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appraisal of heating system options and application of low and zero carbon technology

february 2013

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SM/1308

INTRODUCTION

This report considers the feasibility of a range of heating solutions for the proposed re-development of Grant Lodge, Elgin.

The archive to be located on the first floor of the new extension to the building requires close control air conditioning. This indicates certain solutions for that space. The other areas require heating and ventilation but there is more flexibility over how these might be serviced.

A key element in determining appropriate approaches to the heating of the remainder of the building is the thermal performance of the envelope. The new extension will have a good inherent energy performance. The re-ordered existing historic building is more difficult to treat due to the restrictions of the fabric which imposes limitations on how much upgrading of the energy performance of that (larger) part of the building will be feasible. It is proposed to insulate the roof and the ground floor, but there will be restrictions on any insulation that can be applied to walls and limitations on treatment to existing windows.

We have given consideration to fundamentally different options for heating the historic house and the part of the new extension excluding the archive area and these are discussed below.

APPRAISAL OF HEATING SYSTEM OPTIONS

This part of the report is an appraisal of four different options for heating systems. The options considered range from a 'base case' gas fired heating installation serving the original house and the ground floor of the new extension to a ground source heat pump or a pellet boiler. The options are considered in terms of the economic efficiency and their efficiency in terms of carbon dioxide savings. It should be stressed that this appraisal is necessarily a high level assessment at this stage. No design has been carried out on these options and the capital cost, running costs and carbon dioxide emissions figures are based on approximate data. Having said that, we believe that given the resolution of the data and other assumptions inherent in the assessment the figures are adequate for the purposes of assessing the relative merits of each of the options and for making a robust decision on how to proceed.

It should be noted that the capital costs quoted are costs for the plant and equipment uniquely associated with each option. They do not include, for instance, the entire cost of the new elements of the heating and domestic hot water installations. These costs are common to all options and therefore do not affect the economic assessment of the relative cost effectiveness of each option.

DESCRIPTION OF OPTIONS AND COSTS AT CURRENT PRICES

The total demand for heat for space heating from the house and proposed extension (excluding the archive area) is approximately 150 kW. Domestic hot water demand from the cafe, toilets and the like is 40kW. We have calculated, based on certain assumptions, that the annual requirement for energy from the heating system will be about 295,000kWh. There are a number of ways in which this heating requirement could be met and four options are described in outline below.

Option A – Central gas fired boilerplant for the whole development excluding the archive

This is the 'base line' option for space and domestic hot water heating. A new gas fired boiler or boilers would be utilised to serve the extended building and provide the domestic hot water.

Qualitative Advantages and Disadvantages

The advantage of this option is that it is simple and very low cost. An adequate gas supply is in the vicinity and the cost to connect to this is modest. The disadvantage is that it relies on gas and is therefore not regarded as 'green' technology.

Costs

The capital cost of high efficiency boilerplant in this option would be in the region of £25,000. To that would need to be added the cost of the gas connection of £5000.

Based on the annual demand for heat indicated above and allowing for system efficiency we have computed that at a typical gas price of 5 pence per kWh this translates into an annual fuel cost of approximately £ 16,500 at current prices. Maintenance of such an installation would be in the region of £500 per annum.

Option B – Central ground source heat pump installation for the whole development excluding the archive

A ground source heat pump would be utilised to generate low temperature hot water (LTHW) to serve the heating system instead of a boiler. The heat pump, pressurisation unit and pumping equipment would require a larger plant room as it takes up significantly more room than boilerplant and also makes more noise. This heat pump would be connected to a grid of boreholes located in the surrounding ground and then covered over by the new landscape works. It has been assumed for the purposes of this exercise that the Council would be able to use the land to the north of the building but this would require to be verified. To extract the 150kW required for space heating and make a contribution to the domestic hot water heating would require 28 No 120m deep boreholes. These boreholes would be connected by a network of underground pre-insulated pipework. No lasting evidence of their presence would be left on the surface once the landscaping works had been completed.

The heat pump would provide LTHW for central heating at around 40^{o}C to 45^{o}C. This is considerably lower than the temperature normally utilised in heating systems (around 80^{o}C). This has an implication for the design of the heating distribution system in the existing house, but would be entirely suited to an underfloor heating system in the new extension. To utilise water at this lower temperature the radiators in the existing house would require to be replaced with fan convectors. It also has an implication for domestic water heating, which would have to be either entirely electric or supplemented by electric heating.

