Wood Heating at the Green Shop

for

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CONTENT

1. Introduction

The purpose of this report is to give indicative figures for the heating fuel required for the Green Shops new exhibition and office building. It is intended to heat the building with a combination of a large solar thermal array (40m^2) and a log or pellet burning boiler.

The building is to be built with a high level of thermal efficiency with 250mm of insulation in the cavity walls and 500mmm in the roof space.

Consideration is given in the report to the sizing and system requirements and how the different heat sources may interact.

The building is very similar in use and thermal performance to the Shop and Mail order building at the Centre for Alternative Technology, we have used our experience of this building as a reference to this report.

2. Building Heat Loss. Energy Demand and Passive gains

U values have been calculated for the major elements of the structure, The U values used are shown in the able below.

	U Values (W/m^{2}k)
Floors Internal	1.00
Ceilings Internal	1.00
Floors New	0.15
Roofs New	0.08
Walls Internal	1
Walls New	0.15
Glazing New	1.5
Doors Internal	3

A heat loss calculation has been undertaken for the building. When the outside air temperature is -3^{O}C the building will require 19.5kW of heat, a summary of the results is shown in Appendix 1.

It should be noted the building heat loss is not normally the installed boiler capacity. Allowances need tot be made for service hot water demand and building start up requirements.

A well insulated building such as this is well placed to take advantage of passive gains from the occupation of the building and solar gain through the windows. Electricity consumption might typically be 25kWh of electricity per m^2.annum. For this building this equates to an average day time demand of 3.5kW. There will be 20 staff in the building who will give off a further 1.6kW of heat. Gains from the 51m^2 of south west facing glass are shown in the table below. We have disregarded gains from other glazing as the areas are not significant or the gains minimal.

Month	Solar gain per m^2 of glazing (kWh/day)	Effective average gain to building (kW)	Heat gains from occupant (kW)	Heat Gains from electrical Appliances (kW)	Total (kW)
Oct	1.19	5.5	1.6	3.5	10.6
Nov	0.75	3.8	1.6	3.5	8.9
Dec	0.57	3.6	1.6	3.5	8.7
Jan	0.6	3.8	1.6	3.5	8.9
Feb	0.96	4.9	1.6	3.5	10.0
March	1.47	6.2	1.6	3.5	11.3
April	1.81	7.1	1.6	3.5	12.2
May	1.91	7.0	1.6	3.5	12.1

The passive gains have been used to select an appropriate degree day base with which to assess the buildings heating requirement.
In this assessment we have made the following assumptions:

- The building will be heated for 12 hours per day 6 days per week
- There will be a two hour preheat period each day
- There will be a hot water demand of 200litres per day

The table below shows the results of this analysis

	Demand Delivered (kWh)
Oct	699
Nov	1409
Dec	2650
Jan	2579
Feb	2225
March	1498
April	1178
May	693
Total	12,931

The total figure is the equivalent of 30kWh per square metre of heated floor area per annum which is comparable to the CAT shop buildings actual use.

3. Solar Thermal Output

It is intended to install up to 40m^2 of solar thermal collectors on the south west facing facade, the intention being that the output will be used to contribute towards the space heating of the building.

The performance of a solar thermal system is greatly affected by the demand temperature, solar resource and the ambient temperature. A simple solar thermal modelling programme (RetScreen) has been used to predict the performance of a 39m^2.evacuated tube system. Evacuated tubes give the best performance when the prevailing conditions are poor and the demand temperature is high. We have carried out the analysis of this array when operating at flow / return temperatures of 45/30 and 70/50 the former being the typical operating temperature for an underfloor heating system the later being nearer to an oversized radiator system. The table below shows the maximum likely output from the system

	Solar Thermal Output @ 45-30 (kWh)	Solar Thermal Output at 70 -50 (kWh)
Oct	1060	660
Nov	340	0
Dec	140	0
Jan	220	0
Feb	510	130
March	1270	890
April	1910	1410
May	2350	2060

Note retscreen is unable to resolve outputs of less than 100kWh per month hence the some of figures for Nov Jan Dec are zero.
If these figures are combined with the results of the heat loss analysis we derive final demand figures as shown in the table below

	Demand Delivered kWh	**Solar Thermal Output @ 45-30 (kWh)**	**Shortfall to be met by biomass heater**	**Solar Thermal Output at 70 - 50 (kWh)**	**Shortfall to be met by biomass heater**
Oct	699	1060		660	39
Nov	1409	340	1069	0	1409
Dec	2650	140	2510	0	2650
Jan	2579	220	2359	0	2579
Feb	2225	510	1715	130	2095
March	1498	1270	228	890	608
April	1178	1910		1410	
May	693	2350		2060	
Annual	**12931**		**7,881**		**9380**

The improved performance of the solar water heating system with the underfloor system can clearly be seen as the annual demand drops by around 1500kWh.

