T4 Sustainability Ltd

Over Haddon Hall

Sustainable Refurbishment and Development

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Context and Requirement

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Context and Requirement

Householders, businesses and community groups are all having to spend ever increasing sums in order to maintain standards of thermal comfort, and this situation is likely to persist for the foreseeable future.

This refurbishment scheme seeks to offer facilities to the community, which in the long term, must have as low an operating cost as possible. In addition to direct reductions in fuel consumption and cost, this will contribute to the sustainability of the district in the broadest sense, by contributing to a reduction in greenhouse gas emissions, and setting an example to the local community, by offering an immediate demonstration of lower energy and more sustainable living in its midst.

Energy conservation measures offer the lowest cost short term options for reducing energy use, climate changing emissions, and end user cost, but still leave an ultimate dependence on fossil fuels which is not sustainable. Building design must now look to generate at least some energy on site, so in addition to energy conservation measures and low energy building design, this document looks at renewable energy systems.

Given the age and fabric of the existing building, options for energy conservation and insulation in this section are limited. Although some problems will inevitably remain, the insulation should be brought up to the highest practicable standard, using the most enduring materials. The same principle should be applied to the new part of the building, which as a consequence, should significantly exceed the minimum requirements imposed by Building Regulations.

It is further hoped that this scheme will demonstrate decentralised, distributed, local energy generation, including the use of renewable energy systems to reduce both costs and environmental footprint. This document is intended to start the process of identifying and evaluating the available options, rather than to offer detailed designs.

T4 has undertaken to review the current situation, and suggest the most sustainable energy technology options that are appropriate to the style of building, and the visual amenity of the area. We will also be pleased to help brief the project architects, and to review the design as the project progresses.

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Future Energy Issues

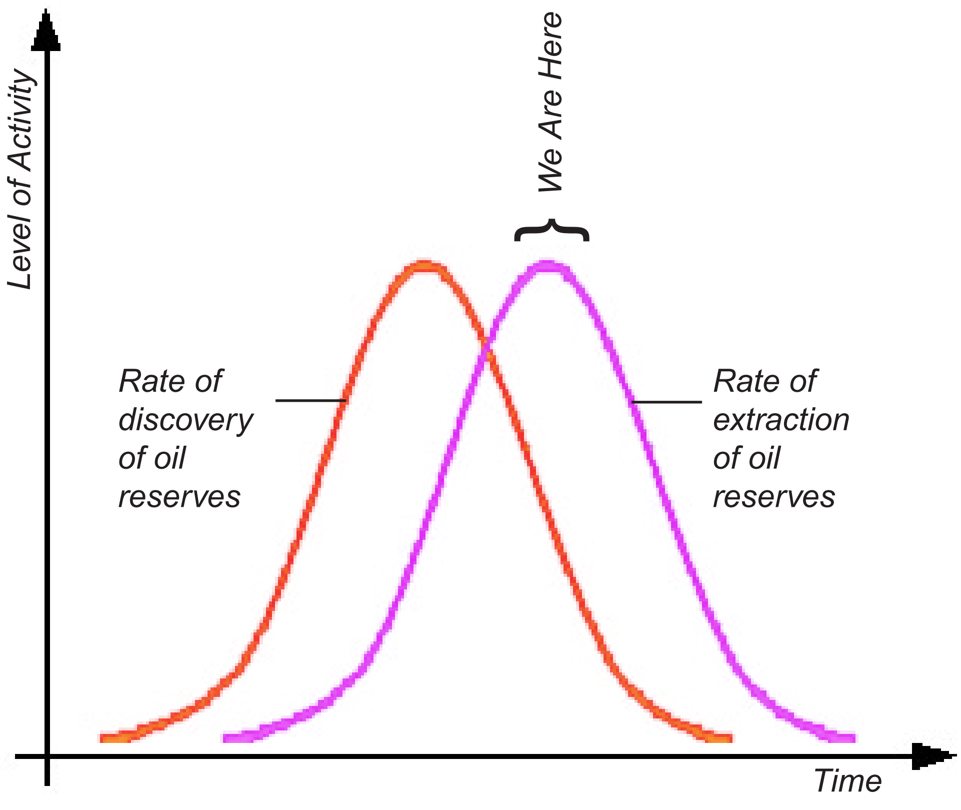
Availability

It is highly likely that fossil fuel reserves will decline in future. Over the years petroleum geologists have observed the trend that in any area where oil is discovered and extracted, the life cycle of the process can be represented by two peaked curves, one (orange left hand curve below) representing the rate of discovery of the resource, the second (purple right hand curve below) following some years later, representing the rate of extraction of the resource.

While it is simplistic to represent these curves as symmetrical distributions, the broad notion holds good for reserves of any size, and can be generalised to include the discovery and extraction of all the reserves on the planet.

The rate of discovery of new oil reserves has now been declining for some years, and although it is not yet clear if world oil production will be able to rise in future years or has already peaked, it seems unlikely that any net increases in production will be significant.

Given that we are now near the peak rate of oil extraction, and world use of fossil oil has only been significant for less than a hundred years, it is likely that we will see a significant decline in world oil production in the next few decades, and in addition to the decline in availability this must inevitably bring about, it is likely that more people will be competing for the remaining resource as developing countries industrialise and their standards of living rise.



Fuel Prices

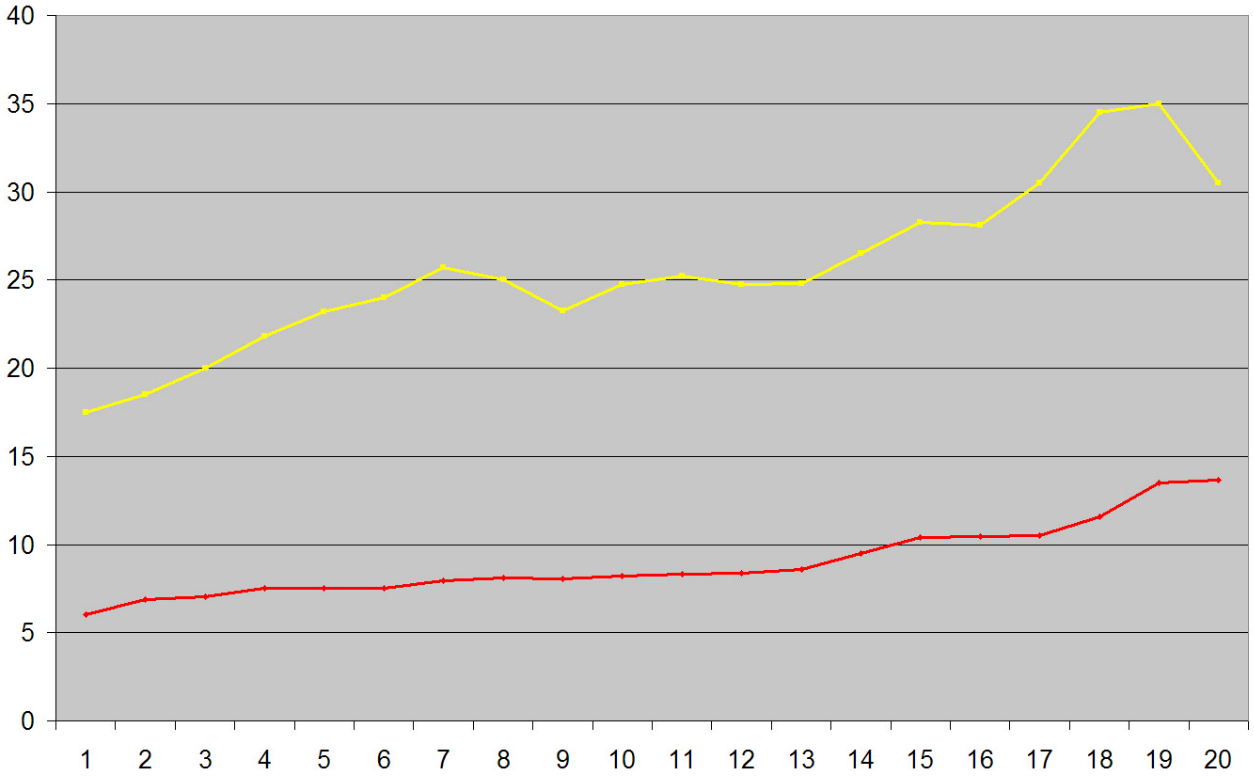
Given the decreasing availability and increasing demand for fossil fuels, price increases are inevitable. These trends may be exacerbated by political instability in oil producing regions, shortfalls in infrastructure capacity and market speculation.

Because of the 'dash for gas' in recent years, UK gas and electricity prices are closely linked, and likely to remain so until the share of our electricity produced from gas is reduced.

The UK is now a net importer of natural gas, and as the proportion of imported gas rises, additional costs may be incurred to cover the shipping of liquified natural gas or the installation of pipelines and their associated infrastructure.

Most energy users have experienced significant price increases in the last few years, and while the rate of increase may vary in future from year to year, there is no reason to assume that energy prices will fall unless radical developments such as nuclear fusion emerge as affordable alternatives to fossil fuels. While such developments cannot be ruled out, it seems unwise to depend on technologies whose efficacy has not been demonstrated on an industrial scale, so it seems appropriate to assume that energy prices will continue to rise, at least for some decades.

Even ten years of 20% annual price increases amounts to a total increase of over 600%, so it should be kept in mind that if a building is designed to last for as little as 50 years, energy prices are likely to have risen to many times their current values before it



2003 to November 2004, wholesale energy prices in pounds per MWh, gas top line in red, and electricity bottom line in yellow.

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is even half way through its design life.

In addition to future increases in the price of fossil fuels themselves, it is likely that further carbon taxes will be imposed, and that heating, and frequently cooling costs, will threaten the operation of buildings with lower environmental performance.

Various schemes are already in use which rate domestic and commercial buildings in terms of environmental management policy, site management, energy use, staff comfort, pollution, water use, environmental foot print of building materials, and life-cycle impacts. The importance of these schemes is growing as the importance of building performance is increasingly appreciated. Although energy rating may appear less important in a building that will be in continuous use by a single community than one which will be bought, sold or leased out many times during its life, environmental performance does matter to the users and community, because the running costs will be a loss of resource within the community, and the environmental impact will be experienced globally.

