducing the useable area in some cases. Safety precautions are needed when carrying out maintenance on a roof in the vicinity of functioning solar panels, even if disconnected.
	Variations to the typical solar panel may be feasible in individual cases such as the solar tiles integrated with the slate roof of St Silas Pentonville – www.saint-silas.org.uk/accommodation.asp.	Architecturally appropriate solutions such as solar tiles are to be encouraged. It is essential that the visual implications of all new solar panels are fully considered in any event, and planning permission as well as a faculty will be needed in most cases.	Typically such alternatives may be more expensive and therefore poorer value for money than standard non-site specific types. Electricity is only generated by photovoltaic panels during the hours of daylight, but may be stored in batteries for use during the night.
	Inverters (see further down) to connect to the grid and associated electrical services are required in addition to solar panels themselves.	Feed-in tariff from all electricity generated, with an additional bonus for units not used on site but fed into grid.	Approx 30 year replacement time for solar panels, 5-10 years for inverters.

Technologies, systems	General remarks and description	Applications and benefits	Disadvantages, challenges, limitations
Wind turbine(s)	Wind power is the largest contributor to renewable energy in the UK, and increasingly so, but in the form of very large offshore and coastal wind farms.	For example, a large offshore wind farm off the Kent coast is now running. The Strata Tower at Elephant and Castle is said to be the world's first wind turbine system fully integrated with the building design. One wind turbine system was installed in a church in Cornwall in January 2010, awaiting experience of productivity and viability. Also under consideration for churches in Norfolk.	The pylons are very tall, typically more than 200 metres, and the potential effects eg on bird life are controversial. However, as of April 2011 its three turbines still appeared not to be operational; and they would only have a capacity of 10% of the power needs of the building. Few studies known to the Diocese of London, if any, have recommended the use of wind turbines as viable for churches on inland or urban sites in the UK, except on very high towers or pylons. Hard to avoid visual impact, unless camouflaged or concealed within a tower, or else separated remotely eg at the other end of a large churchyard.
(Micro)-hydroelectric	The same technology as the traditional water powered mills on many UK rivers can be used to generate small-scale hydro-electric power. Many developing countries are supplying an increasing proportion of their electricity needs from very large hydro-electric dams.	May potentially be suitable in some locations in England and Wales.	But not in London, where other than the Thames and the Lea, there are almost no remaining rivers (the Wandle in South London is one) that have not been co-opted by the sewer system. The feasibility and viability of local tank-stored water at high level on a church roof or in a tower is also likely to be discounted. Countries such as China are accepting the considerable ecological and humanitarian penalties of macro hydro-electric power, as well as the risk of bursting and area flooding.
Inverters	The inverter is the unit connecting a micro-generation system such as solar panels to the mains grid system, converting direct current (DC) to alternating current (AC) and enabling the flow of electricity to pass either way.	Consider type and lifetime, and also the potential for a prominent display on the premises which shows the power generated in real time.	Typical 5-10 year replacement time (in an installation which may itself last much longer).
Electro-chemical –	Battery power is more commonly applicable to motor vehicles.	Charging points for electric cars are already installed in some housing estates and public places.	Contrary to claims made by some manufacturers of electric cars, they are not 'zero carbon', or 'ultra-low carbon', unless charging points have a private wire agreement with a source of renewable electricity rather than being supplied with grid electricity.
lithium batteries	Lithium battery power, especially in hybrid form with a petrol driven engine backup, is increasingly common.	Quiet, compact and non-polluting (except the petrol engine in a hybrid car).	Questions remain about the net benefit of hybrid vehicles. It is reported that new sources of lithium are being sought outside the current sole source in South America.
hydrogen fuel cells	A kind of chemical battery, but needing to be replenished with the hydrogen fuel, rather than re-charged. The waste product is pure water, therefore entirely non-polluting.	The efficiency of hydrogen as a fuel depends on how it is generated eg from water or domestic gas – potentially this could be achievable for buildings, in addition to any central infrastructure to supply vehicles. Some engineers foresee hydrogen fuel becoming increasingly applicable to buildings as well as vehicles.	It was pointed out in correspondence in the Times of 15/12/10 that almost all hydrogen is currently made from hydrocarbons, generating 5-11 tonnes of CO_2 per tonne of hydrogen. It therefore offers no solution to climate change. However this disregards any advantage in motor efficiency; and the potential to separate hydrogen from water using solar power, a technology unviable now but only till a threshold user base develops.
