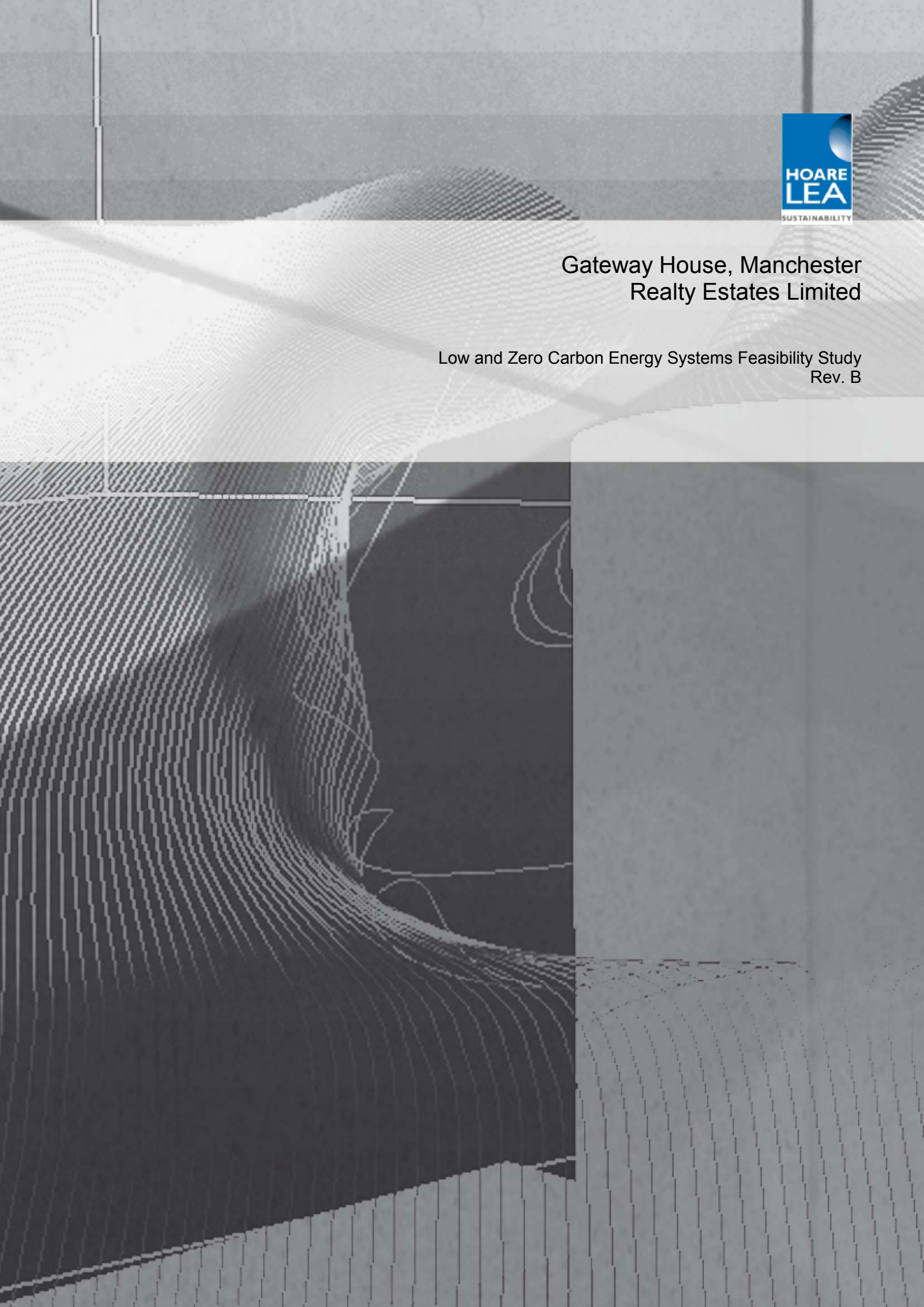


Gateway House, Manchester
Realty Estates Limited

Low and Zero Carbon Energy Systems Feasibility Study
Rev. B

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Audit Sheet

Rev.	Description	Prepared and checked by	Reviewed by	Date
A	LZC Energy systems feasibility study	T. Hegner	A. Bateson	11.03.11
B	Revised layouts	B. Barker		30.08.12

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1.0 EXECUTIVE SUMMARY

This report has been produced by Hoare Lea Sustainability on behalf of Realty Estates Limited to present the findings of a feasibility study on the options for low and zero carbon energy sources for Gateway House, Manchester.

The assessment was carried out to consider alternative ways of meeting the requirements of Manchester City Council planning policy guidance.