The most cost effective way to guarantee adequate performance in the years to come is to implement the best technologies now available, especially insulation, while leaving scope to retrofit emerging and future technologies as they mature and their use becomes economically justified.

In thirty years time ‘prestigious buildings’ may be ones that the occupants can still afford to heat.

Efficiency of Primary Fossil Fuel Use

When considering the use of the various energy sources available, it should be kept in mind that the most cost effective measure will be to minimise energy use by insulation of the building, the selection of low embedded energy materials and equipment, and the exploitation of passive solar architectural features.

Whatever the ultimate heat demand of the building may be, it should be kept in mind that this may be met at more than 90% efficiency with respect to primary fossil fuels by the use of condensing boilers, and that any heat delivered by means of resistive electric heaters is likely to achieve little more than 40% efficient use of the primary fossil fuels burned in power stations over all - a very poor outcome.

Outcomes may be regarded as good when the efficiency of primary fossil fuel use significantly exceeds that of condensing boilers.

Comments on the Existing Building

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Orientation and Location

Originally built in 1957, the long axis of the building runs roughly east to west. The building itself is sited above, and parallel to the nearest road. The south side of the building has a large area of glazing which commands a spectacular view over Lathkill Dale towards Youlgreave.

The West end of the building, a small extension added in the 1980s, is largely used for storage, and occasional use as a changing room. The end wall is not easy to see from the outside because of nearby houses.

The East end of the building is visible from the road, but the view out of the East end of the building can not be seen as the few windows are small and of obscure glass.

The North of the building looks onto a field, and the kitchen has a window which gives a view of this.

Located above Lathkill Dale, the site is exposed.

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Insulation

By modern standards the building has little insulation.

Roofs and ceilings

The roof of the west end extension is tiled and felted, and the loft space is used for storage. The roof here is uninsulated, and while boarded out, there is no insulation between the loft and hall space below.

The roof of the main hall, (see picture bottom right), has not been examined in detail, but the insulating material present is unlikely to be thick. An apparently uninsulated suspended ceiling has been in place for some years, though it is likely that this will be removed in the course of the refurbishment to expose the roof timbers.

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Walls

The extension at the West of the building was added in the 1980s.

It is not clear if the walls of the west end extension have any cavity, though given the date of construction, it is likely that they do, and the inner block-work used, may be of a low density type with a relatively good U value.

While less likely, the other walls may also have cavities. If they do, it will be desirable to insulate any sections of these that continue to be outside walls when the refurbishment is complete.

Glazing

The glazing on the south face of the building is unplasticized PVC (uPVC), framed double glazing, which appears to be in reasonably good condition, although there is possible evidence of minor ingress of damp around the uPVC frames, (see picture bottom left).

The internal gap in the double glazing has not been measured accurately, but appears to be wide enough to offer reasonable thermal insulation.

It is not known if a low emissivity glass was used in this glazing, but if it has been, this will significantly reduce the loss of heat radiated from the room, but also produce an improvement in summer comfort by allowing slightly less heat to enter the building via the windows than traditional window glasses.

The use of good quality curtains will further help to reduce heat losses at night in cold weather.

Doors

The doors of the building do not appear to be well insulated.

The fire door to the North may not be in routine use, but on the basis of its likely thickness and area, it seems probable that this allows significant heat loss in cold conditions.

The main entrance to the building is a simple wooden door.

It may be that these doors allow significant uncontrolled drafts into the building, and with no porch or shelter around the main door of the building, everyday access to the building may bring about significant heat loss during the winter.

Floors

In addition to insulating walls and roofs as well as practicable, it is now regarded as appropriate to insulate floors.

Given the age of the building, there is unlikely to be any significant amount of insulation under the floor of the main hall, and the benefit of installing this might be outweighed by the disruption caused, and the cost of restoring the wooden floor.

Other floors in the building are concrete and will be costly to insulate, as this will either involve removing the existing concrete and replacing it with insulation and a new screed, or raising the floor level by adding an insulating layer under a new floor surface.

The first of these approaches may be preferred if under floor heating is chosen as the emitter of the future heating system. The second is likely to achieve less insulation, and may require door frames to be raised.

Other Issues

Water Use

Low water use appliances and equipment have not hitherto been installed in the building.

Upgrading existing equipment, while ultimately of some benefit to the environment, is unlikely to be cost effective in the short term, though where alterations are made and new equipment is specified, water saving strategies should be adopted as a matter of course.

In addition to reducing water consumption, consideration should be given to the use of grey water or rainwater for flushing toilets and watering any plants on site.

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The use of reed beds to assimilate wastes produced on sites is unlikely to be possible given the limited amount of land available, and the proximity of highways and other buildings.

Lighting

A mixture of light fittings are in use in the hall at the moment.

Except in special circumstances, the use of incandescent lamps should be avoided. A wide range of alternatives now exist, which include fluorescent floodlights and spotlights as well as basic strip lights, many of which are available in variants which can be dimmed as well as switched on and off.

Fluorescent fittings continue to offer the highest efficiencies available, but modern high frequency units with electronic ballasts significantly exceed the performance of older 50Hz units with inductive ballasts.

It should also be noted from a health and safety point of view, that any fluorescent fitting without a diffuser or guard represents a risk which should be assessed carefully in any public area. Such fittings might sensibly be upgraded during the refurbishment.

As the hall is used for events, but has no theatrical staging, thought might be given to the provision of some basic stage lighting and controls to give a visual focus for performance activities. Given the scale of the hall, and the desire to conserve energy where possible, the use of LED lighting with variable lamp brightness and colours might be both flexible and effective if this can be afforded.

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Existing Heating System

Although there appears to be a disused gas pipe visible in the corner of an alcove at the end of the main hall adjacent to the location of the original flued solid fuel stove, there are no gas appliances currently in use on site, no connection to the mains gas supply, and no recollection of where access to gas services might be located. This gas supply may only have been used to light the stove, so any pipe work may be too small to provide gas to a modern heating system.

All current heating and appliances are electrically operated. A number of different types of electric heaters are in use.

The storage heater placed in the entrance hall, at least has the advantage of running from low cost electricity purchased during the night. On busy days however, much of the heat purchased may be lost as the door is opened by users of the building

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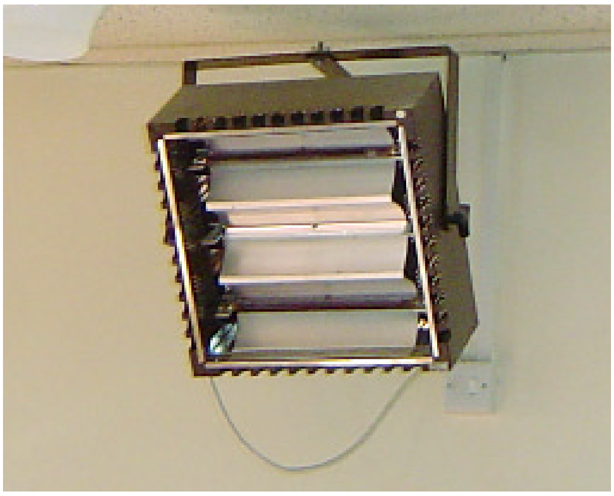
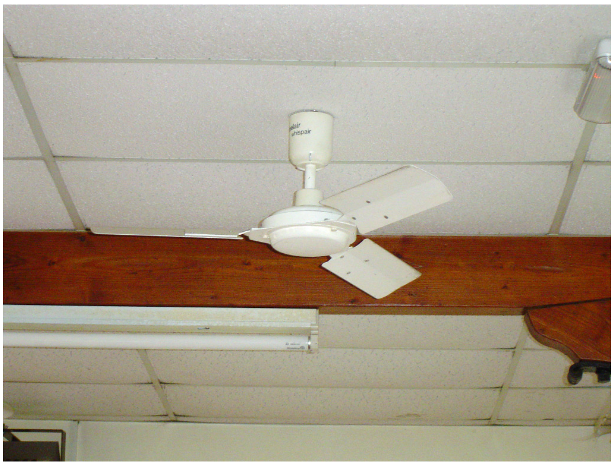


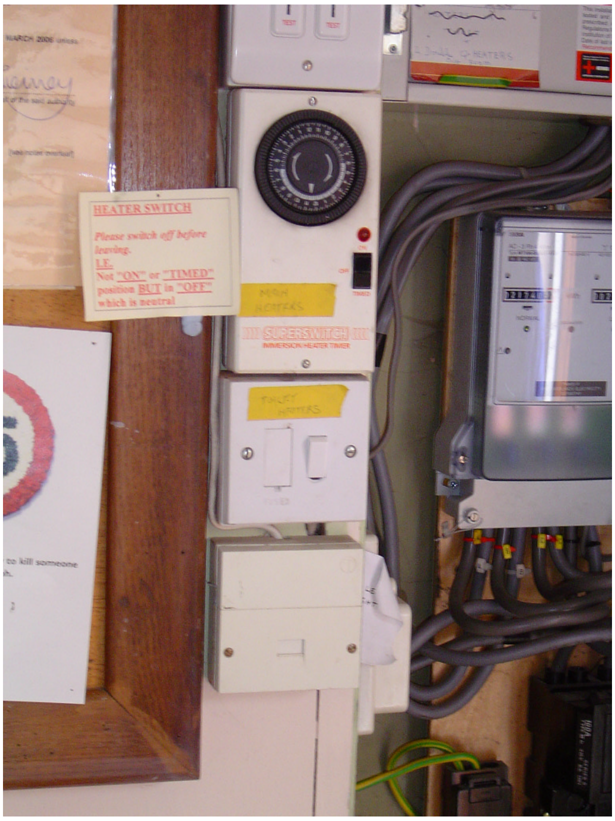
arriving and departing.

In the main hall, heat is delivered by radiant infrared heaters. These have the advantage of producing a sensation of warmth on the skin, even when air temperatures are low.



It is interesting to note that fans have been mounted just under the level of the suspended ceiling. This may be to create some air movement in summer on occasions when the large area of south facing glazing makes the room uncomfortably hot, but might also have a benefit when the heating is running, by reducing temperature stratification caused by the warmest air forming a layer at the top of the room.

