



Biomass Heat Accelerator

Biomass Boiler System Sizing Tool

User Manual

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- This design tool for biomass heating systems has been developed by the Carbon Trust in collaboration with The University of Strathclyde and the Campbell Palmer Partnership Limited, using funding from the Carbon Trust, as a decision support-tool for those investigating and/or specifying biomass heating systems.
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Introduction

The biomass boiler system sizing tool has been designed for both building services design engineers and biomass system installers. The purpose of this manual is to provide both types of users with sufficient information to enable them to use the tool. However, a minimum level of prior knowledge on both building heat load calculations and biomass systems is required in order to understand how to use the tool, and the prior knowledge required is detailed in the next section. Before reading this manual the user should review the definitions given in the glossary at the end of the manual.

The rationale for development of this tool was to provide users who possess limited information about a potential biomass heating project with the means to make an initial feasibility assessment. The tool will provide the user with some quantitative guidance relating to their project, making reasonable assumptions about those aspects that may not yet be subject to detailed design consideration. **A more detailed feasibility study should be undertaken by qualified professionals before completing a final system specification, and certainly before making financial commitments.** This tool is intended to provide such professionals with a starting point for the key issues to be considered, relating to relative boiler size, thermal store capacity, and auxiliary boiler requirements.

This tool was designed for the pre-feasibility assessment of biomass boiler systems rated between 50kW and 3MW. This was for a number of reasons:

- The Tool is not intended for use in domestic applications;
- The cost calculation formula embedded within the tool is based on an analysis of boilers within this size range; and
- Most public sector and commercial applications are within this size range.

Should the tool be used to assist with the evaluation of biomass systems outside this size range it may not produce sufficiently accurate results.

The tool is a Microsoft Excel workbook, and will run in Excel 2007 or later. The workbook contains macros which will need to be enabled before it can be used. How to do this is described in the section *Getting Started - Opening the Tool & Enabling the Macros*.

There are hundreds of manufacturers of biomass boiler systems in Europe with differences, small and large, in boiler products reflecting differences in both proprietary design and in design and operating philosophy. Similarly, there are many variations in hydraulic configurations and control systems among manufacturers, and between products from the same manufacturer. In developing the Biomass Boiler System Sizing Tool it has been necessary to make assumptions about system design and operation because both of these are implicit in the calculations carried out by the Tool. It was decided to focus on two different operating strategies against which the sizing of a biomass boiler, associated buffer vessel and/or thermal storage, and auxiliary boiler could be undertaken.

Both the Minimum Buffer Vessel strategy and the Optimum Biomass Boiler/Thermal Store strategy are associated with implicit hydraulic configurations and control strategies which are described in Part 2 of this Manual. The user should take care to ensure that the results produced by the Tool are appropriate to any manufacturer's system they may be considering, and if not they should adjust the recommended sizings produced by the Tool accordingly.

Users should also interpret the outputs from this tool with a degree of pragmatism. The calculated size of thermal store can be **very large**, and consideration should be given to the space and loading issues of incorporating such storage vessels on site. The tool includes a variation of the Optimum Biomass Boiler/Thermal Store strategy that allows an upper limit to be placed on the size of the thermal store, in case space and loading capacity are limited.

Key Features

- The tool calculates the heat demand and fuel consumption of a biomass heating system, and compares it with a reference (existing) fossil fuel fired or electric heating system.
- A wide range of biomass boiler types can be specified, and the tool will guide the user on suitable combinations, including the system's match for efficient summer load operation.
- The tool includes a capital cost estimator, for the main system components. The user can use their own values if preferred.
- A financial analysis of the project is carried out, including the effect of the Renewable Heat Incentive, and results presented in tabular and summary report formats.
- Heat demand is calculated using one of several methods; data can be input from a detailed building simulation program, from heat meter measurement data, or from fuel bills. Alternatively, the tool can calculate demands based on details of the building.
- The heat demands of housing estates and non-domestic buildings can be calculated, as well as those of swimming pools and glasshouses.
- If a district heat network exists, or is being installed, the distribution losses are accounted for.
- Detailed fuel properties can be specified for wood chip or wood pellet fuels
- The user may specify a system with a buffer vessel (for system overheat protection) or a thermal storage vessel (to reduce boiler size and improve system efficiency across all load conditions). The tool accounts for plant room space cost, and heat losses associated with a thermal storage vessel.
- An auxiliary boiler may be specified to cope with peak loads, or for backup.
- A graphical display assists the user in choosing an optimum combination of biomass boiler and thermal store to meet their requirements, and different options can be easily compared.
- The required size of biomass fuel store can be determined, with several typical types being available for selection.

Prior Knowledge

The user requires a certain level of prior knowledge about heat load calculations in buildings, biomass systems, biomass fuels and fossil fuels.

Biomass Boiler Systems

The user is expected to be familiar with the following aspects of biomass boiler systems:

- Types of stokers: underfed auger, overfed auger and hydraulic ram;
- Types of grates: underfed stokers, stoker burners & moving grates;
- Safety devices: rotary valves & flap valves;
- Boiler ceramic linings: the wetter the biomass the greater the quantity and coverage of ceramic lining in a boiler's combustion chamber;
- Fuel extraction/silos: walking floors & rotating scraper extractors, & hopper bottom silos for pellets.



Building Heat Load Calculations

The user is expected to be familiar with the following aspects of heat load calculations for buildings as assumptions are given in relation to these aspects in the following sections:

- External and internal design temperatures;
- Degree days;
- U-values;
- The concept of lightweight, mediumweight and heavyweight buildings;
- Casual gains: people gains, lighting gains and equipment gains;
- Heat gains from insolation;
- Ventilation requirements for different activities;
- Hot water demands for different building types.

Biomass Fuels

The user requires knowledge of the specifications for both wood chip and wood pellet fuels.

Fossil Fuelled Systems

The user requires an understanding of how the efficiency of fossil fuel boilers has improved over time and the likely efficiency of any existing boiler based on its age, type and condition.



1 Using the Tool

1.1 Getting Started

1.1.1 Opening the Tool & Enabling the Macros

When you download the tool, save it in a suitable folder on your PC. It is a Microsoft Excel 2007 workbook with macros (.xlsm). You may change the name of the workbook to suit your project. When saving the tool, save it with file extension {.xlsm}. Due to the complexity of the tool, we are not able to support its use with earlier versions of Excel.

The file size of the un-zipped workbook is less than 10Mb. Although it should open and run on most modern PCs, ensure that you have sufficient free memory (RAM). We recommend at least 1Mb, and more if you have several other applications running simultaneously.

Ensure that the first two digits of the version of the tool you are using correspond to the version number stated on the cover page of this manual. The version number of the tool appears on the main interface sheet when you open the tool.

The Excel workbook contains macros. Macros are code modules that carry out certain functions within the tool and require to be enabled for correct functioning of the tool. For security reasons, Microsoft Excel does not allow such code modules to run automatically. As the user of your PC, you have to determine that the code came from a trusted source. There are several ways of enabling macros, and the method you choose will depend on which Microsoft operating system you have installed on your PC, and your current security settings. The following is general advice, and in case of difficulty you should seek assistance from an IT expert.

When you open the tool, there will either be an Options or an Enable button in your toolbar area to enable macros.

To avoid having to enable macros every time you open the workbook, you can self sign the macros on your PC. Essentially, the process is to create a Digital Certificate on your PC, save this in a trusted certificates folder, then self-sign the macro code in the workbook (Hint: click Developer/Visual Basic/Tools/Digital Signature). Use your Excel Help facility to find out the details of how to do this with your operating system.

You can then change your security level to “disable all macros except digitally signed macros” (or similar depending on your operating system). Use your computer’s Help function to find out how to alter your security setting. Then close and re-open the tool.

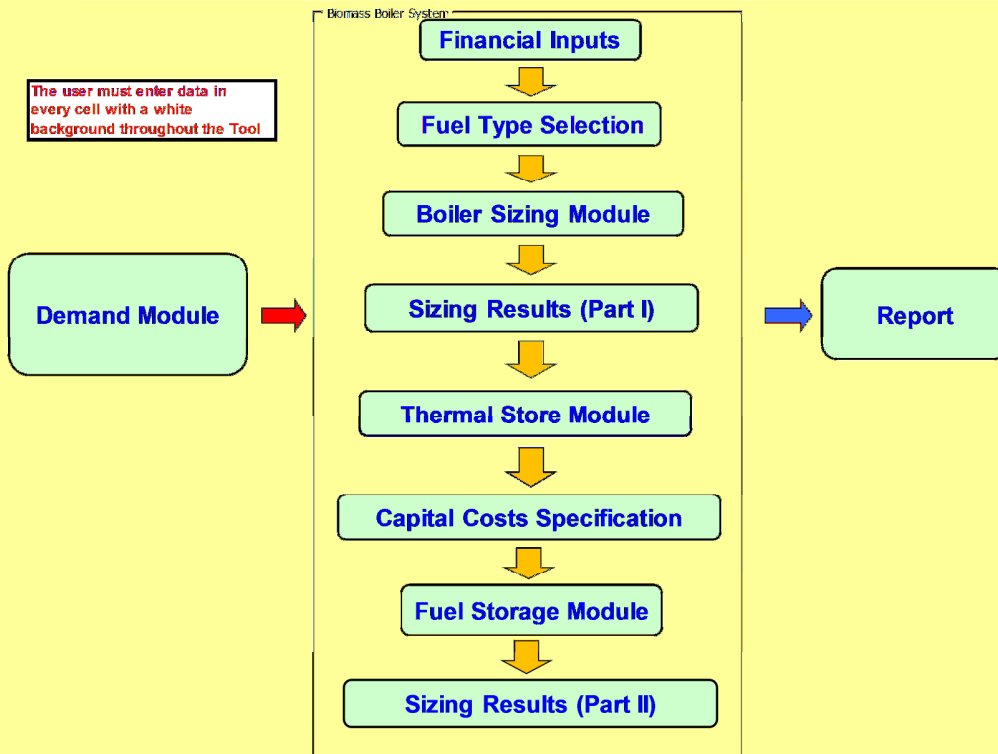
It is always possible to set your security to the lowest setting “Enable all Macros”. This is not advisable as you will be vulnerable to attack by malicious codes that might be embedded in macro code modules in other Microsoft Office documents (Word, Powerpoint, etc). Another option may be to save the tool in a “Trusted” folder on your PC. If in doubt seek the advice of an IT expert for further advice that will allow you to run the macros at a higher security setting.

1.1.2 Structure of the Tool

The Biomass Boiler System Sizing Tool comprises a series of linked modules which lead the user through the process of entering building data through to the production of a final report. The main modules are displayed on the Tool’s main interface page, shown below.

Biomass Boiler System Sizing Tool (Version 6.8.0)

Project Information		
Project Reference No.:	<input style="width: 95%;" type="text"/>	Site:
Project Name:	<input style="width: 95%;" type="text"/>	Analysis by:
Client:	<input style="width: 95%;" type="text"/>	Company:
Project Location:	Glasgow	Date:



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- The tool is intended primarily for customers of the Carbon Trust, typically UK businesses and public sector organisations.
- Permission is granted for informational, non-profitable and personal use (including in the course of business) and provided that you do not remove, adapt, alter or obscure any of the information, content or notices (such as copyright and other proprietary notices) contained in the tool. You may not (without the prior written permission of the Carbon Trust or in accordance with the Copyright, Designs and Patents Act 1988) copy, reproduce, republish, store in any medium (including in any other website), make available, whether free of charge or at cost, to the public, or otherwise use the tool (including, but not limited to, "caching" any part of it) for access by third parties or "mirroring" any part of it in any way except for informational, non-profitable and personal use (including in the course of business). Any other use of the tool requires the prior written permission of the Carbon Trust.
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Throughout the tool, enter input data in the white boxes. This may be by selecting a value in a drop down menu, or simply typing a value in the box. In general, every white box should contain a value. A blank box is interpreted as a zero value in Excel, and this may result in some calculations producing an error value, or failure of macros to function correctly. When the tool is first opened many results cells will contain error values; this is normal, as most of the input cells will be empty.

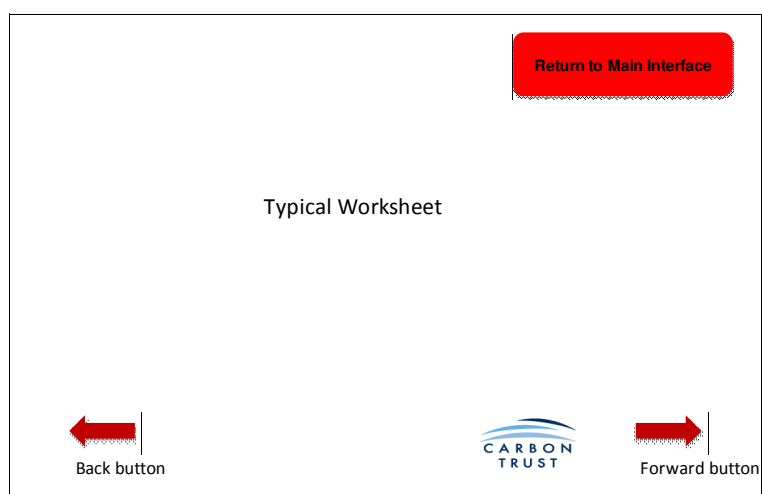
1.1.3 User Inputs on the Main Interface Page

The first task on opening the tool is to enter your project information.

Project Information: The project information is used as the heading and identifying information for the Report produced at the end of the Tool. The Project Information area can be used to assist the User to identify different Reports produced for the same project. For example the User may wish to run a number of variations by entering different information each time the Tool is run. **As a minimum the User must select a “Project Location”.** The available locations are Belfast, Birmingham, Cardiff, Edinburgh, Glasgow, London, Manchester and Plymouth. The project location is used in the calculation of heat demand so the location with the closest *climate* to that of the actual location should be chosen, this not necessarily being the closest geographical location.

1.1.4 Navigating the Tool

Navigation buttons at the bottom of most worksheets of the tool allow the user to navigate forwards (red arrow at bottom right of page) and backwards (red arrow at bottom left of page), according to the sequence shown on the main interface (with a few exceptions). This sequence has been determined to result in a logical order of data entry, but a “Return to Main Interface” button is available top right on most sheets, and from there, any module may be selected. The navigation buttons can be identified by the appearance of a ‘hand’ symbol when the cursor is moved over a navigation button.



1.1.5 Saving the Results

Results can be saved at any time, as an Excel file, with file extension {.xslm}. It is recommended good practice to do so periodically, using “Save As”, and to update the filename each time the tool is saved, incorporating a date or version number in the filename text. In this way, intermediate calculations are not lost and, if an input error is made, it is easy to go back to a previously saved version.

On occasion, the user will be directed to press a “Save” or “Update” button within the tool. After doing so, **wait a few seconds** for the command to complete execution.

1.2 Demand Module

1.2.1 Specifying a Building

In order to calculate the capacity of the biomass boiler, auxiliary boiler, and buffer vessel or thermal store, the Tool needs to estimate the hourly profile of heat demand in a day. The tool will also estimate the annual heat demand, including the proportion that is serviced by the biomass boiler.

The Demand Module provides several ways of specifying buildings, for a variety of different building types. When you click on the Demand Module button, you will see a sheet that shows a summary of heat demands for up to 10 different building specifications. When first selecting this sheet, only one building specification input selection box will be visible. For each building specification, the user can select from four different input modes, allowing users to input energy and buildings data. The four input options are:

- Data from a detailed building simulation program
- Heat meter measurement data
- Data from fuel bills
- An embedded demand calculator requiring the input of detailed building data

The first three options allow the user to specify a non-domestic type of building, and assume that the user already has information to hand about the building's heat demand.

The fourth option, the Embedded Demand Calculator, allows the user to specify:

- A non-domestic building
- A swimming pool
- A glass house
- A housing estate (domestic)

In these cases, it is assumed that the user has no demand data from any other source, and the tool has to estimate this based on user inputs about the building or houses.

Building Heat Demand Inputs

Return to Main Interface

No of building specifications: ▲ ▼ Continuous distribution network power losses: of peak load = kW

Building name:

Number of buildings of this type:

Building name:

Number of buildings of this type:

Demand Data Source

Detailed Building Simulation Program

Heat meter measurement

Fuel bill

Embedded demand calculator

Demand Data Source

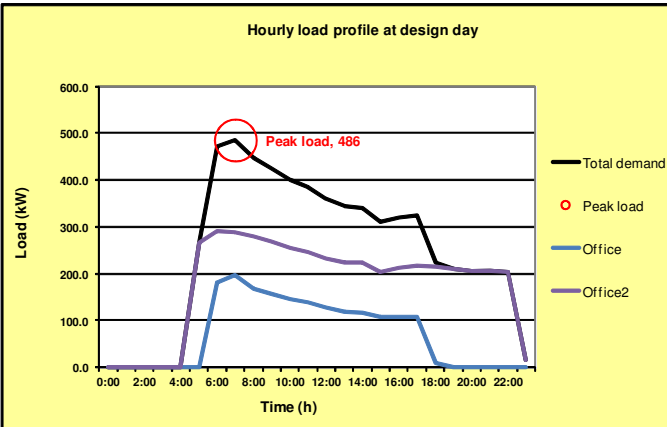
Detailed Building Simulation Program

Heat meter measurement

Monthly fuel bill

Embedded monthly demand calculator

Hourly load profile at design day




Total heating energy required

Average heat demand at design: kW

Energy demand at design day: kWh

Annual energy demand: kWh



The user should enter the number of building specifications he intends to input to the tool. Use the up arrow to increase the number. You may have to wait a moment for the sheet to update. For example, if the user has two non-domestic buildings, and a swimming pool, then 3 specifications should be requested, using the up arrow. If the user has one non-domestic building, two glasshouses, and a housing estate, then 4 should be selected. Note that a housing estate is counted as one building specification, even though a number of houses of different types may be specified within a housing estate. Note that only one housing estate can be specified. Before entering any of the demand input modules, the user should give each building specification a meaningful name, replacing the default Building 1, Building 2, etc.

It is also possible to select the number of identical buildings of each type. So, for example, if the user has specified a building as a hospital ward block, and the project has three such identical blocks on site, the user can enter 3. The only effect of this selection is to multiply the design day and annual heat demands for one building by the figure entered.

It will often be the case, when a biomass boiler system serves several buildings, and especially a housing estate, that a district heat distribution system will be included as part of the project. The user may specify the continuous distribution network power losses. This will be expressed as a percentage of the peak total demand on the winter design day, for all the buildings specified within the tool.

1.2.2 Selecting Options for Non-domestic buildings

The demand profile for non-domestic buildings may be user defined, or an inbuilt profile may be selected within the embedded demand calculator. Irrespective of this, in order to estimate the annual heat demand, the tool uses inbuilt profiles and a weather data frequency distribution for the chosen Project Location. The following building characteristics are required (with typical values shown as a guide):

	<i>Low/Light/Short</i>	<i>Medium/Long</i>	<i>High/Heavy/Continuous</i>
Building thermal mass	Little/no exposed thermal mass at internal surfaces	Substantial exposed thermal mass, at internal surfaces, eg floor	Exposed thermal mass on floor and walls, partitions
Area of glazing	15% of wall façade	30% of wall façade	60% of wall façade
Level of insulation	U-value around 0.7, single glazed	U-value around 0.35, double glazed (Part L 2002)	U-value around 0.25, low-e double glazed (Part L 2005)
Level of occupancy	8:00 - 18:00hrs 5 days / week.	7:00 - 23:00 hrs 7 days / week.	Continuous

Table 1: Building characteristics for inbuilt profile generation.

As described above, any of the input options for a building specification may be selected for a non-domestic building, within the Building Heat Demand Inputs sheet. A detailed description of the input pages for non-domestic buildings follows.

1.2.2.1 Detailed Building Simulation Program, or Heat Meter Measurements.

If you already have a dynamic model of your building in one of the many building simulation tools, then you can use this to generate some of the input data required by the Sizing Tool. Alternatively you may have the same data from actual heat meter measurements.

From the Building Heat Demand Inputs sheet, select Detailed Building Simulation Program, or Heat meter measurement, and click the **Proceed** button.

Depending on which option you select, a page similar to that below will appear. The data required are:

Heating design temperature: Enter the external temperature for the day for which the design day load profile was generated / measured.

Building Characteristics: As previously described. Drop down menus allow the values to be selected.

24 hourly values of heat demand (load) for the design day: The data required is the heat demand, or heat delivered to the building load. Obtain this data by running a simulation for the coldest day of the year. You should include all internal heat gains, ventilation losses, and domestic hot water load. In the case of metered data, enter the 24 hourly metered demands that correspond to the coldest day, or a day that represents your design condition.

Total building floor area and occupancy: Enter the values required.

Return to Demand

Demand From Detailed Simulation Program

Building name: Office

Data input

Building Location: Glasgow

Outdoor design temperature: -3.0 °C

Building thermal mass: Heavyweight

Level of insulation: Low

Area of glazing: Medium

Level of occupancy: Short

Hourly load profile

Time	Load (kW)
00:00	0
01:00	0
02:00	0
03:00	0
04:00	0
05:00	0
06:00	181
07:00	197
08:00	169
09:00	156
10:00	146
11:00	138
12:00	128
13:00	120
14:00	117
15:00	107
16:00	108
17:00	107
18:00	10
19:00	0
20:00	0
21:00	0
22:00	0
23:00	0

Daily demand: 1,684 kWh

Annual demand: 194,467 kWh

Balance temperature: 12.4 °C

Additional Demands

Total building floor area: 1,500 m²

Typical Occupancy: 150 persons

Casual Gain: [Click here to define casual gain](#)

Ventilation Loss & Hot Water Demand: [Click here to specify ventilation loss and hot water demand](#)

Hourly load profile at design day

Annual demand: The annual heat demand should represent a typical year. You might wish to make an adjustment to metered total demand to account for the difference between actual and typical/average degree days for that year.

Casual gains, ventilation losses and domestic hot water demand are also required. Click the links to specify these data as shown below. Equipment gains are specified as the equivalent number of desktop PCs, expressed as number of people per PC. Selection of building type determines the average Domestic Hot Water energy consumption. Select “User Defined” and enter your own figure in the box, if you prefer.

Casual Gains Specification

[Return to Detailed Building Simulation Data Module](#)

Internal (Casual) Gains


Typical occupancy people

Building floor area m²

Gain type

People	<input type="text" value="90"/>	W/person
Lighting	<input type="text" value="8"/>	W/m ²
Equipment	<input type="text" value="1 PC per 3 people"/>	

Total Gains: kW



Ventilation Loss & Hot Water Demand

[Return to Monthly Fuel Bill Data Module](#)

Data Input

Occupancy data

Building Type

Please enter DHW here: l/person (User Defined)

Typical Occupancy people


Ventilation Rate When Occupied litres/person

Results

Ventilation losses and hot water demand (HWD)

Average DHW kW

Ventilation heat losses W/K



A graph of the design day heat demand profile (heat delivered to the building) is generated by the tool. The peak demand on which boiler sizing will be based is highlighted.