Qualitative Advantages and Disadvantages

The advantage of this option is that heating is by electricity using a technology regarded as renewable, and removes reliance on gas which is becoming scarcer and is expected to increase in cost faster than electricity in the medium and long term. The disadvantages are that it is still comparatively new technology, more risky in maintenance terms, and requires special heat emitters due to the low water temperatures generated. Domestic hot water requires to be heated substantially using mains electricity. The electricity supply to the building would require to be upgraded and there would be a cost implication to this also.

Costs

The capital cost of this option, including an allowance for the extra-over cost of emitters in the existing house, is likely to be in the region of £230,000. To that must be added the extra cost of the electricity upgrade to facilitate this form of heating. At this point it is not possible to quantify that accurately as we do not know the implications of this on the local electricity supply network, but for the time being we have allowed a cost of £6000 for this.

We have calculated the input energy demand for the heat pump based on the output heat demand and allowances for the coefficient of performance (ie the efficiency) of the unit. We have also added the consumption of direct electricity for the domestic hot water heating. At a cost of 10.0 pence per kWh this translates into an annual electricity cost for heating of approximately £12,900. Maintenance of such an installation would be in the region of £1200 per annum.

Option C – Central gas fired boilerplant for the existing house and domestic hot water and air source heat pump for the new extension as part of the archive system

This is a hybrid option. Because the existing house is not particularly suited to using the low grade heat from a heat pump, and because the heat pump is not effective at heating domestic hot water, the suggestion is that the existing house and all of the domestic hot water be heated by boilerplant as in option A and the space heating for the new extension building utilise an air source heat pump which would in effect be an extension of the air source heat pump system serving the archive. On the face of it this seems to be a reasonable option and so it was decided to explore its relative performance.

Qualitative Advantages and Disadvantages

The advantage of this option is that it is lower in capital cost and seems to play to the strengths of the two systems. The disadvantage is that most of the heating load is still being served by a gas fired boiler which is not regarded as 'green' technology.

Costs

The capital cost of this option is in the region of £45,000. The gas supply is still necessary at £5,000 and an upgrade of the electrical supply is still probably necessary but it would be more marginal, and less expensive than the larger supply required for option B. Against this possibility it would be prudent to allow, say, £2,000.

Based on the annual demand for heat split between the two systems we have computed that at a gas price of 5 pence per kWh this equates to an annual fuel cost of approximately £15,200 at current prices. Maintenance of the gas fired installation would be in the region of £500 per annum again.

For the heat pump installation in the extension, assuming again a current electricity price of 10.0 pence per kWh this translates into an annual electricity cost for heating of approximately £800. Maintenance of that part of the installation would be in the region of £300 per annum as a marginal extra cost over the maintenance of the archive system.

Option D – Central wood pellet fired boilerplant for the whole development excluding the archive

This option would utilise systems within the house and the extension as option A, but instead of a gas fired boiler it would be possible to install a wood pellet fired boiler. This boiler would be located in a plant space with a remote feed arrangement from a storage hopper. This boiler would be connected to a vertical flue arrangement which would rise up to above eaves level of the main historic house. It must terminate at a height sufficient to ensure that the smoke from the boiler does not cause a nuisance to neighbours.

Qualitative Advantages and Disadvantages

The advantage of this option is that it is regarded as 'green' and in terms of official government figures has the lowest CO_2 emissions of any of the options. It can utilise a normal radiator type heating system in the existing building. The disadvantages are that a reliable and cost effective source of pellets would require to be established which does not have excessive associated transport costs (and CO_2 emissions). At current prices pellets are almost as expensive as oil. The future movement of pellet prices is difficult to predict. The maintenance requirements for pellet boiler installations are greater than for gas fired boilers and the fuel source requires to be managed in terms of deliveries etc. There may be restrictions on the use of this sold fuel in the suburban area which would require to be discussed with the planning and environmental health departments of the local authority.

Costs

The capital cost of the plant and fuel store enclosures etc in this option is in the region of £100,000.

Based on the annual demand for heat indicated above and allowing for system efficiency we have computed that at a typical pellet price of £250 per tonne this translates into an annual fuel cost of approximately £19,500. Maintenance of such an installation would be in the region of £1,200 per annum.