Roof rental and access agreements	Any arrangement to grant a roof-access agreement to a third party company in return for a rent, and in some cases, a share of proceeds and/or representation on the management company.	Such deals are being widely marketed eg for solar panels on domestic properties. The lessee typically takes some 5/6th of the profit due to income from the Feed-in Tariff.	See web page at www.shrinkingthefootprint.org/best_practice.php?CC on this and other pitfalls to consider and avoid.

Technologies, systems	General remarks and description	Applications and benefits	Disadvantages, challenges, limitations
Heating, ventilation and cooling			
Generally	Churches built before the 18th century would not normally have been heated, at which time centrally located stoves with a pipe through the roof became common. Now a reasonable standard of heating for the congregation is widely considered essential - though it is still not universal eg in country parishes.	Heating typically accounts for 45-70% of a church's energy use and carbon emissions – the highest contribution, therefore top priority for improving performance.	Arup citing 'Heating your Church', Bill Bordass and Colin Bemrose, 1996, point out: • the need to heat the structure for several hours before a service of only 1-2 hours • the tendency for convected heat to rise up into the roof • draughts caused by too rapid heating may reduce comfort.
Change oil to gas	Oil has a higher carbon factor than gas, ie it generates a larger amount of greenhouse gases per unit of heat energy delivered (but it is still only half that of electricity). It is also much harder to monitor the amount of oil being used from deliveries or annual tank measurements, compared to metering at the point of use.	Benchmarking of London churches has not so far conclusively demonstrated that an older gas-fired system is more economical than oil, but the improvement in efficiency with newer gas condensing boilers is likely to exceed that of any oil-fired boiler.	Mains gas is still not available in all locations, even in the London Diocese.
Electricity or gas?	The choice between electricity or gas for heating a church is potentially a very difficult one. Unless renewable heat is feasible, biomass for example (see below), it is clearly better to install gas heating now, while planning for the option of switching back to electricity should this become relatively lower in emissions terms due to the introduction of wind, solar energy etc to supply the grid.	At the present time, electricity has a carbon factor above 0.5 kg CO_2 equivalent per kWh, compared to less than 0.2 kg for gas. Gas therefore contributes much less to global warming, so long as its efficiency in delivering heat is the same.	However, within the timescale over which a heating system installed now should remain effective, the national electricity grid should be 'decarbonised', making electricity much lower carbon than gas. Electrical radiant heating may still out-perform gas in the short term, but may be unacceptable visually (see below).
	What seems needed in the long term is a dual fuel type of heating which can run on gas, but be converted later to electricity if the effort to 'decarbonise' the electricity supply grid proves successful.	The problem is under consideration in the Netherlands (cf 'hybrid electric/gas units', below).	But such convertible electrical/gas heaters are not yet thought to be available,
Biofuels	Biofuels are beginning to be used for commercial vehicles and for aviation. Government regulations have required a proportion of biofuel to be included in pump petrol.	The advantage, as with biomass, is that the carbon emissions released are not, unlike fossil fuels, an addition to the natural carbon cycle and should therefore, in principle, be net carbon neutral.	But the growth of biofuel displaces food production from arable land – especially in vulnerable developing countries – and also tends to promote deforestation.
LPG (liquefied petroleum gas)	A portable supply option for premises without any gas supply. The main constituents, propane and butane, are by-products of natural gas production (methane) and oil processing. Natural gas, methane, is simply piped from source to user but propane and butane have lower boiling points - butane's is close to 0°C - and, under pressure, this could cause obstruction in a system that was designed for pumping gas. Thus the separation of what are chemically very similar gases.	It is better that the constituent gases are used not just flared, so that their inherent energy content is not lost. Where there is no mains gas, the choice for heating is between oil and LPG, the latter being less carbon intensive; it also burns more cleanly and so produces less air pollution.	Be aware of and implement safety requirements.

Technologies, systems	General remarks and description	Applications and benefits	Disadvantages, challenges, limitations
New boiler	For many churches, replacing a traditional gas boiler with a new condensing boiler remains a viable option, in conjunction with a low temperature hot water system (see next page). An atmospheric boiler is another category of enhanced efficiency appliance.	A condensing boiler delivers water at a comparatively low temperature, which is well adapted to pew heating and under-floor heating (see following pages). New boilers will generally be specified as modular types, enabling a single module to be withdrawn for repair or replacement without shutting down an entire system, as well as stepwise flexibility in designed capacity and performance.	It may perform less efficiently when connected to existing small-bore pipe distribution systems, due to the need to raise to a higher temperature which prevents the boiler from condensing. Before any works in plant rooms or concealed voids within a building, be aware of the risk of discovering asbestos and comply with the mandatory Control of Asbestos Regulations.