A balance temperature for the building is estimated, based on the daily demand and internal gains. This is the external temperature above which the building would require cooling, and below which would require heating in order to maintain the specified internal conditions. The BS EN ISO 13790:2008 standard method used for assessing the heating demand is implemented for buildings which predominately require heating for most of the year. If the balance temperature drops below 12C, a warning is displayed. You should consider if the subject building is really suitable for heating using a biomass boiler heating system, when the building is likely to require substantial cooling for a large part of the year. Check that internal heat gains are not overstated. The number of occupants, and the figures for people, lighting, and equipment gains will all affect the balance temperature.

When finished, click the “Back” button, or the “Return to Demand” button. Click Save to save your data for this building specification, taking care to select the correct building by checking the Building name that you assigned.



1.2.2.2 Fuel Bill

In this case, the user does not have a daily demand profile, but can estimate the actual building demand based on fuel bill data for the coldest day of the year. From the Building Heat Demand Inputs sheet, select Fuel bill, and click the **Proceed** button. A sheet similar to that below will appear.

From meter readings or fuel delivery information, estimate the fuel consumption on the coldest day in the year. Readings should be for total fuel consumption, including domestic hot water, but not including electrical loads like lighting, small power, etc. Note that for this option, the primary fuel consumed is specified, unlike all other options where building heat demand (heat delivered to the building) is specified. The data required are:

Calendar year for which data is applicable: Enter the year.

Degree days in the coldest day of the calendar year for which the fuel data is available: Use the www.vesma.com website to find the degree days in your area corresponding to that day of the year entered above. This allows the tool to adjust the coldest day heat demand to a demand for the design day, at the outside temperature that you specify.

Insert total fuel energy consumption for the coldest day: This is the total fuel use for heating for the coldest day and must be entered in kWh.

Annual fuel energy use: This is the total fuel use for heating for the specified calendar year and must be entered in kWh.

Existing boiler efficiency: A realistic figure for the existing boiler's **seasonal** efficiency should be chosen. This is required to convert fuel use into heat demand. A good indication can be obtained from CIBSE Guide B, figure 1.4 which shows fossil fuel boiler seasonal efficiency versus average boiler load for different fossil fuel boiler types.

Heating design temperature: Enter the outside temperature for the day for which the design day load profile was generated / measured.

Desired internal temperature: Enter the temperature during the occupied period.

Building Characteristics: As previously described. Drop down menus allow the values to be selected.

Total building floor area and occupancy: Enter the values required.

Casual gains, ventilation losses and domestic hot water demand are also required. Click the links to specify these data.

A graph of the design day heat demand profile is output by the tool. The peak demand on which boiler sizing will be based is highlighted.

Demand Based On Fuel Bill

Return to Demand

Building name: **Building 1**

Data Input

Please Input the following data

Calendar year for which data is available: Insert total fuel energy consumption at design day: kWh for calendar year 2009

Degree days at design day of calendar year for which fuel data is available (see User Manual): Annual fuel energy consumption: kWh for calendar year 2009

Existing boiler seasonal efficiency:

Click the link for degree data: <http://www.vesma.com>

Building Information

Site location: Building thermal mass: Typical Occupancy: persons

Outdoor design temperature: °C Level of insulation:

Desired internal temperature: °C Area of glazing:

Building floor area: m² Level of occupancy:

Additional Demands

Casual Gain: [Click here to define casual gain](#)

Ventilation Loss & Hot Water Demand: [Click here to specify ventilation loss and hot water demand](#)

Demand profile at design day

Energy demand at design day: kWh

Balance temperature: °C

Time	Load (kW)
00:00	0
01:00	0
02:00	0
03:00	0
04:00	0
05:00	0
06:00	1,244
07:00	1,358
08:00	1,289
09:00	1,200
10:00	1,136
11:00	1,076
12:00	1,009
13:00	955
14:00	930
15:00	867
16:00	870
17:00	866
18:00	68
19:00	0
20:00	0
21:00	0
22:00	0
23:00	0

Hourly load profile at design day

Peak Load, 1357.7

As with the previous demand input method, a balance temperature for the building is estimated, based on the design day demand and internal gains. If the balance temperature drops below 12C, a warning is displayed. You should consider if the subject building is really suitable for heating using a biomass boiler heating system, when the building is likely to require substantial cooling for a large part of the year. Check that internal heat gains are not overstated. The number of occupants, and the figures for people, lighting, and equipment gains will all affect the balance temperature.



When finished, click the “Back” button, or the “Return to Demand” button. The Building Heat Demand Inputs sheet will reappear. Click Save to save your data for this building specification, taking care to select the correct building by checking the Building name that you assigned.

1.2.2.3 Embedded Heat Demand Calculator

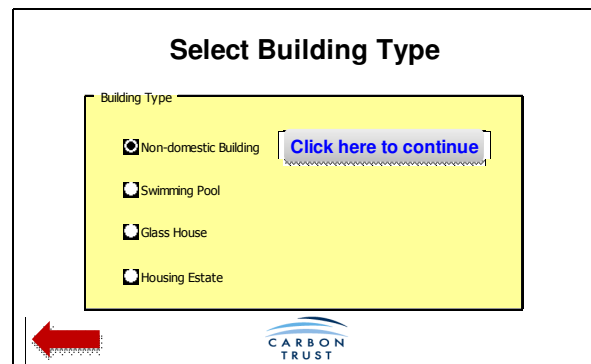
If no other heat demand data is available, use the Embedded Calculator which will estimate annual heat demand, and select an inbuilt design day heat demand profile according to the user inputs. The annual heat demand is calculated by multiplying heat demands for a series of temperature bins, calculated using a simple energy balance method similar to the BS EN ISO 13790:2008 standard approach, by the frequency of occurrence of each temperature. This requires some basic building geometric, fabric, solar, occupancy, and casual gain properties to be entered. As with the other heat demand options, the thermal characteristics also require to be entered, in order to select the most appropriate heat demand profile.

Important: The data must describe a building with a heating demand at most times of the year. The BS EN ISO 13790:2008 method will fail (erroneous demand data will result) if a building is described that essentially needs to be cooled. A balance temperature will be calculated (see below) to assist in making this assessment.

From the Building Heat Demand Inputs sheet, select Embedded demand calculator, and click the **Proceed** button.

A window will open allowing you to select from the different building specifications types available. Select Non-domestic Building, and Click the Continue button.

A new sheet will open, with several input areas which will now be described.





The data required in the first two boxes are:

Internal temperature: Enter the temperature during the occupied period.

Building thermal mass: As previously described. A drop down menu allows the value to be selected.

Outdoor design temperature: Enter the external temperature for the day to which the design day load profile applies.

Overall Building Dimensions: Insert the total area of first, second and third floors, and floor heights. If there are more than three floors, the third floor area should be specified as the total area of the remaining floors, and the height should be the total height of these floors.

Embedded Heat Demand Calculator

Building name:

Building Info

Site location	<input type="text" value="Glasgow"/>	Building thermal mass	<input type="text" value="Lightweight"/>
Internal temperature (°C)	<input type="text" value="21.0"/>	Outdoor design temperature	<input type="text" value="-3"/> °C

Overall building dimensions			
First floor			
Area (m ²)	<input type="text" value="2,400"/>	Height(m)	<input type="text" value="3"/> Volume (m ³)
			7,200
Second floor			
Area (m ²)	<input type="text" value="2,400"/>	Height(m)	<input type="text" value="3"/> Volume (m ³)
			7,200
Third and other floors			
Area (m ²)	<input type="text" value="2,400"/>	Height(m)	<input type="text" value="3"/> Volume (m ³)
			7,200
Building floor area	7,200	Total	21,600

Fabric Heat Loss:

Areas and U-values of doors, windows, rooflights, walls and roof: Enter values as appropriate, starting with the walls. The wall and window areas specified are the total wall and window areas for all floors on each façade. When you enter the areas of doors and windows, the openings in each wall and the resulting net wall areas are automatically calculated.

Ground Floor and Roof: Enter the U-values of the Ground Floor (between occupied area and ground) and the Roof.

Fabric heat loss					
	Gross Area m ²	Openings area m ²	Net Area (m2) m ²	U value W/m ² K	Heat losses W/K
Door 1			5	3.00	15
Door 2			5	3.00	15
Window 1			240	3.00	643
Window 2			90	3.00	241
Window 3			240	3.00	643
Window 4			90	3.00	241
Window 5					0
Window 6					0
Rooflights					0
Ground floor			2,400	1.00	2400
Wall 1 (contains Window 1 and Door 1)	720	245	475	1.00	475
Wall 2 (contains Window 2 and Door 2)	270	95	175	1.00	175
Wall 3 (contains Window 3)	720	240	480	1.00	480
Wall 4 (contains Window 4)	270	90	180	1.00	180
Wall 5 (contains Window 5)		0	0		0
Wall 6 (contains Window 6)		0	0		0
Roof	2,400	0	2,400	1.00	2400
Total area			6780		
				Fabric heat loss coeff	7,908 W/K



Average Occupancy: Enter the average occupancy the during occupied period.

Ventilation rate when occupied: Enter the required ventilation rate. Note that in older ‘leaky’ buildings this rate may need to be increased to represent the actual ventilation rate. A too low value may suggest a building that requires cooling in summer to avoid overheating. The tool is not designed to cater for this.

Building type: Used here for the calculation of the DHW load. Select from drop down menu. You may select “User defined”, in which case an additional input box will appear. Enter the DHW consumption in litres / person / day.

Building occupancy		
Average occupancy	<input type="text" value="500"/>	people
Ventilation rate when occupied	<input type="text" value="12"/>	litre/s/person
Building type	<input type="text" value="Offices"/>	

Ventilation losses		
Air flow	<input type="text" value="6.0"/>	m ³ /s
Ventilation heat losses coeff	7,236	W/K

Building heat losses		
Heat loss coefficient	<input type="text" value="15,144"/>	W/K
Thermal transmittance	<input type="text" value="2.1"/>	W/m ² K

Hot water demand (HWD)		
Average HWD	<input type="text" value="21"/>	kW
Average energy consumption	<input type="text" value="14,875"/>	kWh (month)

As a sanity check, review the reported values of building heat loss coefficient (W/K), average thermal transmittance (W/m²K) and hot water demands, and satisfy yourself that the values are sensible.

Solar gains: On the right hand side of the sheet, input the orientation, shading, total area on façade, inclination from horizontal, type of glazing, and frame type. Use the drop down menus where provided.

Solar gains					
Irradiance data Glasgow					
Orientation	% of façade permanently shaded by obstacles	Total glazing area on façade (m ²)	Inclination from horizontal	Type of glazing	Frame type
N	>80%	90	90	Double glazed (air or argon filled)	PVC-U
S	>80%	240	90	Double glazed (air or argon filled)	PVC-U
E	>80%	90	90	Double glazed (air or argon filled)	PVC-U
W	>80%	240	90	Double glazed (air or argon filled)	PVC-U
E	80% - 60%		90	Triple glazed (air or argon filled)	Wood
SW	80% - 60%		90	Double glazed (Low-E, soft coat)	Wood
S	80% - 60%		90	Single glazed	Metal thermal break
SE	80% - 60%		90	Triple glazed (air or argon filled)	Wood
E	80% - 60%		90	Window with secondary glazing	Metal
NE	80% - 60%		90	Triple glazed (Low-E, hard coat)	PVC-U
E	80% - 60%		90	Triple glazed (High-E, soft coat)	Wood
W	80% - 60%		90	Double glazed (air or argon filled)	Metal
Total solar heat gains:			2,131	W	
Total solar heat gains after utilization factor:			1,924	W	

Internal (Casual) gains (W)		
Gain type	Use	Total gains (W)
People	90 W/person	45,000
Lighting	4 W/m ²	28,800
Equipment	1 PC per 4 people	25,000
Total internal gains after utilization factor:		89 kW

Internal (Casual) gains:

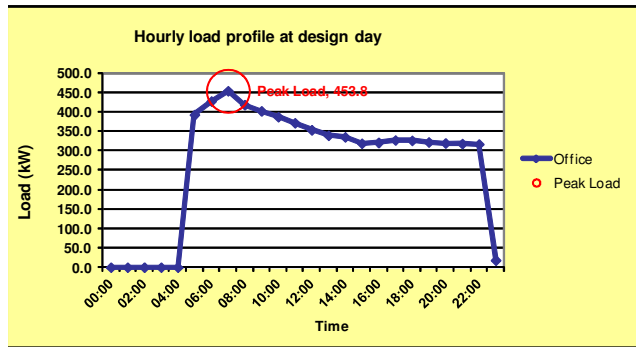
Enter the heat gain per person, lighting load in W per m², and the equipment load, expressed as number of PCs per person.

Building characteristics: Enter the remaining building characteristics using the drop down menus.

Building Balance Temperature

As before, a balance temperature for the building is shown. If the balance temperature drops below 12C, a warning is displayed. You should consider if the subject building is really suitable for heating using a biomass boiler heating system, when the building is likely to require substantial cooling for a large part of the year. Check that you have entered realistic values for insulation of walls and windows, and that internal heat gains are not overstated.

Total heating energy required	
Average heat demand at design day:	269 kW
Energy demand at design day:	6,467 kWh
Annual energy demand:	326,200 kWh
Balance temperature:	14.3 °C



Hourly demand profile	
Building thermal mass	Lightweight
Level of insulation	Medium
Area of glazing	Medium
Level of occupancy	Long
Heating days a week	5
Time	Load (kW)
00:00	0
01:00	0
02:00	0
03:00	0
04:00	0
05:00	392
06:00	427
07:00	454
08:00	418
09:00	402
10:00	387
11:00	371
12:00	353
13:00	339
14:00	335
15:00	319
16:00	321
17:00	327
18:00	326
19:00	322
20:00	319
21:00	318
22:00	317
23:00	19

Various parameters output by the BS EN ISO 13790:2008 calculation are displayed. The sheet also shows the calculated design day and annual heat demands, and the design day profile, according to the user selections.

When finished, click the “Back” button, or the “Return to Demand” button. The “Select Building Type” window will be displayed. Click the “Back” button again, to return to the Heat Demand Inputs sheet. Click **Save** to save your data for this building specification, taking care to select the correct building by checking the Building name that you assigned.

1.2.2.4 Review Results in the Demand Input Sheet

The design day heat demand profile for the building that has just been specified will be shown on the graph, along with the profiles for any other building specifications input, and a total profile for all buildings so far specified. The average heat demand on the design day, the total energy demand on the design day, and the annual energy demand are all shown to the right of the graph. These figures include any distribution network losses that have been specified.

Before proceeding to specify another building, it is important to click the **Save** button for the building just specified. This will save all the input data for that building, for later editing using the Retrieve button.

It is vital that the user **Saves** a building specification before proceeding to specify another building. Failure to do this may result in the loss of the data, which will then need to be completely re-entered.

In the example below, two buildings have been specified, with one of each type.

Building Heat Demand Inputs

Return to Main Interface

No of building specifications: Continuous distribution network power losses: of peak load = kW

Building name: Demand Data Source:

- Detailed Building Simulation Program
- Heat meter measurement
- Fuel bill
- Embedded demand calculator

Number of buildings of this type:

Building name: Demand Data Source:

- Detailed Building Simulation Program
- Heat meter measurement
- Fuel bill
- Embedded monthly demand calculator

Number of buildings of this type:

Hourly load profile at design day

Total heating energy required

Average heat demand at design: kW

Energy demand at design day: kWh

Annual energy demand: kWh

1.2.3 Selecting Options for a Swimming Pool

From the Building Heat Demand Inputs sheet, select Embedded monthly demand calculator for the next building to be specified, and click the Proceed button.

Demand Data source:

- Detailed Building Simulation Program
- Heat meter measurement
- Fuel bill
- Embedded monthly demand calculator

In the Select Building Type window, select Swimming Pool, and click Continue.

An Embedded Calculator sheet will open for specifying a Swimming Pool. Many of the inputs will be similar to those for a non-domestic building, but a few are unique to the definition of a swimming pool.

Select Building Type

Building Type:

- Non-domestic Building
- Swimming Pool
- Glass House
- Housing Estate

Swimming Pool Heat Demand Calculator

Name:

General Info

Site location: Ground insulation:

Type of Pool: Heating days a week:

Is a pool cover used outside operating hours?: Pool water temperature: °C

Operating hours per day: Outdoor design temperature: °C

Dimensions of swimming pool and pool hall

<p>Pool</p> <p>Length: <input type="text" value="25"/> m</p> <p>Width: <input type="text" value="12"/> m</p>	<p>Pool hall</p> <p>Floor area: <input type="text" value="300"/> m²</p> <p>Height: <input type="text" value="5"/> m</p>
---	---

The data required in the first two boxes are:

Type of Pool: Enter the pool type from the drop down menu. A typical pool water temperature based on this selection is displayed to the right. The Pool hall will operate at a temperature 1K above this. The rate of pool hall ventilation is also based on the selection. The options are:

Type of pool	Pool water temp. C	Ventilation l/s/m ²
Hotel/school	28	10
Private leisure	29	10
Public pool (no water features)	29	10
Leisure pool (few water features)	29	14
Leisure pool (many water features)	29	18
Olympic pool	27	8

The pool hall relative humidity is assumed to be 60% for all pool types.

Is a pool cover used outside operating hours?: This is strongly recommended, to reduce evaporative loss from the pool surface. Select Yes or No from the drop down menu.

Operating hours per day: If the pool is typically used only during the working day, select Short. If the pool is often opened into the evening, then select Long.

Ground insulation: modern pools will be insulated to reduce heat loss from the pool water into the ground. This insulation should extend under the pool surround to the external walls. If the pool is insulated in this way, select Yes, otherwise select No.

Heating days a week: Select 5 or 7 from the drop-down menu.

Outdoor design temperature: Enter the external temperature for the day to which the design day load profile applies.

Pool Length and Width: Insert the length and width of the actual pool. For odd shaped pools, enter values here that equate to the same pool area. If there is more than one pool, enter values that equate to the total area of all pools.

Pool Hall area and height: Enter values for the overall pool hall floor area and average height.



Fabric heat loss of pool hall: the data to be input is exactly the same as for a non-domestic building (see section 1.2.2.3).

Occupancy: Enter the average number of bathers during the operating hours.

Ventilation rate outside operating hours: Enter “Ventilation off”, or 50% or 100% of the ventilation rate during operating hours.

Type of Heat Recovery System: There are four options:

- No heat recovery. The ventilation air is heated to the pool hall temperature, and 100% extracted to outside, with no heat recovery. This option will result in a very high heat demand.
- Run-around coil: Heat is transferred via a heat exchanger in the extract duct to a water circulation loop, connected to a second heat exchanger in the intake duct. This will recover some of the sensible heat and, during colder weather, some of the latent heat in the exhaust air stream.
- Air to air heat exchanger: This will transfer heat directly from the exhaust air to the intake air, via a heat exchanger, usually of the parallel plate type. This is somewhat more efficient than a run-around coil.
- Heat pump dehumidifier: A heat pump system will transfer a high proportion of the sensible and latent heat from the exhaust air to the intake air, and may also contribute to pool heating. This is by far the most efficient option for a pool hall.

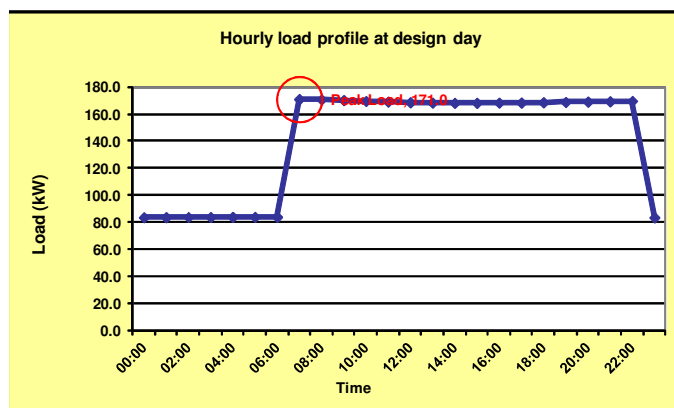
Solar gains: as for fabric losses, the input data is the same as for non-domestic buildings (section 1.2.2.3)

A breakdown of the average heat losses on the design day are shown. Domestic Hot Water demand is based on 2.3 kWh/bather. The user may decide to re-visit some selections based on this feedback.

Occupancy, ventilation and heat recovery	
Average number of bathers	<input type="text" value="20"/> people
Ventilation rate outside operating hours	<input type="text" value="Ventilation off"/>
Type of Heat Recovery System	<input type="text" value="Heat pump dehumidifier"/>

Heat loss breakdown and DHW	
Pool water heat demand (occupied)	35.8 kW
Pool water heat demand (unoccupied)	11.2 kW
Ventilation heat demand (occupied)	23.9 kW
Ventilation heat demand (unoccupied)	8.3 kW
Fabric heat demand	64.4 kW
DHW demand (occupied)	46.0 kW

Total heating energy required	
Average heat demand at design day:	<input type="text" value="141"/> kW
Energy demand at design day:	<input type="text" value="3,377"/> kWh
Annual energy demand:	<input type="button" value="UPDATE"/> <input type="text" value="931,700"/> kWh



Hourly demand profile	
Time	Load (kW)
00:00	84
01:00	84
02:00	84
03:00	84
04:00	84
05:00	84
06:00	84
07:00	171
08:00	171
09:00	170
10:00	170
11:00	169
12:00	169
13:00	168
14:00	168
15:00	168
16:00	168
17:00	168
18:00	169
19:00	169
20:00	169
21:00	169
22:00	170
23:00	84

As for the non-domestic input sheet, the design day profile is displayed, along with a summary box showing the average design day heat demand, the total heat demand on the design day, and the annual energy demand. Click the “**UPDATE**” button to ensure that the latest calculated annual results are displayed.

When finished, click the “Back” button, or the “Return to Demand” button. The “Select Building Type” window will be displayed. Click the “Back” button again, to return to the Heat Demand Inputs sheet. Click **Save** to save your data for this building specification, taking care to select the correct building by checking the Building name that you assigned.

The design day heat demand profile for the swimming pool will be shown on the graph, along with the profiles for any other building specifications input, and a total profile for all buildings so far specified.

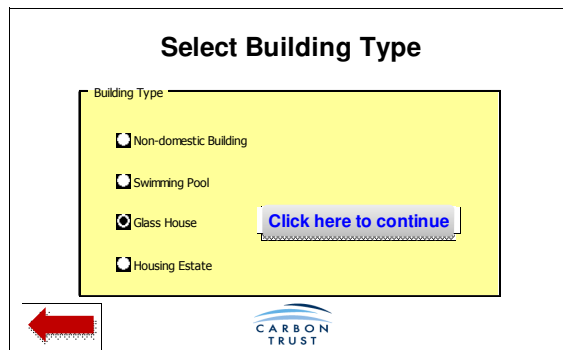
1.2.4 Selecting Options for a Glass House

From the Building Heat Demand Inputs sheet, select Embedded monthly demand calculator for the next building to be specified, and click the Proceed button.