While the use of fans can avoid thermal stratification, only weak draughts are needed to overcome convection, and fans of this size may cause more discomfort from perceived draughts than they bring about benefit by distributing the heat within the space more evenly, unless speed con-



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trols are fitted.

A small heater has been installed in the toilet, presumably to avoid freezing of the pipes as much as to maintain user comfort. If such equipment is not installed in the kitchen, it may be appropriate to consider the installation of frost protective heating there too, unless new underfloor heating will keep the pipes warm enough to control this risk.

In zones where there is no gain in comfort to users of the building, frost protection might be delivered by 'heating tape' and pipe insulation, i.e. localised, thermostatically controlled, low power resistive electric heating, provided by wrapping a flexible heat source around pipes that might be vulnerable to freezing. The insulation reduces the power required to avoid freezing, and also offers the benefit that in normal use, less energy is wasted in the delivery of hot water.

A timer has been provided, presumably to allow the most beneficial use to be made of off peak electricity.

While the use of off peak power may help to minimise running costs, reduce the peak load on the national grid, and the amount of infrastructure necessary to support that, it does not minimise the total amount of energy required to provide day time heat for a building, and nor will it minimise the amount of primary fuel consumed in the power station to supply the energy used, nor the total emissions arising as a consequence.

While the use of resistive electric heating is an abysmal waste of resources in the sense that about 60% of the energy in the fuel delivered to the power station is lost at the power station and in distribution as low grade heat, further inefficiency caused by heating the building hours in advance of the time the building needs to be warm, will also reduce the over all fuel efficiency of heating the building. Cheap and simple data logging would allow this problem to be analysed and addressed if desired, but given the impending changes, it is unlikely that this would be a significant benefit.

Improving the heating system in the future will significantly lower the environmental impact arising from the use of the hall, and also the ongoing costs.

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Analysis of Energy Use

No significant data is available on the energy consumption of the building. Despite the construction of the walls and other limitations, it is likely that significant improvements will be made through improvements to the building fabric, and raising awareness of energy issues among the village community using the hall.

Despite the proposed work, energy costs are likely to continue to place financial resources under increasing strain, and this will increase as fuel prices rise, unless strategies are put in place that can offset long term fuel cost increases.

The energy savings such measures are likely to bring about, need to be delivered in a way which is consistent with the character of the area, sound environmental aims, and the available resources.

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Aspirations for the Finished Building

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Adaptation of the Existing Building

It is likely that the new building will comprise the existing building with some refurbishment, and an extension in an aesthetically compatible style.

As part of the refurbishment of the existing building, it has been suggested that the suspended ceiling of the main hall be removed, and the timbers that support the roof be exposed for aesthetic gain.

This may limit the amount of insulation which can be incorporated in a large part the roof, so emphasis should be placed on the selection of thin materials with excellent U values that offer pleasing interior finishes.

Where existing walls will be on the outside of the new building, these should be explored to see if any cavities exist into which good quality cavity insulation might be blown or pumped.

Even if some additional cavity wall insulation can be put in place, the extent to which the existing wall can be insulated is limited, and it may be appropriate to design the extension of the building, as far as possible, to wrap around the existing walls.

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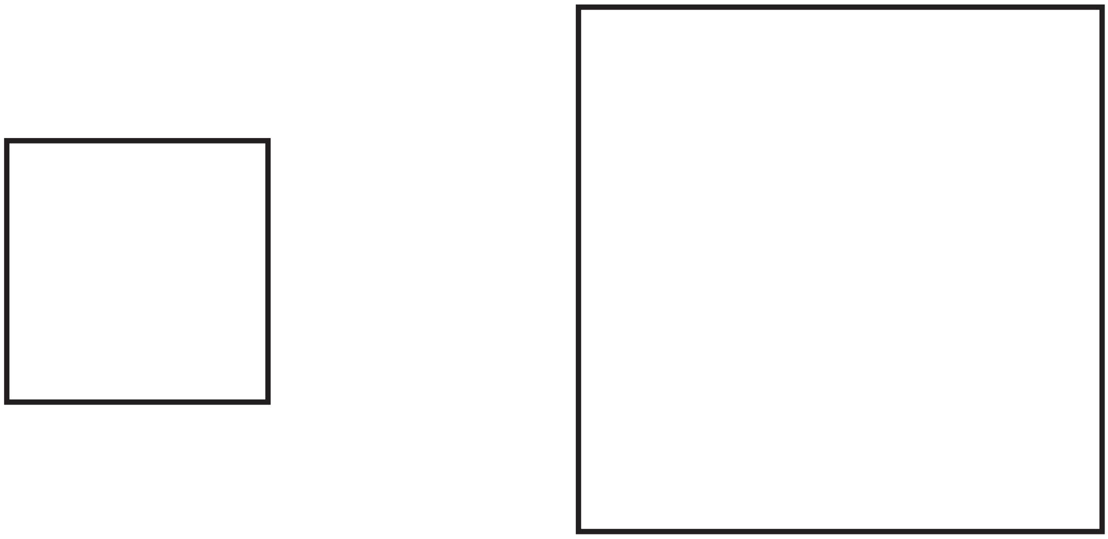
Extention to the Existing Building

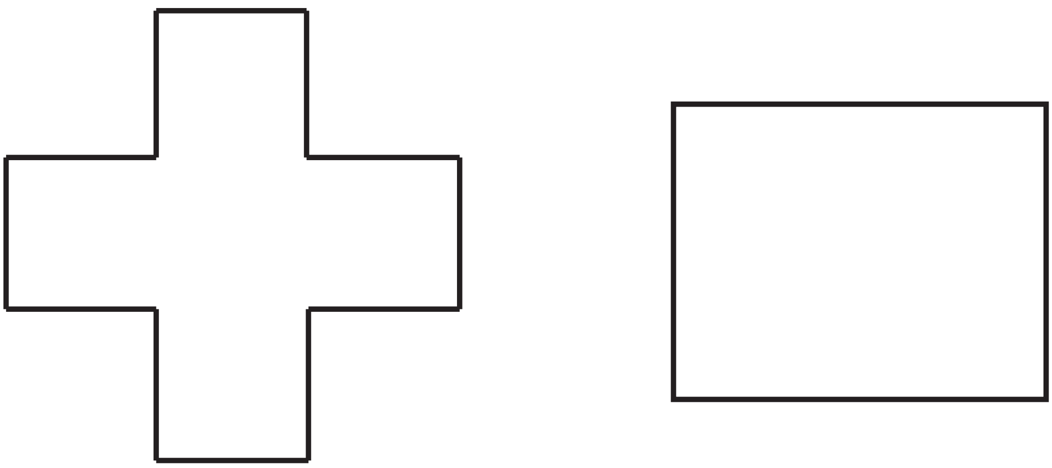
Because much of the lost by the building passes through the envelope, i.e. the walls floors and roof, larger buildings generally loose less heat as more floor area is enclosed per length of wall. For example,

> the left hand square below encloses 1 unit of area with 4 unit lengths of wall giving a floor area to wall ratio of 1:4, and
>
> the rectangle on the right encloses 4 units of area with 8 unit lengths of wall, giving a floor area to wall ratio of 1:2.

The larger square thus has half the heat loss through the walls per area of the smaller one.



Further, structures with simple shapes generally loose less heat than those with more complex designs. Both the layouts below enclose twenty units of area, but the left hand shape uses 24 unit lengths of wall, while that on the right uses 18, thus the simpler



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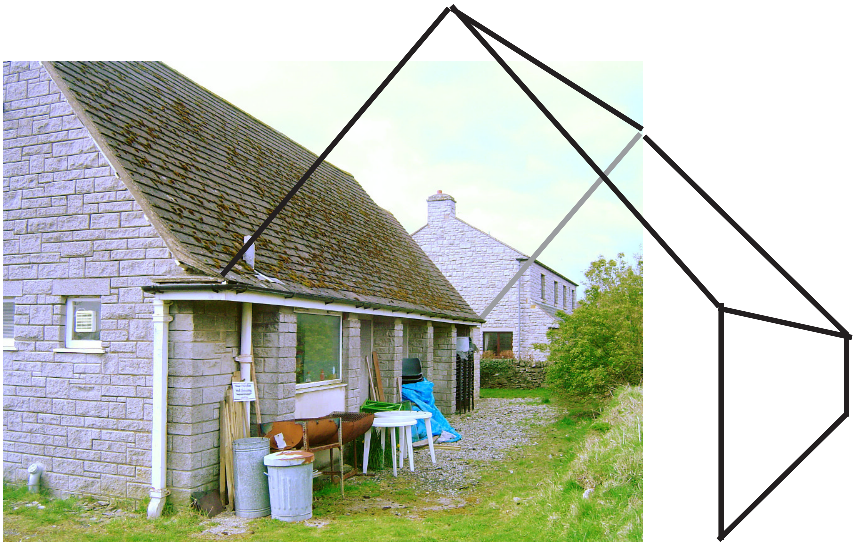
shape has 75% of the heat loss through the walls of the more elaborate design, and might also be simpler and cheaper to construct.

The same idea can be applied in three dimensions giving rise to the notion of surface area to volume ratio.

The design objective should be minimise the length of external wall, (optimise the surface area to volume ratio), and deliver the best possible insulation in the outside walls. ‘Wrapping’ the new walls of the extension around the existing structure will deliver this.

Extending backwards from the north wall with a pitched roof structure would improve the quality of the insulation on the north side of the building, and if the new roof is insulated under the tiles, the new loft space should offer substantial storage space, while the south face of the roof should offer a platform on which solar equipment can be installed without it being visible from around the building or Lathkill Dale below.



Extending to the east and west would enclose more area within the finished building, and also upgrade the thermal properties of the end walls.

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Construction materials

Life Cycle Analysis

In an ideal world it would be possible to select materials on the basis of minimum environmental impact using the technique of Life Cycle Analysis (LCA), analysing the full implications of their use from the extraction and processing of virgin materials, to their eventual disposal as waste.

Unfortunately, little of the necessary information for formal LCA is collected, and even less is made available by companies supplying goods.