The following technologies have been appraised, in terms of technical and physical feasibility:

- Gas-fired combined heat and power
- Solar water heating panels
- Ground source heat pumps
- Biomass heating boilers
- Wind turbines
- Photovoltaic (PV) modules for electricity generation

The following energy sources are considered as possible options for the development at this stage and will be reviewed in more detail at the next stage of design:

✓ A CHP plant is proposed for the serviced apartment / hotel area of the Gateway House (approximate size: 51kWe). The CHP and its associated thermal stores would reduce CO_2 emissions by approximately 15%.

✓ An installation of PV modules provides an opportunity to reduce the CO_2 emissions by approximately 2%. The feed-in-tariffs could make a small PV installation commercially viable.

The following technologies are considered not appropriate and are not recommended:

× The installation of small scale wind turbines could reduce the CO_2 emissions by about approximately 1%, although there is uncertainty about the nature of the wind conditions at the top of the building which are likely to be turbulent and not ideal for wind power. There is also a visual impact that could be unacceptable.

× A ground source heat pump system is not considered feasible due to the site constraints and challenges of installing an adequate heat exchange system in the ground below the site.

× A biomass boiler is considered not appropriate due to air quality, fuel storage and delivery logistical issues

Table 1 shows the results of the LZC energy assessment for the Gateway House, Manchester.

All values are related to the whole building areas.

Strategy	Reduction of Energy Consumption [%]	Thermal Contribution [%]	Electricity Contribution [%]	Cooling Contribution [%]	Reduction of CO2 Emissions [%]
CHP [51 kWe] [1]	9.5	-	-	-	15.2
Solar thermal panels [2]	4.5	4.8	-	-	2.5
Biomass boiler [240 kW]	32.5	43.6	-	-	19.4
PV modules [2]	2.0	-	3.8	-	1.9
Wind Turbines (2no. small scale turbines)	1.3	-	1.4	-	0.7

Table 1 LZC Calculation Results

[1] Serves 90% of DHW

[2] 400 m2 = 20% of roof area

2.0 INTRODUCTION

The energy strategy for Gateway House, Manchester will take a three-stage approach to reducing the building's carbon emissions:

1. Reduce energy demand through passive design measures

2. Reduce the building's energy consumption through the use of energy efficient mechanical and electrical engineering systems.

3. Reduce the building's carbon dioxide emissions through the use of low and zero carbon (LZC) energy systems.

Hoare Lea has carried out a preliminary assessment of the low and zero carbon energy options for the project.

The reason(s) for considering low and zero carbon energy systems on this project are:

- To achieve Manchester City Council planning requirement that at least 20% of final site energy demand is to be met by on-site renewable energy technologies, where feasible.
- To support a BREEAM assessment
- To achieve a reduction in energy costs.
- To reduce the building's carbon footprint.

The assessment comprised the following stages:

1. Estimating the total annual energy consumption of the building (broken down into heating, hot water, cooling and other electricity loads), based on good practice benchmark energy consumption data for buildings of similar use(s)

2. Assigning target percentage reductions to these energy consumption figures to be achieved through energy efficiency measures, and applying these factors to the estimated annual energy consumption figures

3. Developing estimated monthly and hourly load profiles for the heating, hot water, cooling and other electricity loads, based on simulation results for typical buildings of similar use(s)

4. Estimating the potential contribution of various low and zero carbon energy systems that could be used on the project.

2.0 ASSESSMENT OF ENERGY CONSUMPTION AND CARBON DIOXIDE EMISSIONS (BASELINE SCHEME)

For the purpose of this study the energy consumption and carbon dioxide emissions for the development have been estimated using benchmark figures based on the floor area for the appropriate parts of the development.

The industry standard source for such benchmarks is CIBSE Guide F: 'Energy Efficiency in Buildings' .

The floor areas and uses used in this analysis have been obtained from architect's drawings (L(--) 000 rev B, L(--) 001 rev B, L(--) 002 rev B).

Table 2 shows the areas of each type of use on which the assessment was based.

Building Area		
Building Type	**Heated m^2**	**Cooled m^2**
Existing Retail	1910	1910
Office	670	670
Hotel	13830	13830

Table 2 Building Area

Table 3 shows the energy consumption benchmarks used in the assessment.

Benchmark Data				
Building Type	**Heating**	**Hot Water**	**Cooling**	**Electricity**
Existing Retail	210	14	25	57
Office	85	12	14	106
Hotel	160	60	2	78

Table 3 Benchmark Data

Table 4 shows the fuel carbon emissions factors used in the assessment.

Carbon Factors	
Natural Gas	0.198
Electricity	0.517
Elec Displaced	0.529
Biomass	0.009

Table 4 Carbon Factors

Table 5 shows the basis of benchmark and % of gross used in the assessment.