In the Select Building Type window, select Glass House, and click Continue.

An Embedded demand calculator sheet will open for specifying a Glass House.





Type of Glasshouse: There are four options to select from. These are:

- Small - typically a small nursery or for winter protection of plants in an estate.
- Commercial - a glass house covering a large area, used for commercial growing of plants, fruit and veg.
- Victorian - high ceilings, often open to the public for display purposes.
- Orangery - designed for growing fruit trees, with a solid brick wall to the north.

Select the option that most closely represents your glasshouse.

Internal temperature: Select 10C, 15C, 20C or 25C average internal temperature that the heating system would be designed to maintain in winter.

Irrigation rate: This input will determine the evaporation rate that the heating system will have to maintain. The irrigation rates that can be selected are:

Tropical:	1.0	litre/m ² /hr
Temperate:	0.3	litre/m ² /hr
Arid:	0.005	litre/m ² /hr

The user may enter their own user defined value, in litre/m²/hr.

Glasshouse dimensions: input the total floor area and average roof height of the glass house.

Solar gains: input the orientation, shading, total area and inclination from horizontal. Use the drop down menus where provided. Glass house designs can be quite complex, with multiple ridges for example. Space is provided for up to ten glass descriptions, but several glazed areas can be approximated by a single glass specification. In the example shown, all the roof glazing is described as a single area, with zero degree inclination. Single glazed horticultural glass is assumed throughout.

Wall heat loss and ventilation rate: specify the areas of walls and their U-values. Note that walls and windows are specified as separate fabric elements; windows are not contained within walls as for non-domestic buildings. Specify the ventilation rate as air changes per hour. The range of possible ventilation rates is high, and depends on the age of the structure, the quality of construction, and how well the glass house has been maintained. For example, a modern commercial glass house, or small glass house, where doors and windows are closed in winter, will have an air change rate of 1-2 ac/h, whereas an old, poorly maintained Victorian glass house could have a ventilation rate as high as 8 ac/h.

In a similar manner to other input sheets, a summary of heat demands is displayed, along with a graph and table showing the design day profile. Click the “**UPDATE**” button to ensure that the latest calculated annual results are displayed.

Glass House Demand Calculator

Return to Demand

Name: Glasshouse

Glasshouse general information

Site location: Glasgow Type of glasshouse: Orangery

Internal temperature: 15 °C Outdoor design temperature: -3 °C

Irrigation rate: Temperate

Glasshouse dimensions:

Floor area: 250 m² Average height: 3 m

Solar gains

Orientation	Percentage permanently shaded by obstacles	Total glazing area (m ²)	Inclination from horizontal (degree)
Window 1	S	150	90
Window 2	E	15	90
Window 3	W	15	90
Window 4	W	250	0
Window 5	E		0
Window 6	SW		90
Window 7	S		90
Window 8	SE		90
Window 9	E		90
Window 10	NE		90
Window 11	E		90
Window 12	W		90

Total solar heat gains: 10.4 kW

Total solar heat gains after utilization factor: 8.4 kW

Glasshouse wall heat loss

	Area m ²	U value W/m ² K	Heat losses W/K
Wall 1	60	1.80	108
Wall 2			0
Wall 3			0
Wall 4			0
Wall 5			0
Wall 6			0
Window	430	5.90	2537

Ventilation losses

Ventilation rate: 2.0 ach

Ventilation heat losses coeff: 503 W/K

Total wall and window heat loss

Window heat loss: 45.7 kW

Wall heat loss: 1.9 kW

Total heating energy required

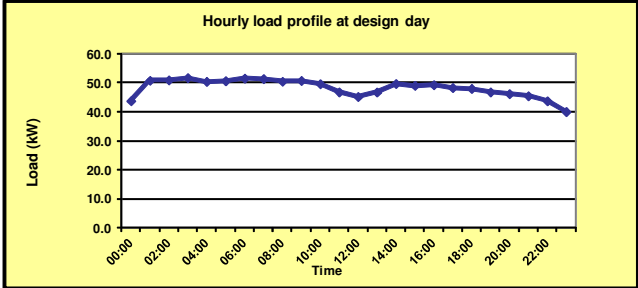
Average heat demand at design day: 48 kW

Energy demand at design day: 1,159 kWh

Annual energy demand: 67,717 kWh

Hourly demand profile

Time	Load (kW)
00:00	44
01:00	51
02:00	51
03:00	52
04:00	50
05:00	51
06:00	52
07:00	51
08:00	51
09:00	51
10:00	50
11:00	47
12:00	45
13:00	47
14:00	50
15:00	49
16:00	49
17:00	48
18:00	48
19:00	47
20:00	46
21:00	46
22:00	44
23:00	40





When finished, click the “Back” button, or the “Return to Demand” button. The “Select Building Type” window will be displayed. Click the “Back” button again, to return to the Heat Demand Inputs sheet. Click **Save** to save your data for this building specification, taking care to select the correct building by checking the Building name that you assigned.

The design day heat demand profile for the glass house will be shown on the graph, along with the profiles for any other building specifications input, and a total profile for all buildings so far specified.

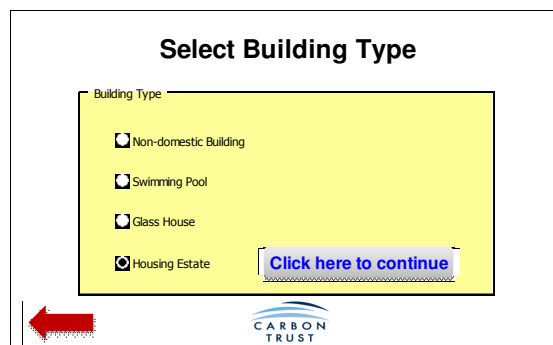
1.2.5 Selecting Options for a Housing Estate

From the Building Heat Demand Inputs sheet, select Embedded monthly demand calculator for the next building to be specified, and click the Proceed button.



In the Select Building Type window, select Housing Estate, and click Continue.

An Embedded demand calculator sheet will open for specifying a Housing Estate.



Outdoor design temperature: input the outdoor design temperature.

Inputs: Up to 10 house specification can be input. For each house specification, the following inputs are required-

Type: Eight types are available; select from the drop-down menu.

Age: Four age bands are available. The age band determines the likely insulation levels, given the building regulations in force at that time.

Number of bedrooms: This input determines the total house floor area, and the DHW requirement.

Number of houses of this type: This specifies the number of houses defined by the inputs for this type.

An average domestic hot water consumption input specifies the kWh/person/day consumed for DHW use.

In a similar manner to other input sheets, a summary of heat demands is displayed, along with a graph and table showing the design day profile. This profile is the aggregate profile for all the houses specified on the housing estate. Click the Update button to ensure that the latest calculated annual results are displayed.

The occupancy profile used for each house is based on that underlying the government’s Standard Assessment Procedure (SAP). To avoid unrealistically high peak loads that would occur if all houses were assumed to follow the exact same heating profile, an element of demand diversity has been introduced; the demands for each hour of the design day have been distributed normally around the demand hour, with the spread increasing with number of houses. The reduction in peak demand for a large (>100) houses is around 33%.

Housing Estate Demand

Return to Demand

Name:

Outdoor design temperature °C

Location:

Inputs				
	Type	Age	Number of bedrooms	Number of houses of this type
House Type 1	<input type="text" value="Detached"/>	<input type="text" value="Pre 1983"/>	<input type="text" value="3"/>	<input type="text" value="20"/>
House Type 2	<input type="text" value="Semi-detached bungalow"/>	<input type="text" value="1983-2002"/>	<input type="text" value="2"/>	<input type="text" value="30"/>
House Type 3	<input type="text" value="Mid-terrace"/>	<input type="text" value="Post 2007"/>	<input type="text" value="2"/>	<input type="text" value="2"/>
House Type 4	<input type="text" value="Mid-floor flat"/>	<input type="text" value="Post 2007"/>	<input type="text" value="1"/>	<input type="text" value="40"/>
House Type 5	<input type="text" value="Ground-floor flat"/>	<input type="text" value="Post 2007"/>	<input type="text" value="1"/>	<input type="text" value="4"/>
House Type 6	<input type="text" value="Top-floor flat"/>	<input type="text" value="Post 2007"/>	<input type="text" value="1"/>	<input type="text" value="4"/>
House Type 7	<input type="text" value="Detached"/>	<input type="text" value="Pre 1983"/>	<input type="text" value="1"/>	<input type="text" value="0"/>
House Type 8	<input type="text" value="Detached"/>	<input type="text" value="Pre 1983"/>	<input type="text" value="1"/>	<input type="text" value="0"/>
House Type 9	<input type="text" value="Detached"/>	<input type="text" value="Pre 1983"/>	<input type="text" value="1"/>	<input type="text" value="0"/>
House Type 10	<input type="text" value="Detached"/>	<input type="text" value="Pre 1983"/>	<input type="text" value="1"/>	<input type="text" value="0"/>
			Total houses	<input style="width: 50px;" type="text" value="100"/>
Average Daily DHW:		<input style="width: 50px;" type="text" value="2"/>	kWh/person/day	

Outputs	
Total heating energy required	
Average heat demand at design day:	<input style="width: 50px;" type="text" value="361"/> kW
Energy demand at design day:	<input style="width: 50px;" type="text" value="8,664"/> kWh
Annual energy demand:	<input style="width: 50px;" type="text" value="1,255,983"/> kWh
	<input type="button" value="UPDATE"/>
Hourly load data at design day	
Time	Load (kW)
00:00	178
01:00	245
02:00	282
03:00	306
04:00	327
05:00	337
06:00	347
07:00	749
08:00	531
09:00	190
10:00	273
11:00	304
12:00	309
13:00	321
14:00	338
15:00	334
16:00	741
17:00	531
18:00	464
19:00	397
20:00	369
21:00	356
22:00	344
23:00	93





When finished, click the “Back” button, or the “Return to Demand” button. The “Select Building Type” window will be displayed. Click the “Back” button again, to return to the Heat Demand Inputs sheet. Click **Save** to save your data for this building specification, taking care to select the correct building by checking the Building name that you assigned.

The design day heat demand profile for the housing estate will be shown on the graph, along with the profiles for any other building specifications input, and a total profile for all buildings so far specified.

1.2.6 Reviewing and Editing Building Specifications

After entering all Building specifications, the continuous network distribution losses may be entered as a percentage of the peak load (heat demand). This is because the distribution system is sized based on the peak load that it is required to handle, and therefore pipework losses will be a function of the peak load.

To edit the input data for any Building Specification, click on the **Retrieve** button corresponding to the specified building, and the tool will open the input data sheet corresponding to the selected building, ready for editing. Don’t forget to **Save** any changes to the correct Building specification after returning to the Building Heat Demand Inputs sheet. Data may be edited at any time by returning to the Demand Module from anywhere within the tool.

Below is an example showing six building specifications. Three are for non-domestic buildings, and one each for a Swimming Pool, Glass house and Housing Estate. District heat system losses have been entered as 1.0% of peak load.

Building Heat Demand Inputs

Return to Main Interface

No of building specifications: Continuous distribution network power losses: of peak load = kW

Building name: Demand Data Source:

Number of buildings of this type:

Detailed Building Simulation Program Heat meter measurement Fuel bill Embedded demand calculator

Building name: Demand Data Source:

Number of buildings of this type:

Detailed Building Simulation Program Heat meter measurement Fuel bill Embedded monthly demand calculator

Building name: Demand Data Source:

Number of buildings of this type:

Detailed Building Simulation Program Heat meter measurement Fuel bill Embedded monthly demand calculator

Building name: Demand Data Source:

Number of buildings of this type:

Detailed Building Simulation Program Heat meter measurement Fuel bill Embedded monthly demand calculator

Building name: Demand Data Source:

Number of buildings of this type:

Detailed Building Simulation Program Heat meter measurement Fuel bill Embedded monthly demand calculator

Building name: Demand Data Source:

Number of buildings of this type:

Detailed Building Simulation Program Heat meter measurement Fuel bill Embedded monthly demand calculator

Hourly load profile at design day

Total heating energy required

Average heat demand at design: kW

Energy demand at design day: kWh

Annual energy demand: kWh

When satisfied with the building inputs, click on the forward button, or Return to the Main Interface and select Financial Inputs.

1.3 Financial Inputs

The financial input page allows the user to input non-biomass system and other project specific capital cost information, for example, grants and annual inflation rates.

Enter Start Year for Project: The year entered here is the base year for Net Present Value (NPV) and Internal Rate of Return (IRR) in the report.

Buffer Vessel/Thermal Storage Cost: An analysis of buffer vessel and thermal store costs carried out for the Carbon Trust produced a mean cost of thermal storage of £1.10 per litre. However, as considerable variations in the cost of thermal storage are possible, the user is able to insert their own figure here.

Non-Biomass System Capital Cost: The costs of other elements of a new system can be included here, e.g. district heating mains or the conversion of buildings to wet heating.

Capital Grant: Any available capital grant should be input here. A capital grant from a public sector source is mutually exclusive with the Renewable Heat Incentive. Should the user wish to accept a grant from a public sector source, after entering the value of the grant the user should click on 'View and adjust RHI rates' and set the User Defined rates in all of the User Defined cells to zero.

Specify Relevant Financial Parameters	
Enter Start Year for Project	2012
Buffer Vessel/Thermal Storage Cost	1.10 £/litre
Non-Biomass System Capital Cost	100,000 £
Capital Grant (see section 1.3 of User Manual)	£
Enhanced Capital Allowance	£
Contingency Sum	£
Renewable Heat Incentive	View and adjust RHI rates
Annual Maintenance Cost	3.0% of capital cost of boiler + feed mechanism
Annual Insurance Cost	1.0% of total capital cost
Saving from Carbon Reduction Commitment	0.00 £ per tonne CO ₂ saved
Discount Rate	8.0% for NPV Calculation
Reference Fuel Cost Inflation Rate	5.0%
Biomass Fuel Cost Inflation Rate	1.0%
Auxiliary Fuel Cost Inflation Rate	5.0%
Annual Maintenance Cost Inflation Rate	1.0%
Annual Insurance Cost Inflation Rate	1.0%
€/£ exchange rate	1.12
RPI Inflation Rate	1.0%


Enhanced Capital Allowance: If the project is eligible for an Enhanced Capital allowance (ECA) an estimate of that should be inserted here.

Contingency Sum: If desired, a contingency capital cost can be input here.

Renewable Heat Incentive: The Renewable Heat Incentive (RHI) subsidy was introduced on March 2011, and is applicable to all new installations. The tariffs used in the tool are as published in the RHI document at www.decc.gov.uk/rhi. The tool automatically calculates the positive contribution to cash flow, year on year, as a result of receipt of the RHI, based on the boiler size and annual heat demand calculated by the tool. The RHI rates will be inflated annually by Ofgem based on the Retail Price Index (RPI), and the user should check that the current rates are being used in the tool. The user can check that the RHI rates are up-to-date by clicking on “View and adjust RHI rates”. The user can define new rates if necessary, or, if disqualified from receipt of RHI (e.g. due to receipt of a capital grant from a public sector source), set the values to zero.

Renewable Heat Incentive						
Boiler Rating	TIER 1 (p/kWh)			TIER 2 (p/kWh)		
	Default	User Defined	Value Used	Default	User Defined	Value Used
less than 200kW	8.3		8.3	2.10		2.10
200kW and above, less than 1MW	5.1		5.1	2.10		2.10
1MW and above	1.0		1.0	-	-	-

[Return to Financial Data Input](#)





Annual Maintenance Cost: Insert the annual maintenance cost of the biomass boiler and fuel handling system as advised by the biomass boiler supplier. This figure is usually in the range 1% - 4% of the capital cost of the biomass boiler and fuel handling system.

Annual Insurance Cost: Additional insurance is frequently required for a biomass system and a figure, expressed as a percentage of the total capital cost, can be inserted here.

Saving from Carbon Reduction Commitment: This figure represents the avoided cost of CO₂ saved under the scheme. Currently the figure is £12 per tonne of CO₂.

Discount Rate: This is the discount rate required for the NPV calculation.

Reference Fuel Cost Inflation Rate, Biomass Fuel Cost Inflation Rate, Auxiliary Fuel Cost Inflation Rate, Annual Maintenance Cost Inflation Rate and Annual Insurance Cost Inflation Rate: These cells allow the user to input annual inflation rates for all these costs, the data being used in the IRR and NPV calculations for the report.

€/£ Exchange Rate: The algorithm used to calculate biomass boiler system costs requires the current exchange rate to be input.

RPI Inflation Rate: The renewable heat incentive rates are expected to increase in line with the Retail Price Index. An estimate of RPI inflation rate should be inserted to cover the duration of the project payback period.

1.4 Biomass Fuel Type

The biomass fuel modules comprise:

- Woodchip fuel data input sheet
- Wood pellet fuel data input sheet

The fuel type is selected either by proceeding directly from the main interface sheet to the Biomass Fuel Module, which brings up the screen shown below, or on the Biomass Boiler System Sizing sheet: selecting the fuel type in one location alters the selection in the other location.

Select Biomass Fuel Type

Biomass Type

Wood Chip [Click here to continue](#)

Wood Pellet

CARBON TRUST

1.4.1 Fuel Data Input - Woodchip

Fuel Data - Woodchip

[Return to Main Interface](#)

NOTES: Fuel storage can be sized after sizing the boiler.

	Moisture content*	Kind of wood	Ash content (%)		Fuel density		Net Calorific value		Price per tonne delivered	Transport cost per tonne per mile (£)	Distance (Miles)	Total cost £ per kWh
			dry basis	as received	kg/m3	kWh/m3	MJ/kg	kWh/kg				
Woodchip1	M30	Soft Wood	A1.5	1.05	279	945	12.2	3.4	95			0.028
Woodchip2	M30	Soft Wood	A1.5	1.05	279	945	12.2	3.4	110			0.032
Woodchip3	M40	Soft Wood	A1.5	0.9	325	914	10.1	2.8	105			0.037

*The elevate: The values for "woodchip 1" are used in subsequent calculations and the financial analysis

Default net calorific value (LHV) for dry wood taken is (MJ/kg)

Soft Wood - 18.5 Hard Wood - 19.5

Other Values

Woodchip1	Woodchip2	Woodchip3
14.00	14.00	14.00

Source: Smith, K.R.; Kaltschmitt, M.; Thrän, D. 2001 "Renewable Energy from Biomass"

Default dry bulk density (kg/m3)

Soft Wood - 195 Hard Wood - 260

Other Values

Woodchip1	Woodchip2	Woodchip3
250	250	250

Source: UBET Unified BioEnergy Terminology

***When dealing with the fuel supplier, following the CEN/TS 14961:2005, the specifications of the fuel properties are given as below**

Moisture (M)		Ash content (dry basis)	
M20	Moisture ≤ 20%	Dried	
M30	Moisture ≤ 30%	Suitable for storage	
M40	Moisture ≤ 40%	Limited for storage	
M55	Moisture ≤ 55%		
M65	Moisture ≤ 65%		
		A0.7	Ash content ≤ 0.7%
		A1.5	Ash content ≤ 1.5%
		A3.0	Ash content ≤ 3.0%

The following have drop-down boxes with selections to be made:

- Moisture content:** Select the desired fuel moisture content
- Kind of Wood:** Select hardwood or softwood
- Ash Content:** Select the fuel's ash content as advised by the fuel supplier
- Fuel Price:** Select the fuel price per tonne, per tonne delivered or per kWh

A warning will be displayed if the fuel moisture content is 40% or higher.


Click the heading box (shaded orange) and a menu will appear. If fuel price is inclusive of delivery select "Price per tonne delivered" or "Price per kWh". If the fuel price is exclusive of delivery select "Price per tonne" and the transportation entries boxes will appear; insert a price per tonne, a transportation cost per tonne per mile and the distance from the fuel supplier. Note that fuel prices here (and throughout the tool) are specified in pounds (not pence).

Default values for the net calorific value of dry wood and dry bulk density are used in the calculations. These values can be overwritten by selecting Kind of Wood as "Other", and inserting values in the areas below the main fuel input box.

The Tool allows for the comparison of fuel from up to 3 different suppliers (or 3 types of fuel from one supplier), shown as **Woodchip 1**, Woodchip 2 & Woodchip 3. The **Woodchip 1** selection is in bold type to remind the user that it is the values entered in this line which are used in subsequent fuel use and fuel cost calculations.

1.4.2 Fuel Data Input - Wood Pellets

Fuel Data - Pellets



Return to Main Interface

NOTES: Fuel storage can be sized after sizing the boiler.

	Moisture content*	Ash content (%)		Fuel density		Calorific value		Price per tonne delivered (£)	Total cost £ per kWh
		dry basis	as received	kg/m ³	kWh/m ³	MJ/kg	kWh/kg		
Pellet1	M10	A3.0	2.7	722	2,952	14.7	4.1	150	0.037
Pellet2	M10	A3.0	2.7	722	2,952	14.7	4.1		0.000
Pellet3	M10	A3.0	2.7	722	2,952	14.7	4.1		0.000

The values for "Pellet1" are used in subsequent calculations and the financial analysis

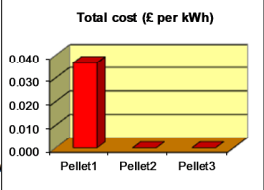
Net calorific value (LHV) for dry wood taken is (MJ/kg)

	Pellet1	Pellet2	Pellet3
LHV used	16.62	16.62	16.62
Default	16.62	16.62	16.62
User Input	<input type="text"/>	<input type="text"/>	<input type="text"/>

Dry Bulk density taken is (kg/m³)

	Pellet1	Pellet2	Pellet3
Density used	650.0	650.0	650.0
Default*	650.0	650.0	650.0
User Input	<input type="text"/>	<input type="text"/>	<input type="text"/>

Total cost (£ per kWh)




*the listed data are typical dry bulk density for pellet

*When dealing with the fuel supplier, following the CEN/TS 14961:2005, the specifications of the fuel properties are given as below

	Moisture (M)
M10	Moisture ≤ 10%
M15	Moisture ≤ 15%

	Ash Content (dry basis)
A0.7	Ash content ≤ 0.7%
A1.5	Ash content ≤ 1.5%
A3.0	Ash content ≤ 3.0%

* - Physical Characterisation and chemical composition of densified biomass fuels with regard to their combustion behaviour. Published in: Proceedings of the 1st World Conference on Pellets

←

→

The following have drop-down boxes with selections to be made:

- Moisture content:** Select the desired fuel moisture content
- Ash Content:** Select the fuel's ash content as advised by the fuel supplier

Insert a delivered price per tonne or per kWh (click on the orange box to change between tonnes and kWh).