Although this information flow is improving as more companies in, and suppliers to, the building industry deploy Environmental Management Systems (EMS), it is unlikely that formal LCA will generally be possible for some time to come, and the deployment of an EMS, while an indicator of commitment to environmental improvement, can not guarantee better supplier environmental performance than a company without an EMS. (For many small companies, an EMS will not generally be affordable, but their environmental practices, while not formally assessed, may still be excellent.)

Although the information required for formal LCA is largely unavailable, our recommendations will be guided by the principles of LCA where possible, the limited information available from suppliers and the construction industry, and on knowledge of local and traditional resources.

Judgements about the environmental merits of various materials and construction methods may also take into account broader ecological issues, as well as addressing societal and community needs, including community involvement in the build, conservation of local craft skills, the use of local materials, and the provision of training to the local community.

Regardless of environmental and technical issues, the selection of materials in the external facade of the finished building must be influenced by the appearance of the existing building and the local vernacular, i.e. stone facing.

Quarries

Given that the existing building facade is stone, it is likely that more stone will need to be sourced, and if none is available for reuse, new stone will have to be purchased. If there is a choice of quarry, it should be kept in mind that less environmental impact will result from the use of locally sourced material, and that the environmental impacts of quarrying depend significantly on the scale of the activity. On a scale that removes whole features from the landscape, it is hard to see the outcome of quarrying as a long term asset, but on a more moderate scale, small abandoned quarries may contribute to local biodiversity, providing niches to wildlife otherwise unavailable in a given area. Selection of the source of the stone might take account of such issues as the size of the quarry, the future of the Derbyshire landscape, and the provision of habitat.

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Sourcing of Bulk Materials

With a view to the delivery of significant financial and environmental benefits, much government resource is being committed to the standardisation and utilisation of recycled materials within the construction industry.

The use of these materials depends on the confidence in the products available, and their compliance with relevant British and European standards.

Materials for reuse are generally covered by waste management legislation. The transfer and storage of such material requires clear audit trails in order to comply with this.

Most recycled materials used by the construction industry should be tested and certified by laboratories accredited by the United Kingdom Accreditation Service (UKAS). This will provide independent data to prove that the materials used meet the necessary standards.

To benefit from the use of recycled building products and materials, specification and procurement have to be carefully managed and constantly monitored. By its nature the process of recycling is opportunistic, the proximity of raw materials, and supply and processing companies to the construction site being paramount if cost and environmental benefits are to be maximised.

'Green' sentiment is not enough. Effective management of the process has to be established with concise and clearly understood parameters and procurement pathways. The process may be summed up by the following steps.

> Identify the material requirements of the project and the subset that can be sourced as recycled products.
>
> Identify the necessary material specifications, (EU and BS standards), to meet the civil engineering requirements of the project.
>
> Select appropriate suppliers within a suitable radius of the site which can meet the specified requirements. Invite tenders.
>
> Evaluate tenders assessing best value in terms of price, environmental benefit, and fit to specification.
>
> Manage contracts to ensure the timely delivery of the correct grades of material, performing the necessary testing and qualification of goods at the agreed price.

To optimise the economic and environmental benefits of this activity, it essential to utilise local and on site Construction, Demolition and Excavation Waste (CDEW) materials as far as possible. This minimises the amount of material brought onto the site, the distance other materials travel to site, and the amount of waste that must be transported to landfill.

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The materials available from recycling are mainly aggregates which can fulfil a range of functions from site stabilisation to concrete ballast and vibro stone columns. The amount of material used for each function will vary according to local opportunity, and the efficacy of the management and procurement systems that can be put in place.

A number of resources are now available which identify sources of construction materials which may be recycled or reused, including the Waste and Resources Action Programme, http://www.wrap.org.uk/. Typical percentage figures for achievable displacement of some virgin materials in a number of applications are indicated below, though recycling is not limited to these elements.

Deep foundations.	
Bored and cast in situ concrete	66%
Steel Pile	60%
Reinforcing Steels	100%
Structural Steels	60 %
Granular Fill	100%
Drainage	
Fin Drains	73%
French Drains	44%
Rubble	100%
Edgings and Chambers	
Concrete Gullies	88%
Concrete Kerbs	62%
Brick Chamber	79%
Concrete Chamber	86%
Floor Slabs	
Ground Bearing	64%
Suspended Floor Slab	70%
Raft	63%
Ground Improvements	
Deep Mixing	10%
Shallow Stabilisation	100%
Vibro stone Columns	100%
Vibro Concrete Columns	51%
Geotextile	90%
Pavements and Roads	
Granular Capping	100%
Stabilised Soil Capping	100%
Asphalt Base Coat	95%
Asphalt Surface Coat	95%
Wet Lean Concrete	62%
Hydraulically Bonded Mixes	100%
Pipe Lines	
Pipe Surround	100%
Concrete Pipe	20%
Iron Pipe	90%
Granular Pipe Bed	100%
Pipe Haunches	62%

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Summary of Advantages

Many recycled materials can be sourced at much lower costs than virgin materials.
The use of recycled aggregates eliminates the payment of the Aggregates Levy, a financial instrument introduced in 2002 to reduce the demand for primary aggregates by increasing their cost, making the use of recycled materials more viable, and stimulating the market for reused and recycled materials.

Transport costs can be greatly reduced if any on site and locally sourced materials can be recycled.

Landfill taxes can be avoided if wastes are reused rather than dumped.

Time and fuel can be saved by local and on site movements of material instead of longer trips to landfill sites and quarries.

Local cleaning of, and damage to roads and the associated liabilities, can be reduced if traffic movements accessing the site are reduced.

Carbon dioxide emissions due to transport are reduced in proportion to the reduction of road miles travelled and mass transported.

In most circumstances the use of recycled or reused material produces less carbon dioxide than use of, and production from virgin materials.

Reuse of aggregate reduces the need to quarry, thus conserving the natural environment.

Reduced traffic movement can improve local public relations due to reduced congestion, noise and emissions.

Summary of Disadvantages

There may be a need for additional management to oversee the procurement programme.

There needs to be clear instruction and a firm commitment from the client.

The commitment to recycled products needs to be established at as early a stage as possible in the design process.

There is a lack of reliable suppliers offering the range of materials required by the industry.

The quality of the recycled product needs to be monitored.

The specification of some materials used in the project may have to be compromised to accommodate the use of recycled materials.

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Natural vs Synthetic Materials

Where choices may be made between natural and synthetic materials, it should not automatically be assumed that either one will necessarily be more enduring, lower cost, higher quality or more sustainable.

Assumptions might be made that for example, that PVC makes a poor choice of material for window frames relative to wood, yet it is a recyclable engineering plastic which takes little virgin material to produce, and may give many decades of service. By contrast, the production of wooden window frames used less toxic material initially, and might help preserve traditional craft skills, but to be sustainable, the wood must be sourced from appropriately managed sources, ideally FSC certified, preservatives may be used in manufacture, and ongoing maintenance effort will be required in the form of manpower and paint.

Under such circumstances, understanding of the ‘life cycle’ of each product does not facilitate direct comparisons of environmental impacts, but LCA does at least expose the issues that should inform the choice to be made, and should reduce prejudice.

Similar issues may arise for example, when selecting insulation materials where different products may be natural, synthetic, or made from recycled materials, each with different performances and life expectancies.

The life expectancy of an insulation product is particularly significant, as they are frequently installed in parts of buildings where the labour and opportunity costs of replacement are significant.

Cavity wall insulations that will settle in a small number of decades for example, will only be partially effective for much of the remaining life of the building, and once lost, full thermal performance is seldom restored.

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Standards of Insulation of the Building Envelope

The highest environmental priority must be the insulation of the building envelope. Retrofit of insulation in future will be disproportionately expensive, and if more insulation is installed during the build, not only are operating costs reduced from the start of the buildings life reducing revenue costs, but the size of the heating plant may be reduced reducing capital cost. This is especially significant if systems such as heat pumps are used because of their higher capital costs.

The level of insulation should not be selected to merely exceed building regulations, but should be chosen with fuel prices thirty or more years hence in mind.

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Further Energy Conservation - Ventilation, Zones and Controls

Ventilation

Before considering more radical measures such as the installation of renewable energy systems, it is worth considering that once insulation in a building has been brought up to the best practicable standard, the majority of the heat loss may be due to mass flow ventilation rather than the conduction of heat through the building envelope.

Although nuisance drafts should be excluded as far as possible, the ventilation requirements specified by building regulations must be met. These include adequate supplies of air for combustion appliances if installed, to eliminate any chance of carbon monoxide release within the building.

Where fans are fitted in kitchens and toilets, they must be large enough to comply with current building regulations, and consideration should be given to their replacement with heat recovery fans or systems.

In kitchens, bathrooms, and other wet areas, these can recover 80% or more of the heat in the exhausted air by using it to heat incoming air using a contraflow heat exchanger.

The ventilation system will have to meet the requirements of current building regulations, ensuring the correct number of air changes per hour to the building, maintaining healthy conditions, controlling energy losses, controlling humidity, and maintaining the perceived freshness of the air in the building. Modern fan systems may also make provision to reduce unnecessary ventilation by operating in response to humidity and other factors, including odours and carbon dioxide levels. As the number of people using the hall at any time will vary over a wide range, variable rates of ventilation seem particularly desirable, and particularly likely to contribute to energy savings.

Consideration should be given to recovering heat from all ventilated air in cool wintery conditions, and in warm summer conditions, provision might be made to draw cool air through the building to chill it at night, (night purge), and to draw air from the cool north side of the building to the south on hot sunny days. In spring and autumn, it may be desirable to duct warm air from the south side of the building to the cool north.

Passive stack ventilation might be considered for summer cooling, but this might result in an unorthodox roof shape and a perceived loss of visual amenity.

Zones

As the building is enlarged, it may be that many activities undertaken will only use part of the building. Under these circumstances it will be appropriate to split the heating into a number of zones so that unused parts of the building need not be heated.

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Controls

Whatever type of heating system is used, it is desirable to minimise cost and maximise comfort.

To save money it is essential that space should not be heated while it is not being used.

The objective of the heating control system is that as far as possible,

> only zones that are in use should be heated,
>
> a zone should not be brought up to temperature until it is going to be used, but should be warm enough by the time it is to be used,

and

> a zone should never overheat while in use.