Boiler controls –	Includes boiler sequencing and stop-start to switch on and off at optimum times for pre-heat and occupancy periods, limiting heating to different parts of the buildings at different days and times and so on. Modern software-driven controls can be installed at higher cost.	Versatile use enables optimisation according to patterns of building occupancy and uses. Eg selection is beneficial of controls with default settings to revert after temporary re-set.	New controls must be compatible with existing systems especially an existing boiler and pipe circuits, and have regard to thermal characteristics of a building including rate of warming, set-backs between maximum and minimum temperatures etc. They also need to be readily understood by building users and managers and well integrated into the building's management regime.
boiler thermostat	Controls the temperature to which water is heated before the boiler cuts out. This is not the same as a room or space thermostat, since a boiler will continue to re-fire every time its internal water temperature falls below the pre-set value, until the space is heated to the temperature set by the room thermostat.	Reduces heat losses in transmission round the circuit. Thermostatic controls to an existing electrical heating system (and hot water storage) can also substantially improve its efficiency and reduce waste and carbon emissions.	Too low a setting may prevent the pre-set room thermostat temperature from being reached in cold weather. Too high a temperature especially in mild weather may increase wastage, and there may be little awareness that this is occurring or why.
boiler firing optimisation	Sensor system wired to a microprocessor to optimise boiler firing eg according to user habits – usually in conjunction with a building management system (BMS).	Savings in fuel consumption and extension in boiler life are both claimed.	Systems are known of which can operate at large scale (larger than most parish churches), and more recently are coming onto the market at domestic scale. The habits of individual households may be easier to 'learn'. No such systems at parish church scale are currently known.
'The Tadpole'	This accessory for domestic scale heating uses a centrifuge mechanism to strip air from the heating circuit. Associated with the company marketing 'Quattroseal' (see page 4 above, and www.tadpoleenergy.com/).	Very high gains in efficiency are claimed, associated with stripping close to 100% of entrained air.	Only available so far at domestic scale.
Heating controls –	A range of refinements of increasing sophistication are possible, eg smart sensors, thermal response controls etc. A simpler solution may be to provide thermostatic radiator valves (see below), enabling individual radiators to be turned up or down as well as switched off.	External temperature compensation is needed to ensure the correct flow-rate for the desired internal temperature. Savings in energy and cost disproportional to capital cost may be saved by installing the best controls that can be afforded.	A high level of management and user discipline is needed to get the best value from the installed hardware.
room thermostats	The familiar wall-mounted unit, which signals boiler firing to cease when pre-set room temperature is reached.	Thermostat positioning is crucial for optimal performance. This needs to be considered in relation to external wall and radiator positions – in general not on an external wall.	If in too cold a position, warmer areas will be over-heated; if in a position of maximum temperature there may be cold spots elsewhere, eg close to windows and doors.
modular heating & zoning	May provide for isolation of sub-circuits serving rooms or areas of the building – eg separating a church worship area from a crypt. These may be served by time switches and/or manual control.	Cuts out unnecessary heating of unoccupied areas entirely, bringing considerable saving on wastage.	Since the layout of the heating circuit must be designed to suit, may only be feasible with a new system rather than retrofitted to an existing heating system.
thermostatic radiator valves (TRVs)	Can be installed to a new system or easily retrofitted at low cost to an existing system.	These enable temperature to be controlled locally much more accurately.	But there are risks of individual radiators being turned up high by users then left up for long periods, or of being left up close to open windows – but this is probably not enough to outweigh the benefits.

Technologies, systems	**General remarks and description**	**Applications and benefits**	**Disadvantages, challenges, limitations**
Insulate heating components	Where insulation is absent it can be installed at low cost, and should also be renewed where missing or damaged.	In particular, energy loss should be minimised by insulating all pipework externally, in unheated spaces etc.	Be aware of asbestos risk and comply with Control of Asbestos Regulations. Allow a contingency to remedy concealed faults, eg leak repairs.
Foil backing to radiators	A further low cost measure, applicable to radiators on outside walls, where this is feasible without visual detriment.	This can save significant heat loss from the back of the unit through the wall.	A small scale DIY-style solution.