Default values for the net calorific value of dry wood and dry bulk density are used in the calculations. These are the values published in "Physical Characterisation and chemical composition of densified biomass fuels with regard to their combustion behaviour." Published in: Proceedings of the 1st World Conference on Pellets. These values can be overwritten in the areas below the main fuel input box. Simply type in your own values in the white boxes, and they will be used in preference to the defaults.

The Tool allows for the comparison of fuel from up to 3 different suppliers (or 3 types of fuel from one supplier), shown as Pellet 1, Pellet 2 & Pellet 3. The Pellet 1 selection is in bold type to remind the user that it is the values entered in this line which are used in subsequent fuel use and fuel cost calculations.

1.5 Biomass Boiler Sizing

The Biomass Boiler Module is at the heart of the software. It is an interactive module allowing the user to assess system performance against different fuel types and two different operating strategies. The core of the module is a Macro which calculates the boiler, auxiliary boiler and buffer vessel or thermal storage sizes, displaying the results graphically for the user to examine.

There are six steps involved in boiler system sizing. These are arranged in logical order, but there is nothing to prevent the user skipping a step, or returning to a previous step, especially after the first run through the tool. Make sure however that all input boxes are filled. The six steps are now summarised, and more detailed instructions for entering the required data follow in the next section.

1. **Inputs:** here the type of biomass boiler, auxiliary boiler and reference boiler are specified, with some parameters on which the sizing will be based. Fuel costs are also specified, so that annual energy costs may be calculated. At this stage, the user selects a system sizing strategy to be evaluated:
 - Sizing based on minimum buffer vessel size (for boiler protection)
 - Sizing based on optimum boiler and thermal store combination
 - Sizing based on optimum boiler and thermal store combination, but with a limit on the maximum thermal store size.
2. **Sizing Results Part I:** A range of boiler and thermal store sizes are evaluated, and the user can choose a particular size combination, based on capital cost, energy cost, or any other relevant criteria.

The user can then save selected results in a table from which side-by-side comparisons can be made of the key features of each selected option.

3. **Thermal Storage Vessel:** The dimensions and number of thermal storage vessels can be determined iteratively, taking into account such constraints as boiler house roof height. It is also possible to position the thermal storage vessels outside the boiler house, thereby reducing the cost of additional plant room space. It may be convenient to position the vessel horizontally rather than vertically. By adjusting these dimensions, storage vessel volume can be specified to match the volume required according to the latest size combination selected at the previous step. Note that the dimensions are external dimensions, i.e. for the fully insulated vessel. The annual energy calculations will take account of the heat loss from the storage vessels, and the boiler house capital cost that is calculated later will allow for the additional floor space required to accommodate them, in the case that they are selected to be located internally.

After dimensioning the thermal storage vessel, the user should go back and re-run the strategy. Otherwise, the results in the Sizing Results Part I sheet will not reflect the heat losses and plant room costs associated with the thermal store.

Note that the capacity of vessel required is equal to the sum of the thermal store and minimum buffer vessel calculated by the tool, and displayed in the table in Sizing Results Part 1. If sizing is based on Minimum Buffer Vessel, the user may skip this step, as the heat losses from a well insulated vessel will be negligible, compared to the boiler output. The tool makes a standard allowance for plant room space and cost for a minimum buffer vessel, and ignores any data on this sheet.

4. **Capital Costs Specification:** Having made a system selection, the user then has an opportunity to view and make changes to the capital costs generated by the tool.
5. **Fuel Storage Module:** Based on the fuel requirements of the chosen boiler selection, the fuel storage type and size can be determined.

6. Sizing Results Part II: The final step is to view a summary of the boiler system component sizes and a side-by-side comparison of fuel, electricity and CO₂ emissions for the biomass and auxiliary boilers, and the comparative reference boiler.

At this point the user can go back to any stage and revise his assumptions, alter the equipment sizes, or try a different strategy.

In any case, it is advisable to return to step 2: Sizing Results Part I for each strategy run, as some of the data included in the comparison table is affected by the thermal storage inputs, capital cost additions, and fuel storage selection. It is important to reset the required boiler size in the Sizing Results Part I sheet before saving, or re-saving a particular results combination, and reviewing changes to the thermal store size, capital costs and the Sizing Results Part II.

By iterating around this area of the tool, the user should arrive at the optimum solution for a project.

1.5.1 Inputs

Biomass boiler system parameters: Select the features relevant to the boiler type being considered for the installation. It may be necessary to check this information with the manufacturer of the boiler it is proposed to use before selecting the data.

The tool has been designed to guide those who are not familiar with the finer details of biomass boiler systems in the selection of realistic combinations of boiler features. The options now described represent the most commonly encountered combinations of features found on biomass boilers. However, the wide range of types of boiler available from numerous manufacturers mean that a particular combination of features from any given manufacturer may not be selectable.

Biomass Boiler System Sizing

Return to Main Interface

Biomass boiler system inputs

Specify biomass boiler system parameters

Biomass boiler type	<input type="text" value="Stoker Burner"/>
Type of fuel feed mechanism	<input type="text" value="Auger"/>
Level of refractory lining	<input type="text" value="High"/>
Ignition type	<input type="text" value="Manual"/>
Fuel consumption in slumber mode	<input type="text" value="Typical"/>
Biomass boiler seasonal efficiency	<input type="text" value="80"/> %
Biomass boiler flow temperature	<input type="text" value="90"/> °C
Circuit return temperature	<input type="text" value="65"/> °C

Select biomass boiler system sizing strategy

Minimum buffer vessel size
 Optimum biomass boiler/thermal store combination
 Limit thermal store size

Auxiliary boiler data

Is auxiliary boiler required for system backup?

Minimum back-up boiler size requirement kW

(Notes: Any auxiliary boiler calculated by this tool will be increased to this capacity.)

Fuel type

Unit price £ per litre

CO₂ Factor (if different from the default value) [Click here to define carbon factor](#)

Seasonal efficiency %

Reference boiler inputs

Reference Boiler Information

Fuel source

Unit price £ per litre

CO₂ Factor (if different from default value) [Click here to define carbon factor](#)

Reference boiler burner type


Days of operation in a year days

Seasonal efficiency %

Existing district heating network

Other items

Unit price for electricity £ per kWh



The first selections in this box are used in the calculation of the minimum buffer vessel size required.

Biomass boiler type: Input the boiler type using the drop-down menu. Stoker Burner, Underfed Stoker or Moving Grate can be selected.

Type of fuel feed mechanism: There are two possible selections: **Ram Stoker** and **Auger**. If **Ram Stoker** is selected the fuel feed system will comprise a hydraulic ram with a flap valve or lifting gate between the stoker ram and the boiler. This type of fuel feed can only be selected for a **Moving Grate** type boiler. It is assumed that for auger-fed Stoker Burner and Moving Grate boilers, the auger is always emptied on boiler shut down. It is permissible to leave the fuel in the feed auger of an Underfed Stoker. **Auger** can be selected for any boiler type.

Level of refractory lining: A high level of refractory lining is required if the boiler is required to burn wood chips with a high moisture content (>40%). If the boiler has a low level of refractory lining, this may remove the need for a buffer vessel into which heat is dissipated on boiler shut down even though boiler efficiency may be improved by the inclusion of a buffer vessel. Select **Yes** or **No**.

Ignition type: Boilers are supplied with either an automatic or a manual ignition system. An automatic ignition system will allow the boiler to turn off when there is no demand, and will automatically relight when heat is required. A manual ignition boiler will reduce the fuel feed rate to a minimum sufficient to keep the fire alight on the grate (slumber, or kindling mode). This means that the boiler is always consuming fuel, even when there is no demand for heat. In general, this type of boiler is unsuitable for meeting summer loads (e.g. DHW only). However, if the user proceeds with this selection, the tool will calculate the resulting total fuel consumption, including that used in slumber mode. Select **Automatic** or **Manual**.

Fuel consumption in slumber mode: If a manual boiler has been selected, then this input box appears, allowing the user to select the rate of fuel consumption in slumber (or kindling) mode. Manufacturer's Data (usually a very low figure) or Typical (a more realistic value based on systems observed in practice). See section 2 of this manual for details of formulae used.

Biomass boiler efficiency: Values from 75% to 92% are selectable.

Biomass boiler flow temperature: Values from 81C to 120C are selectable.

Circuit return temperature: Values from 50C to 81C are selectable.

The user should check that the input data in this section represents a valid boiler specification. Although the tool will usually warn the user if an invalid combination of inputs has been specified, it will not always do so, and erroneous results may appear later on.

Select biomass boiler system sizing strategy: Select **Minimum buffer vessel size** if a buffer vessel is required to avoid overheating on boiler shut down. Select **Optimum biomass boiler / thermal store combination** if a thermal store is required to allow a reduction in biomass boiler size. Select **Limit thermal store size** if a thermal store is required to allow a reduction in biomass boiler size, but there is a space limitation that limits the capacity of the thermal store. A box will appear to allow input of the limiting capacity, in litres.

Auxiliary boiler data: The majority of biomass systems are designed with an auxiliary boiler to meet peak loads. The required data on the auxiliary boiler should be entered at this point.

Is an auxiliary boiler required for system backup?: The auxiliary boiler can also be used to provide up to 100% backup to the biomass system. If **Yes** is selected **Minimum back-up boiler size requirement** appears and the user should enter the size of the back-up boiler required. This does not prevent the tool from calculating an auxiliary boiler of larger capacity than that specified here, if the tool determines that this is required. If **No** is selected there is no requirement to enter a back-up boiler size.

Fuel Type: Select the fuel type to be used for the auxiliary boiler from: Natural Gas; LPG; Gasoil; or Kerosene.

Unit Price: Enter the unit price for the fuel type selected in the units which appear to the right of the box.



CO₂ Factor: To substitute alternative carbon factors, click the link “Click here to define carbon factor”. A new window will open, showing the default factors, and allowing the user to define alternative values. The values used in the tool are shown in the right hand boxes. Calorific values can also be adjusted, if necessary. However, the tool does not presently use the values of calorific value for wood fuels entered here. Use the Biomass Fuel Type input sheets described earlier to specify wood fuel calorific values. Click “Return to Boiler System Sizing Module” when finished.

Fuel Properties Data							
Boiler fuel type	Carbon Emission Factors (kg CO ₂ /kWh)			Density (kg/m ³)	Calorific Values (kWh/kg)		
	Default	User Defined	Value Used		Default	User Defined	Value Used
Coal	0.316		0.316	850	8.05		8.05
Gasoil	0.32331		0.32331	803	11.89		11.89
Grid Electricity	0.517		0.517				
Kerosene	0.29247		0.29247	803.21	12.18		12.18
LPG	0.24127		0.24127	508.13	12.75		12.75
MFO	0.31108		0.31108	977.50	11.38		11.38
Natural Gas	0.20322		0.20322	0.746	13.22		13.22
Wood Chips	0.01579		0.01579	250.0	3.89		3.89
Wood Pellets	0.03895		0.03895	1538.46	4.62		4.62

Notes:
Carbon emission factors for coal, gasoil, grid electricity kerosene, LPG, MFO and natural gas are measured based on gross calorific value.
While for wood chips and wood pellets are measured based on net calorific values.

Efficiency: Enter the seasonal efficiency of the auxiliary boiler. Values from 50% to 100% can entered.

Reference Boiler Information: Fuel cost savings are calculated against a reference boiler which would be required if a biomass system is not to be used. This boiler could be a boiler (or boilers) in an existing building. In this case information on it should be entered including an estimate of its seasonal efficiency. The carbon factors are the same as those used for the auxiliary boiler, and can be defined using the link.

Fuel Source: The fuel types available for the reference boiler are: Coal; Gasoil; Grid Electricity; Kerosene; LPG; MFO and Natural Gas. The Grid Electricity option allows both for data from electric boilers (such as electrode boilers) and from electrically heated buildings to be inserted.

Unit Price: Enter the price per unit of delivery for the fuel type selected in the units which appear to the right of the box. The tool takes into account the calorific value of the fuel to calculate the cost per kWh.

CO₂ Factor: Again, the carbon factors can be adjusted if necessary.

Reference boiler burner type: Select Pressure Jet or Atmospheric (gas boilers only) burner type. A pressure jet burner will consume more electricity than an atmospheric type, and this is reflected in the running cost and CO₂ emission analyses.

Days of Operation per year: Enter the number of days of operation of the reference boiler per year.

Seasonal efficiency: Enter the seasonal efficiency of the reference boiler. Values from 50% to 100% can be input. Where an electric heating system is being compared the efficiency is fixed at 100%.

Existing district heat network: If the reference system already includes a district heat network, then enter Yes from the drop down menu. The tool will then include the district heat system losses in calculating the total boiler loads for both biomass and reference boiler systems. Otherwise enter No, and the district heat losses will apply only to the biomass system.

Unit Price of Electricity: Enter a unit price for electricity, £/kW.

1.5.2 Warning Messages:

The tool may display various warning messages in the top right area of the sizing sheet, if the boiler selection parameters are inconsistent with the fuel type and operating strategy selected. In the example above, a Manual boiler has been selected, with a High level of refractory lining, and sizing with Minimum buffer vessel only. The first warning indicates that “Flue gas recirculation may be required”. This warning appears when a high level of refractory lining has been specified. Boilers that are required to burn wood chips with moisture content greater than 40% need to be specified with a high level of refractory lining. If a low moisture content fuel is specified, then this warning will only appear if a high level of refractory lining is specified.



The second warning reminds the user that “Manual ignition boilers are not suitable to supply summer loads.” A manual ignition boiler in slumber mode will consume fuel continuously throughout the summer months, just to service the occasional DHW load. However, the user may continue with this selection, and the tool will calculate fuel use including that consumed during slumber mode in the summer months.

Other warnings may appear, and the table below indicates what causes the warning, and what the user should consider changing to improve the match of the boiler parameters to the other system selections.

Warning	Cause	Remedy
Flue gas recirculation may be required.	High refractory lining has been specified for a boiler burning dry fuel.	Select Low level of refractory lining, or allow for the additional cost of flue gas recirculation when specifying capital costs.
Automatic ignition not possible, reduce fuel MC to 30% or lower.	Automatic ignition boilers cannot be used with high moisture content wood chips.	Select a manual boiler type, or reduce the fuel moisture content.
Fuel incompatible with boiler. Reduce fuel MC to 30% or lower	High moisture content wood chips are not compatible with Underfed Stokers.	Select a different boiler type, or reduce the fuel moisture content.
Reduce fuel MC to 30% or lower	Boilers that are to burn wood chips with high moisture content require a high level of refractory lining.	Select a high level of refractory lining, or reduce the fuel moisture content.
High thermal mass boiler, may be unsuitable to supply summer loads	If a boiler with a high level of refractory lining has no (or minimum) buffer vessel, it will waste a lot of energy during summer operation, as most of the energy stored in the lining on boiler start up will be lost to the flue on shut down.	Select a boiler with a low level of refractory lining, or select an operating strategy that includes a thermal store.
High thermal mass boiler, may be unsuitable to supply summer loads if the thermal store is too small	If a boiler with a high level of refractory lining has too small a thermal store, not all the heat contained within the lining may be recovered on boiler shut down.	Ensure that the thermal store is of sufficient size to recover the heat from the boiler on shut down, or specify a low level of refractory lining.
Manual ignition boilers are usually not suitable to supply summer loads. You may inspect the Annual Load Duration Curve on the Results Part 1 sheet, and modify your design to optimise the match between the boiler and summer heat demand. You may opt to switch off the boiler in summer and meet loads from an alternative heat source.	Self explanatory.	Either follow the suggestions given, or change the ignition type to Automatic.

Table 2 Boiler Selection Warning Messages

The user may choose to ignore any warnings, and continue to size the boiler system based on the chosen selections. The user then needs to analyse the results carefully, and be satisfied that they are not in error.

In the example above, the user may decide to change the boiler type to Automatic, and change the level of refractory lining to Low. The warnings then disappear, as shown below.

Biomass Boiler System Sizing

Return to Main Interface

Biomass boiler system inputs

Specify biomass boiler system parameters

Biomass boiler type	Stoker Burner
Type of fuel feed mechanism	Auger
Level of refractory lining	Low
Ignition type	Automatic
Biomass boiler seasonal efficiency	80 %
Biomass boiler flow temperature	90 °C
Circuit return temperature	65 °C

Select biomass boiler system sizing strategy

Minimum buffer vessel size
 Optimum biomass boiler/thermal store combination
 Limit thermal store size

Auxiliary boiler data

Is auxiliary boiler required for system backup? Yes

Minimum back-up boiler size requirement 500 kW

(Notes: Any auxiliary boiler calculated by this tool will be increased to this capacity.)

Fuel type Gasoil

Unit price 0.60 £ per litre

CO₂ Factor (if different from the default value) [Click here to define carbon factor](#)

Seasonal efficiency 80 %

Reference boiler inputs

Reference Boiler Information

Fuel source Gasoil

Unit price 0.60 £ per litre

CO₂ Factor (if different from default value) [Click here to define carbon factor](#)

Reference boiler burner type Pressure jet


Days of operation in a year 240 days

Seasonal efficiency 60 %

Existing district heating network No

Other items

Unit price for electricity 0.12 £ per kWh

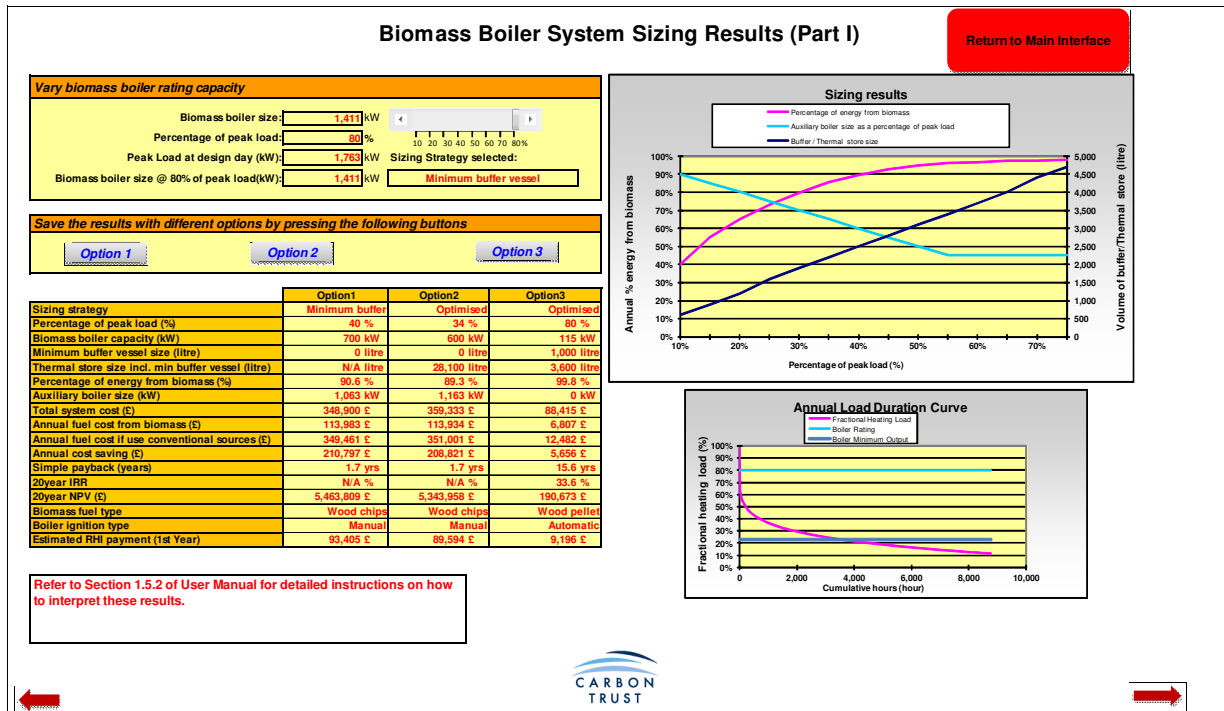
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The user should now click the **red navigation** button (forward button) at the bottom right corner (or, return to Main Interface and select Sizing Results Part I.)

1.5.3 Biomass Boiler System Sizing Results Part I, and Thermal Storage Vessel

1.5.3.1 Sizing with a minimum buffer vessel

The results of running the calculation are shown on the Biomass Boiler System Sizing Results (Part I) page. The three areas of this page are the boiler sizing graph, a boiler size input box, a table where different options can be saved and compared, and an Annual Load Duration Curve. Shown below are example graphs produced with the calculation run for the Minimum Buffer Vessel Option.



At this point the graphs can be examined. The percentage of annual energy from biomass increases as the boiler size increases, so it can be observed that the vast majority of energy can be supplied by a boiler sized at less than half of the peak design day load. The size of the auxiliary boiler decreases as biomass boiler size increases, levelling off if a minimum auxiliary boiler size was specified. The required buffer vessel size increases linearly with biomass boiler size.

The lower graph is an Annual Load Duration Curve. This can be used to assess the suitability of the chosen boiler type and system combination for summer heating. This will be discussed shortly.

An operating point can now be chosen to save as an option. If it is decided that 90% of the annual energy should be provided from biomass, from the red curve it can be seen that a biomass boiler sized at 42% of the peak load will provide this. Use the slider to adjust the boiler output (briefly release the slider to see the currently selected percentage of peak load) until a suitable value is selected. It may be that an odd boiler size is displayed (not available from your chosen manufacturer) so adjust the slider until a valid size is shown. This can then be saved as **Option 1** by clicking on the Option 1 button, and the left hand side of the page looks like this (the sizing graph does not change).

Vary biomass boiler rating capacity

Biomass boiler size: kW

Percentage of peak load: %

Peak Load at design day (kW): kW

Biomass boiler size @ 80% of peak load(kW): kW

Sizing Strategy selected:

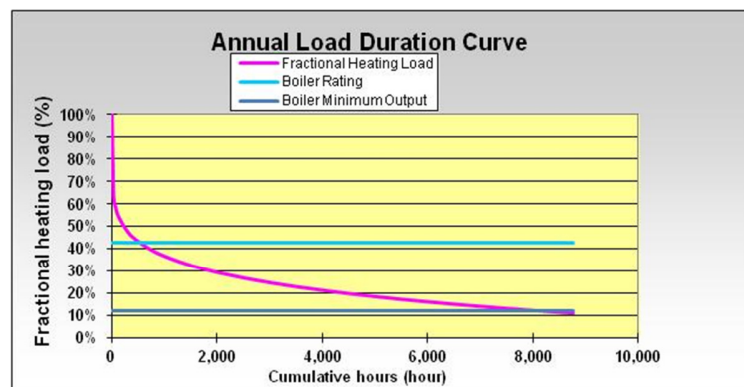
Save the results with different options by pressing the following buttons

	Option1	Option2	Option3
Sizing strategy	Minimum buffer	Optimised	Optimised
Percentage of peak load (%)	43 %	34 %	80 %
Biomass boiler capacity (kW)	750 kW	600 kW	115 kW
Minimum buffer vessel size (litre)	2,600 litre	0 litre	1,000 litre
Thermal store size incl. min buffer vessel (litre)	N/A litre	28,100 litre	3,600 litre
Percentage of energy from biomass (%)	91.4 %	89.3 %	99.8 %
Auxiliary boiler size (kW)	1,013 kW	1,163 kW	0 kW
Total system cost (£)	477,684 £	359,333 £	88,415 £
Annual fuel cost from biomass (£)	114,659 £	113,934 £	6,807 £
Annual fuel cost if use conventional sources (£)	375,482 £	351,001 £	12,482 £
Annual cost saving (£)	236,615 £	208,821 £	5,656 £
Simple payback (years)	2.0 yrs	1.7 yrs	15.6 yrs
20year IRR	741.6 %	N/A %	33.6 %
20year NPV (£)	5,795,658 £	5,343,958 £	190,673 £
Biomass fuel type	Wood chips	Wood chips	Wood pellet
Boiler ignition type	Automatic	Manual	Automatic
Estimated RHI payment (1st Year)	95,714 £	89,594 £	9,196 £

Now, a summary of the performance of the selected option can be seen in the table. Note that in this case, the thermal store size displays as N/A. This is because we have not yet specified a thermal store, only a minimum buffer vessel.