4. Fuel Consumption and Handling

Two possible biomass heating systems are considered these are a log batch burner with a heat store (accumulator) and a pellet boiler.

Assuming logs can be sourced which have been stored under cover for one year bringing the moisture content down to 30% and the batch burner is 85% efficient then only 2.9tonnes of fuel will be required for the underfloor heating system and 3.5 tonnes for the radiator based system. In practice this figure would be higher than this as an underfloor heating system would be unlikely to be shut down overnight but set back to a lower temperature. These figures equate to approximately 10m^3 of stacked softwood logs and 6.3m^3 of hardwood logs.

The issue of obtaining dry wood should not be underestimated. Most log wood suppliers will typically deliver wood with a moisture content of 40% plus. This fuel is not suitable for use in a batch burner which needs the moisture content to be below 30% and ideally 25%. We would recommend that under cover storage space is found on site so that logs can be stored for at least a year.

Logs could be stored in pallet cages like the ones in the picture below.

Cage pallet retention units from Key Industrial

These are available from Key industrial and can be stacked up to 3 high with up to a tonne of material in each. The larges unit sold by Key has an internal volume of 1.3m^3 if the logs were loosely thrown into the cage then each would hold around 635kg of hard wood with a 30% moisture content. Six of these cages should be able to hold a years worth of fuel. In practice there would probably need to be ten cages to ensure continuity of supply.

Pellets have a higher calorific value than logs (4.8kWh/kg as opposed to 3.2kWh/kg) additionally the boilers can operate at very high efficiencies 90% plus. The two options would require between 1.8 and 2.3 tonnes of pellets each year with a volume of 3 and 3.8m^3.

5. System Design Considerations

5.1. Wood Batch Burner

A batch burner burns a single load of logs quickly and efficiently the heat is then either delivered directly to the building or stored in a hot water accumulator. Once the fire has gone out, heat stored in the accumulator is used by the building. The accumulator can be heated up to a temperature of 90^{o}C. Two factors affect the amount of useful energy the accumulator can store, its volume and the temperature range over which it can operate. Hence a space heating system utilising underfloor heating at 40^{O}C will be able to extract twice the amount of useful energy as a radiator system working at 65^{O}C.

A 50kW log batch burner on left and accumulator on right.

The use of the accumulator can be optimised by the use of a weather compensator. These devices lower the flow temperature to the heat emitter when the weather is mild, thus the stored heat lasts longer.

The Baxi Solo Innova 30 has a fuel box with a volume of 135 litres which is capable of holding 42kg of softwood which can deliver 116kWh of heat. If hard wood is used this rises to around 204kWh. On a day when the outside air temperature remains at -3^{O}C all day the building will require 223kWh of heat. There will therefore be a requirement to reload the boiler and fire it again. Fortunately this is only likely to occur on one or two days per year. A more typical winter outside air temperature would be 5^{O}C in this case the building would need 118kWh which could be achieved by either fuel.

If hard woods are used the boiler will take approximate 7 hours to burn a full load of fuel. Once the building is up to temperature the remaining fuel capacity has to be stored so that it can be released at a later time. The table below shows the profile of the heating requirement on a cold day.

Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
	Preheat		**12 hour Heating Day**												**SUM**
Demand (kWh)	19	19	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9	
Output (kWh)	32	32	32	32	32	32	32								224
Heat to store (kWh)	13.0	13.0	18.1	18.1	18.1	18.1	18.1								116
Heat in store (kWh)	13.0	26.0	44.1	62.2	80.3	98.4	116.5	102.6	88.7	74.8	60.9	47.0	33.1	19.2	

At the beginning of the day the building is cold and the demand is high. After two hours staff come in and the demand reduces due to increase gains. After 7 hours the wood is consumed and the accumulator starts to discharge. The maximum amount of energy that needs to be stored under these conditions is 116kWh. If the useful temperature range of the store is 50 degrees then a capacity of 2000litres will be required.