To maximise comfort, some cooling equipment may need to be installed, which should also be controlled, ideally by the same system.

At times of year when heating is needed, it is common practice to make the time at which heating starts depend on the temperature outside, so that the colder the conditions, the earlier the heating starts. This compensation avoids heating the building for hours before it will be occupied.

Ventilation however may require as much control as heating, with night purge, south to north and north to south air transfers, and possibly dampers on ventilating stacks all requiring control if implemented.

Although each element requiring control is simple, the complexity and amount of control equipment can be minimised by the use of a building management system, (BMS). T4 would be pleased to identify and specify the behaviours required.

The use of BMS may also allow some elements of performance logging and remote access. This might allow the person who books the use of rooms within the new building to control the heating schedule.

Fans in kitchens, toilets and bathrooms will need to operate in response to odours, humidity, etc, but might also be integrated with the BMS system so that they can contribute to the managed ventilation of the whole building as well as responding to local requirements.

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Energy Supply Cost Cutting and Environmental Performance Improvement

Cogeneration, Heat Pumps or Renewables

Beyond insulation and ventilation improvements, there are two ways to get better value for money out of conventional fuels.

The first, termed cogeneration, burns a fuel, but in addition to a thermal output, generates some electricity. The main benefit to this is not the overall efficiency of combustion, but the higher financial value of the electrical component of the output.

The second, the heat pump, typically uses a relatively modest electrical or mechanical energy input to extract low grade heat energy from the environment at a low temperature, introducing it to the building at a higher temperature where its use displaces expensive fossil fuels, and reduces the associated carbon releases to well below those of electric or gas heating.

From an environmental perspective the above options are an improvement over simple fossil fuel boilers and resistive electrical heaters, but generally make some use of primary fossil fuels.

The best environmental option where it is affordable and aesthetically acceptable, is to make increasing use of renewable energy, which while it has a significant capital cost, has little or no ongoing fuel cost or adverse global environmental impact.

Within most non industrial buildings, space heating consumes the bulk of purchased energy.

Renewable space heating is best accomplished by designing high thermal mass buildings to exploit opportunities for passive solar gain. This allows the building to store and release a significant amount of heat without significant change of temperature.

In a refurbishment on this scale there is scope to further exploit the building orientation. Passive solar techniques, active solar water heating and photovoltaic electricity production, and possibly wind power should also be considered along with biomass heating.

Few if any planning restrictions are anticipated with respect to solar energy, heat pump or cogeneration technologies, though if biomass heating is used, an external boiler house and fuel store may be required, extending the footprint of the building.

The aesthetic issues that complicate wind schemes may also be an issue, especially in a National Park, even if no wind related health and safety or noise nuisance issues arise. This said, if the wind available justifies it, it may be appropriate for the community to install a moderate and appropriate wind turbine in the interests of the more sustainable development of the village.

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District Heating

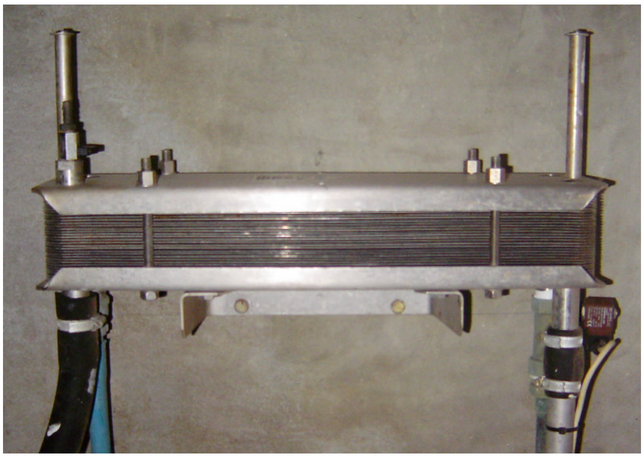
District heating systems have been common practice in many parts of Europe for some decades. While the perception persists that such systems are rare in the UK, it should be kept in mind that a number of cities do use them, including Lerwick, Sheffield, Nottingham, Leicester, London and Southampton. There is no reason however why these schemes need be on such a large scale, and in many parts of Europe, village schemes are common.

While some of these systems such as Lerwick and Nottingham have been based on environmentally contentious ‘energy from waste’ schemes, Southampton uses a geothermal heat source, and the ‘tri-generation’ system emerging in London with the participation of EDF Energy, provides both cooling and heating in addition to electricity generation. Where these schemes generate electricity, they may improve utilisation of primary fossil fuels by as much as a factor of three compared to conventional power generation.

Because the ‘rejected heat’ from conventional electricity generation is generally wasted on an incredible scale, the combination of local medium scale power generation and district heating should perhaps be considered a strategic national priority, though there is no reason why other technologies with thermal outputs should not contribute to such a scheme, nor any reason why such a scheme should only use a single source of heat from a single site. Indeed there is no technical reason why any connected building should not be able to export as well as import heat.

Although district heating schemes require the cooperation of a large number of parties, the energy and cost savings, and reduction of environmental footprint make this an outcome worth striving for.

From the point of view of an end user of the heat, one major benefit is the outsourcing of heat production, and a reduction in the amount of plant required within the house. All that need be installed in the house is a simple heat meter to integrate thermal



Left - A plate heat exchanger. Separate fluids are passed though alternate layers in the heat exchanger so that a large surface area is available to allow the transfer of heat from one to the other. Such heat exchangers operate most effectively if the liquids flow through the device in opposite directions - contraflow heat exchange.

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energy consumption over time, and a contraflow plate heat exchanger. In its entirety, this equipment need be no bigger than a shoe box.

We will assume for now however, that despite the broader benefits, there will be no desire to develop a district heating scheme as part of this project, and that this building will be heated in isolation from the rest of the village, though if any neighbouring buildings would benefit from sharing heating plant, this refurbishment would be a good time to consider such an option.

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Heat Pump Options

A heat pump is a machine which uses mechanical energy and low grade heat (thermal energy at a low temperature) to produce higher grade heat (thermal energy at a higher temperature). Generally these systems are driven by an electric motor, so they are widely perceived as electrical machines.

An indication of the efficiency of these systems is given by the Coefficient Of Performance (COP), which is the ratio of electrical or mechanical energy input, to thermal energy output.

In heating applications, the COPs of heat pump systems improve as the heat source temperature rises and as the heat load temperature falls. They are thus at their most efficient when used to draw heat from a large volume of high thermal capacity material that cools as little as possible during operation, while providing a minimal temperature increase to maintain comfortable conditions in the heated building.

Because COP values are typically in the range 3 to 5, well designed heat pump systems, (ones with bigger COP values), may deliver more thermal energy per unit of primary fuel, (gas or oil used to run a power station or boiler), than a domestic gas or oil boiler, even though the heat pump is typically run from a mains electrical supply which typically only makes about 40% efficient use of its primary fossil fuel.

Heat pumps can draw heat from a number of media, but common varieties include ‘air source’, ‘ground source’ and ‘water source’.

Air source heat pumps tend to use high surface area ‘radiators’ with fans to cause air movement to bring heat into the system. These can be noisy, and as the atmosphere tends to be coolest when the demand for heat is greatest, COP figures are not typically as high as other types of heat pump system.

Ground source heat pumps typically draw heat from a large volume of earth. Heat is slowly transferred to this from inside the planet, and from above the ground, but the high thermal capacity of the soil limits the rate of temperature change as heat is drawn out of it, so if the system is sized correctly, COP values can be significantly better than air source systems. Generally, ground source heat is ether collected from closed loops of pipe buried one to two and a half meters deep, or from boreholes which may be hundreds of meters deep and are expensive to drill.

Water source heat pumps have the advantage that even in a still pond, changes of temperature cause water to move by convection, and this ‘mass flow’ of water, (which has a high thermal capacity), transfers heat more quickly than conduction through a solid medium. Moving water in a stream or river offers an even better heat source, as flows are often large, and cooling this bulk of moving water, even by a fraction of a degree, yields a significant energy output. Unfortunately there is no appropriate body of water in the area.

Although it is desirable to let heat collection loops run at as high a temperature as

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possible, more lower grade heat may be extracted if necessary by letting the heat pump input temperature fall with some efficiency penalty. If the input loop temperature can fall below 0°C, an antifreeze must be used to prevent the formation of ice damaging the system. Although ethylene glycol has been used for this purpose, this is quite a toxic material to many species including man. Should antifreeze be required, we would thus prefer to see the use of a propylene glycol based product. MSDS hazard identification for this material states “No particular hazards known“.

Various hybrids of the above systems are also possible, and ‘open loop’ systems may be constructed which draw water from one location, extract heat via a heat exchanger, and returning it to the same body of water. Although there is no open water on site, an alternative is to draw ground water from one borehole, and return it to another nearby. As water flows back from the second borehole to the first, it draws heat from the ground in between, giving it access to large reserves of low grade heat, but such a system might not be cost justified on a small scheme, which being at the top of a hill, may be a long way from the water table.

Problems With Heat Pumps

In practice the requirement to keep the heat pump output temperature as low as possible means that the best COP values will be obtained when using wet underfloor heating rather than radiators, as underfloor heating, having a much larger surface area, need only run at a much lower temperature. In this instance there may be little possibility of installing any underfloor heating in the existing hall. As a rule of thumb the use of radiators reduces the COP by about 1. This can be mitigated by fitting more and larger radiators, and possibly using fan assisted radiators where space is limited. This approach might be used in the old parts of the building if a heat pump is selected. Fan assisted radiators also have the benefits of transferring heat directly to the air around users of the building, and help to avoid temperature stratification.

One of the biggest issues with electric heat pumps is the supply current required to start them. With little or no ‘soft start’ provision, a heat pump with a thermal output as low as 1.2kW can have a start up surge current of over 90 amps. Many modern units use ‘soft start’ electronics to mitigate this problem. This makes the switch on surge current smaller, but of longer duration.

A heat pump with a COP of 4 and a thermal output of 10kW would require a 2.5kW electrical input. In a single phase electrical 250VAC system, this would require a 10 amp supply current to run.