If the user selects a Manual Ignition boiler, then a buffer vessel is not required, and the tool will enter a value of zero for the buffer vessel size. However, this does not mean that a thermal storage vessel cannot be specified to optimise system efficiency, just that a buffer vessel is not required to protect the boiler against overheating.

Also, observe the Annual Load Duration Curve. This is a cumulative frequency distribution of load, so that any point on the curve of Fractional Heating Load represents the number of hours in the year for which the heating demand will be greater than the value indicated. Also shown are the boiler maximum and minimum firing rates (based on boiler size and turndown ratio). It can be seen that for almost all the year, the load will exceed, or only marginally fall short of the minimum firing rate.



This suggests that the choice of system is well suited to summer operation of the system, when only domestic hot water loads and district heat losses, if present, will need to be met. Compare this curve with that shown on the previous page, for a boiler sized at 80% of peak load. This boiler would clearly be oversized for the summer load, even at boiler minimum firing rate, and would likely need to be turned off and the load met using the auxiliary boiler. This becomes more of an issue with a Manual ignition boiler, which runs continually in summer, in slumber mode. If the minimum boiler output cannot be reduced below the load to the right of the Annual Load Duration Curve, when using a Manual ignition boiler, the user should seriously consider changing the selection of ignition type to Automatic.

As a rule of thumb, the user should aim for at least 5,500 hours of annual operation with load above the minimum boiler output.

To improve the suitability of a system for summer load operation, the following modifications can be readily investigated using the tool:

- Further reduce boiler size. This is advisable, even at the expense of slightly increased auxiliary boiler use.
- Incorporate a thermal store (see next section) allowing the boiler size (and minimum firing rate) to be reduced, without compromising on maximising utilisation of biomass fuel.
- Choose a boiler with a larger turndown ratio. Stoker burner and underfed stoker boilers with a low level of refractory lining generally have the best turndown ratios.

1.5.3.2 Sizing using a thermal store

To compare the performance of a biomass system designed for optimum performance using a thermal store, the user should press the **red navigation** button (back button) at the bottom left corner (or, return to Main Interface and select Boiler Sizing Module.) Now the **Optimum biomass boiler/thermal store combination** should be selected. Press the **red navigation** button (forward button) at the bottom right corner (or, return to Main Interface and select Sizing Results Part I.)

This returns the user to the Sizing Results Part I sheet, but this time displaying the graphs for the optimum boiler / thermal store solution:

Return to Main Interface

Biomass Boiler System Sizing Results (Part I)

Vary biomass boiler rating capacity

Biomass boiler size: kW

Percentage of peak load: %

Peak load at design day (kW): kW

Biomass boiler size @ 80% of peak load(kW): kW

Sizing Strategy selected: Optimum boiler/thermal store

Save the results with different options by pressing the following buttons

Option 1
Option 2
Option 3

	Option1	Option2	Option3
Sizing strategy	Minimum buffer	Optimised	Optimised
Percentage of peak load (%)	43 %	34 %	80 %
Biomass boiler capacity (kW)	750 kW	600 kW	115 kW
Minimum buffer vessel size (litre)	2,600 litre	0 litre	3,600 litre
Thermal store size incl. min buffer vessel (litre)	N/A litre	28,100 litre	3,600 litre
Percentage of energy from biomass (%)	91.4 %	89.3 %	99.8 %
Auxiliary boiler size (kW)	1,013 kW	1,163 kW	0 kW
Total system cost (£)	477,684 £	359,333 £	88,415 £
Annual fuel cost from biomass (£)	114,659 £	113,934 £	6,807 £
Annual fuel cost if use conventional sources (£)	375,482 £	351,001 £	12,482 £
Annual cost saving (£)	236,615 £	208,621 £	5,656 £
Simple payback (years)	2.0 yrs	1.7 yrs	15.6 yrs
20year IRR	741.6 %	N/A %	33.6 %
20year NPV (£)	5,795,658 £	5,343,958 £	190,673 £
Biomass fuel type	Wood chips	Wood chips	Wood pellet
Boiler ignition type	Automatic	Manual	Automatic
Estimated RHI payment (1st Year)	95,714 £	89,594 £	9,196 £

Refer to Section 1.5.2 of User Manual for detailed instructions on how to interpret these results.

Sizing results

Annual Load Duration Curve

Increase the thermal store size!

At this point the graphs can again be examined and another operating point chosen to save as an option. It can be seen that 90% of energy from biomass can now be supplied with a boiler sized at 35% of the peak load. The thermal store requirement is, of course, greater than that required for a minimum buffer vessel, and increases in size until a point is reached that the system can meet 100% of demand from biomass. Further increases in boiler size would allow the biomass boiler to meet an increasing proportion of demand directly, so the thermal store size requirement decreases. However, significant issues would now arise due to frequent on/off operation of a very large boiler.

If the slide is adjusted so that 34% of peak load appears in the box, and the result saved as **Option 2** the left hand side of the page looks like this (again the graphs do not change). Again, 95% of annual energy could be supplied by biomass fuel, but with a much smaller boiler (600kW). A summary of the performance of this option is now displayed in the second column of the table. Note that the Thermal Store size is displayed, and includes the required minimum buffer vessel volume (which has decreased because the boiler is smaller).

However, although the tool has calculated a size for the thermal storage vessel (considerably greater than that required for a minimum buffer vessel) it has not yet taken into account the thermal losses or additional plant room cost to accommodate this vessel. A message usually appears below the graphs to warn the user of this (see above). The user now has to provide some additional information about the thermal storage vessel. Note that the volume includes that required for both the thermal store and the minimum buffer vessel. In practice, these two volumes, though separate from a sizing strategy viewpoint, will be implemented as a single thermal storage system, with appropriate temperature sensors and controls to ensure the buffer vessel function can operate at any time.

At this point, the user should click the forward button, and enter dimensions for the Thermal Storage Vessel. Note that this step is not required when the Minimum Buffer Vessel sizing strategy is being considered.

The number, height and width of the vessel(s) are entered. Also, indicate if the vessel is to be located in the plant room (indoor) or outdoor. This will affect the calculation of heat loss, and the cost of the plant room. Note that the inputs relate to the outer dimensions, including the insulation layer. Input the insulation thickness in mm, and the insulation type.

The aim is to obtain a Specified Tank Water Volume equal to the displayed Required Tank Water Volume. A message is displayed to indicate if the currently specified tank has to be increased, or decreased in size to meet this aim. Note that the water volume required is equal to the sum of the optimum thermal store volume, and the buffer vessel volume. To allow for the fact that vessels may only be manufactured in discrete sizes, the tool allows the vessel to be oversized by up to 15%.

Next, press the back button, and rerun the Optimum Biomass Boiler / Thermal Store strategy (ensure that Optimum biomass / thermal store combination is selected, and click the forward button). Select the 34% (600kW) boiler as before, and resave as option 2. It will be seen that the system cost and annual fuel costs will change, as the cost of the thermal store is now being fully accounted for.

Vary biomass boiler rating capacity

Biomass boiler size: kW

Percentage of peak load: %

Peak Load at design day (kW): kW

Biomass boiler size @ 80% of peak load(kW): kW

Sizing Strategy selected:

Save the results with different options by pressing the following buttons

	Option1	Option2	Option3
Sizing strategy	Minimum buffer	Optimised	Optimised
Percentage of peak load (%)	43	34	80
Biomass boiler capacity (kW)	750 kW	600 kW	115 kW
Minimum buffer vessel size (litre)	2,600 litre	2,100 litre	1,000 litre
Thermal store size incl. min buffer vessel (litre)	N/A litre	24,900 litre	3,600 litre
Percentage of energy from biomass (%)	91.4	87.5	99.8
Auxiliary boiler size (kW)	1,013 kW	1,163 kW	0 kW
Total system cost (£)	477,684 £	465,818 £	88,415 £
Annual fuel cost from biomass (£)	114,659 £	110,241 £	6,807 £
Annual fuel cost if use conventional sources (£)	375,482 £	377,022 £	12,482 £
Annual cost saving (£)	236,615 £	231,500 £	5,656 £
Simple payback (years)	2.0 yrs	2.0 yrs	15.6 yrs
20year IRR	741.6 %	670.9 %	33.6 %
20year NPV (£)	5,795,658 £	5,595,566 £	190,673 £
Biomass fuel type	Wood chips	Wood chips	Wood pellet
Boiler ignition type	Automatic	Automatic	Automatic
Estimated RHI payment (1st Year)	95,714 £	89,998 £	9,196 £

Thermal Storage Vessel For Biomass Boiler System

Parameter specification for thermal storage vessels

Number:

Location:

Position:

Length/Height (l): m

Outer diameter of each vessel (d_o): m

Insulation thickness (δ): mm

Insulation type:


Volume and heat loss results

Required Tank Volume: litre

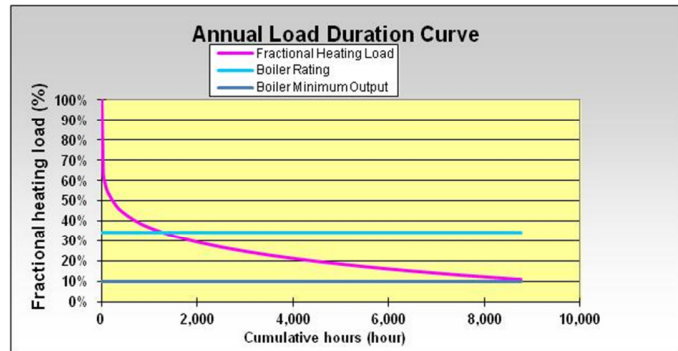
Specified Tank Water Volume: litre

Design Day Heat Loss: kWh

Assumptions:
Thermal storage vessel is in cylinder shape.
Heat losses due to radiation and convection are neglected.



At this stage, the Annual Load Duration Curve may be reviewed. The reduction in boiler size will have resulted in fewer hours of operation when the load is less than the minimum boiler size. This particular boiler selection is now very well suited to summer time operation.



1.5.3.3 Reducing the size of the thermal store

The optimum size of thermal store in this case has a total water volume of around 23,000 litres.

Let us suppose that the plant room height is limited, and that we cannot accommodate a vessel capacity greater than 15,000 litres. Press the back button to return to the Biomass Boiler Sizing Sheet, and select the Limit Thermal Store sizing strategy option. Enter a value of 10,000 litres as the maximum thermal store size. Click the forward button to see the results sheet. It can now be seen on the graphs that the thermal store size is limited to 10,000 litres total volume (including the minimum buffer vessel volume).

Biomass Boiler System Sizing Results (Part I)

Return to Main Interface

Vary biomass boiler rating capacity

Biomass boiler size: kW

Percentage of peak load: %

Peak Load at design day (kW): kW

Biomass boiler size @ 80% of peak load(kW): kW

Sizing Strategy selected: Limit thermal store size

Save the results with different options by pressing the following buttons

Option 1
Option 2
Option 3

Sizing strategy	Option1	Option2	Option3
Percentage of peak load (%)	36 %	25 %	36 %
Biomass boiler capacity (kW)	430 kW	300 kW	430 kW
Minimum buffer vessel size (litre)	3,500 litre	1,100 litre	1,500 litre
Thermal store size incl. min. buffer vessel (litre)	N/A litre	14,300 litre	10,000 litre
Percentage of energy from biomass (%)	95.2 %	90.1 %	97.3 %
Auxiliary boiler size (kW)	779 kW	909 kW	779 kW
Total system cost (£)	249,567 £	216,896 £	262,913 £
Annual fuel cost from biomass (£)	49,621 £	47,063 £	50,801 £
Annual fuel cost if use conventional sources (£)	165,714 £	166,046 £	166,046 £
Annual cost saving (£)	110,167 £	106,707 £	111,885 £
Simple payback (years)	2.3 yrs	2.0 yrs	2.3 yrs
20year IRR	417.2 %	673.2 %	340.9 %
20year NPV (£)	2,692,791 £	2,571,928 £	2,710,728 £
Biomass fuel type	Wood chips	Wood chips	Wood chips
Boiler ignition type	Automatic	Automatic	Automatic
Estimated RHI payment (1st Year)	48,029 £	43,139 £	48,093 £

Refer to Section 1.5.2 of User Manual for detailed instructions on how to interpret these results.

Decrease the thermal store size!

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It is no longer possible to meet 95% of the annual energy use from biomass with a 600kW boiler (34% of peak load), due to the thermal store limitation. A boiler sized at 40% of peak load should meet our objective. Select this size (700kW) with the slider, and save as option 3. Note the warning message, informing the user that the thermal storage vessel must be decreased in size. Move forward to the thermal store sizing sheet, and adjust the dimensions to obtain a 15,000 litre store. Click the back button to re-run the “limited thermal store” strategy. Re-adjust the slider to 40% (700kW) and save again as option 3. The costs will now reflect the smaller vessel size.

The user should again review the Annual Load Duration Curve, to ensure that the increase in boiler size has not adversely impacted the suitability of the system for summer operation.

The user could now return to the fuel selection sheet, change the fuel type to Wood Pellets and re-run the calculations (click “Return to Main Interface”, select “Fuel Type Selection”, select “Wood Pellet”, enter cost of wood pellets, click the forward button, select the “Optimum biomass boiler / thermal store combination” sizing strategy, click the forward button, and see the results. If it is desired to examine 95% of energy from biomass using wood pellet fuel, move the slider to 34% (600kW boiler) and save as **Option 3** overwriting the previous data in the column. Adjust the thermal store dimensions, and then re-run the strategy. It can be seen that the wood pellet boiler requires a larger buffer vessel, due to the higher calorific value of the fuel, and therefore larger burn-off volume on the grate at boiler shutdown. The payback time is longer, due to the higher cost of wood pellets.

The results displayed in this table are representative of typical results achieved when running the Tool.

Before proceeding, be sure that the boiler size inserted in the Sizing Results Part I sheet above is the size for which a report is required. All subsequent financial calculations will be based on this boiler size.

It is important to note that the calculation macro which generates the graph in the Results Part I sheet inserts a range of values in the boiler size cell, and that this cell will always display the final value of 80% whenever this sheet is selected, because the calculation runs automatically when the sheet is selected. The user needs to change this value to the desired boiler size every time this sheet is selected.

Vary biomass boiler rating capacity

Biomass boiler size: kW

Percentage of peak load: %

Peak Load at design day (kW): kW

Biomass boiler size @ 80% of peak load(kW): kW

Sizing Strategy selected:

Save the results with different options by pressing the following buttons

	Option1	Option2	Option3
Sizing strategy	Minimum buffer	Optimised	Size constrained
Percentage of peak load (%)	43 %	34 %	40 %
Biomass boiler capacity (kW)	750 kW	600 kW	700 kW
Minimum buffer vessel size (litre)	2,600 litre	2,100 litre	2,500 litre
Thermal store size incl. min buffer vessel (litre)	N/A litre	24,900 litre	15,000 litre
Percentage of energy from biomass (%)	91.4 %	87.5 %	91.2 %
Auxiliary boiler size (kW)	1,013 kW	1,163 kW	1,063 kW
Total system cost (£)	477,684 £	465,818 £	486,030 £
Annual fuel cost from biomass (£)	114,659 £	110,241 £	114,746 £
Annual fuel cost if use conventional sources (£)	375,482 £	377,022 £	376,543 £
Annual cost saving (£)	236,615 £	231,500 £	236,989 £
Simple payback (years)	2.0 yrs	2.0 yrs	2.1 yrs
20year IRR	741.6 %	670.9 %	614.1 %
20year NPV (£)	5,795,658 £	5,595,566 £	5,754,133 £
Biomass fuel type	Wood chips	Wood chips	Wood chips
Boiler ignition type	Automatic	Automatic	Automatic
Estimated RHI payment (1st Year)	95,714 £	89,998 £	93,809 £

Vary biomass boiler rating capacity

Biomass boiler size: kW

Percentage of peak load: %

Peak Load at design day (kW): kW

Biomass boiler size @ 80% of peak load(kW): kW

Sizing Strategy selected:

Save the results with different options by pressing the following buttons

	Option1	Option2	Option3
Sizing strategy	Minimum buffer	Optimised	Optimised
Percentage of peak load (%)	43 %	34 %	34 %
Biomass boiler capacity (kW)	750 kW	600 kW	600 kW
Minimum buffer vessel size (litre)	2,600 litre	2,100 litre	5,400 litre
Thermal store size incl. min buffer vessel (litre)	N/A litre	24,900 litre	28,200 litre
Percentage of energy from biomass (%)	91.4 %	87.5 %	87.5 %
Auxiliary boiler size (kW)	1,013 kW	1,163 kW	1,163 kW
Total system cost (£)	477,684 £	465,818 £	470,383 £
Annual fuel cost from biomass (£)	114,659 £	110,241 £	158,963 £
Annual fuel cost if use conventional sources (£)	375,482 £	377,022 £	377,042 £
Annual cost saving (£)	236,615 £	231,500 £	182,799 £
Simple payback (years)	2.0 yrs	2.0 yrs	2.6 yrs
20year IRR	741.6 %	670.9 %	320.2 %
20year NPV (£)	5,795,658 £	5,595,566 £	5,022,630 £
Biomass fuel type	Wood chips	Wood chip	Wood pellet
Boiler ignition type	Automatic	Automatic	Automatic
Estimated RHI payment (1st Year)	95,714 £	89,998 £	89,998 £

1.6 Capital Costs Specification

It is necessary to confirm the capital cost assumptions, prior to proceeding to the second part of the Sizing Results. From the Thermal Store sheet, click on the lower right red (forward) button to view the Capital Cost Specification sheet.

The system capital cost at the bottom right of the screen is derived from a cost formula prepared for the Carbon Trust from an analysis of a large number of biomass installations, and is described in Part 2 of this manual. The baseline year of this analysis was 2008. The user may wish to inflate capital costs appropriately.

The calculated cost is for a boiler sized as per the figure in the percentage of peak load box on the Results Part I page.


Return to Main Interface

Capital Costs Specification

Biomass Boiler Capital Cost Information

Note: If you have actual costs for any of the items please insert them in the user input capital costs

System parts	Calculated capital costs	User input capital costs	Final capital costs
Boiler	116,435 £	£	116,435 £
Fuel Feed System	15,950 £	£	15,950 £
Fuel Storage	34,293 £	£	34,293 £
Boiler House	94,673 £	£	94,673 £
Buffer/Thermal Storage	31,020 £	£	31,020 £
Flue	12,760 £	£	12,760 £
Design, PM & Commissioning	16,748 £	£	16,748 £
Delivery	5,583 £	£	5,583 £
Pipework	3,190 £	£	3,190 £
Electrical & Controls	7,178 £	£	7,178 £
Auxiliary Boiler fully installed	32,555 £	£	32,555 £
		System Capital Cost:	370,383 £
		Net Capital Cost:	470,383 £



The user may insert alternative costs for each of the items listed down the left hand side. It is designed for installers to insert their own costs to assist with building a quotation, and for other users who may have actual costs for some of these items. A zero cost may be entered in any of the cells, for example, if a piece of equipment is already installed on site.

Where the user has inserted their own costs, the final capital costs column on the right reflects the revised costs for those items and calculates a new system capital cost. This figure then appears in the System Capital Cost box. The Net Capital Cost takes account of additional capital costs, grants and loans on the Financial Inputs sheet.


Return to Main Interface

Capital Costs Specification

Biomass Boiler Capital Cost Information

Note: If you have actual costs for any of the items please insert them in the user input capital costs

System parts	Calculated capital costs	User input capital costs	Final capital costs
Boiler	116,435 £	90,000 £	90,000 £
Fuel Feed System	15,950 £	£	15,950 £
Fuel Storage	34,293 £	£	34,293 £
Boiler House	94,673 £	£	94,673 £
Buffer/Thermal Storage	31,020 £	25,000 £	25,000 £
Flue	12,760 £	£	12,760 £
Design, PM & Commissioning	16,748 £	£	16,748 £
Delivery	5,583 £	£	5,583 £
Pipework	3,190 £	£	3,190 £
Electrical & Controls	7,178 £	£	7,178 £
Auxiliary Boiler fully installed	32,555 £	£	32,555 £
		System Capital Cost:	337,928 £
		Net Capital Cost:	437,928 £



1.7 Biomass Storage

The Biomass Storage sheet allows selections appropriate to the type of fuel selected.

Biomass Storage

Return to Main Interface

User Inputs

Biomass type name:

How many days storage do you need at winter design day?: days

Storage option:

Biomass consumption at design day: kWh

Dimensions for the Selected Storage

Storage type	Depth/Height	Width/Diameter	Length	Fall angle to the horizontal	Exit diameter	Extractor angle	Storage volume
	<i>m</i>	<i>m</i>	<i>m</i>	<i>degrees</i>	<i>m</i>	<i>degrees</i>	<i>m³</i>
Square silo sloping floor	2.4	4.5	4.5	N/A	N/A	10	44.3

Diagram for Square Silo Sloping Floor

Diagram for Gravity Hopper (wood pellet only)

Diagram for V-shape pellet store (wood pellet only)

Notes: Please adjust the user inputs for storage dimensions to match the "storage volume" with the "required storage volume".

Suggested Biomass Storage Option

Required Storage Volume: m³

Storage Capacity: tonnes

Cost per delivery: £

Note: The storage page for pellets is shown. That for wood chips is almost identical.

Biomass type name: Select Woodchip 1, 2 or 3 or Wood Pellet 1, 2 or 3 as appropriate.

How many days storage do you need?: The number of days storage required should be entered. The calculation here assumes that the boiler will be operating continuously for the numbers of days entered. This represents the worst case winter scenario if designing with a minimum buffer vessel or the normal operating scenario if designing with a thermal store. This is explained fully in section 1.5 Biomass Boiler Sizing. The user should check that the fuel storage quantity reported is at least sufficient to accept the fuel supplier's re-order delivery quantity, plus sufficient emergency capacity in case of delivery delays (due to weather for example).