Building Area		
Building Type	**Basis of benchmark**	**% of gross**
Existing Retail	Sales floor area	67
Office	Treated floor area	90
Hotel	Treated floor area	95

Table 5 Basis of Benchmark and % of Gross

Figure 1 shows the estimated baseline energy consumption broken down by end use.

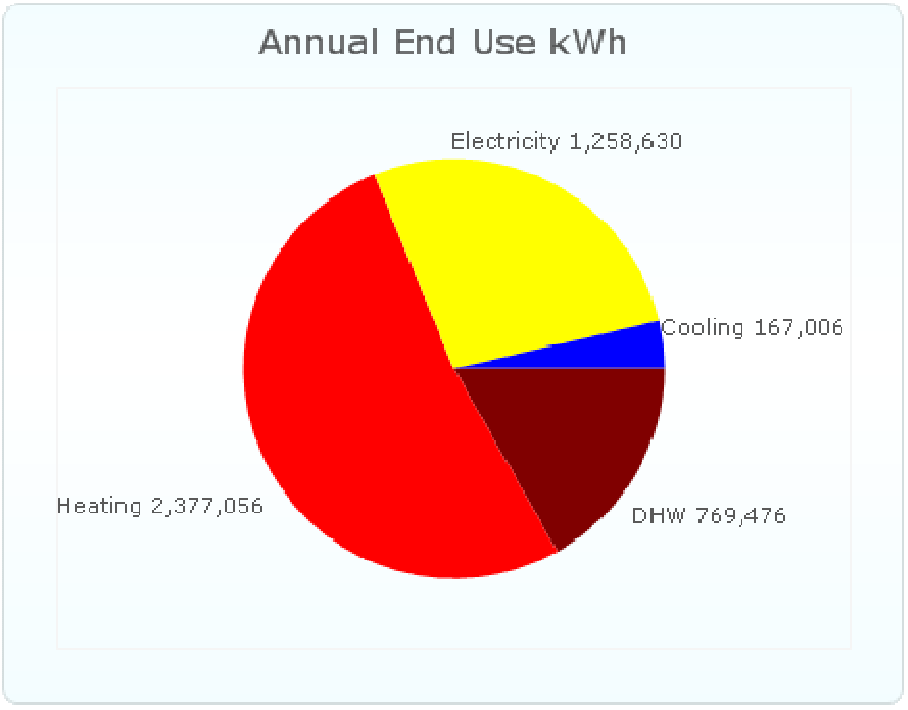


Figure 1

Figure 2 shows the estimated baseline energy consumption broken down by type of use

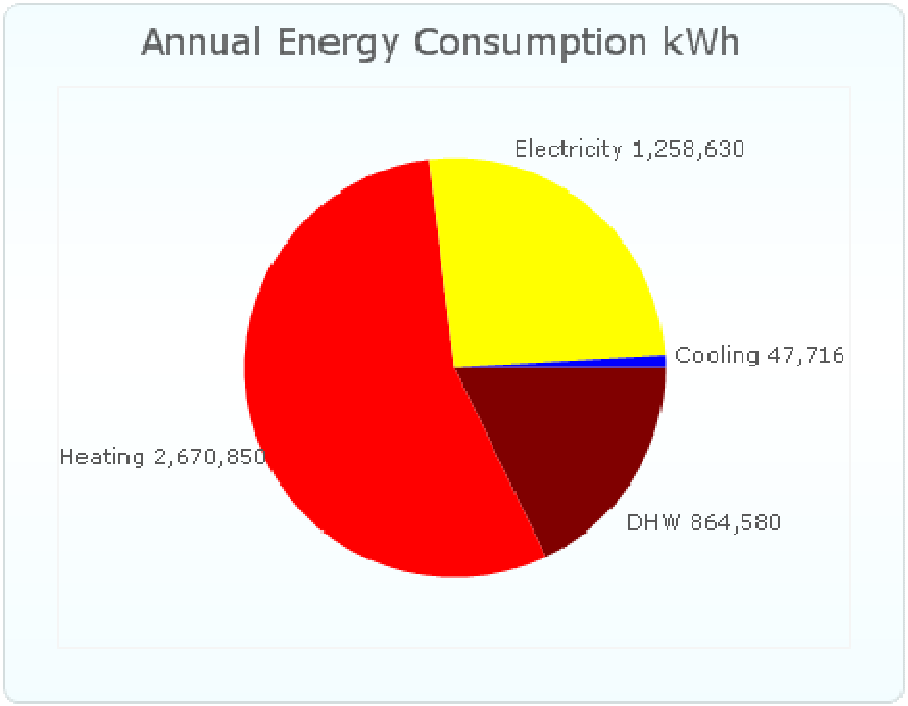


Figure 2

Figure 3 shows the estimated baseline carbon dioxide emissions broken down by type of use.