The largest Consolar store has a capacity of 2200litres if the demand from the building is lower then the store will have insufficient capacity to store the heat from the boiler and a smaller amount of wood will have to be used to prevent over heating of the store. As this could be difficult to gauge it may be advisable to put a heating circuit in the warehouse which comes on once the store is full.
There are two principle disadvantages of the batch system.

1. In cold weather the store will nearly empty by the end of the working day and so either a further smaller firing will be required to ensure there is heat first thing in the morning or a member of staff will have come in early to ensure the building is warm at the beginning of the working day.
2. The thermal store will have to be at high temperatures throughout most of the working day. If the same store is to be used as the solar store the ability of the solar to contribute towards the space heating will be severely compromised.

A further store of similar capacity could be added specifically for the solar element but there would be considerable additional cost.

A boiler such as this will require approximately five square metres of the warehouse floor area.

5.2. Pellets Fired Boiler

A pellet fired boiler will have a higher running cost but has the advantage of having automatic ignition and control. Consequently the majority of the thermal store capacity can made available for the solar thermal system. Because the boiler is able to modulate it will be able to track the building demand and automatically start first thing in the morning. This should make the day to day operation of the boiler much more user friendly than the log alternative.

Okofen Boiler and Bag Store

If a pellet boiler is decided on, care should be taken to ensure that the boiler is not oversized, this helps to ensure that the boiler does not spend too much time in dwell. Some heat storage can considerably enhance the performance of these systems.

6. Conclusions and Recommendations

The building has been shown to have a calculated heat loss of 19.5kW when the outside air temperature is -3^{O}C.

Both pellet and log fire heating systems are viable for this site with annual consumptions of around 2 and 3 tonnes respectively. A number of causes could increase these figure, including overnight heating, different usage patterns, failure to construct the building to the standards indicated, and losses from the heat store.

The solar water heating will have a relatively small contribution to the space heating demand unless a low temperature delivery system is used such as underfloor heating.

Serious consideration should be given to summer over heating of the solar system. In July the system will produce over 2200kWh. With no appreciable load or dump there will be a real danger of over heating the store. Even if the system is switched off it will leave the collector at stagnation temperatures of in excess of 100^{O}C for large periods of the summer. A removable shading device may be worth considering although safe access and operation could an issue.

If a batch burner is the preferred option then an additional thermal store will be required to ensure that the demand temperature on the solar system is kept as low as possible.

A batch burning system has been shown to be able to meet the buildings demand on the worst likely day when a single burn of 135litre of hard wood logs will meet most of the heating requirement. If the suggest fuel handling arrangement a single pallet cage will provide sufficient fuel for 10 full firings of the boiler.

The Green Shop should carefully consider the logistics of the batch burning system, Issues to be considered would be

- Health and Safety, increased risk of staff getting burnt and injured during loading and firing
- If the accumulator is empty at the end of the working day will staff be available early the next morning or that night to fire the boiler.
- Will there be sufficient space for both the boiler and the fuel storage area
- Will the local fuel suppliers be able to deliver fuel of suitable quality for the boiler?

A pellet fired boiler might have higher fuel costs but would be much more user friendly providing a suitable unit with automatic de-ash and auto ignition was selected.

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7. Appendix 1 Room Heat loss when Outside Temperature =-3^{o}C

	Design Temp (^{o}C)	Ventilation Rate Air (Changes/hour)	Calculated Buffer temperature (^{o}C)	Heat loss (W)	Area (m^2)	Heat loss (W/m^2)
Showroom	21	1		4269	73	58
Ground Floor Stair	Buffer	1	9	0	15	0
WC	21	2		592	6	93
Store	Buffer	0.5	14	0	14	0
Research & Demo	20	0.5		1379	34	40
Stairs 2	Buffer	2	10	0	7	0
Warehouse	Buffer	2	6	0	94	0
Office	20	1		2590	30	87
Stairs 1 1st floor	Buffer	1	5	0	17	0
Toilets	18	2		445	11	40
Rest room	20	1		947	21	45
Offices	20	2		5710	83	69
Office/Flat	20	1		1516	52	29
Corridor	18	1		2037	47	43
Total				**19487**		**46**