Storage Option: If Woodchip: Select 'Square silo sloping floor' or 'Walking floor'
if Wood Pellet: Select 'Square silo sloping floor', 'Walking floor', 'V-shaped pellet store, or 'Gravity Hopper'

The slope of a square silo sloping floor must be not more than 15°. A gravity hopper fall angle must be greater than 45°.

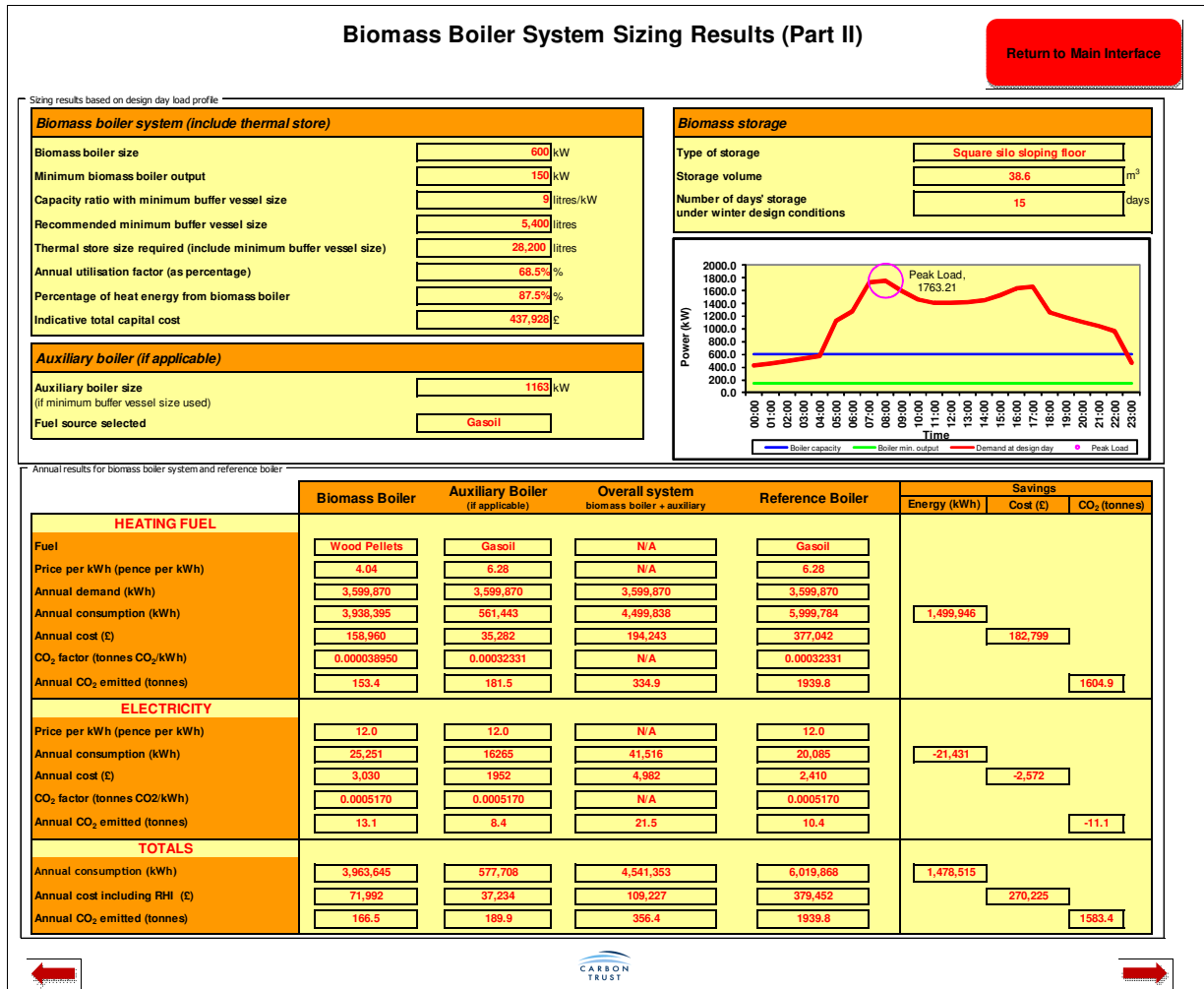
Dimensions for the Selected Storage: Enter dimensions for the selected type of storage and compare the calculated Storage Volume with the Required Storage Volume in the box below. Increase or decrease the dimensions of the fuel store until the Storage Volume matches the Required Storage Volume. Messages will appear advising the user to increase or decrease the storage volume as

appropriate. The user is of course free to specify a store larger than that calculated by the tool, to allow a reserve in case of winter delivery difficulties, for example.

1.8 Biomass Boiler System Sizing Results Part II

Having selected the system equipment sizes, including the fuel store, and adjusted the capital cost data, the second part of the Sizing Results can now be viewed.

The design day heat demand is shown in the graph (red line), and also the biomass boiler size (blue line), and the likely minimum output, (green line) below which load demand the boiler must switch off.



Biomass boiler size: The recommended boiler size calculated by the software.

Minimum biomass boiler output: Assumes a turndown ratio based on the boiler system selections. For details, see Section 2 of the manual.

Capacity ratio with minimum buffer vessel size: This is a calculated ratio expressed as the capacity of the buffer vessel in litres per kW of biomass boiler rating, and follows logically from the calculation of both biomass boiler and buffer vessel sizes. This figure is included because capacity ratios are frequently quoted by installers and in literature on biomass systems. The capacity of the heating system supplied by the boiler / buffer vessel is not included in this calculation. *It is important to note*



that this ratio varies with the temperature difference across the buffer vessel (calculated as the difference between the biomass boiler flow temperature and the circuit return temperature).

Recommended minimum buffer vessel size: Displays the minimum buffer vessel size calculated from the algorithms within the software. These algorithms are described in Part 2 of this manual.

Thermal store size required: If the Optimum sizing strategy was selected, then the calculated volume of thermal storage required is displayed. This figure includes the minimum buffer vessel size shown in the previous box. If the Minimum Buffer Vessel strategy was selected, the box is blank.

Annual utilisation factor: This is the boiler total annual output as a percentage of the number of hours in the year; 8,760hrs, times the boiler capacity.

Percentage of heat energy from biomass boiler: The software calculates the percentage of heat energy which could be provided from the biomass boiler by considering the percentage of the heat load profile which could be met from the biomass system for temperature bins from the outside air temperature entered on the demand sheets up to 14C outside air temperature. A description of this calculation can be found in Part 2 of this manual.

Indicative total capital cost: This figure is obtained from the capital costs calculation.

A summary of the auxiliary boiler size and fuel type, and the fuel store size are provided.

Annual Results for Biomass Boiler System and Reference Boiler: Annual results in terms of energy, costs and CO₂ emissions for the operation of the biomass boiler, auxiliary boiler, overall system, and for the reference boiler are tabulated as shown. Note that the annual demands may differ slightly from those shown on the Boiler Heat Demands Inputs sheet. This is due to the adjustment of the annual demands to include losses from the thermal store, and to deduct district heat system losses from the reference boiler demand if the reference system does not include a district heat network. If a manual ignition boiler has been specified, then the fuel consumption during operation in slumber mode is included in the total. The energy and CO₂ emissions are displayed for both the fuel use, and for electricity use. The electricity use for the reference boiler is based on this boiler being sized to the peak design day load. This sizing assumption only affects the calculation of electricity consumption.

The total costs of biomass fuel include the effect of the Renewable Heat Incentive (RHI) subsidy. The amount of subsidy is shown in the Report sheet (see next section). The total cost of fuel in this table could be negative if the biomass boiler is operating with a high capacity factor. This is because the total fuel subsidy could be greater than the annual cost of fuel

The energy, cost and CO₂ emission savings are also shown.



1.9 Financial Analysis and Reporting Module

The report provides a summary of many of the input values and calculations, and is structured in several sections:

- Title and information on the Project
- Technical Specification
- Energy & CO₂ Analysis
- Financial Analysis including a capital cost breakdown, details of grants loans and inflation assumptions, and a Cashflow and Savings analysis for a 20 year period including IRR, NPV and Net Annual savings. Note that these calculations include the income from RHI payments.

Report on Biomass Project for		Newtown Council	
Project Reference Number		AB123	
Project name		New Admn Office	
Site		Newtown Redevelopment Area	
Prepared by		J. Smith	
Company		Ace Heating	
Date		10 October 2011	

TECHNICAL SPECIFICATION			
Biomass Boiler			
Size		Moving Grate	110 kW
Type		Automatic	
Ignition		Auger	
Efficiency		Fuel	Wood Pellets
Fuel feed System		Minimum boiler output	37 kW
Buffer Vessel and Thermal Storage			
Minimum buffer vessel size			1,100 litres
Capacity ratio			10 litres/kW
Annual energy from biomass			95.9
Size of thermal store (incl. min buffer vessel)			23,000 litres
System Temperatures			
Flow			95 °C
Return			70 °C
ΔT			25 °C
Auxiliary Boiler			
Size		Gasoil	377 kW
Fuel		Efficiency	80%
Reference Boiler			
Fuel		Gasoil	60%
Fuel Storage			
Number of days storage required			15 days
Storage volume required			6.62 m ³

ENERGY & CO ₂ ANALYSIS	
Biomass Boiler System with optimum biomass boiler/thermal store combination	
Reference System	
Energy Used by Reference Boiler	570,469 kWh
CO ₂ released by Reference Boiler	182.2 tonnes/year
Biomass System	
Energy Used by Biomass Boiler	385,801 kWh
Energy Used by Auxiliary Boiler	22,939 kWh
Annual Biomass Consumed	94 tonnes/year
Total CO ₂ released by Biomass System (include auxiliary boiler)	25.6 tonnes/year
Annual Savings	
Energy Saving	161,728 kWh
CO ₂ Saving	156.6 tonnes/year
Design Day Load Profile	
Time	kW
00:00	0
01:00	0
02:00	0
03:00	0
04:00	0
05:00	429
06:00	467
07:00	487
08:00	447
09:00	430
10:00	414
11:00	396
12:00	377
13:00	361
14:00	357
15:00	338
16:00	341
17:00	348
18:00	347
19:00	343
20:00	339
21:00	338
22:00	337
23:00	20

Biomass Report for Newtown Council Page 4

FINANCIAL ANALYSIS - continued

Cashflow & Savings Analysis

Simple Payback Period years

Year	Cash Flows (£)	Internal Rate of Return	Net Present value (£)	Net Annual savings (£)
0	-109,301			37,426
1	36,542		-75,466	39,041
2	38,217	22%	-42,701	40,741
3	39,981	25%	-10,962	42,531
4	41,838	16%	19,790	44,413
5	43,794	23%	49,595	46,394
6	45,852	28%	78,490	48,479
7	48,019	31%	106,598	50,671
8	50,299	33%	133,683	52,978
9	52,698	35%	160,045	55,404
10	55,223	36%	185,624	57,956
11	57,880	36%	210,448	60,640
12	60,675	37%	234,543	63,463
13	63,615	37%	257,934	66,431
14	66,708	37%	280,645	69,553
15	69,963	38%	302,700	72,834
16	73,384	38%	324,120	76,285
17	76,982	38%	344,926	79,913
18	80,767	38%	365,138	83,727
19	84,747	38%	384,775	87,736
20	88,931	38%	403,855	91,951

Biomass Report for Newtown Council Page 3

FINANCIAL ANALYSIS

Start Year for Project

Boiler sized to meet % energy from biomass

Indicative Range of Capital Costs

Capital Cost	131,727 £
Likely Maximum Capital Cost	171,245 £
Likely Minimum Capital Cost	92,209 £

Capital Cost Breakdown based on Indicative Capital Cost

Boiler	33,926 £
Fuel Feed System	4,647 £
Fuel Storage	9,992 £
Boilerhouse	29,448 £
Buffer Vessel	25,300 £
Flue	3,718 £
Design, PM & Commissioning	4,880 £
Delivery	1,627 £
Pipework	929 £
Electrical & Controls	2,091 £
Auxiliary Boiler	15,168 £

Costs, Grants & Loans

Non-Biomass System Capital Cost	10,000 £
Capital Grant	0 £
Enhanced Capital Allowance	0 £
Contingency Sum	5,000 £
Carbon Trust Zero Interest Loan	0 £
Net Capital Cost	126,727 £
Biomass Fuel Cost (1 st Year)	22,883 £
Auxiliary Boiler Fuel Cost (1 st Year)	1,099 £
System Electricity Cost (1 st Year)	1,184 £
Renewable Heat Incentive (1 st Year)	15,291 £
Net Annual Fuel Cost (1 st Year)	9,875 £

Assumptions

Annual maintenance cost	3.0%
Annual Insurance cost	1.0%
Discount Rate	8.0%
Reference Fuel Cost Inflation Rate	5.0%
Biomass Fuel Cost Inflation Rate	1.0%
Auxiliary Fuel Cost Inflation Rate	5.0%
Annual Maintenance Cost Inflation Rate	1.0%
Annual Insurance Cost Inflation Rate	1.0%
Saving from Carbon Reduction Commitment	12.00 £/tonne CO ₂ Saved
	1,879 £/year

Figure 1 Financial Analysis and Report

2 Underlying Algorithms, Assumptions and Formulae

2.1 Project Location User Input on Main Interface Page

The user must select a relevant project location, and the available locations are Belfast, Birmingham, Cardiff, Edinburgh, Glasgow, London, Manchester and Plymouth. The project location is used in the calculation of heat demand so the location with the closest climate to that of the actual location should be chosen, this not necessarily being the closest geographical location. The eight locations are those contained in Table 2.3 of CIBSE Guide A 2006 (7th Edition). The frequency of occurrence of daily average temperatures for each location over a range from -3C to +14C was calculated using this data, and a statistical analysis of annual temperature data.

2.2 Demand Module

2.2.1 Overview

In order to calculate the size of biomass boiler system components, the daily profile of hourly heat demand for the building has to be estimated, for a design day. Clearly a profile that does not vary much over the 24 hour period will require less thermal storage to meet peak demand, than one that has very large peaks, e.g. on morning start-up, even though the total daily demand may be no greater. The scope for selecting a larger thermal store and smaller boiler will also be strongly influenced by the shape of this profile, as will the sizing of any auxiliary boiler requirement. Similarly, to estimate the annual energy demand of a particular system combination, the hourly profiles of demand at different times of year will be required.

Ideally, the user could input a complete annual profile of hourly load data for the building. This would require some interfacing between this tool, and, for example, dynamic computer modelling and simulation software for determining building heat loads. Such an interface is out of the scope of this tool. A number of alternative, simple, methods for estimating the building heat demands have been incorporated into this tool.

For non-domestic buildings, and for glass houses, these rely on a database of pilot building heat demand profiles, generated by the ESP-r computer modelling and simulation program, and can be used as the basis to estimate the heat demand profile of any building. For non-domestic buildings, the pilot models are based on a 20m x 10m plan building, 8m high. Three levels of thermal mass, three levels of insulation, three levels of glazing, and three intensities of occupation result in 81 combinations. These 81 models were simulated over a range of outside temperatures from -3C to +14C. So, by entering a few building parameters, and an outside air temperature into the tool, the most appropriate pilot building model is identified, and its heat demand profile is accessed from the database. This profile excludes the effects of internal heat gains, hot water demand, and ventilation load above a minimum infiltration level assumed in the model. The pilot building heat demands then have to be scaled, as the actual building heat demand will be greater, or less, than that of the pilot building. In order to generate an estimate of the profile of heat demand for the design day, for example, the actual design day total net heat demand needs to be known, either from measurement, or detailed simulation software, or based on other calculation methods, e.g. using a method similar to BS EN ISO 13790:2008 standard. This net heat demand is then modified by subtracting the actual building internal heat gains, adding the ventilation load, and subtracting the hot water demand. The result is a gross heat demand comparable to that for the pilot building, at the corresponding design outside air temperature. The ratio of the two gross heat demands is a scaling factor, which can then be used to generate a complete hourly profile for the design day.

A similar method is used for glass houses. Four typical glass house types were modelled, with four different internal temperature setpoints. All glass houses have fabric of mainly glass, and there are no significant casual gains due to occupancy. This results in 16 combinations, which were simulated over a range of outside temperatures from -3C to 20C.

For non-domestic buildings and glass houses, the same technique can be applied to other daily heat demands, in order to calculate heat demand for any outdoor air temperature. The frequency of



occurrence of heat demands at each outdoor air temperature is used to arrive at an annual heat demand estimate. In the case of non-domestic buildings, if the actual annual heat demand is known, then this final heat demand estimate can be scaled as necessary. This allows for differences in assumptions about the number of days of operation for the building, which may be more or less than that assumed in the simulations.

For swimming pools, the fabric loss can be a relatively small component of the heat demand; considerable heat demand also arises due to the ventilation required to maintain acceptable pool hall humidity levels, and pool heating in order to make up the considerable evaporative loss from the exposed pool surface. Simplified profiles of outside air temperature were estimated based on the maximum and minimum outside air temperatures for any given daily mean, for each of the selectable climate locations. The frequency of occurrence of these average outside temperature profiles were then used to estimate hourly fabric and ventilation losses.

For housing estates, ESP-r models of eight typical housing constructions corresponding to four age ranges were constructed. Properties of the houses were selected based on building regulations in force in each age range. Simulations were then carried out on the resulting 32 house models to calculate annual heat demand. The total floor area of each house was adjusted based on number of bedrooms, and the heat demands simply scaled according to the area ratio, compared to the baseline simulations. Occupancy was also based on the number of bedrooms, so that domestic hot water demand could be estimated.

2.2.2 Heat demand calculations for non-domestic buildings

2.2.2.1 Nomenclature

The following nomenclature is used in the subsequent sections:

Gross heat demand	Heat demand excluding internal heat gains and ventilation load above a minimum infiltration level.
Net heat demand	Heat demand after subtracting internal heat gains (people, lights, equipment) and adding additional ventilation heat load to Gross heat demand.
H	Heat demand kWh
S	Scaling factor = Gross heat demand for actual building / Gross heat demand for pilot building.
F_t	Number of days for which bin t heat demand data contributes to annual heat demand.

Suffixes:

a	Relates to auxiliary boiler
b	Relates to biomass boiler
d	Relates to design day.
e	Relates to heat demand profiles generated for a pilot building by ESP-r dynamic simulation.
g	Relates to internal heat gains.
i	Relates to heat demand at hour i.
j	Relates to average heat demand in month j.
n	Relates to actual building net heat demand.
p	Relates to annual heat demand estimate, not scaled to account for actual annual heat demand.
t	Identity of bin, containing heat demand profile for one day, for an average outside temperature T_t .
v	Relates to ventilation heat load.
y	Relates to annual heat demand.
w	Relates to hot water demand.

2.2.2.2 Scaling Procedure

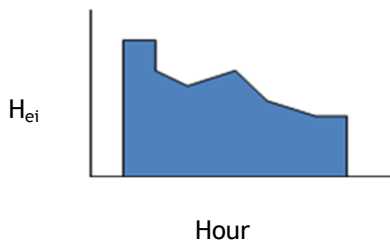


Figure 2: Typical ESP-r generated profile

Each of the profile generating and annual energy calculation methods depends on a scaling procedure, to convert the ESP-r generated profile into a profile that fits the user's actual building. First, the total heat demand for the pilot building is calculated as the sum of the hourly demands:

$$\Sigma H_{ei} = H_{et} \text{ total heat demand of pilot building.}$$

where H_{ei} gross heat demand of pilot building at hour i .

The hourly net heat demand for the actual building at hour l is given by adding the ventilation load, subtracting the internal heat gains and adding the hot water demand to the scaled heat demand for the pilot building:

$$H_{ni} = S \times H_{ei} + H_{vi} - H_{gi} + H_{wi}$$

The total daily demand of the actual building at outside temperature T_t is:

$$\Sigma H_{ni} = H_t$$

Therefore, $H_t = S \times H_{et} + \Sigma H_{vi} - \Sigma H_{gi} + \Sigma H_{wi}$

So:

$$S = \frac{H_t - \Sigma H_{vi} + \Sigma H_{gi} - \Sigma H_{wi}}{H_{et}}$$

For annual scaling factor calculation (monthly fuel bill, dynamic building simulation and heat meter demand input methods):

$$S_y = \frac{H_y}{H_p}$$

Where $H_p = \Sigma(H_{et} + H_{vi} - H_{gi} + H_{wi})$

2.2.2.3 Heat demand from building simulation program, or heat meter measurement data

User inputs:

- Design temperature, T_d
- Design day heat demand, H_d
- Hourly profile of demand, H_i profile
- Annual heat demand, H_y
- Internal gains and ventilation rates
- H_d and H_y include DHW heat demand.
- Building characteristics for profile selection.

In this case the user inputs a profile for the design day, obtained from a building simulation program, or heat meter measurements. This can be used directly for boiler system sizing. The annual demand is then estimated making use of the ESP-r generated profiles for other outside temperatures, and the user input value of annual heat demand. Figure 3 summarises the procedure.

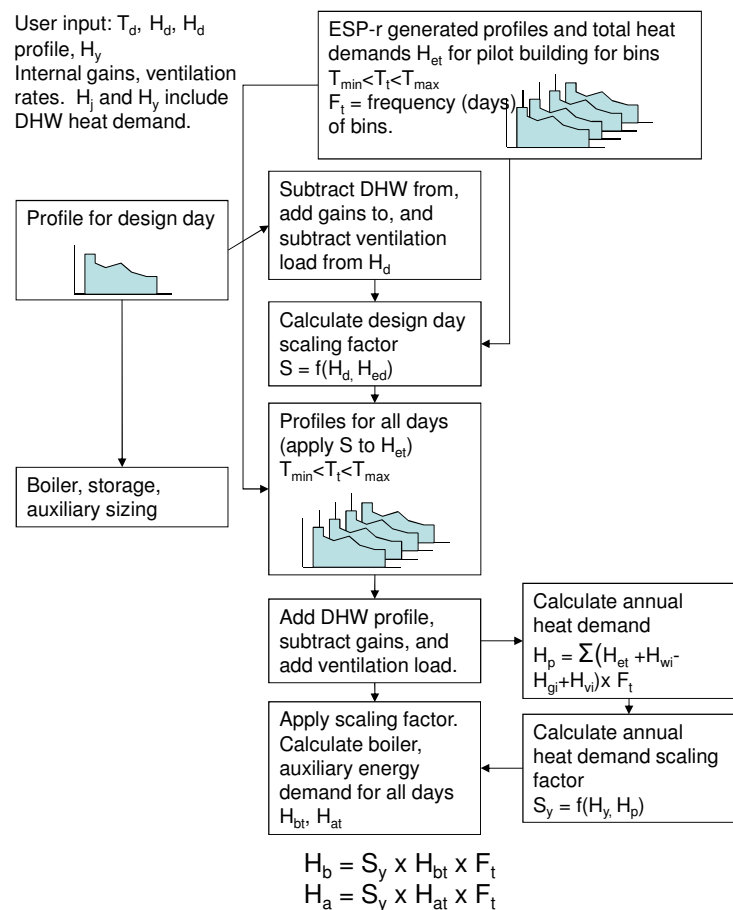


Figure 3 Calculation of demand from building simulation program, or heat meter data.