ECONOMIC APPRAISAL

It is obvious that there are significant cost differences between the options, with the 'base line' gas fired installation option A costing significantly less than the others in capital cost terms. We must consider however the anticipated rate of increase of fossil fuel based energy costs over the next decade or so, which is expected to be significantly greater than general inflation. The question then is to weigh the life cycle costs of these options against each other so that a rational choice may be made taking into account capital and operating costs.

The fairest way in which to carry out this appraisal is to apply a method that discounts future costs taking into account inflation and opportunity cost of capital so that the total effective cost of each option over a set time horizon may be brought back to a common present day equivalent cost or so-called 'Net Present Value'.

A key consideration in this evaluation is the cost of the energy. The future cost of any fuel is difficult to assess due to the volatility of the markets. The cost of electricity is similarly affected by volatility in the energy markets and the cost of fuel, although in the UK the contribution to generation made by renewable systems like hydro and wind and in future from nuclear generation leads some commentators to suggest that the rise in cost of electricity may be less rapid than the rise in cost of gas. Finally an assessment must be made of the inflation rate to apply to pellets.

For the purposes of this appraisal we have set the rate of general inflation at 5%, the rate of inflation of electricity at 8% and the rate of inflation of gas at 12%. It is assumed that pellets will rise in cost by the general rate of inflation. The cost model can be run with any combination of the variables.

Another factor in this assessment is the Renewable Heat Incentive (RHI). This is a government funded payment that applies to heating technologies regarded as renewable. In the context of this development, the heat pump or pellet boiler options might potentially qualify. However the government has just concluded a consultation process which has recommended setting a minimum standard for the energy performance of the building to which the technology applies. Given the nature of the existing historic building it is not obvious that overall this development would meet the criteria. The results of the consultation and the recommendations were due to be published at the end of 2012 but at this time the position is unknown. We have carried out the assessment ignoring the effects of the incentive payments for the time being. If the client is interested in pursuing a particular technology then a more detailed assessment of the effect of the incentive payments could be carried out when the position with the RHI is clarified shortly.

The net present value cost analysis attached illustrates the net present value of each installation after 12 years. Interrogation of the cost model demonstrates that option D, the pellet boiler installation, breaks even with option A in a little less than 12 years. Option B, the whole building heat pump option, breaks even with the base line gas option A in a little under 15 years. Option C, the hybrid option, does break even with option A in a little under 17 years, however the life of the heat pump machine will not be more than 20 years and at 15 years there is the increased risk of major maintenance operations or component replacement being required, so in fact this breakeven point is not likely to be reached.

CARBON DIOXIDE EMISSIONS APPRAISAL

Economics are only one consideration in assessing the options of course. The object is to reduce carbon dioxide emissions and so the annual emissions of each option should also be a factor in the decision between these.

It should be stressed that evaluating the emissions is an even more approximate calculation than the cost assessment. The carbon dioxide emissions of any given fuel type will vary through time depending upon how that fuel is extracted, processed and conveyed to the building. The current official DECC data on carbon dioxide emissions associated with the fuel types considered for these options is as follows:

Gas – 0.18 kgCO_2/kWh
Wood Pellets – 0.039 kgCO_2/kWh
Electricity – 0.52 kgCO_2/kWh

The annual emissions associated with each option are therefore:

Option A – 56 tonnes
Option B – 67 tonnes
Option C – 57 tonnes
Option D – 14 tonnes

The result that may seem surprising in the above is that the heat pump options are worse in carbon dioxide emission terms than the gas fired boiler. That is because almost always heat pumps are options considered in rural areas against oil or lpg heating rather than heating with natural gas as the fuel. Against oil or lpg they do perform somewhat better, but natural gas has a relatively low carbon dioxide emissions factor and as a result heat pumps do not offer the same environmental benefits. If carbon dioxide emission is the key driver in the decision, then the wood pellet option is significantly lower than the others, assuming that the relevant permissions to use wood pellets could be secured. This figure is sensitive to the transport distances for pellets however and may be somewhat greater if that distance is more than about 50 miles.

This assessment does not take into account other factors such as the embodied carbon dioxide emissions in the equipment itself. There is a dearth of reliable data on this subject and no adequate assessment of this is possible at present.

CONCLUSION

Once the client has had an opportunity to consider the report we anticipate that they will wish to consider one or two of the recommendations in more detail. The position with the RHI should become clearer shortly in terms of the eligibility of the project given the energy performance of the existing listed building. We will then be able to clarify the position with potential RHI payments for the heating options.

SM/1308
February 2013