In practice, heat pumps above 10 to 15kW tend to require three phase power supplies which reduce the current required per phase, cutting power losses from the supply cables by a factor of nine. The difficulty of three phase provision may be overcome in a domestic setting by using a number of small single phase machines, though these may have a higher capital cost. As three phase motors tend to be more efficient than single phase, and three phase power is already available on this site for the existing electric heating, (see picture at top of next page), there is no advantage to the use of single phase machines whatever the heat demand.

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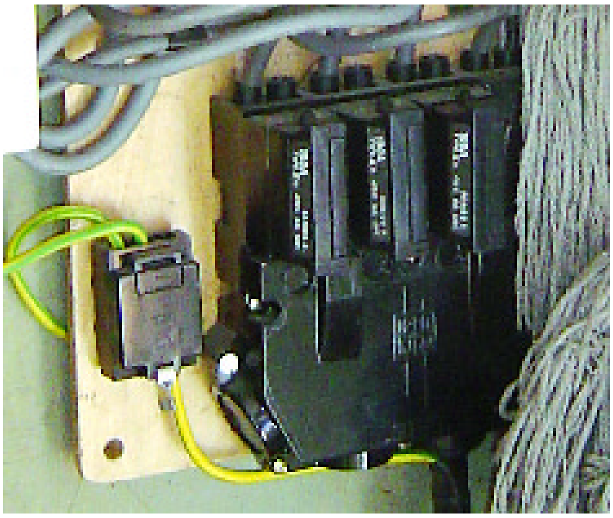

Possible Ways Forward With Heat Pumps

Ground source heat needs to be collected from outside of the buildings to be heated. MDPE pipe work is normally used for near surface heat collection (pipes at a depth of 1 to 2.2 metres).

Although the heat demand of the finished building is not known, it is likely that there will be enough external ground area to collect heat from the land surrounding the building, and if the groundworks are done while JCBs etc are on site, their cost may be within acceptable limits.

As a rule of thumb, 10 metres of linear trench is required per kilowatt of installed heating capacity, with each 10 meters of trench containing about 60 meters of looped MDPE ‘slinky’ pipe. While this can be installed around the new building, this must be considered when the final building configuration is known, and the pipe layout may need to be chosen to facilitate access for trench digging equipment. Given the gradients on parts of the site, it may be unwise to put heat collection pipe work under roads and pavements in case this contributes to ice formation in winter.

The main practical heat collecting alternative is the drilling of boreholes. These are generally regarded as relatively expensive, but a significant part of the cost may be getting drilling equipment to site. This overhead becomes less significant as the size of the system increases.

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Biomass Heating

As the hall is in a rural area, of which a significant part is woodland, it is worth considering wood burning as a means of space heating.

Wood is generally burned either in the form of logs (cordwood), chips or pellets.

Cordwood burners require manual handling of significant amounts of fuel and tend not to be very efficient.

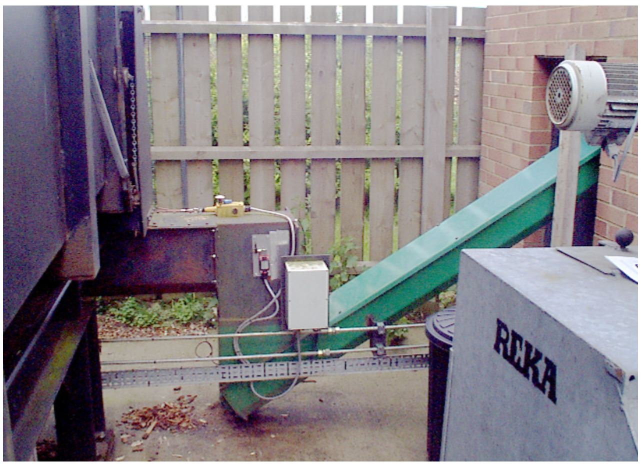
While pellets can be handled automatically and some are now manufactured in the UK, considerable energy and perhaps some chemical inputs are required to form the pellets, which may be shipped considerable distances prior to use. As the use of woof fuels is only environmentally virtuous if the wood is consumed within a few tens of miles of the point where it is grown, the use of pellets can be hard to justify environmentally.

Wood chip offers a compromise between the amount of processing required prior to burning the wood and combustion efficiency. Unless pellets made from locally grown and processed wood can be sourced, wood chip may well be the most environmentally satisfactory way to burn wood.

Wood burning boilers are fairly large items of equipment compared to other space heating plant, and the energy density of wood fuel is considerably lower than oil, so it should be kept in mind that stores of wood based fuel stores are comparatively bulky.

Assuming that cordwood is eliminated because of inefficiency, the choice of chipped and pelleted fuels remains. Until the full heating requirements are fully known however, the choice between these options cannot be made, but it is worth noting that pellets are the more expensive fuel per unit energy delivered, and while both present some risk of dust explosion, which has implications for fire insurance, this is particularly acute with pellet handling equipment, which requires careful design. A benefit to the use of pellets however, is that their uniform physical characteristics make automatic handling of the fuel simpler and more reliable, especially on a small scale.

Left, a large wood chip store. Right, moving the chip from the store can be accomplished by various screw feed mechanisms such that painted green in the picture.



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If pellets are used, it is likely that they will be purchased, stored until required, then transferred to a small hopper above to boiler.

Wood chip may be purchased on the same basis, but it may also be possible for the village community to participate by growing fuel and managing the process of processing it for use.

If locally produced wood chip is to be used, it must first be dried and chipped.

Correct moisture content is critical to good performance from a wood burner, and it should also be kept in mind that if woodchip is stored in a damp condition, it is inclined to compost, producing material which if it will burn at all, will offer much less heat than the original wood chip.

While it is possible to chip green wood and burn the chips immediately, the efficiency of this process is compromised by the high water content of the chip. A more common practice is thus to dry the cut cord wood out of doors for a year, or ideally two, to bring the water content down to about 35%.

High quality wood chipping equipment that can handle large logs is expensive, and the volumes of material that must be handled to justify such investment are large. For equipment which can chip twelve inch cordwood, we have seen prices quoted of over £100,000. It should be noted however that such a machine is likely to be able to chip enough wood to run a system of the size required to heat the hall for a year, in less than half a day, and can be hired for around £400 per day. Wood chipping costs thus need not be prohibitive, nor need the community take the risk of owning such expensive equipment and having it stand idle most of the time while the warranty expires.

While there are many trees in the area which might be used as fuel, their sustainable use requires that they be replaced with species that are appropriate for periodic coppicing. These might include poplar (populus), alder (alnus glutinosa), eucalyptus (eucalyptus) and willow (salix spp.), and will take some time to become established, but it is possible that appropriate existing trees will be able to meet the halls needs until the first coppice crops become available.

Short rotation coppice (SRC) fuel crops are likely to be harvested every three or four years, and long rotation coppice (LRC) crops every five to ten.

If land is available to grow it, myscanthus might also be used initially, until SRC harvests can begin.

Although it is tempting to select SRC crops because the first crop becomes available sooner, a mixture of SRC and LRC crops will contribute to biodiversity and the aesthetic amenity of the site. The local biodiversity action plan should be consulted.

A survey of the existing trees available for fuel use should be undertaken, taking aesthetic, habitat, and wider ecological and environmental needs into account, as well as the condition and age of the trees, their potential as fuel, and their ease of access and handling.

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Once cut, dried and chipped, the dry chip will need to be stored which will require dedicated dry space.

The boiler will consume a significant volume of fuel each day, and provision must be made to handle this material, either manually or using a screw feed.

The use of a woodchip burner invites a number of strategies, but it should be kept in mind throughout, that as with any heating plant, if the insulation of the building can be upgraded, it may be possible to reduce the size, space requirement and capital cost of the required plant.

The obvious approach is to fit a single boiler to replace the existing electric heating. It is likely that a modern boiler will be able to modulate its output in the range of about a quarter of full power to full power.

Another strategy, is to fit a smaller wood burner to be used to meet the bulk of the heat demand, but on the coldest days, to make up any short fall by the use of other heating equipment This option combines low cost of operation on typical days with high peak power availability on the coldest of days and reduced infrastructure cost. It also offers more fault tolerance than any single boiler solution can.

A final approach might be to use two wood chip boilers, each offering half the peak load requirement . Acting together, these boilers would offer a range of output powers from about an eighth of full power to full power. - a very flexible range of output powers, coupled with fault tolerance.

Given the size of the equipment, the use of a plant room and fuel store seems inevitable, but one alternative remains. Some manufacturers will also supply wood chip boiler systems in ISO containers. Such preassembled installations are simply delivered whole, and plumbed back to the building.

Although wood is excellent as a fuel with net zero carbon dioxide emissions, it is worth making one or two comments that might help to further reduce the environmental impact if its use. Wood is not a perfect fuel in terms of polluting emissions, especially if it is not burned in a dry enough state. Like fossil fuels it may contribute to environmental problems such as visible smoke, acid rain and reduced air quality, and of the domestic fuels, it has the highest dioxin emissions.

Poor quality wood chip containing green waste and unlignified material with a high water content may burn with significant NOx emissions, though some processes press the moisture content out of such plant material, and this nitrate rich extract can be recycled as a fertiliser.

The best emissions come from winter harvested deciduous wood which tends to emit less NOx on combustion, due to nitrates and other nutrient resources being drawn into the rootstock of the plant at the time of harvest.

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Cogeneration - Combined Heat and Power

Combined heat and power systems may operate on a wide range of scales. At the macroscopic scale, they may be linked to district heating systems, yet at a domestic scale, may replace ordinary gas boilers.

Cogeneration systems may use a number of technologies to generate electricity. Depending on scale, Stirling engines, internal combustion engines, steam or even gas turbines may be used to generate shaft power for electrical generators, but the thermodynamics of the process dictate that about two thirds of the applied heat from the primary fuel will typically be rejected as low grade heat, and it is this, collected from engine water jackets, oil coolers, exhaust gasses and the condensation of used steam and combustion gasses, that can be used to operate a district heating system or provide heat to a single building.

Small scale domestic CHP systems have been relatively common practice in Europe for some time. Historically, internal combustion engines have been used, but these have required significant maintenance, and local experience calls the reliability and viability of small scale internal combustion engine CHP into question, especially in situations where viability depends on generating electricity all year, but heat is only required in the winter months.