New heating	Sections below set out some of the alternatives available.	Replacement of an entire heating system offers the potential of huge improvements to comfort standards, energy efficiency and cost.	Total replacement is a major high cost project, often only viable on a life-cycle replacement basis. There is a temptation to make savings eg by retaining existing radiator circuits, which may be the best thing to do in some circumstances, but may also greatly limit the efficiency and viability of boilers, radiators and the new system as a whole. It is essential to obtain good quality professional advice. Timing of heating works is critical, especially a full system replacement, to avoid the winter months.
Radiant heating –	Panels or strips with steel or copper pipework attached to a radiant surface.	Low, medium, high temperature, water and steam. Wall mounted, free hanging, surface mounted or recessed. Radiative heating in general improves efficiency by heating occupants directly at lower air temperature. It is only necessary to heat surfaces to say 10^{o} to control damp, while warming occupants to a higher standard.	If without any convective element, can result in temperature contrasts which are uncomfortable to users.
low temperature hot water	Panel or column units, the latter of the kind often seen in Victorian schools and hospitals, as well as churches, fed by hot water pumped through circulating pipework. Hot water heating units are customarily described as 'radiators', although likely to have a high proportion of convective heat for which they are designed by maximising the surface area.	Traditional low temperature hot water heating has hitherto been a preferred method for heating of church buildings. Significant improvements are claimed for new models of radiator, due to improved heat transfer and optimised surface area to volume ratios.	Often the least bad feasible option, rather than the ideal from an energy efficiency and carbon reduction point of view. Courage may be needed to break free and insist on the best – such as underfloor heating (with or without biomass, heat pump technology etc.)
high level radiant heaters –	Eg at cornice level, on column capitals etc.	These may be cheap and efficient (even those that use electricity – because the heat is delivered so directly to the occupant).	Radiant heating, when mounted at high level on significant architectural features, tends to be visually intrusive and unlikely to be recommended by most DACs. Most people prefer their feet to be warmer than their heads. Arup's point out, electrical or gas radiant heaters 'need to be mounted at high level to avoid the effect of warm heads and cold feet' – but in fact they merely reduce this effect slightly which can still be very uncomfortable especially to the 'follically challenged'.
electric	Most systems currently on offer are electrically powered.	Rapid warm-up, ease of installation, relatively low cost way of heating large internal areas.	Electricity produces more than double the carbon emissions per unit than gas.
gas	Some older systems which use gas burning radiant heaters may still be seen.	Maybe more economical for cost and carbon emissions.	They are noisy (and dramatic) in use and liable to hazard in the event of any gas leak.

Technologies, systems	General remarks and description	Applications and benefits	Disadvantages, challenges, limitations
Low level radiant heaters –			
portable electric units	May be essential in the event of central heating failure.	Simple and convenient from the user's point of view.	Very wasteful of energy and carbon emissions. To be avoided except in emergency – not for compensating for deficiencies in a central heating system.
pew heating –	Can be under pews, in seat backs, under floor, in pew platforms.	Delivers 'near ideal temperature gradient in a high thermally heavyweight nave', an 'efficient way of heating a high lofted space creating a micro-environment in the occupied area, and avoiding heating the full volume'. Recommended especially as an alternative for greater flexibility in floor layout (of the heating, not the seating). Compatible with condensing boilers or ground source (or air source?) heat pumps.	Requires fixed pewing, would not work well with flexible seat layouts.
electric	Pew heating with electric conducting foil: glass fibre impregnated with a conducting polymer.	Rapid warming to comfort levels. If under the seat or behind the seat back, warms the person directly!	Relatively high carbon footprint per unit.
hot water	Or below seat water coil at low temperature.	A low temperature system avoids burns on contact. More carbon efficient per unit.	But slower to warm up. Wire guards may and in some cases should be provided.
Floor warming –	'A strategy to provide the micro environment around the occupied area'.	Can be zoned and thermostatically controlled for flexible or intermittent space use.	Can be awkward and expensive to trace and repair leaks.
floor ducts	Finned tube radiators (or convectors) in floor ducts are frequently seen in churches.	Existing vacant floor ducts can frequently be re-used for a new installation.	Heat distribution may be sub-optimal, if the ducts are under aisles rather than seating areas.