2.2.2.4 Heat demand from fuel bill

User inputs:

- Design temperature, T_d
- Average fuel consumption (from bills) on coldest day, H_j
- Average temperature on coldest day T_j
- Annual heat demand, H_y
- Internal gains and ventilation rates
- H_j and H_y include DHW heat demand.
- Building characteristics for profile selection.

In this case the user inputs the demand for the coldest day, and the annual heat demand. In the case of fuel bill data, the tool converts the fuel use to a heat demand figure, based on the calorific value of the delivered fuel. In the case of billing data, this data is also adjusted using degree day input to represent a typical year's data. There are then two steps to arrive at a design day demand profile. The first step is to adjust the coldest day demand to a design day demand. This is done by selecting the corresponding ESP-r data corresponding to the design temperature, and applying the ratio of these demands to the user input data (after adjusting for DHW, internal gains, and ventilation load). The second step is to apply the scaling procedure described above to the ESP-r generated profile to obtain a demand profile for the design day. After calculating the annual energy demand using this scaling factor, a further adjustment is made to take into account the actual building annual energy demand specified by the user. Figure 4 summarises the procedure.

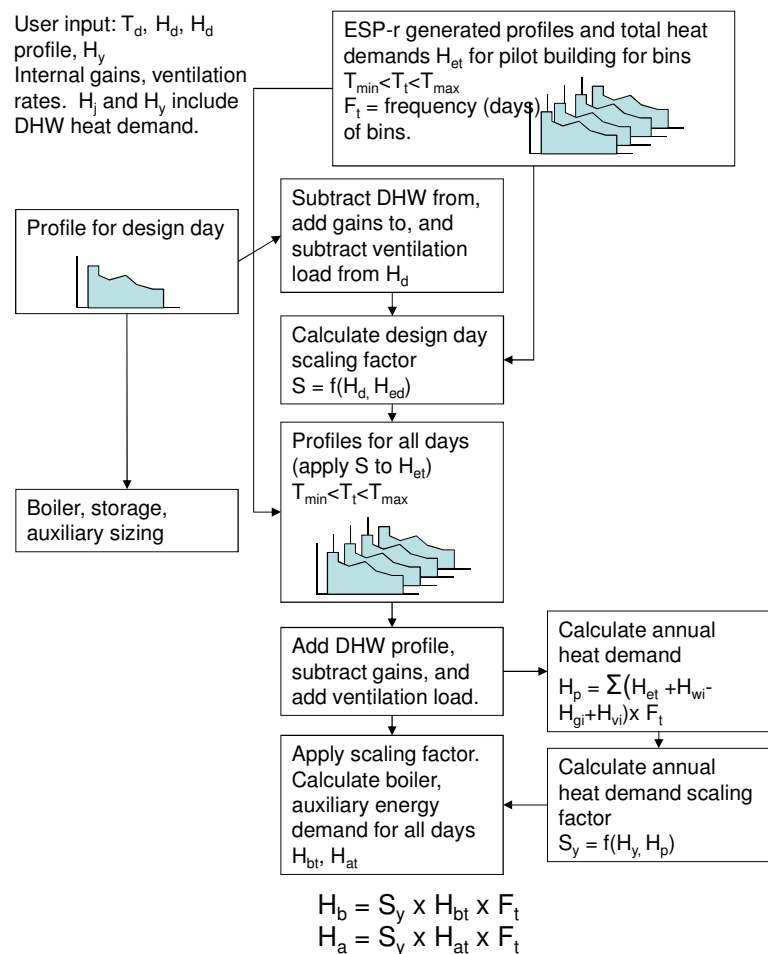


Figure 4: Calculation of demand from fuel bill data.

2.2.2.5 Embedded heat demand calculator – non-domestic buildings

User inputs:

- Information about the building characteristics for profile selection: thermal mass of building, level of insulation, proportion of façade that is glazed, and occupancy period
- Areas and U-values for external walls, roof, floor, windows, doors.
- Glazing properties
- Outdoor design temperature, T_d
- Internal gains and ventilation rates

In this case, no user demand data is available for the building, so demands are estimated using a method similar to BS EN ISO 13790:2008 standard, with basic building properties specified by the user. This data is then used to scale the ESP-r generated profiles to obtain profiles for the actual building. Figure 5 summarises the procedure.

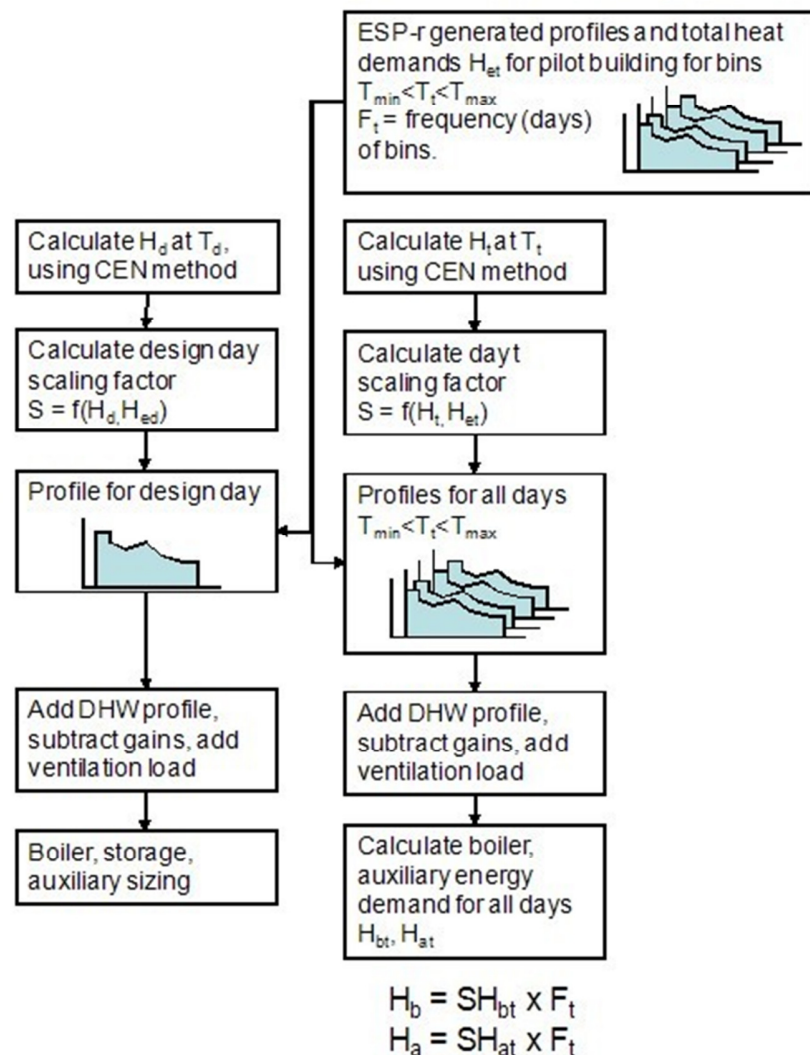


Figure 5: Calculation of demand using embedded method.

2.2.2.6 Ground temperature beneath building

The mean annual ground temperature for each climate location is obtained from the NASA climate data available in the RETSCREEN software www.retscreen.net

2.2.3 Embedded heat demand calculator for glasshouses

The process for calculating the heat demand for glass houses is a simplified version of that used for non-domestic buildings, in that internal gains and domestic hot water do not have to be considered. However, full account is taken of fabric and ventilation losses, and solar gains, as described above. The user inputs are:

- Information about the type of glass house for profile selection: small, Victorian, commercial, orangery.
- Indoor design temperature
- Outdoor design temperature, T_d
- Areas for glazing, and areas and U-values for areas of any external walls.
- Orientation and shading of glazing
- Ventilation rate
- Irrigation rate: the quantity of irrigation water can be selected.

The U-value for horticultural glass is set at $5.9 \text{ W/m}^2\text{K}$.

The calculation is then carried out similarly to that described above for non-domestic buildings. It is assumed that all irrigation water supplied has to be evaporated, and the latent heat required to achieve this is added to the heat demand.

2.2.4 Embedded heat demand calculator for swimming pools

Ground floor heat loss is calculated according to the method outlined in CIBSE Guide A, equations 3.20 and 3.21, assuming a wall thickness of 250mm, ground thermal conductivity of 1.5 W/mK (clay) and insulation resistance of $3.125 \text{ m}^2\text{K/W}$.

A simplified outdoor temperature profile is assumed for each outdoor temperature bin used in the embedded tool as described for non-domestic buildings. The profile is of the form:

$$T_a = f_1 * T_{\min} + f_2 * T_{\max}$$

Where f_1 and f_2 are given by the following table (CIBSE Guide A 1986):

Hour	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
f_1	0.69	0.78	0.85	0.92	0.96	0.99	1.00	0.96	0.85	0.69	0.50	0.31	0.15	0.04	0.00	0.01	0.04	0.08	0.15	0.22	0.31	0.40	0.50	0.60
f_2	0.31	0.22	0.15	0.08	0.04	0.01	0.00	0.04	0.15	0.31	0.50	0.69	0.85	0.96	1.00	0.99	0.96	0.92	0.85	0.78	0.69	0.60	0.50	0.40

Table 3 Factors for simplified outside temperature profile

The frequency distributions of outside air temperature bins for each climate location are used as previously for non-domestic buildings. The values of Tmin and Tmax, which apply to all climates, have been determined for each outside air temperature bin as:

Outside Temperature Bin	T _{min}	T _{max}
C	C	C
-3	-5	-1
-2	-4	0
-1	-3.25	1.25
0	-2.25	2.25
1	-1.5	3.5
2	-0.75	4.75
3	0	6
4	1	7
5	1.75	8.25
6	2.5	9.5
7	3.25	10.75
8	4	12
9	4.75	13.25
10	5.5	14.5
11	6.5	15.5
12	7.25	16.75
13	8	18
14	8.5	19.5
15	9.25	20.75

Table 4 Minimum and maximum temperatures for outside temperature bins

Built-in profiles of heat demand are not used, as the dynamic effects are not considered to be of importance, due to dominant high ventilation rates which impose an instantaneous load on the heating system, and the evaporative loss from the pool, which is assumed to be a relatively steady state process. The equation for outside air temperature is:

The saturation vapour pressure at the pool surface is given by:

$$P_{sw} = 610.78 e^{\left(\frac{t_w}{t_w+278.3} * 17.2694\right)} \text{ Pa, where } t_w \text{ is pool water temperature in C.}$$

The saturation vapour pressure of the pool hall air is given by:

$$P_{sa} = 610.78 e^{\left(\frac{t_a}{t_a+278.3} * 17.2694\right)} \text{ Pa, where } t_a \text{ is pool hall air temperature in C.}$$

The vapour pressure in the pool hall is given by:

$$P_a = P_{sa} \times RH/100 \text{ Pa where RH is the relative humidity \%}$$

For an occupied pool, the evaporation rate is given by (Biasin & Krumme):

$$m = 7.88 * 10^{-5 * (P_{sw} - P_a)} - 0.059 \text{ kg/m}^2\text{h for an unoccupied pool (uncovered)}$$

$$m = 0.118 + 1.5 * 10^{-4 * (P_{sw} - P_a)} * \frac{n}{A_p} \text{ kg/m}^2\text{h for an occupied pool}$$

Efficiency of various methods of heat recovery are as follows:

Heat recovery method	Efficiency %
Run-around coil	$-0.00012 * Ta^2 - 0.0024 * Ta + 0.367$
Air to air plate heat exchanger	$-0.0002 * Ta^2 - 0.004 * Ta + 0.611$
Heat pump dehumidifier	80

Table 5 Heat recovery efficiencies

2.2.5 Embedded heat demand calculator for housing estates

The number of floors, number of bedrooms, occupancy and floor areas of the house models used are shown in the following table. The baseline heat demands for each house type, as calculated by dynamic simulation, are scaled according to the number of bedrooms specified by the user. The number of occupants is always assumed to be one more than the number of bedrooms. The number of occupants is then used to calculate the domestic hot water heat demand.

Table 6 Floor areas of house types

Built Form	No. of Floors	Number of bedrooms	Occupancy	Floor area (m2)
Detached	2	3	4	52x2
Semi-detached	2	2	3	45x2
Mid terrace	2	1	2	39x2
Detached bungalow	1	2	3	90
Semi-detached bungalow	1	2	3	90
Flat top	1	2	3	90
Flat mid	1	2	3	90
Flat ground	1	2	3	90

The details of the construction of the house models used to assemble housing estates are shown in the following tables.

Table 7 Ventilation rates of house types

Air change rate	ach
pre 1983	1
1983-2002	0.7
2003-2007	0.5
post 2007	0.3

Table 8 U-values of house constructions, W/m²K

U-values	pre 1983	1983-2002	2003-2007	post 2007
wall	2	0.6	0.31	0.31
roof	2	0.35	0.16	0.14
floor	0.88	0.46	0.25	0.22
glazing	5.6	3.4	2.1	1.7
door	3	3	2	1.7

The heating control is set to turn heating on from 07:00 to 09:00 and from 16:00 to 23:00 each day. The thermostat setpoint is 21C in the living zone, and 18C in the non-living zone.



The same heating control profile is used in all houses included in the demand calculation. Simply adding the individual contributions from each house's 24hr demand profile would result in an unrealistically high peak demand. Work by Marks and Stockwell¹ suggest a 33% reduction in peak demand in large populations due to demand diversity to be typical. Each hourly demand is modified by spreading the demand over the previous and following hours following a normal distribution, with standard deviation equal to $2(1.2 - e^{-n/220})$ where n is the number of houses.

¹ Marks W.L. & Stockwell D.H. Group Heating Schemes - the prediction of boiler heat load allowing for uncertainties in the heat loss terms. Building Serv Eng Res Technol 1980 1: 185

2.3 Biomass Fuel & Storage Modules

2.3.1 Woodchip Fuels

2.3.1.1 Calorific Value

The formulae for the calorific value of woodchip fuels used in this Tool have been derived from a fuel calculator developed by EVA, the Austrian Energy Agency. The default calorific values for dry wood of 18.5MJ/kg for softwood and 19.5MJ/kg for hardwood are derived from “Renewable Energy from Biomass” by KR Kaltschmitt and M Thrön 2001.

For softwood woodchips the calorific value is $CV = (18.5*(100-MC)-2.442*MC)/100$ MJ/kg

For hardwood woodchips the calorific value is $CV = (19.5*(100- MC)-2.442* MC)/100$ MJ/kg

where MC is the fuel moisture content in percent.

The moisture content and ash content range values are derived from CEN/TS 14961:2005.

2.3.1.2 Bulk Density

The default values for dry bulk density of 195kg/m³ for softwood woodchips and 260kg/m³ for hardwood woodchips are derived from UBET Unified Bioenergy Terminology.

For softwood woodchips the bulk density = $195/((100- MC)/100)$ kg/m³

For hardwood woodchips the bulk density = $260/((100- MC)/100)$ kg/m³

where MC is the fuel moisture content in percent.

2.3.2 Wood Pellet Fuels

The user can input the calorific value for dry wood pellets for each of Pellet 1,2 & 3 on the Fuel Data - Pellets sheet. The formula for the calorific value of wood pellets is:

$$CV = (CVDW *(100-MC)-2.442*MC)/100$$

where CVDW is the calorific value for dry wood inserted by the user (default value 20MJ/kg) and MC is the fuel moisture content in percent.

2.3.3 Biomass Storage

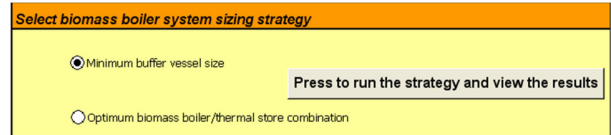
No assumptions have been made in the construction of the Biomass Storage page.

2.4 Biomass Boiler Module

2.4.1 Boiler Sizing Module

2.4.1.1 Buffer Vessels and Thermal Stores

When the selection of either minimum buffer vessel or optimum boiler/thermal store is made for the sizing strategy, it implies particular hydraulic configurations and control algorithms. In order for the results indicated by the software to be achieved the systems need to be operated as described below.



Biomass Boiler and Buffer Vessel

The typical configuration of a biomass boiler and buffer vessel is shown here ². The software assumes that the buffer vessel contributes to meeting the peak load on start-up, reducing the energy required from an auxiliary boiler. In order for this to happen Pump 2 must be a variable speed pump sized to draw stored hot water from the buffer vessel as well as the boiler on start-up. Once the buffer vessel has depleted the speed of Pump 2 needs to be reduced to match that of Pump 1.

The majority of systems with a buffer vessel are controlled using a simple on/off control strategy using two temperature sensors as shown here. However, some systems use the progressive control described below for systems with thermal stores.

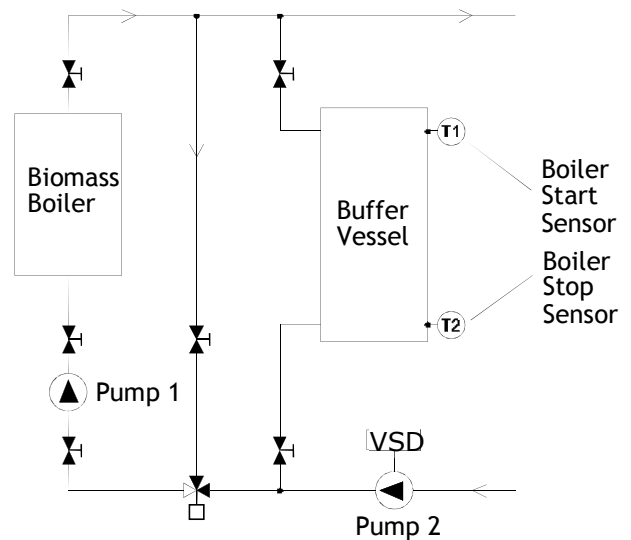


Figure 6: Biomass boiler and buffer vessel piping schematic.

Biomass Boiler and Thermal Store

The typical configuration of a biomass boiler and thermal store is shown here. The software assumes that the biomass boiler operates continuously charging the thermal store at times when the output of the biomass boiler exceeds the load demand, typically overnight when there is no demand from a building.

The majority of systems with a thermal store are controlled using a progressive control strategy using several temperature sensors as shown here. Again, once the buffer vessel has depleted the speed of Pump 2 needs to be reduced to match that of Pump 1.

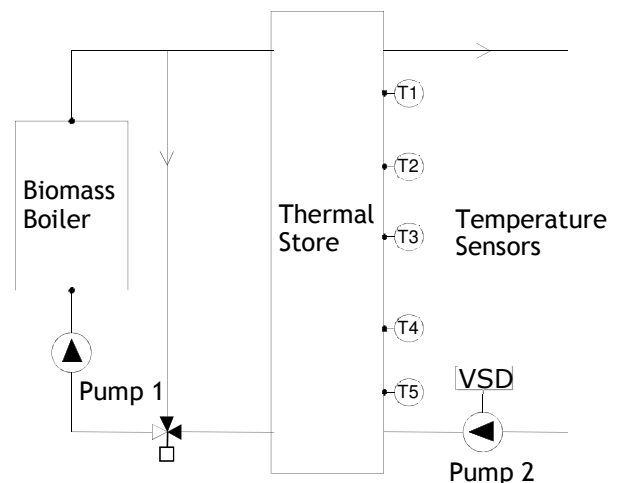


Figure 7: Biomass boiler and thermal store piping schematic.

² A description of the operation of buffer vessel and thermal storage systems is beyond the scope of this manual.

2.4.1.2 Minimum Buffer Vessel Sizes and Turndown Ratios for Automatic boilers

The following formulae have been calculated from a detailed analysis of the fuel feed systems, grate systems and refractory linings of biomass boilers, and the results produced appear to consistent with the range of values recommended for each type of boiler. There are significant variations in the sizes of buffer vessels recommended by different manufacturers, and the volumes derived from the formulae below should be used as a guide to the size of buffer vessel likely to be required.

A typical fuel feed configuration is a rotary valve followed by up to 1m of feed auger to the grate, and in these cases the fuel content of the auger is taken into account when calculating the buffer vessel size. This is because it is usual to empty the feed auger on cessation of boiler firing to prevent burn-back along the auger on over-fed stokers, whereas for a boiler with an underfed stoker it is often permissible to leave the underfed auger full of fuel because burn-back rarely occurs downwards. Similarly, if a hydraulic ram stoker is used, or a flap valve is located immediately prior to the grate (as can be found on some over-fed stokers), there will be no fuel prior to the grate and the fuel content of the auger can again be ignored.

The size of minimum buffer vessel will also depend on the level of refractory lining.

The ΔT in the formulae is the temperature difference across the buffer vessel when charging. It is derived in the software by calculating the difference between the **Biomass boiler flow temperature** and **Circuit return temperature** which are inputs on the Biomass Boiler System Sizing page. The results from the formulae are in litres per kW of boiler capacity, where V is the volume of buffer vessel capacity required in litres/kW.

Also shown in the table is the typical turndown ratio for each boiler type.

Fuel	Boiler type	Fuel feed mechanism	Refractory lining	Buffer Vessel Formula (l/kW)	Turndown Ratio
Wood chips	Stoker burner	Augur	Low	$V = 89.17\Delta T^{-1.0031}$	3.5:1
Wood chips	Stoker burner	Augur	High	$V = 120.4\Delta T^{-1.0015}$	3:1
Wood chips	Moving grate	Augur	Low	$V = 202.19\Delta T^{-0.9982}$	3:1
Wood chips	Moving grate	Augur	High	$V = 371.06\Delta T^{-1.0011}$	2.5:1
Wood chips	Moving grate	Ram stoker	Low	$V = 158.27\Delta T^{-0.997}$	3:1
Wood chips	Moving grate	Ram stoker	High	$V = 374.1\Delta T^{-1.0009}$	2.5:1
Wood chips	Underfed stoker	Augur	Low	$V = 57.946\Delta T^{-1.006}$	3.5:1
Wood chips	Underfed stoker	Augur	High	$V = 89.17\Delta T^{-1.0031}$	3:1
Pellets	Stoker burner	Augur	Low	$V = 223.46\Delta T^{-0.9989}$	4:1
Pellets	Stoker burner	Augur	High	$V = 255.64\Delta T^{-1.0002}$	3.5:1
Pellets	Moving grate	Augur	Low	$V = 249.53\Delta T^{-1.001}$	3:1
Pellets	Moving grate	Augur	High	$V = 463.45\Delta T^{-1.0003}$	2.5:1
Pellets	Moving grate	Ram stoker	Low	$V = 124.62\Delta T^{-0.9991}$	3:1
Pellets	Moving grate	Ram stoker	High	$V = 338.1\Delta T^{-0.9989}$	2.5:1
Pellets	Underfed stoker	Augur	Low	$V = 57.946\Delta T^{-1.006}$	3.5:1
Pellets	Underfed stoker	Augur	High	$V = 130.27\Delta T^{-0.9955}$	3:1

Table 9 Equations for Buffer Vessel Sizing, and Turndown Ratios for Automatic Ignition Boilers

2.4.1.3 Turndown Ratios for Manual Ignition Boilers

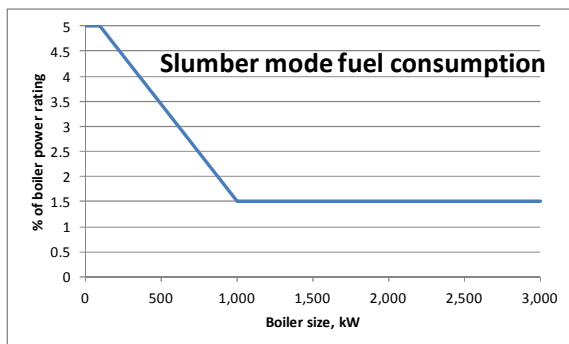
(Buffer vessels are not required for Manual Ignition boilers.)