Small scale free piston Stirling engine and generator systems are now coming on sale. Such systems are still very new, and typically natural gas or oil fuelled. These systems may well herald the direction the boiler industry is taking, and should the Committee decide to use oil to heat the building, one or more such boilers might be used because of the higher cash value of the electrical energy output, and the 'reuse' of this electrical energy as heat is dissipated by appliances within the building that use the electricity produced. The use of more than one boiler offers a degree of fault tolerance which may be felt desirable given the degree of disruption that failure of the heating system might cause.

Left and above - The Whisper Gen co-generation system, about the size of a dish washer, up to 1.2kW electrical, and 8kW thermal output. An oil fuelled version of this boiler is available.

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Wind Electricity Production

Site Issues

Because there is a cube law between wind speed and the amount of energy that can be extracted from that wind, the viability of sites for wind energy production depends far more on wind speed than is immediately obvious.

Sites for commercial wind production are generally held to be viable at annual average winds speeds of 6.5 metres per second or more at the turbine hub height. Large commercial grid connected systems will generally seek to optimise output by mounting the turbine nacelle between 30 and 100 metres from ground level, but planning guidance suggests that dwellings be excluded within a 400 meter radius of machines of this size.

On a sight such as this, if conventional wind turbines are used at all, mast heights must be much lower, and the equipment designed and selected, as far as possible, to blend into the landscape. In some emerging ‘ridge turbine’ designs the use of a mast may be eliminated altogether, but these are not yet commercially available.

Estimates of the wind resource and a scenario based around a moderately sized stand alone turbine are presented in the document “***Over Haddon Hall: Wind Turbine Site Assessment***”, but there are other options that might be considered.

Range of Turbines Available

An ever wider range of small wind turbines is available. On the smallest scale these are intended to be mounted directly on to buildings, though we have grave reservations about this, as vibration levels during high winds might loosen fastenings or crack masonry, potentially causing structural damage and injury. We advise any prospective users of building mounted turbines to obtain a structural engineers report before installing such a system, and concerns may also be encountered with respect to the aesthetic consequences of the use of these turbines on traditional buildings. On new build, the use of such a turbine should be considered as part of the structural design.

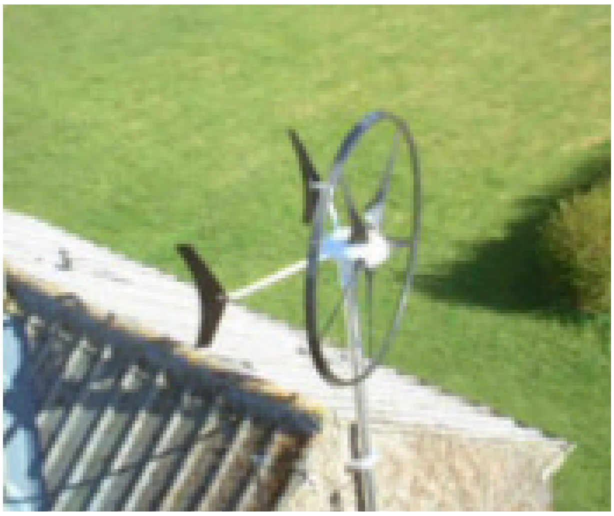
Larger turbines are generally installed as stand alone structures, mounted on concrete ‘pads’. Either a simple mast standing on a single concrete pad may be installed, or the mast may be guyed, with each guy line attached to its own pad, pile or ground anchor, the mast itself standing on a possibly smaller central pad. Unguyed masts tend to be thicker, but the consequent loss of visual amenity is traded for much smaller footprint on the ground.

Most ‘off the shelf’ wind products intended for grid connection are ‘bundled’ with inverters operating to the G59 or G77 specification for grid connected generating equipment, which meets the necessary safety and statutory requirements.

When assessing wind turbines, it is important to look, not just at the manufacturers rated

Left - A Windsave turbine. 1kW nominal power output at a 12.5 ms^{-1} wind speed.

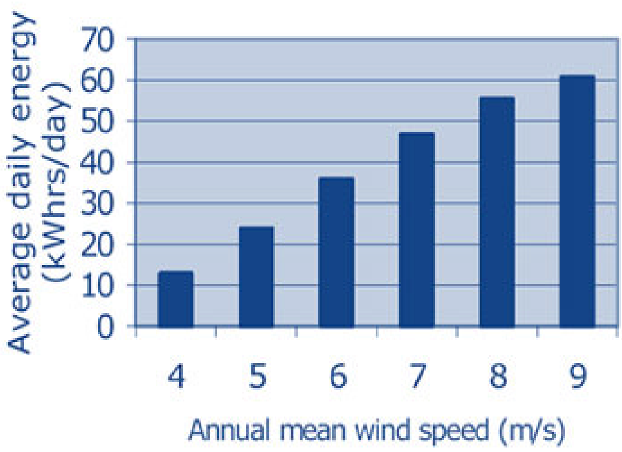
Below - A Renewable Devices 'Swift' turbine.



output figures which may be specified under poorly defined or extreme conditions, but also at the output under the range of wind conditions that typically prevail where the machine is to be installed.

It is interesting to note for example, that the Windsave machine quotes a 1kW rated output at a 12.5 ms^{-1} wind speed, yet applying the ratio of cubes method to estimate the output available at a location with a wind speed of 6 ms^{-1}, it appears that only about 125 watts might typically be produced. Although the UK has world class wind resources, sites with an average wind speed of 12.5 ms^{-1} are very rare !

Manufacturers should produce a 'power curve' graph for each model of turbine they sell, showing the relationship between average wind speed and energy output in kWh per unit of time. For example Iskra Wind Turbines Limited show this graph for their AT5-1 machine.



Iskra AT5-1 power curve.

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While wind turbine power output generally improves as a function of wind speed as the mast height increases, another factor which improves both power output and the life of the equipment is the avoidance of turbulence.

To avoid turbulence, horizontal axis wind turbines are generally installed as far away as possible from buildings, trees and other obstructions, but many vertical axis machines are far less affected, and may be installed close to buildings and other structures. Although a horizontal axis turbine might be appear to be mounted well clear of a roof top, it is hard to prove that wind blowing over a complex roof shape will not be turbulent under any given set of wind conditions. This may make vertical axis machines a better choice in many built up environments.

Without long blades that sweep out a large disk, a vertical axis machine may look more like an architectural feature or mobile phone mast from a distance, especially if it can be painted in a neutral colour and mounted on a building in such as way as to appear consistent with the local vernacular from a distance.

A vertical axis turbine. These may be more tolerant of turbulent air than horizontal axis systems.

Much more work could be done to blend all types of wind turbine into landscapes, but in this situation, noise might also be a significant concern, as well as the proximity of dwellings. Manufacturers noise data should be consulted, and visits should be made to see and listen to any turbine which is to be considered for purchase.

Most of the machines pictured here are very small, and it has been our experience, that especially when moving, the blades of such turbines are generally hard to see from any significant distance. The largest turbine that we feel appropriate to this site is the 5kW Iskra AT5-1. To give an idea of scale, a set of blades for this machine is shown on grass on the bottom left of the next page. Although machines of this sort of size raise significant planning issues, some have been installed over areas accessed by the public as architectural features of large buildings, which at least suggests that such applications have not been rejected on health and safety grounds.

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The following page shows Proven wind turbines, painted white to offer some camouflage against their surroundings, (top left on the following page), and uncamouflaged ‘tall and proud’ (top right on the following page) which makes a bolder statement.

Unguyed turbines such as the Proven machine, (top right on the following page), require thicker masts which tend to make them more visible. Contrast the visual impact of this Proven machine with the Iskra AT5-1 machines at the bottom of the next page, which use a guyed mast that is little thicker than a lamp post.

Micro wind technology is evolving at a significant pace, so if no appropriate product can be identified now, it may be worth checking again in a year or two. ‘Ridge turbines’ which are mounted over the apex of a roof are a particularly interesting new

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Above left and right - Proven 600W and 6kW machines. Below - Two Iskra AT5-1 5kW machines.

technology that may come to dominate wind in the urban environment, and also find applications where a tall mast might not be aesthetically acceptable.

As well as being mounted on the apex of pitched roofs as the name implies, similar machines may also be installed vertically on the corners of tall buildings, especially where the gap between buildings funnels the prevailing wind, increasing its velocity, and the power available in proportion to the cube of the velocity.

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Left - The dark line indicates the possible location of a ‘ridge turbine’.

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Building Orientation and Solar Opportunities

Due to the south facing orientation of the building, passive solar heating reduces space heating costs in autumn, winter and spring, though in summer this sometimes results in overheating of the south facing spaces.

The south facing orientation of the existing roof is ideal for most active solar applications, and the construction of a second south facing roof, behind and parallel to the existing one, offers the opportunity to increase the amount of space that might be available for solar panels, as well as offering a location where they may be hidden from view.

Beyond passive space heating of the building, active solar thermal and photovoltaic systems might be used to heat water and produce electricity respectively, though the ideal orientation of panels for water heating depends on the time of day the water will be used. The earlier or later the hot water is needed, the further east or west it is useful for the panels to deviate from facing south, should there be any choice of orientation.

Because of the level investment required and the time taken to recover the installation costs, the best sites on any roof should be reserved for PV panels if these are to be used. In ideal circumstances these might be mounted on 'tracking arrays' on the ground, but as these are unlikely to be aesthetically acceptable, south facing mounting on the front roof is likely to be the best option, offering the least risk of shadowing when the sun is low in the sky. If traditional PV panels are too aesthetically provocative, roof integrated PV tiles might be considered.

Left - The highly visible south facing front roof with little to shadow it. Right - view of the existing rear north facing roof with an indication of where the plane of part of the roof over the extension might lie. This might be shadowed by the front roof when the sun is low.