Under-floor heating –	Concealed network coil of plastic hot water pipes.	Typically most cost-effective and often included in major internal reordering. 'Closest to meeting the optimum comfort profile … (with) relatively higher temperature at the floor …than the ceiling.' Best where the heated area is in regular use.	Very costly to install and disruptive to internal fittings especially platform-mounted pews (unless to be mounted within new or reconstructed platforms).
hot water pipes	Arup describe three constructions – buried under screed, floating and with a wooden suspended floor. The option they illustrate is of a reinforced floor screed, above a layer of insulation on a concrete floor slab. The other two alternatives use aluminium plates to distribute the heat evenly.	Commonly used in conjunction with condensing boiler or a heat pump (ground source or air-source?).	Slow response to control. Burying water pipes in concrete is prone to leaks, making the hollow – and accessible – alternatives generally preferable.
electric coils	A less usual (and on balance inferior) alternative, could resemble an electric blanket.	Rapid warming to comfort levels. Avoids risk of leaks.	But expensive and productive of high carbon emissions per unit.
External heaters	Eg the so-called 'patio heaters' – freestanding gas burning units.	No benefits are sufficient to justify their use. If outside in winter or on a cold evening, please wear a coat!	These are self-evidently so wasteful of energy and productive of carbon emissions that there have been frequent calls for them to be banned.

Technologies, systems	General remarks and description	Applications and benefits	Disadvantages, challenges, limitations
Convective heating/cooling –	Blown air forced by concealed fans via ducted distribution and/or a central plenum.	Often recommended by consultants as the most effective way of heating a space as a whole, especially where an effective distribution of local heaters or radiators is not feasible due to fittings, furnishings etc.	Leads to stratification, with heat rising to high level and under-heating at the level of the congregation. Noisy and potentially damage to fittings, especially any pipe organ. Uses electricity to power fans as well as gas or electricity for the air warming itself – therefore tends to consume large amounts of energy and produce high carbon emissions.
'punkah' fans	The term 'punkah' most commonly refers to an eyeball-shaped nozzle as installed in cars, coaches and aircraft. These are also called 'punkah louvres'.	Potentially beneficial in smaller rooms.	May be aesthetically questionable in some cases. .
	Can also refer to ceiling-mounted slowly rotating fans for cooling, as seen in colonial style hotels and restaurants (and is used in this sense in Arup's *Generic Building Solutions* report).	A relatively low cost solution to the problem of stratification.	But not easy to be sure whether it will succeed, without trying in the particular space concerned.
de-stratification fans	More usual description of the rotating fans, when designed to return heat downwards from a high ceiling.	Not to be ruled out, if well chosen and deployed according to the building and situation.	Aesthetic issues in some cases – but may be visually 'lost' in a dark roof space.
Local balance flue units	Eg the popular 'Drugasar' heaters, which burn air taken directly from the outside, and discharge the products of combustion, through concentric compartments in the individual flue for each appliance.	Drugasar claim 'minimal' fuel consumption for their units. Heat loss from distribution pipework is avoided.	This is compared to conventional gas burning appliances which draw air from inside the space. Heat distribution may be inferior, compared eg to underfloor heating. And the limited number of wall-mounted heaters is likely fewer than there would be in a conventional low pressure hot water system, therefore the heat is more concentrated in those locations.
Fan coil units –			
gas	Fan assisted gas convectors have historically been installed in several London churches.	The convection element may improve heat distribution.	But electricity and gas are both used, therefore fuel efficiency is low and carbon emissions relatively high.
electrical –	Whereas a gas unit uses some electricity, this is 100% electrically powered.		High emissions. Not to be advocated, except in the absence of viable alternatives.
over-entrance heaters	So called 'heat curtains' are common at the entrances to retail premises and not unknown in churches.	Comfort is improved within the space by counteracting draughts, and may reduce the load on internal space heating.	High electricity use, wastage of heat to the outside air, and high emissions. All alternatives should be exhausted first.
air conditioning units	Numerous types are on the market, including the packaged split aircon units seen dangling from buildings throughout the tropics.	Enables room by room filtration and cooling, in climates where heating is only needed for a minority of the time if at all, and avoiding the need for ducted distribution. Market pressure for their use is likely to increase in the UK as the climate warms.	Not suitable for churches except possibly in windowless rooms where there are no alternatives for combined heating, ventilation and cooling.
hybrid electric/gas units	A variety of systems are coming on the market eg in the US and the Netherlands, which integrate an electrically power aircon unit for hot weather use with gas space heating in winter – the system automatically switching between one and the other.	Some of these may be worth examining for their efficiency relative to other alternatives, in the event of becoming available in the UK.	Not yet known to be available in the UK.