Fuel	Boiler type	Fuel feed mechanism	Refractory lining	Turndown Ratio
Wood chips	Stoker burner	Augur	Low	3.5:1
Wood chips	Stoker burner	Augur	High	3:1
Wood chips	Moving grate	Augur	Low	3:1
Wood chips	Moving grate	Augur	High	2.5:1 (2:1 for MC>40%)
Wood chips	Moving grate	Ram stoker	Low	3:1
Wood chips	Moving grate	Ram stoker	High	2.5:1 (2:1 for MC>40%)
Wood chips	Underfed stoker	Augur	Low	3.5:1
Wood chips	Underfed stoker	Augur	High	3:1
Pellets	Stoker burner	Augur	Low	4:1
Pellets	Stoker burner	Augur	High	3.5:1
Pellets	Moving grate	Augur	Low	3:1
Pellets	Moving grate	Augur	High	2.5:1
Pellets	Moving grate	Ram stoker	Low	3:1
Pellets	Moving grate	Ram stoker	High	2.5:1
Pellets	Underfed stoker	Augur	Low	3.5:1
Pellets	Underfed stoker	Augur	High	3:1

Table 10 Turndown Ratios for Manual Ignition Boilers

2.4.1.4 Fuel Consumption of Manual Boilers in Slumber (Kindling) Mode

When there is no heat demand, a manual boiler will reduce its firing rate to a low level, sufficient to keep the boiler alight. This is termed Slumber, or Kindling mode. Manufacturers typically claim that their boiler will consume only 0.5% of the boiler power rating whilst in slumber mode. Practical experience suggests that boilers consume rather more than this, typically as shown in this graph.



If the user selects Manufacturer's data in the slumber mode input box, the tool will assume slumber mode fuel consumption of 0.5% of the boiler power rating. If the user selects Typical, then the tool will select a value according to this graph.

Table 11 Typical Slumber Mode Fuel Consumption

2.4.1.5 CO₂ Emission Factors and Calorific Values of Fuels

The tool uses emission factors and calorific values approved by the Carbon Trust. These will be updated periodically. The following are the values used in this version of the tool. The fossil fuel values are based on the gross (higher) calorific values, whereas the wood chip and wood pellet values are based on the net (lower) calorific values. Note that the tool does not currently use the calorific values listed here for wood fuels. If the user wants to use these values, they should enter them directly on the Biomass Fuel Input sheets.

Fuel	CO ₂ Factor kg CO ₂ /kWh	Density kg/m ³	Net CV kWh/kg
Coal	0.318	850	8.05
Gasoil	0.32231	803	11.89
Grid Electricity	0.517	-	-
Kerosene	0.29247	803.21	12.18
LPG	0.24127	508.13	12.75
MFO	0.31108	977.5	11.38
Natural Gas	0.20322	0.746	13.22
Wood Chips	0.01579	250	3.89
Wood Pellets	0.03895	1,538.46	4.62

Table 12: Calorific values and CO₂ emissions of fuels.

2.4.1.6 Pound Sterling/Euro Exchange Rate

See Section 2.5.1.1.

2.4.2 Calculation of the Percentage of Heat Energy from Biomass

Figure 8 indicates a typical design day heat demand profile, showing a biomass boiler that has been sized to meet a fraction of the peak heat demand. Biomass boiler, auxiliary boiler, and buffer vessel / thermal store are all sized based on the design day demand profile. This profile is calculated based on the data supplied in the Demand Module. See section 2.2 Demand Module for a detailed description of Demand Module calculation processes.

The annual heat demand met by the biomass and by the auxiliary boilers is calculated by considering the heat demand profiles for other outside temperatures. These are calculated based on the data supplied in the demand module. Each resulting demand profile is associated with a frequency of occurrence (number of days), depending on the location selected on the Main Interface. These calculations of annual heat demands depend on the system selections made in the Sizing Module.

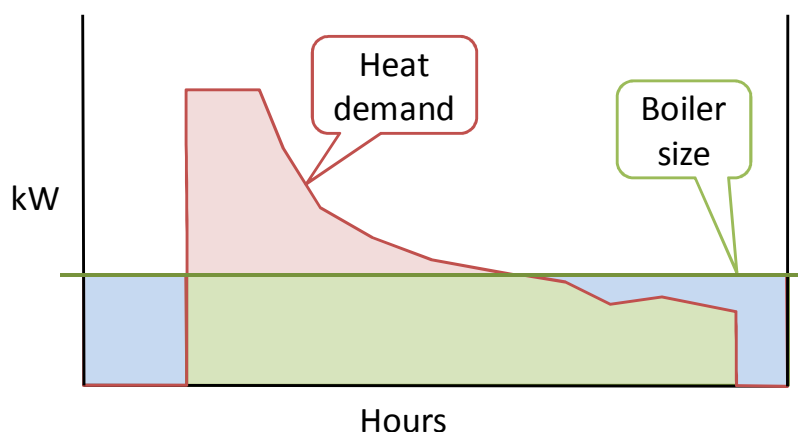


Figure 8: Typical design day head demand profile, and boiler size.

There are two cases to consider:

- a. The user has requested that the tool calculate the minimum buffer vessel size required for boiler protection;
- b. The user has requested that the tool calculate optimum biomass boiler and thermal store sizes. The thermal store is used to allow a given biomass boiler to meet a larger proportion of the annual heat demand.

2.4.2.1 Calculation of the Percentage of Heat Energy from Biomass for the Minimum Buffer Vessel Size and Auxiliary Boiler Sizing

In this case the tool calculates a buffer vessel size as described in Part 2 - Minimum Buffer Vessel Size. The auxiliary boiler size is then the difference between the biomass boiler capacity and the peak heat demand. The heat demand supplied by the biomass boiler is simply the total heat demand that is less than or equal to the boiler capacity (green shaded area) plus the heat required to top up the buffer vessel (on boiler shut down). The excess demand is met by the auxiliary boiler (red shaded area in the diagram on the previous page), less the capacity of the buffer vessel, which is assumed to meet part of the initial load on boiler start up. The tool repeats this calculation for each of the outside temperature profile bins and then multiplies the heat demands met by biomass boiler and by auxiliary boiler for each bin by the frequency of occurrence of the outside temperature for each bin.

2.4.2.2 Calculation of the Percentage of Heat Energy from Biomass for the Optimum Combination of Biomass Boiler and Thermal Store, and Auxiliary Boiler Sizing

In this case the tool calculates an optimum combination of biomass boiler and thermal store for a range of biomass boiler sizes that meet from 10% up to 80% of the design day peak demand. The calculation is automatic, and the user can then inspect the graphical output to examine particular combinations of interest in more detail.

For each boiler size, the tool adds up, for each hour, the difference between the boiler capacity and the heat demand, for periods when the boiler capacity exceeds the heat demand (blue shaded area). This represents the residual boiler capacity available to charge up a thermal store. The tool also calculates the difference between the boiler capacity and the heat demand when the boiler capacity is less than the heat demand (red shaded area on diagram on previous page). There are then two possibilities:

1. If the boiler capacity excess is less than the excess heat demand, then the thermal store size will be equal to the boiler capacity excess. In that case, when system starts up, the thermal store will meet the excess demand until the thermal store is exhausted (orange shaded area in Figure 9). There will be insufficient capacity of thermal storage to meet all of the excess demand, so an auxiliary boiler will be required, with its size set to meet the highest excess load after the thermal store is exhausted. The remaining excess demand will then be met by this auxiliary boiler.

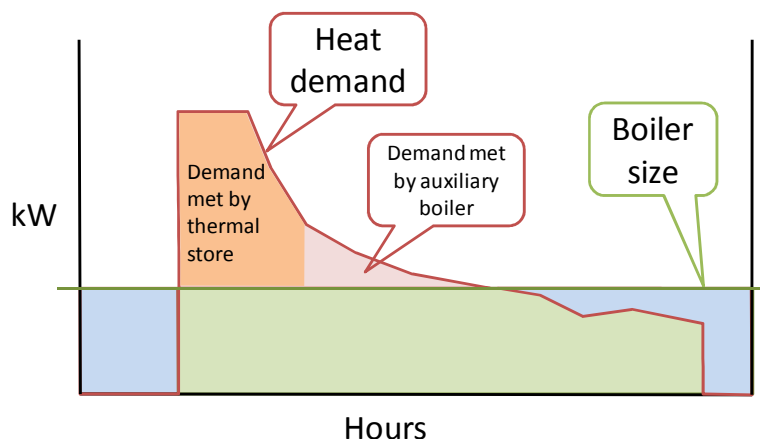


Figure 9: Sizing of thermal store and auxiliary boiler.

2. If the boiler capacity excess is greater than the excess heat demand, then the thermal store size will be equal to the excess heat demand. In that case, the combination of biomass boiler and thermal store will be sufficient to meet the demand at all times, and an auxiliary boiler is not required.

In both these cases, the tool repeats the calculation for each of the outside temperature profile bins and then multiplies the heat demands met by biomass boiler and by auxiliary boiler for each bin by the frequency of occurrence of the outside temperature for each bin.

Note that the user may request that an auxiliary boiler is required for back-up purposes. This option will not affect the calculations described above.

2.4.3 Biomass Boiler Results for Different Options

2.4.3.1 Creation of Sizing Graph

The graph has been created using a macro which inputs values of biomass boiler size as a percentage of peak load in 5% steps from 10% to 80%. The resulting values are then plotted for:

- Percentage of energy from biomass
- Auxiliary boiler size
- Buffer vessel or thermal storage size (including the buffer vessel volume)

2.4.3.2 Creation of Annual Load Duration Curve

The Annual Load Duration Curve equation is given by Sochinsky as:

$$\text{Heat load that is exceeded for } T \text{ hours in year} = 1 - (1 - \beta_{min}) * T^{\frac{\beta_m - \beta_{min}}{1 - \beta_m}}$$

where: β_{min} = ratio of minimum load (DHW + district heat losses) to the peak load,
 β_m = average load as fraction of maximum load (utilisation factor)

The graph is only an approximate representation of the load data entered into the tool. It is a simplified illustration of how load is typically distributed over the year, so that the user can judge the likely performance issues that will result if a boiler is too large to meet the lower loads in summer.

2.5 Financial Analysis & Reporting

2.5.1 Financial Analysis

2.5.1.1 Pound Sterling/Euro Exchange Rate

The vast majority of biomass boilers, their ancillary equipment and fuel feed systems are manufactured in Europe and priced in Euros. At the time the biomass cost formula was derived, and for the preceding several years when the installations analysed to produce the formula were costed, the £/€ exchange rate was in the region of €1.40 to the £. The global financial crisis of 2008/2009 saw this exchange rate drop sharply, so the user has the option to insert a current exchange rate in the **Additional data input** box on the Biomass Boiler System Sizing page. The biomass boiler system cost formula has been modified on the basis that 50% of the overall system capital cost is from Europe.

2.5.1.2 Biomass Boiler System Cost Formula

The formula used to calculate the total cost of a biomass system was derived from an analysis of a large number of installed systems ranging in size from 50kW to 3MW. The original formula derived for the Carbon Trust publication CTG012 - Biomass heating: A practical guide for potential users has been modified as described above. The original formula produced the curve shown in Figure 10 which is included within CTG012.

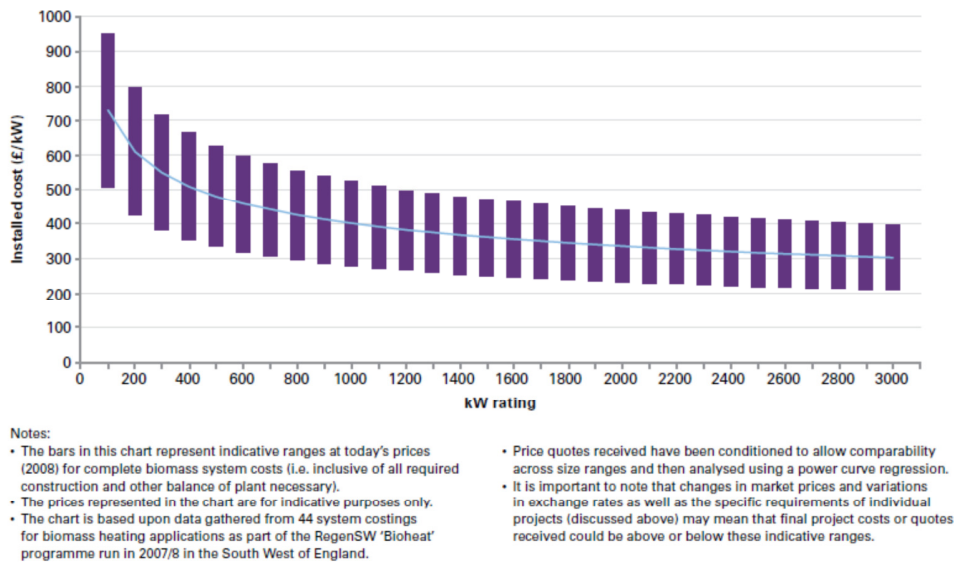


Figure 10: Capital cost ranges for a biomass boiler system.

The modified overall biomass system cost formula used in the software is:

$$\text{The cost of a biomass system} = (BR \times 2535.2 \times BR^{0.2731}) \times (1 + (1.4 - ER)/2)$$

where BR = the calculated biomass boiler rating in kW

and ER = the £/€ exchange rate input on the Biomass Boiler System Sizing page

This formula will be updated by the Carbon Trust at regular intervals.



The breakdown of costs, prepared for the Carbon Trust, and displayed on the Financial Analysis page and in the Report is as shown in Table 13.

Boiler	39.0%
Fuel Feed System	5.3%
Fuel Storage	11.5%
Boilerhouse	27.3%
Buffer Vessel*	1.6%
Flue	4.3%
Design, Project Management & Commissioning	5.6%
Delivery	1.9%
Pipework	1.1%
Electrical & Control	2.4%
Total	100.0%

Table 13: Biomass boiler system cost breakdown.

*In the current version of the tool, the 1.6% proportion of cost for buffer vessel is not included in the system cost. The tool substitutes a cost based on the cost per litre for Buffer Vessel / Thermal Storage on the Financial Inputs sheet, and for thermal stores, adds a cost to account for additional plant room space required based on the floor area derived from the Thermal Store module; see next section.

2.5.1.3 Heat loss calculation, and plant room space requirement.

In the Thermal Storage Vessel for Biomass Boiler System sheet, the user inputs dimensions for the thermal store. These are outer dimensions, including insulation. Based on these inputs the tool calculates the total heat loss from the stored water to ambient, assuming the thermal store temperature to be the maximum boiler output temperature, and the ambient temperature to be either the external temperature, or the external temperature plus ten degrees C, depending on the location of the thermal store; outdoor or indoor. In the indoor case, the minimum plant room temperature is assumed to be 5C.

The heat loss for each vessel is given by: $Q_j = \frac{\lambda \cdot A \cdot (T_i - T_o)}{D_o/2 \cdot \ln\left(\frac{D_o}{D_i}\right)}$

Where,

- Q_j: heat loss of the jth thermal store (in W)
- λ: thermal conductivity of insulation material (in W/m.K)
- A: surface area of thermal store (in m²)
- T_i: average temperature of water temperature inside thermal store (in degC)
- T_o: average temperature outside thermal store (in degC)
- D_i: inner diameter of thermal store (in m)
- D_o: outer diameter of thermal store (in m)

The plant space requirement for an indoor vessel is based on an area of plan dimensions equal to a square with sides equal to the vessel diameter plus 0.5m for a vertical vessel, or a rectangle with sides equal to the vessel length plus 0.5m, and the diameter plus 0.5m for a horizontal vessel. This area is costed at £850 / m² and this cost is included in the total system cost.

The values of thermal conductivity for the insulation types are:

- Polyurethane 0.02 W/mK
- Rockwool 0.045 W/mK
- Glasswool 0.04 W/mK

The above calculations are only carried out for Thermal Stores. Minimum Buffer Vessel sizes are relatively small, so heat losses are negligible, compared to the boiler output.

2.5.1.4 Calculation of Fossil Fuel Boiler Costs

The capital costs of auxiliary and back-up boilers are calculated from a series of formulae. A leading European boiler manufacturer provided costs for both natural gas and gas-oil fired boilers in the size range 70kW to 3MW (6 boilers in the size range for each fuel). These costs were then increased by 25% to allow for the cost of a flue, and the resulting figures were doubled to represent installed boiler costs. The resulting formulae are shown in Table 14.

	Installed Cost (IC) (£)
Natural gas boilers	
70kW - 890kW	$IC = 2,000 + 34.21 \times BR$
890kW - 3MW	$IC = 16,000 + 18.82 \times BR$
Gasoil boilers	
70kW - 800kW	$IC = 5,000 + 22.52 \times BR$
800kW - 3MW	$IC = 9,000 + 17.14 \times BR$

Table 14: Auxiliary and back up boiler cost calculation.

2.5.1.5 Calculation of Electrical Consumption of Boiler Ancillary Equipment

Biomass and fossil fuel boilers require several items of ancillary equipment, for example, burners, pumps, fuel feed mechanisms, flue particulate removal cyclones. The tool includes an estimation of the energy consumption of these items according to boiler type, for the biomass, auxiliary, and reference boilers. The CO₂ emissions due to these consumptions are also accounted for. The table below shows the main assumptions used in carrying out these calculations.

Ancillary Item	Electrical Consumption as a Percentage of Boiler Thermal Rating P_{th}	Notes
Fuel Store Type & Outfeed Mechanisms		
Walking Floor (Pushrod hydraulic pack):		
Pellets	0.12 %	
Woodchips	0.17 %	
Rotating/Sweeping Arms (Spring Outfeeder):		
Pellets	$(10^{-5} \cdot FA + 0.0002) \%$	FA = Floor angle (between 0° & 15° as input by user on fuel storage sheets)
Woodchips	$(2 \cdot 10^{-5} \cdot FA + 0.0005) \%$	As above
‘V’ Shaped Fuel Silo - Pellets	None	
Hopper Bottom Silo - Pellets	None	
Fuel Feed from Fuel Store to Boiler		
Conveyor Auger (between fuel store and rotary valve)	0.03%	
Rotary Valve or Flap Valve	None	Consumption insignificant
Boiler feed Auger	None	Already included in boiler data
Ram Stoker (between fuel store & boiler)	0.15 %	
Boilers		
Biomass Boilers	$(0.0121 \cdot P_{th}^{-0.1822})\%$	Averaged across many boiler types
Fossil Fuel Boilers	0.05 %	
Cyclone Fan		
Used for boiler sizes $\geq 400\text{kW}$ only	$(1.4 \cdot 10^{-7} \cdot P_{th} + 0.0005) \%$	
Boiler Back-end Pump		
$P_{th} \leq 2,000\text{kW}$	$(0.28 - 0.000075 \cdot P_{th}) \%$	
$P_{th} > 2,000\text{kW}$	0.13 %	

Table 15 Electrical Consumption of Boiler System Components

- 1 There is no electrical consumption associated with a hopper bottom silo
- 2 If ‘Minimum buffer vessel’ is selected the boiler will operate only for the hours corresponding to the profile type (Short, Long or Continuous + 5 days or 7 days)
- 3 If ‘Optimum thermal store’ is selected the boiler will operate continuously for the number of days per year input on the Biomass Boiler System Sizing page.

2.5.2 The Report

The report contains many of the results calculated by the Tool and already described above. At the end of the Report is a table showing cashflows, Internal rate of Return (IRR), Net Present Value (NPV) and the Net Annual Savings. The NPV and IRR are calculated using Excel functions in the format used by Excel in its examples of how to implement these functions. Each row represents the values of IRR and NPV that would result from a project terminating in the stated year.

2.6 Glossary

Accumulator Tank: Variously used to describe buffer vessels and thermal stores. This term is not used in the software or in this manual in an attempt to clarify the definitions used in the sector.

Auxiliary Boiler: Used to meet the difference in load between the biomass system output and the peak load.

Back-Up Boiler: Used to provide 100% back-up to the biomass system. Usually also functions as an auxiliary boiler

Buffer Vessel: Used to improve system efficiency by capturing residual heat on boiler shut-down. It also has a number of other functions and is usually associated with a particular hydraulic configuration described in this manual

Fuel Consumption: Fuel used by the heating plant. In this tool, the fuel quantity is converted to energy units, kWh, based on the net calorific value.

Heat Demand: Heat required by the building, to be delivered by the heating system. Also referred to as Load, or Delivered Heat. Units are kWh.

Reference Boiler: In the case of replacing a boiler on an existing system the Reference Boiler is the boiler being replaced. In the case of a newbuild system it should be the boiler against which a biomass boiler system is being compared.

Seasonal Efficiency: The average efficiency of a boiler over a year. This will always be lower than the boiler efficiency as measured by a combustion gas analyser

Thermal Store: used to enable a relatively small boiler to provide the majority of the annual energy demand from biomass. It can also function as a buffer vessel and is usually associated with a different hydraulic configuration from that associated with a buffer vessel. This hydraulic configuration is described in this manual



Appendix 1 - Guidance on Flue Sizing

The chart below provides some general guidance on flue sizing. Manufacturers' recommended minimum flue heights are boiler specific, and the manufacturer must be consulted in every case where the maintenance of a safe negative combustion chamber pressure relies on flue height alone. In all other cases a calculation of flue height to satisfy the requirements of the Local Authority is likely to be required, and must be carried out in accordance with Technical Guidance Note (Dispersion) D1. Where the boiler is not fitted with an induced draught fan the flue height will be the greater of the manufacturer's or Local Authority's requirement.