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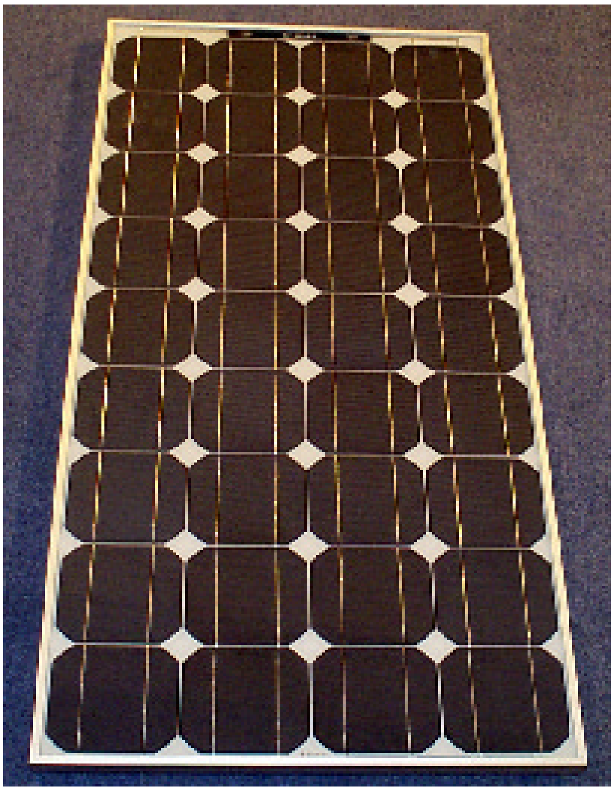
Photovoltaic Electricity Production

Photovoltaic (PV) panels might be installed to generate part of the electricity used in the buildings. These are most effective in cold bright conditions, but performance may be badly compromised if even a small part of the panel area is in shadow, or covered with leaves etc.

When considering the power available from PVs, it is important to remember that the maximum rated power is seldom delivered in UK conditions, and no power is given at night, so a significant area of panel is required to make a useful contribution to the needs of a building.

Common PV panel technologies fall into three broad classes, all based on silicon semiconductor materials. Monocrystalline panels typically offer the most power per area, affordable models having efficiencies up to 16%. Polycrystalline panels are a little less efficient with efficiencies up to about 14%. Both these technologies are long lived and well tested. Products from reputable manufacturers such as Kyocera and BP are likely to have design lives of about 25 years, but may last well beyond that, their outputs diminishing very slowly over time. A third technology, ‘amorphous silicon’ has a much lower efficiency, typically in the range 4% to 6%, and early devices degraded rapidly, their outputs sometimes falling by as much as 10% per year, though the derived ‘triple junction’ PV technology claims to be more efficient and long lived than amorphous silicon. While we do not generally recommend the use of this third family of products, it has given rise to flexible sheet PV materials which can be cut to form roof tiles.



The monocrystalline panel shown left is about 1500mm long, has a peak output of 75 watts, and is among the best PV technologies currently available. As far as possible, access to PV panels should be easy to allow occasional maintenance, but it must be appreciated that this might make them accessible to vandals. At a cost of about £250 per 75W panel, theft and vandalism are a significant threat to the viability of this technology.

Like wind power, a G77 or other approved specification of inverter is required for grid connection, and the solar version might incorporate Optimal Power point Tracking (OPT) regulation, which optimises the power transfer between the panels and their load by drawing the maximum possible current from the panels at their optimum operating voltage.

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It is interesting to note, (left top and middle pictures), that monocrystalline panels can be quite a good colour match with ‘slate grey’ roofing materials, but even where the colours match well, the differences in texture and reflectivity may contrast significantly when viewed from some angles, particularly compared to old roofs that are weathered, and may have growths of mosses and lichens, (bottom left picture).

This may raise planning issues, but allowing the growth of mosses and lichens on PV tiles, such that they blend into the roof better, will inevitably compromise the limited performance of an already costly asset, and ideally periodic cleaning of any PVs should be part of the scheduled maintenance of the building.

If access, orientation or planning issues make the mounting of panels on the building problematic, they may be mounted on frames on the ground. As these may be seen as a non permanent installation, they may fall outside the scope of planning regulations.

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Solar Thermal

Above - Evacuated tube collector mounted on a flat roof.

Below - A large mixed 'on roof' system commissioned by Derby City Council in 1998, (designed by John Beardmore). To the left acrylic fronted Filsol flat plate collectors, and to the right Nippon Electric Glass evacuated tube collectors. The height of these collectors has offered significant protection from vandalism, but to date at least one of the evacuated tubes has been damaged by a brick thrown by vandals.

Of the commonly installed renewable energy technologies, solar water heating generally offers one of the quickest rates of return on investment, and the more hot water is used, the greater the benefit it offers.

For details of the theory, design and implementation of solar water heating systems, please see T4's publication “Solar Power for Dairy Farms“. Although this is aimed at dairy systems, most of the content applies equally to medium and larger sized domestic and community solar water heating systems. It is available as a free download.

One rule of thumb from the solar industry suggests a panel area for domestic systems of $1m^2$ plus $1m^2$ per user of the system, and T4 tends to use this as a guide for its private work, though some European guidelines would suggest the installation of even larger collectors than this. There is no single correct rule that can be applied to system sizing, and in community schemes, a careful analysis must be made of the distribution of hot water demands throughout the week so that the system can be appropriately sized. Some hot water surplus on good days in summer is inevitable, and in winter virtually no solar heat may be delivered, but the greater the collector area used, the more solar energy can contribute to user requirements in spring and autumn.

As with PV, it may occasionally be appropriate to mount solar collectors on frames outside the building, though in all designs, the length of pipe work should be kept to a minimum, and this must be insulated to a high standard, being able to withstand high stag-

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Above - A 2.75m² meter Zen flat plate collector mounted 'in roof' with flashings.

Below - the same type of panel installed 'on roof'. (Both drain back installs by T4).

Above - A 5.4m² Schuco 'in roof' collector flashed into a roof. (Installed by T4).

nation temperatures, weather proof, and remaining undamaged by years of UV radiation.

A considerable choice of panels is now available. The best performing collectors at higher temperatures are generally held to be evacuated tube designs, but these are also among the most fragile. As the tubes are evacuated, they implode on breaking and can scatter glass fragments. They also fail with a bang which vandals may find attractive, and may have toxic coatings inside the glass which could be hazardous to anybody involved in clearing up after a tube has fractured.

The alternative is to use good quality flat plate collectors. These come in a variety of forms, but again risk assessment may dictate the selection made. If vandalism is a significant issue, glass panels might be rejected because of risk of injury in the event of the glass being broken, but fortunately there are a variety of plastic fronted panels available.

Flexible sheet plastic front covers are perhaps best avoided because they are easy to puncture and not easy to repair. Triple wall polycarbonate designs might be avoided because experience with conservatory roofs suggests that this material is likely to become brittle and crack as it ages. This leaves panels with acrylic and Lexan (sheet polycarbonate) fronts which should be quite adequate in normal use. Of these, one is a fairly conventional design using a 240 volt AC power supply for its controller and pump (Filsol), and the other uses a small PV panel and requires no external power (Imagination Solar), providing a minor energy saving over the provision and long term use of mains power for the pump, see picture over.

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Above - View of a 3m² (Imagination Solar) PV powered pumped solar water heating system installed by T4. The PV panels on the right provide electrical power for the systems controller and pump. Systems having PV and solar thermal collectors might add some awareness raising value if PV is not used elsewhere in the district.

The T4 publication "Solar Power for Dairy Farms" can be downloaded from:

http://www.T4sLtd.co.uk/

by following the "T4 Downloads" link.

Options and Interactions

Although least conspicuous, where their use is possible, energy conservation measures should be prized as the most cost effective choices.

It must be kept in mind that Renewable Energy use will become more cost justified as fuel prices continue to increase. Where affordable, Renewable Energy systems should be valued over options which merely optimise the use of fossil fuels, as fossil fuel use is not ultimately sustainable. Some of the options discussed, such as the use of PV panels, solar water heating and small scale wind power, if implemented, will also add value beyond the Hall itself, by helping to raise awareness of wider sustainability issues. Hands on experience of these systems by end users within the village is likely to have far more effect than any amount of urging and advice from outside parties.

Matching Supply and Demand

While any excess electricity produced on site might be exported to generate a modest income, in the absence of a large heat store or district heating system to allow heat sharing, any excess solar or CHP heat may be lost in summer simply because there is no demand for it.

Interactions Between The Options and Technologies

Interactions between sources of supply are also significant. For example, if heat from CHP can meet the domestic hot water requirement in full, the deployment of a solar water heating system is unlikely to be justified. Any increase in output from one subsystem may render the deployment another less viable.

The economic viability of some types of CHP plant if used, will depend on running it for a large proportion of the year, and finding uses for excess ‘rejected’ heat, which is frequently difficult in summer.

Surplus heat can be used to provide cooling or air conditioning at the hottest times of year, but it is doubtful that this would be cost effective for a single community building. District cooling is more easily justified where glass walled office buildings are common. While there is little cost to wasted solar heat, failure to match CHP use to demand wastes expensive fuel, and harms the environment directly.

Buildings that use electric heatering, or other high cost high carbon energy sources, will generally be better targets for renewable energy deployment than those with cheaper and lower carbon alternatives. The existing building is thus an excellent candidate for upgrade to renewable and lower carbon energy systems.

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What Next ?

Consideration of the Options

It is now appropriate for the Management Committee to consider the options and the approaches they would most like to follow into detailed costed designs. Once a small number of options have been identified, specified and costed, calculations can be carried out to estimate capital cost, fuel and carbon savings, and implementation decisions taken.

Grants

It is likely that most of the technologies considered here will be eligible for some streams of grant funding.

Although the Low Carbon Building Program may part fund the renewable and sustainable energy projects, the ‘Community Energy’ scheme, administered by the Energy Saving Trust, might offer some scope for funding any district heating element in the scheme, though at least in the past, a condition of funding has been that at least one public building such as a school benefits the project.

Community Development

Although the deployment of Renewable Energy Systems is virtuous, education of householders in the community to conserve energy and manage demand in their own homes will also be a significant environmental benefit, both reducing fossil fuel consumption, and in the longer term, allowing renewable energy to provide a greater proportion of their energy requirements.

If there is sufficient public interest, local awareness raising work might also cover a wider range of environmental issues including transport, alternative fuels and improving local environmental practices and standards. Community participation and joint working between neighbours might further promote social cohesion in the area.

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Appendix 1 - Project Contact Details

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