Technologies, systems	General remarks and description	Applications and benefits	Disadvantages, challenges, limitations
Ventilation systems –	Often called 'air conditioning' – though this is a misnomer unless filtration, humidity control etc are included which is very seldom called for in a church building in the UK.	The time may come when much higher summer temperatures cause artificial ventilation to be more widely considered.	Currently mainly applicable to hot climates. Artificiial ventilation should be avoided in UK churches if at all possible.
natural ventilation	Natural ventilation is almost universal in churches in the UK's temperate climate (and even hot climates outside the UK).	Windows need to be chosen for opening and cleaning eg in church extensions.	Older churches often have opening windows at high level in clerestoreys which can presented maintenance difficulties.
passive ventilation/ cooling	A variety of engineering systems exist which derive benefit from upward convection current in hot weather.	See for example Malta Stock Exchange which occupies a converted place of worship – www.acca.it/euleb/en/p12/index_s0.html - though the cooling system is said not to fully function.	Can be difficult to integrate with smaller spaces in a subdivided interior, without loss of sound exclusion.
portable fans	A wide variety of types are available, especially free-standing on floor or desk.	Short-term use in smaller spaces for user comfort in hot weather.	Justifiable only for occasional use on a very small scale: the electricity is fuel inefficient and productive of carbon emissions.
Centralised cooling	The new underground areas at St Martin-in-the-Fields in Trafalgar Square are a rare example of a centralised air cooling system (see 'Aquifer thermal storage', below).	Very occasional major reordering or extension projects.	Very expensive to install and use, high consumption of energy with proportionate carbon emissions, albeit limited by building management system (BMS).
Air conditioning systems	Centralised full air-conditioning systems though widespread in commercial and publics premises must be all but unknown in UK churches.	Air conditioning, properly so called, is justified mainly for purposes of air quality, humidity control etc – eg in art galleries, laboratories and other specialist applications. Temperature control is secondary as this can be achieved by ventilation and cooling (above) without need for full air conditioning.	It should not be necessary in relatively pollution free UK conditions including towns, except perhaps very limited locations on major traffic arteries through London. Often it is deployed as an amenity for no better reason than to maximise commercial rents.
Heat recovery –			
from neighbours	Heat recovery eg from a neighbouring telephone exchange or data centre may be feasible in rare cases.	A system to transmit steam from Imperial College for use in Holy Trinity Prince Consort Road is in operation, at a tariff apparently at least comparable to the same heat delivered by gas.	Complex to set up, subject to agreement with third parties.
		 Holy Trinity Prince Consort Road	The demand for electricity to serve any such heat pump is likely to make such a system unviable in energy and carbon terms.
active heat recovery	Powered systems have been suggested to extract heat from a church at high level, and re-use it elsewhere on the premises.	Heat would need to be directed to other areas than the main worship area.	To avoid a feedback effect accelerating the convective transport.
'heat harvesters'	A system of active heat recovery to reduce stratification at high level.	Thought by some superior to destratification fans (see previous page).	Hard to evaluate effectiveness and value for money.

Technologies, systems	General remarks and description	Applications and benefits	Disadvantages, challenges, limitations
Hot water services			
Centralised	Hot water may be heated by an indirect system of pipework from the same boiler as the heating, but on a separately controlled circuit passing through a coil around a hot water storage vessel. Any hot water storage vessel should be provided with its own thermostat, mounted just above floor level.	This is normal for domestic and some non-domestic heating and hot water systems.	In a church, a large body of water may be kept warm for the sake of a relatively small hot water demand. Stored water needs to be raised to 60^{o} at least one hour each day. More than 60^{o}C wastes energy and raises the risk of scalding. Less than 60^{o} risks legionella. Legionella can only breed below 50^{o} at the most – but the water must be hotter than that to kill any bacteria already present.
		A hot water storage vessel may also have an electrical immersion heater, which it is essential be fitted with its own working thermostat, for safety as well as efficiency.	Only for use in emergency in the event of boiler failure.
		Some systems often have a 'combi boiler' which heats water on demand and lacks storage.	The need for hot water storage is generally now considered to outweigh any benefits from a 'combi' system.
De-centralised	This should be considered, ie a gas or electric heater providing instantaneous hot water on demand.	Appropriate when the balance between heat and hot water of the demand and configuration/length of distribution runs prevents optimal efficiency from combining them in a single system.	Not suitable when a regular high volume hot water supply is needed for baths or showers.