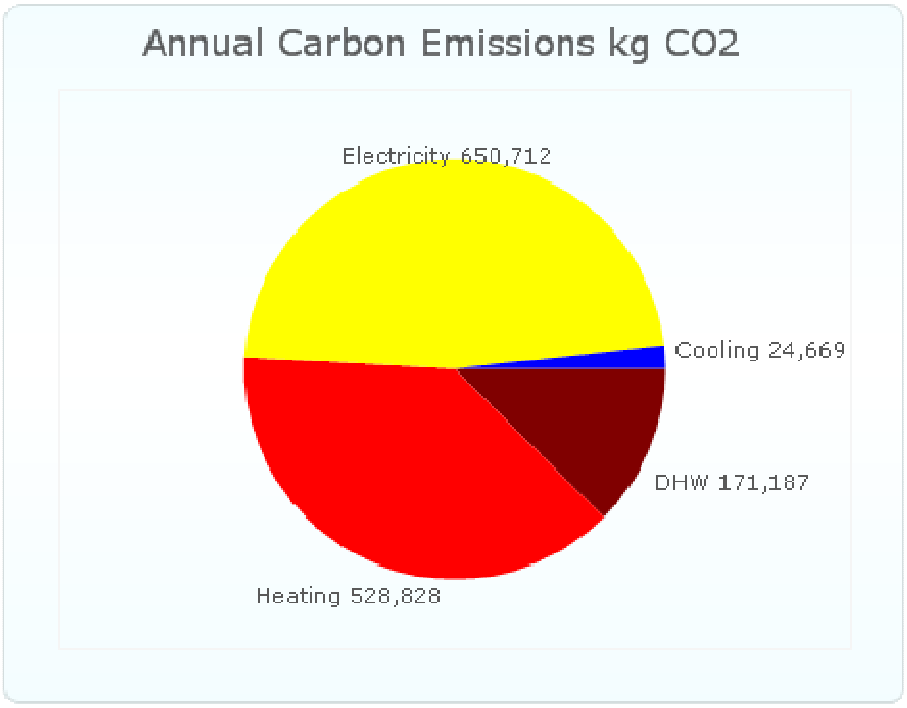


Figure 3

Figure 4 shows the estimated baseline energy consumption broken down by fuel.

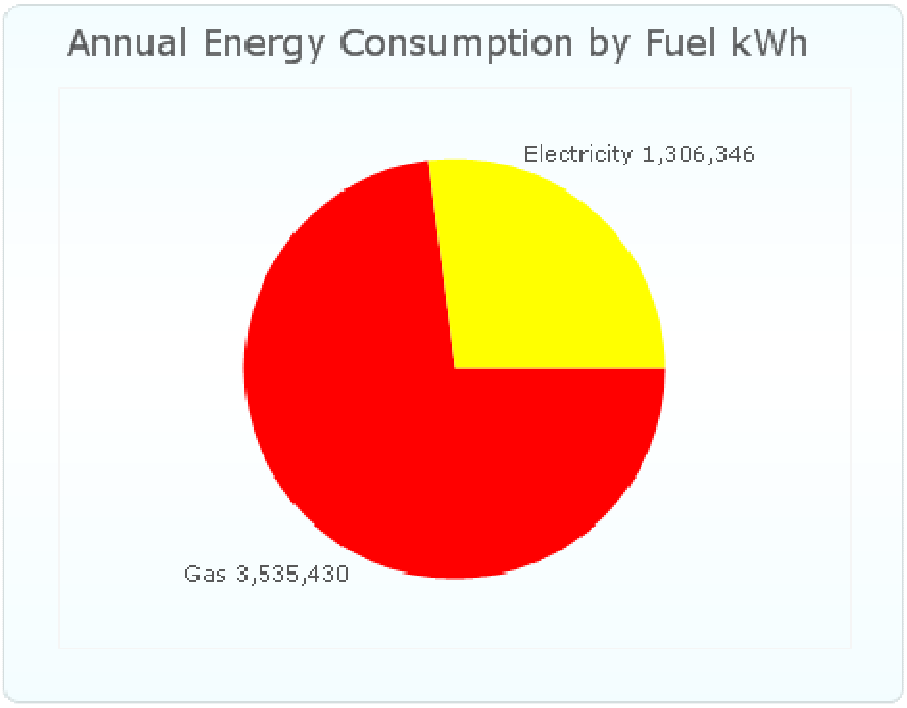


Figure 4

Figure 5 shows the estimated baseline carbon dioxide emissions broken down by fuel.

