District Heating System at CAT

Using a heat main for year round sustainable heating and hot water...ideal for small scale housing projects or communities.

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Introduction

We use energy in the UK for a wide range of activities: everything from driving to work to watching the television. The single largest end use (over 40 per cent) is heating buildings and the hot water in our taps to temperatures below 80°C. The vast majority of this requirement is supplied by the burning of natural gas. The national gas network delivers over twice as much energy as the national electricity grid in a year, a fact often overlooked by energy policy makers.

Of course the burning of such a huge amount of fossil fuel has a big impact on the environment, contributing to global warming, acid rain and other atmospheric pollution. In addition the UK's gas reserves in the North Sea are beginning to run out, in the next couple of years the UK will become a net importer of natural gas.

At CAT we have been trying to reduce the impact of our heating demands by a number of measures. Principally these are

- heavily insulated buildings;
- solar water heating for domestic hot water;
- the use of renewable fuels such as wood from managed woodland;
- efficient heating systems and controls.

IN 1997 we started design work on the new information and shop complex (Ateic). The brief required that the building would collect as much energy in a year as it was likely to use.

With the installation of the woodchip boiler in 1996 CAT started to make a move away from the use of gas heating in buildings to renewable energy sources. We discovered that the woodchip burner performed well when running at full power in winter, but in summer when demand was lower problems occurred. If output of the woodchip boiler outstripped demand, there was a danger of water overheating and boiling within the pipes.

The solution that we came up with was to incorporate a large solar collector in the roof of the Ateic building to produce hot water with it's output peaking in summer months. There was no use for this heat in the Ateic building itself in summer, but there was a big demand for hot water from the restaurant. A way of transporting heat 270 metres across site had to be found. The solution was to install a system of insulated pipes (known as a heat main or district heating system) with Ateic at one end and the restaurant and woodchip boiler at the other. Such systems are quite common on the continent, but have failed to catch on in the UK because of the ready availability of natural gas. In winter Ateic would import heat from the woodchip boiler, in the spring and autumn it would be largely heated from the output of the solar collector, and in summer it would supply the majority of heating for the site.
Figure 1 shows the proportion of energy delivered by district heating schemes in a number of European countries.