Technologies, systems	General remarks and description	Applications and benefits	Disadvantages, challenges, limitations
Renewable heat			
Solar thermal	Domestic solar-thermal heating of hot water comprises a roof-mounted installation, either of evacuated tubes or flat plate collectors, containing hot water as an indirect heat-transfer medium conducting solar heat to a hot water cylinder below. Small scale solar thermal systems as described above are to be distinguished from concentrated solar-thermal power, a means of large-scale electricity generation.	This is advocated, for example, by David J C Mackay ('Sustainable Energy - Without The Hot Air). Packaged installations of solar heating may be obtainable, eg from Baxi UK: www.baxi.co.uk/products/solar-heating.htm  Baxi 'Solarflo'	Sufficient water use is needed for the system to be viable – unlikely to be satisfied in most churches. It is necessary to have hot water storage on the premises (rather than, say, a combi-boiler), but this is likely to prove an advantage in the long-term in any event – combi-systems are not necessarily recommended, due to the absence of storage.
Biomass –	Biomass employs a wood burning heating stove, using either processed wood pellets or wood chips. The burning of wood is almost zero in net carbon dioxide emissions when compared with fossil fuels such as coal or gas, because the latter take carbon from deep underground and release it directly into the air – whereas the carbon in plant material including wood was itself taken from the air in the recent past and is therefore not any addition to the natural carbon cycle. After solar panels, biomass is the highest priority renewable technology for rolling out in the Diocese of London. Biomass and solar panels are not mutually exclusive, they can be used together in one building. The following is a summary only. See detailed analysis in *Generic Building Solutions* report by Arup.	Biomass although traditional, and in wide use in Europe and N America, is not yet widely used in the UK. There are currently no functioning biomass boiler systems in the Diocese of London, but case studies may be referenced in the Diocese of Exeter (St Paul Gulworthy, Devon – www.exeterstf.org.uk/case-studies#TOC-Energy-in-buildings), Diocese of Gloucester and the Roman Catholic Cathedral in Norwich. As demonstrated in Withington, Gloucestershire – www.bbc.co.uk/news/uk-england-gloucestershire-11123992	Teething troubles experienced with biomass systems include boiler room sizing (which needs to be sufficient) and layout (must be rigorously planned), accommodation and accessibility of fuel storage – not to be underestimated – and mechanical reliability of the auger which collects fuel and feeds the combustion chamber. Fuel sources are uneven in quality and availability, especially wood chips. The products of combustion may affect local air quality, but are subject to regulation, including the Clean Air Act and the Pollution Prevention and Control Regulations. Maintenance is also a significant additional cost and administrative burden.
wood pellets	Reconstituted wood dust from a saw mill, with an adhesive binder. Arup recommend wood pellet boilers to deal with remaining space heat load (supplementary to electric pew heating).	Gas load is transferred to wood pellets eliminating the carbon emissions from gas heating.	More expensive than wood chips.
wood chips	Direct off-cuts, chipped but not reprocessed.	Cheaper than pellets. Potentially derivable from off-cuts from tree management?	Wood chips perform inconsistently under combustion, have variable moisture content and are subject to irregularity of supply.

Technologies, systems	General remarks and description	Applications and benefits	Disadvantages, challenges, limitations
Heat pumps –	An alternative to biomass – this technology also displaces gas use for heat.	An Energy-Saving Trust study of September 2010 (www.energysavingtrust.org.uk/Resources/Publications) concluded that 'the potential carbon savings' from air and ground-source heat pumps were 'very good'. This was for housing, whereas Arup's study (caveat to the right) was for churches – and ground source only, though air source would likely be inferior. Heat pumps may be better applied to heating water than space heating.	But a heat pump increases electricity use. For this reason, and because heating only is required in most churches not cooling, Arup has estimated net carbon savings to be very small.
air source heat pump	Appropriate in conjunction with under-floor heating (see page 15 above). Heat exchanger is fitted externally (resembling the back of a refrigerator and working similarly though in reverse).	Compatible with floor heating systems. Of most benefit if cooling is required as well as heating.	Visually obtrusive on any exposed elevation, but may be acceptable eg at the rear or when hidden by shrubbery. An air-source heat may only be cost-effective for sites with an electricity supply but no gas, and then only relative to the cost of electricity.
ground source heat pump –			
closed loop –	A closed circuit of hot water pipes is buried in the ground and used for heat transfer from ground to the building when the former is warmer, and (if cooling is required) vice versa when the ground is cooler.	Preferred to an open loop on anything other than very large sites.	