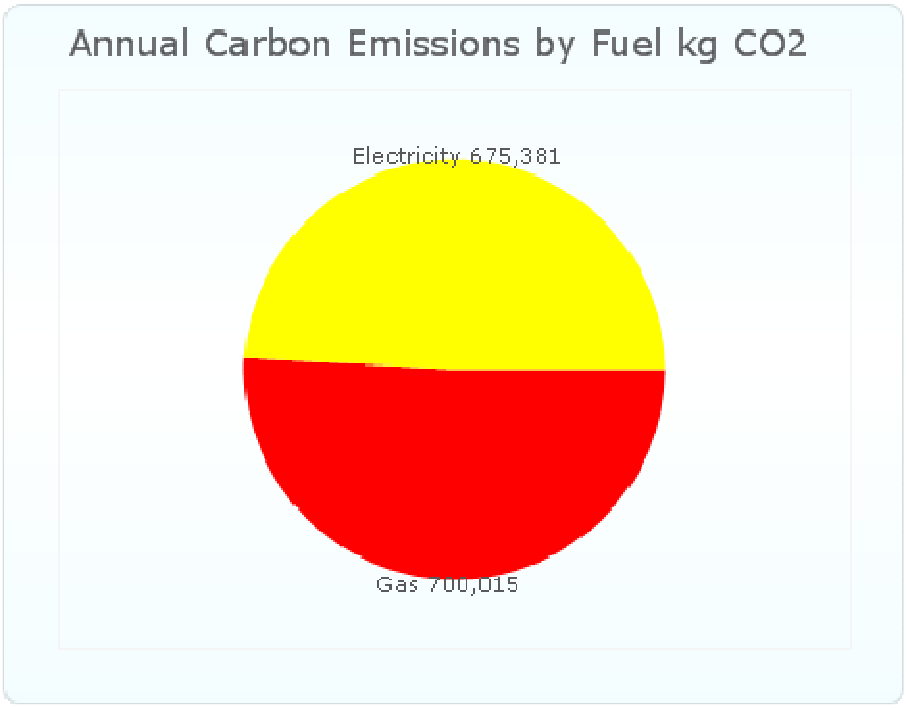


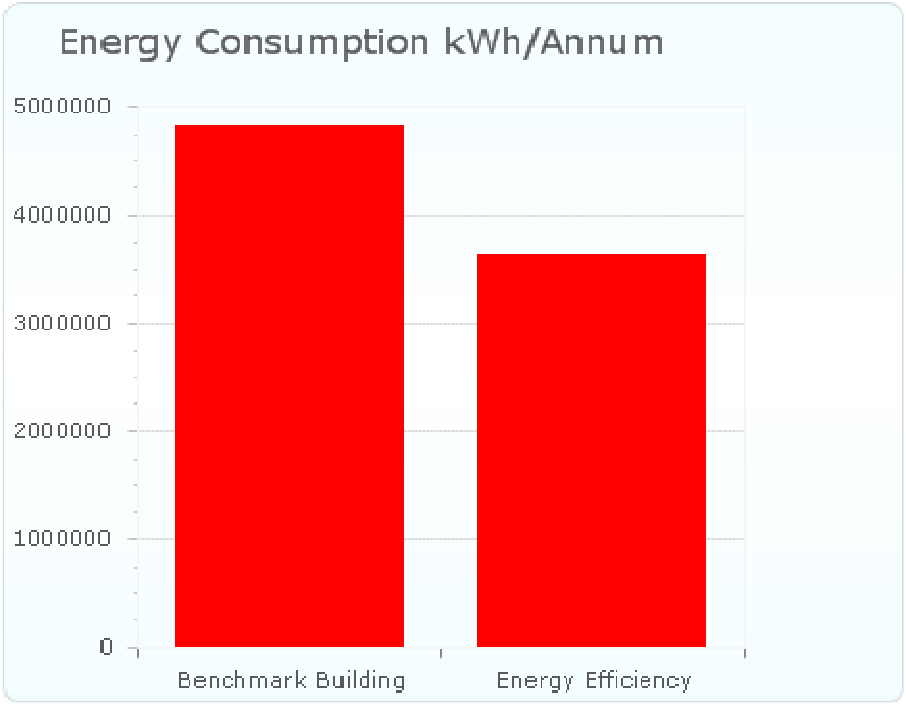
Figure 5

3.0 ENERGY EFFICIENCY

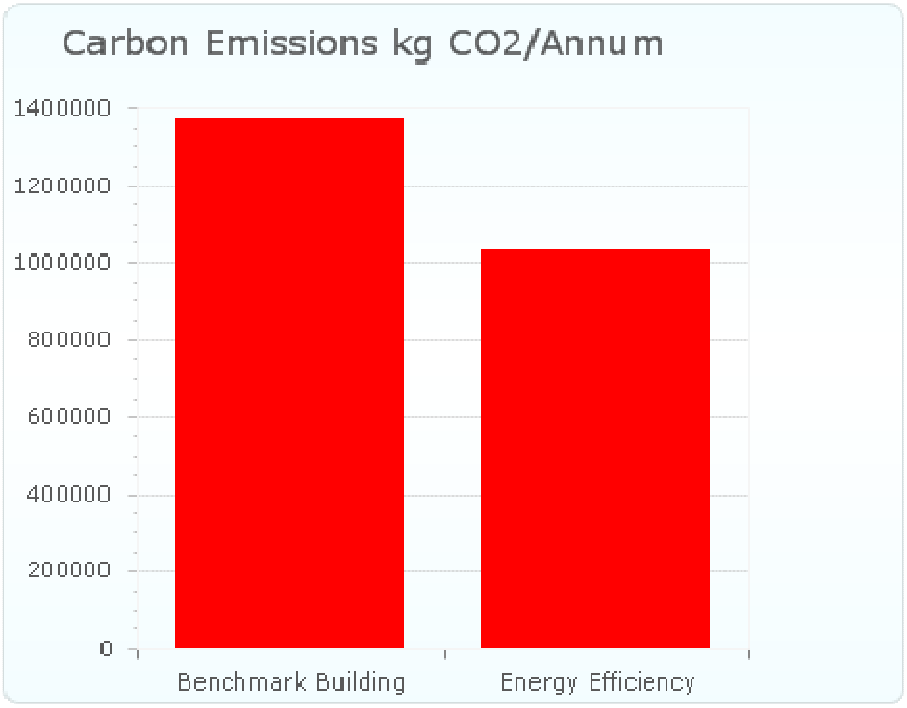
The energy consumption of the building will be reduced, from that of the baseline scheme, by the incorporation of energy efficiency measures in the design of the mechanical and electrical engineering systems. The following energy efficiency measures will be considered for incorporation into the scheme design:

- Heat recovery
- Variable speed pumps
- DC fan coil units
- Energy efficient chilling plant with options for free cooling
- Variable speed fan drives
- Night-time ventilation and use of thermal mass