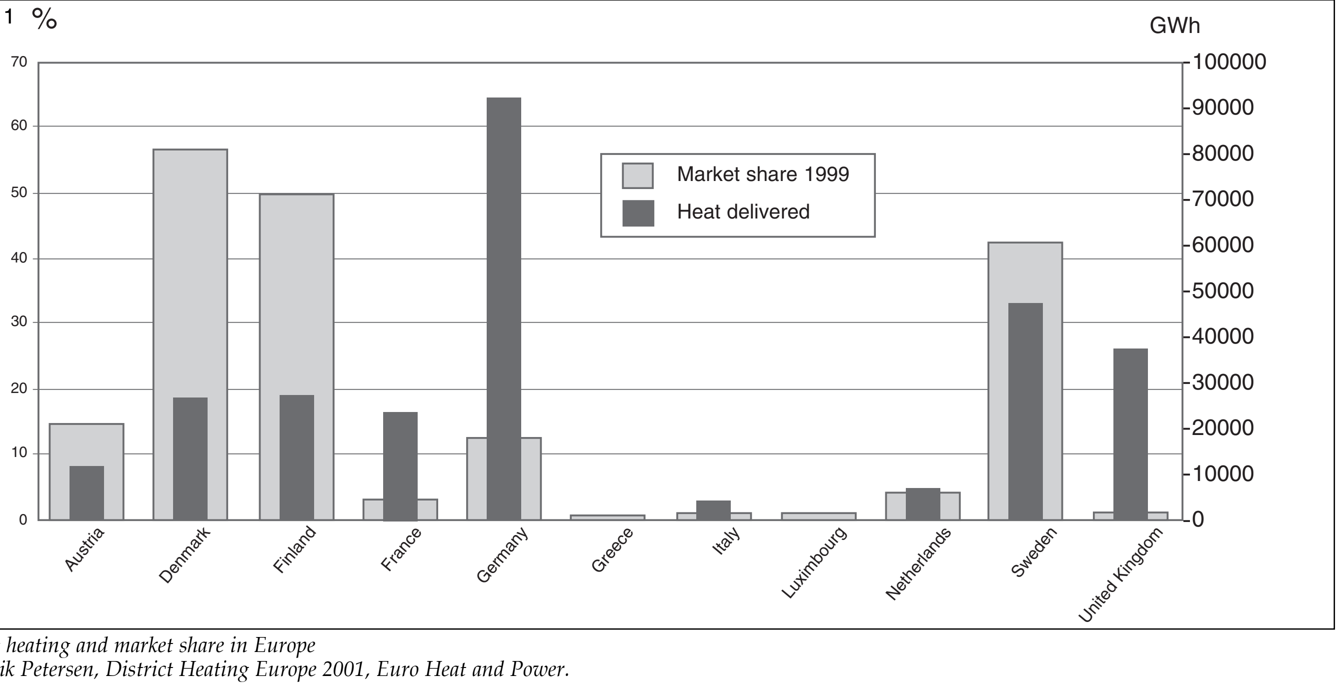
Analysis

For our solution to be feasible there would have to be a good match between the output of the solar collector and the demand. This is important otherwise a large investment might result only in low reductions in gas usage. We needed to know three things: the likely output of the solar collector, the heating demand of the Ateic building and the demands of other buildings to be connected to the district heating system. Figure 2 shows the results of this research. The output of the solar array will meet all demands in the summer months with very little wastage in June and July. To check our model we looked at the actual energy consumption of existing buildings on site and found a close correlation with the estimate.

Technical

Our initial system layout is shown in Figure 3. In practice the finished system is much more complicated because of the need for water to flow in both directions within the heat main.

Figure 1



District heating and market share in Europe
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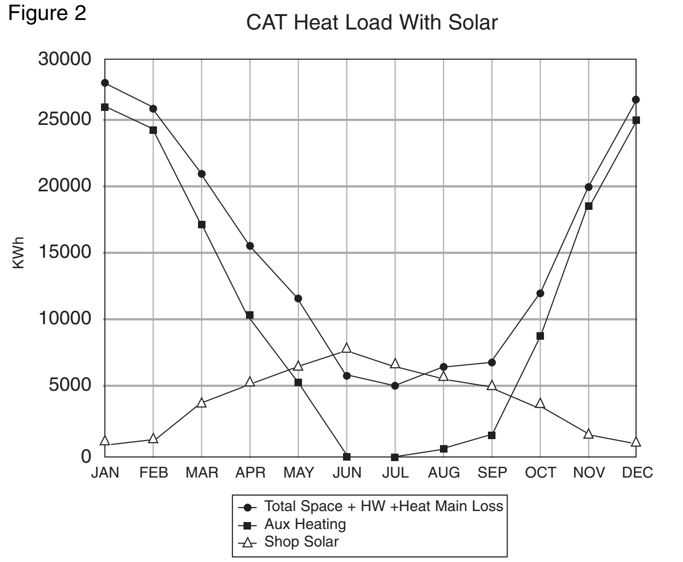
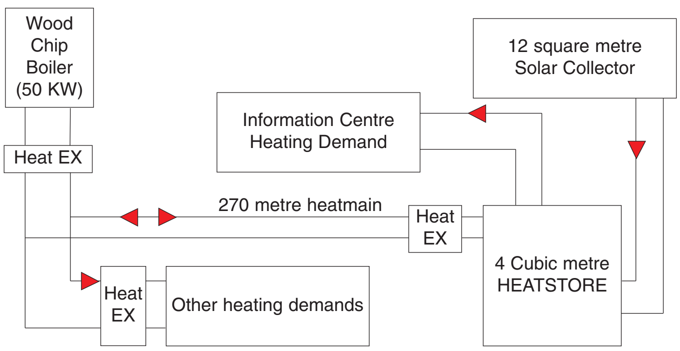
Figure 2



Solar

The final solar system utilises 112m² of custom built solar absorber integrated into the roof of the Ateic building. Such a large array (possibly the largest of its type in the UK) can produce very large amounts of hot water on a sunny day, and it is therefore essential to have heat storage. If the next day is less sunny we have hot water in reserve. To achieve this we have incorporated 4500 litres of storage in the form of an insulated tank. We anticipate the temperature of this tank reaching 90°C, enough to meet our daily summer demands for nearly two days. The amount of energy stored depends on the temperature range the store operates over; in the Ateic building this range is 35–90°C giving 290kWh of storage capacity.