horizontal coil	Buried just under ground and spreading through the curtilage (or eg in a new housing estate under gardens).	Lower capital cost and less invasive than a vertical coil.	But requires a larger unoccupied curtilage area, and (therefore) suitable only for small installations.
vertical coil	The coil is driven into the ground to the necessary depth (80-120m).	Requires less spare site area. May be more appropriate in a churchyard (where there are no burials or antiquities),	But has higher capital cost and risk of disturbing antiquities or human remains.
open loop	In this option, water at the desired temperature is taken from the ground directly, and returned to the ground after cooling (or warming) through a second bore hole at least 100m from the first.	See also 'Aquifer thermal storage' (next page).	Requires a large site area for sufficient separation between ground bores.
bivalent system	Heat pump to provide base load, topped up with a supplementary heating system.	Easier to make the economic case than for a heat pump by itself.	High 'hassle factor' – and still requires mitigation of the capital cost.
Anaerobic digestion	Produces methane-rich biogas. Like photovoltaics, one of the technologies for which a Feed-in Tariff has been established by the government.	Eg for transport. Should be effective in reducing waste of a continuously available resource.	Of limited application to buildings.

Technologies, systems	General remarks and description	Applications and benefits	Disadvantages, challenges, limitations
Energy storage			
Battery storage	In conjunction with solar panels, to provide electricity during hours of darkness.	Potentially feasible and beneficial, if the cost exceeds the difference between the Feed-in Tariff supplement for feeding surplus power into the grid and the cost of buying it back again.	No experience yet at small scale. Considered a major obstacle to large scale solar power generation, eg by Desertec scheme of concentrated solar-thermal power in the desert.
Thermal energy storage	Might potentially be used eg as a supplement to mini CHP (combined heat and power – see above) when there is a surplus of heat at times of peak electricity use.	A large thermal mass eg a water pool is required.	Unlikely to be viable in churches.
Aquifer thermal storage	Where cooling is required. Eg at St Martin-in-the-Fields, where it is used to pre-cool air in a subterranean void which is then circulated via fan convection within ancillary parish rooms – www.maxfordham.com/projects/st-martin-in-the-fields/.	Heat is generally swapped by extracting and re-introducing ground water between two bore-holes alternately in summer and winter when cooling and heating respectively are required.	Requires deep bore-holes at a minimum distance of separation to avoid short circuiting.
Kinetic heat storage	Mechanical potential energy are suggested by Aardvark EM as an energy storage medium in some cases.	Such as clock weights in a church tower?	This has yet to be explored, but it is thought unlikely that the necessary technology could be integrated into existing spaces or systems (and clock weights are progressively being replaced by auto-winding). Nor would it be viable for installation as a free-standing system.

3 Notes

1. Commentary on 'generic solutions' given in this tabulation include the outputs of, among other sources, the following (but it supplements and does not replace them):
   - The *Generic Building Solutions* project, by Arup working with the Diocese of London and the Carbon Trust, as part of the Diocese's *Climate Action Programme*: see www.london.anglican.org/Shrinking-the-Footprint-Generic-Building-Solutions
   - *Greening the Spires,* a study by AECOM (formerly Faber Maunsell) working with the national Church of England Shrinking the Footprint team and the Carbon Trust: for Summary see www.shrinkingthefootprint.cofe.anglican.org/misc_lib/20.pdf
   - *Environmental Audits* (www.london.anglican.org/Shrinking-the-Footprint-Environmental-Audits), by Aardvark EM with the Diocese of London; being the second of three projects in *Climate Action Programme* (www.london.anglican.org/Shrinking-the-Footprint-Climate-Action-Programme)
   - Other technologies available in the market place or under development, which appear to have promising applications. Any assessment is provisional: claims may be as yet unvalidated.
2. Information and opinion here is not necessarily that of the authors of the studies referred to above, which should be consulted. It is non-specific and not to be applied on its own to any project or premises. It is intended to assist in guiding decisions on options to explore, or which may be discarded as not likely to be beneficial. It should be read in conjunction with engineers' reports, and feasibility studies for the PCC of the church concerned.
3. For more information or to discuss, contact Brian Cuthbertson, Head of Environmental Challenge, Diocese of London, brian.cuthbertson@london.anglican.org, (020) 7932 1229.

Cover thumbnails (L to R):
St John Brownswood Park
St Paul Old Ford
St Silas Pentonville
St Martin-in-the-Fields