- Lighting management system

Figure 6 shows the estimated energy efficiency and carbon reduction improvements resulting from these measures in combination.



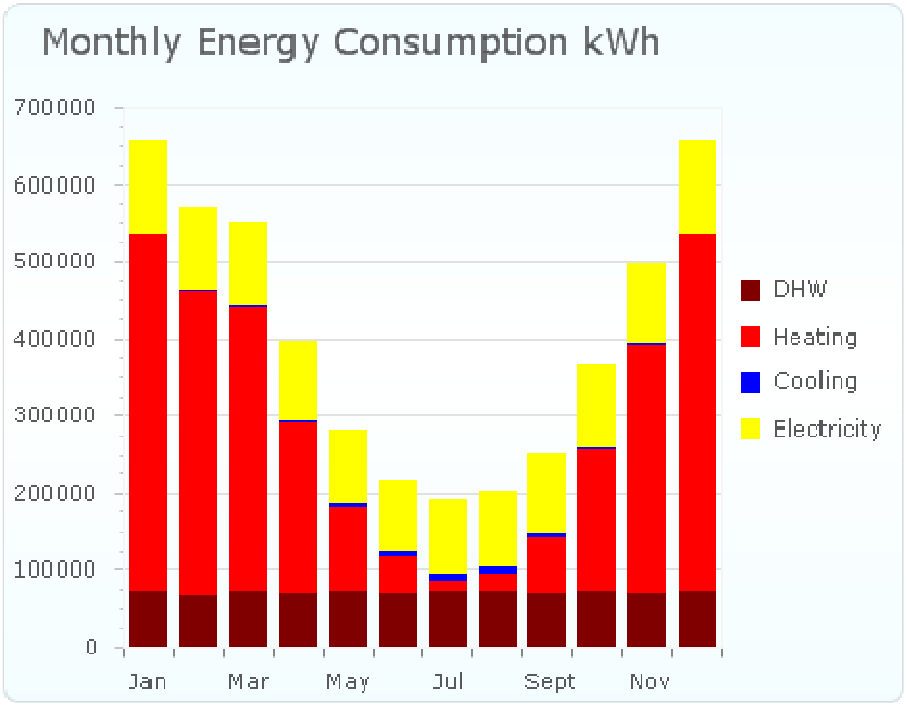
Energy Consumption kWh/Annum			
	Gas	Electricity	Total
Base Building	3,535,430	1,306,346	4,841,776
Energy Efficiency	2,651,572	979,760	3,631,332



Carbon Emissions kg CO2/Annum				
	Gas	Electricity	Total	Reduction%
Base Building	700,015	675,381	1,375,396	
Energy Efficiency	525,011	506,536	1,031,547	25.00

Figure 6

Figure 7 shows the estimated monthly energy profile for the building, incorporating the energy efficiency improvements.



