An environmental solution for two holiday cottages

The brief

A proposal for space heating and hot water generation was requested for two holiday cottages in a barn conversion in Hope Valley.

The planning department wanted the solution to have the lowest possible carbon footprint by incorporating solar thermal or ground-source heat pump technologies. The owner also wanted possibilities for minimisation of energy consumption and running cost to be investigated.

Under-floor heating was planned for the ground floor and radiators for the first floor of both cottages. Natural gas and single-phase electricity connections were available at the cottages.

The options

Option 1 - Heat pump

A heat pump transfers energy in the form of heat from a cooler location to a warmer location. It uses the refrigeration process and transfers low temperature energy to a refrigeration loop, compresses the refrigerant to a high temperature, and transfers this heat to the hot water and heating distribution system, or, in the summer, removes it from the home.

There are several different kinds of heat pumps available, depending on where the energy is sourced. For this project a ground-source heat pump was requested by the planning department. Ground-source systems use heat extracted from pipes laid horizontally or vertically in the soil.

The capacity of a heat pump is limited by the electrical connection. The cottages have a single phase connection, which would enable only a lower power heat pump. A hot water storage tank would therefore be necessary in combination with the heat pump. Since heat loss in the tank is unavoidable, more hot water would need to be generated than would be used. The tank would also take up space, which comes at a premium in the cottages. It would also take time to heat up the storage tank once emptied.

Heat pumps use electricity, which is currently mostly generated in coal fired power plants. Coal has the highest level of carbon dioxide emission per kWh generated and over 66% of the heat generated in a fossil fuel or nuclear power plant is lost generating and transporting electricity. From a carbon footprint point of view it makes more sense to heat the house with the fuel directly rather than to generate electricity with it in a power plant.

Option 2 - High-efficiency condensing boiler

A high-efficiency condensing boiler would easily generate the required heating output for the under-floor heating and radiators and would also meet the requirements for hot water. A condensing boiler normally has an efficiency higher than 90%.

As the heating would be instantaneous, no heat loss would be incurred for storage, since no hot water tank would be necessary.

Condensing boilers use gas, which has the lowest carbon emission of all fossil fuels. The carbon footprint of a condensing boiler is much lower than that of a heat pump, because the heat pump uses electricity generated by coal-fired power plants.

The price difference between gas and electricity in p/kWh also makes a condensing boiler much more cost efficient than a heat pump.

Installation of a condensing boiler would be about half the price of a horizontal ground-source heat pump installation. A vertical ground-source heat pump installation can be as much as five times more expensive, depending on the cost of drilling.

Although COP (coefficient of performance) figures for heat pumps indicate higher efficiency, various factors such as the need to generate hot water at a temperature >50ºC and the need for hot water storage effectively reduce the COP. Therefore, if a natural gas connection is available, a condensing boiler is the more economical and environmental option.

Reducing heating cost – Ventilation with heat recovery system

A previously commissioned SAP rapport showed that ventilation losses were expected to be 33% of the total heat losses in the properties. At current energy prices this would amount to a cost of approximately £100 per year. A heat recovery system would recoup 90% of these losses. The pay back time would be well in the lifespan of the recovery unit.

A heat recovery system extracts air from the kitchen, bathrooms and utility room through a heat exchanger. The system then supplies fresh air to the bedrooms and living rooms through the same heat exchanger with 90% of the heat being transferred.

This would mean that the cottages would benefit from a constant supply of heated fresh air without the need to open windows. The system would eliminate condensation and filter the air to improve the quality for asthma and hay fever sufferers. Noisy bathroom extractor fans and window trickle vents would not be needed. It would also reduce any incoming noise from traffic and provide increased security against burglars.

Sensors in the heat recovery unit would bypass the heat exchanger in summer, so the unit would act as a cooler during hot periods.

If it is assumed that 1 m^2 of solar thermal panel generates 1000 kWh of heat during one year, ventilation with heat recovery would replace approximately 1.5 m^2 of solar thermal panels.

Recommendations

A small high efficiency (condensing) gas boiler would be the most cost effective and environmental solution for providing heating and hot water to the two cottages.

To even further reduce the need for space heating by 30%, the properties could use whole house ventilation with heat recovery.

Since no hot water storage would be needed, it would be difficult to add solar thermal panels to the project. However, if the funds reserved for solar panels would be used for ventilation with heat recovery, the total effect on the carbon footprint would be similar.

With under floor heating, feed temperatures of 35 ºC would enable heat transfer from the heat source into the properties. If small radiators were to be used, higher feed temperatures would be necessary. As a result, the efficiency of the boiler would be reduced. To mitigate this, large surface radiators should be used.