Figure 3



In any solar system, antifreeze would normally be added to protect the pipe work from freezing. The cost of this for such a large system would be prohibitive so a drain back system has been designed in which the collector stays dry (empty) until the collector is warm enough to heat the water to the desired temperature. At this point the pumps are switched on and the water in the store is pumped up to the array and then back to the storage tank. Once the array cools down, the pumps are switched off and the water drains back to the storage tank leaving the collector dry again. Hence the water circulates intermittently round the system and never cools sufficiently to freeze even on the coldest days.

So as to optimise the performance of the solar array for heating the Ateic building, we have installed underfloor heating throughout this building. The one advantage of underfloor heating is that it can run at much lower temperatures (35°C) than radiators (80°C). Operating the solar collector at low temperatures improves efficiency.

Heat Exchangers

So that the water in any one building is isolated from the water in the heat main, heat exchangers are used on each building connected to it. These devices consist of a series of metal plates stacked up like slices of bread: the water flows between the slices transferring the heat as it goes. Using heat exchangers means that we can isolate the heating system in any building connected to the heat main without having to shut down the entire system.

In the future these heat exchangers will replace the boilers in the buildings around site. As they are around the size of a shoe box, this will reduce the amount of building space taken up by heating equipment.

Heat mains

The key component of a district heating system is the insulated piping system that connects the buildings together. In conventional district heating systems these pipes are buried under the pavement and roads and can have diameters up to a metre in large schemes. At CAT we have a system of service ducts that enables us to install new pipes and cables without having to dig up the entire site. Space was available for the inclusion of a district heating system.

Many different pipes can be used in district heating including steel, copper and plastic. The system we selected is based on two 32mm cross linked polyethylene pipes encased in a circular sheath of insulation, protected by a tough polyethylene outer case. The advantage of this system is that it is flexible and is available in long lengths, making installation much easier, with joins only occurring at the connection to buildings.

We have been asked why CAT hadn't installed a district heating system sooner. The answer is that because heating demands have been very modest, due to the construction techniques in the buildings, heat loss from the pipe would have been too great in proportion to the heat transmitted. With the construction of Ateic heating demand has nearly doubled to around 30kW, which meant that the installation of larger pipes could be justified and the heat loss per delivered unit of heat reduced. We anticipate that losses will be less than 10 per cent on the whole system. If the system were larger the proportional heat loss would be even less. This explains the large size of most schemes in Europe.

Costs

The entire cost of the project was around £43,000, the solar component of which was approximately £30,000, the balance being spent on the district heating system.

We anticipate that the solar collector will produce approximately 37,000kWh per annum which will replace the burning of propane gas, reducing our CO^2 emissions by 12 tonnes per year.

Payback will be achieved in 12 years, which may seem a long time, but the financial return comes out at around 7 per cent, which is considerably better than you would see from most investments.

Progress/performance to date

The pipe work was laid in January 2000, however because of various delays the first sections were not connected until October 2000. Initially, just a short length between Ateic and the top station was connected, the building being heated over winter by a gas boiler. This system has proved reliable. Around the same time we were getting our first hot water from the solar array. Even on days when the sun was only shining for part of the time the temperature of the water in the storage tank would be up to 50 or 60°C by lunchtime, heating up incrementally each time the pump circulated water through the solar collectors.

As of April 2001, Ateic has been meeting all its own heating demand from the solar system. By July we hope to have the link back to the restaurant complete, with the whole system finished for the winter of 2002.

Over the next two years, we hope to monitor the performance of the system to see if our predictions are accurate.

Other examples

In the UK there are relatively few examples of district heating schemes. There are some exceptions though, notably the Sheffield 'energy-from-waste' scheme. On the continent there are many more; in Denmark 58 per cent of heating needs are met from such systems. Traditionally they have been fuelled with coal but it is very easy to convert them to more benign fuels, such as heat from combined heat and power plants, which generate electricity and heat very efficiently, or even fuel crops such as willow or forestry wastes. Seventy five per cent of the heat supplied to Swedish district heating systems is sourced from renewable energy.

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