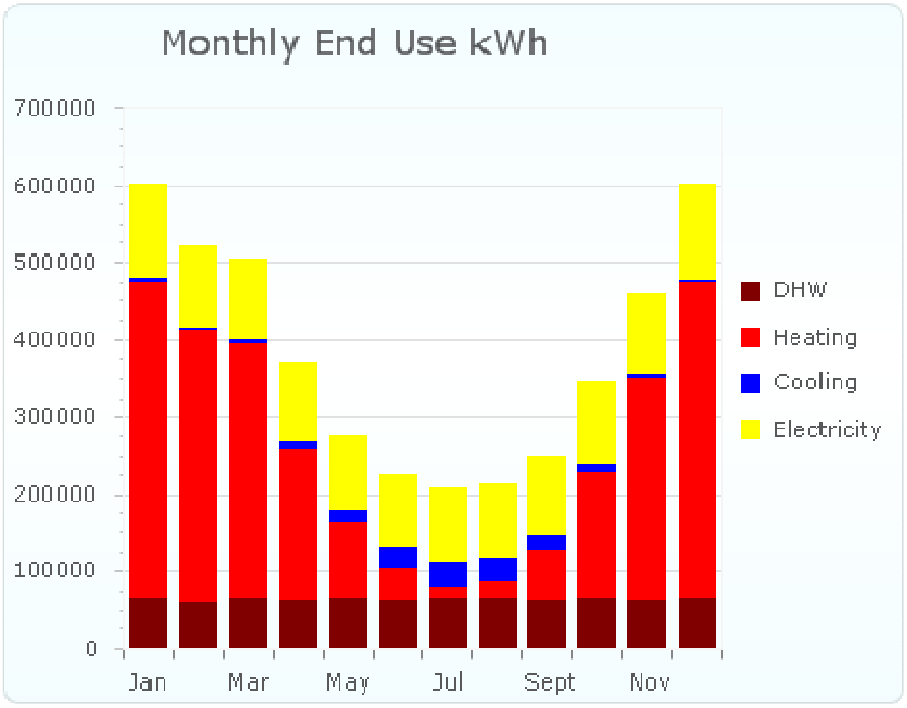


Figure 7

Figure 8 shows the estimated revised energy consumption, incorporating the energy efficiency improvements, broken down by end use.

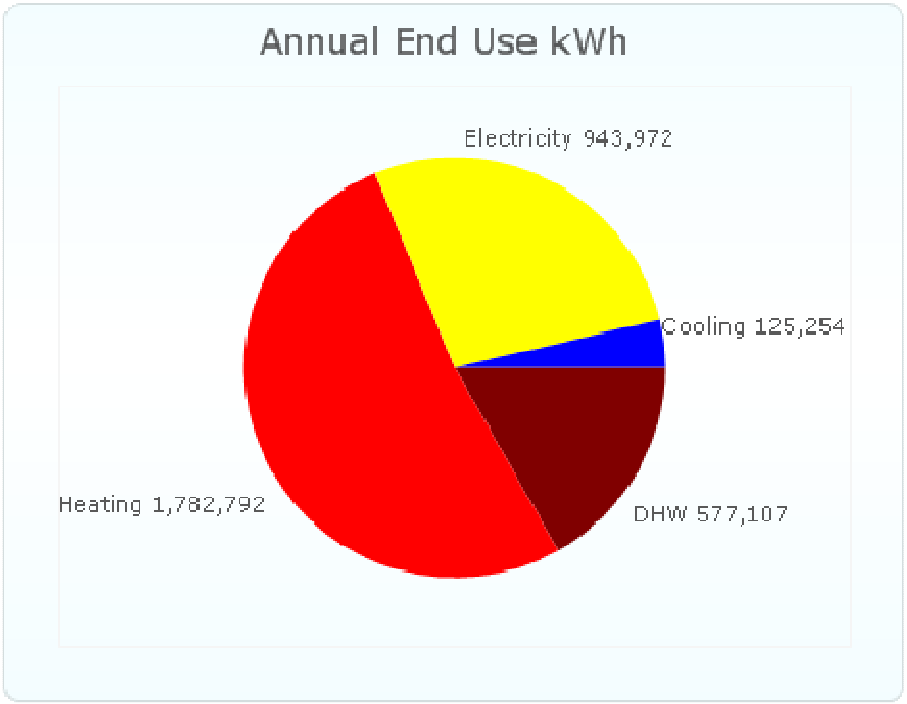


Figure 8

Figure 9 shows the estimated revised energy consumption, incorporating the energy efficiency improvements, broken down by type of use.

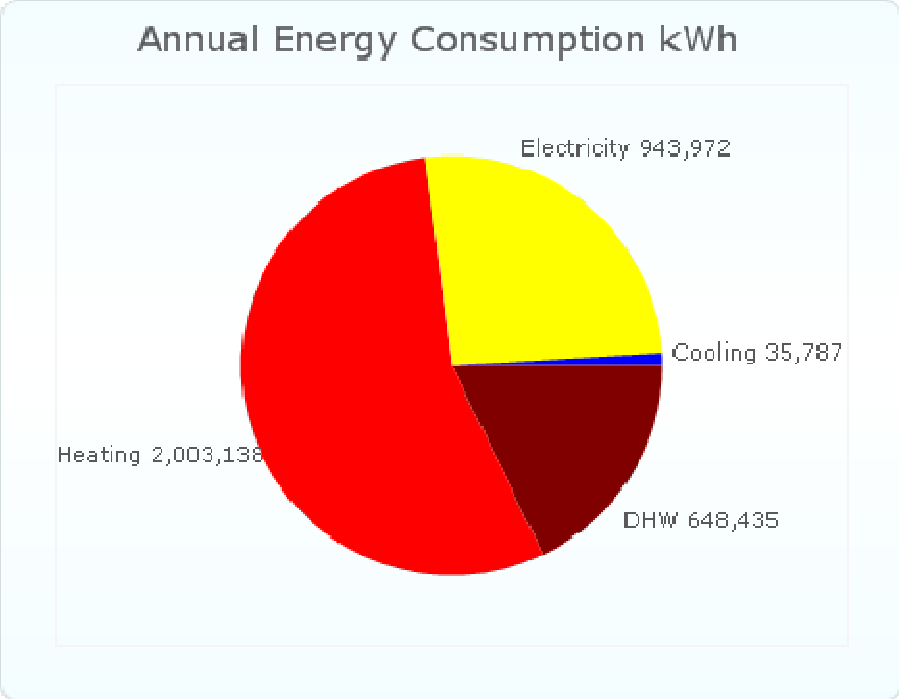


Figure 9

Figure 10 shows the estimated revised carbon dioxide emissions, incorporating the energy efficiency improvements, broken down by end use.

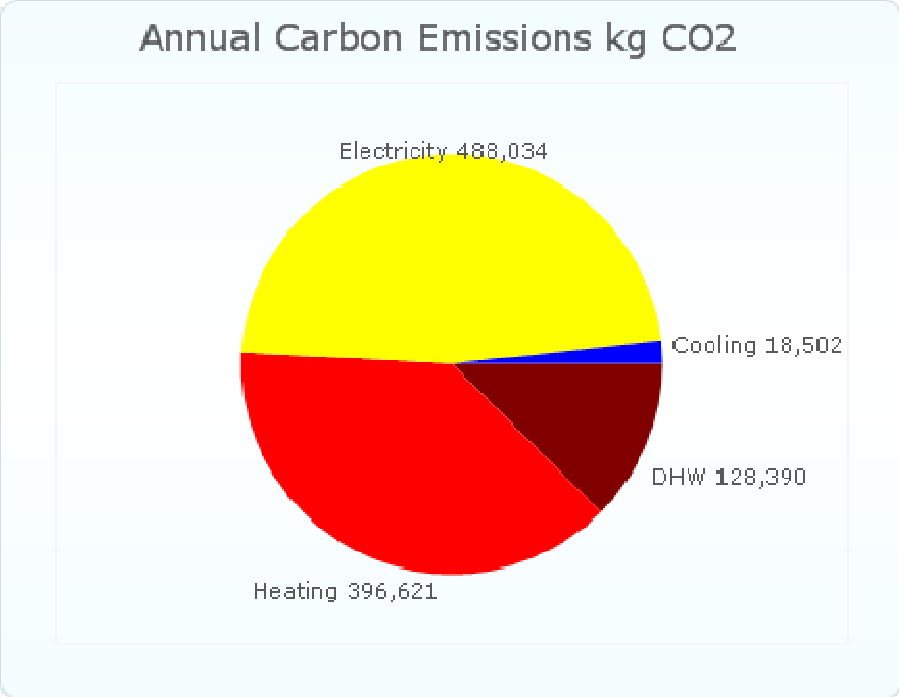


Figure 10

Figure 11 shows the estimated revised energy consumption, incorporating the energy efficiency improvements, broken down by fuel.

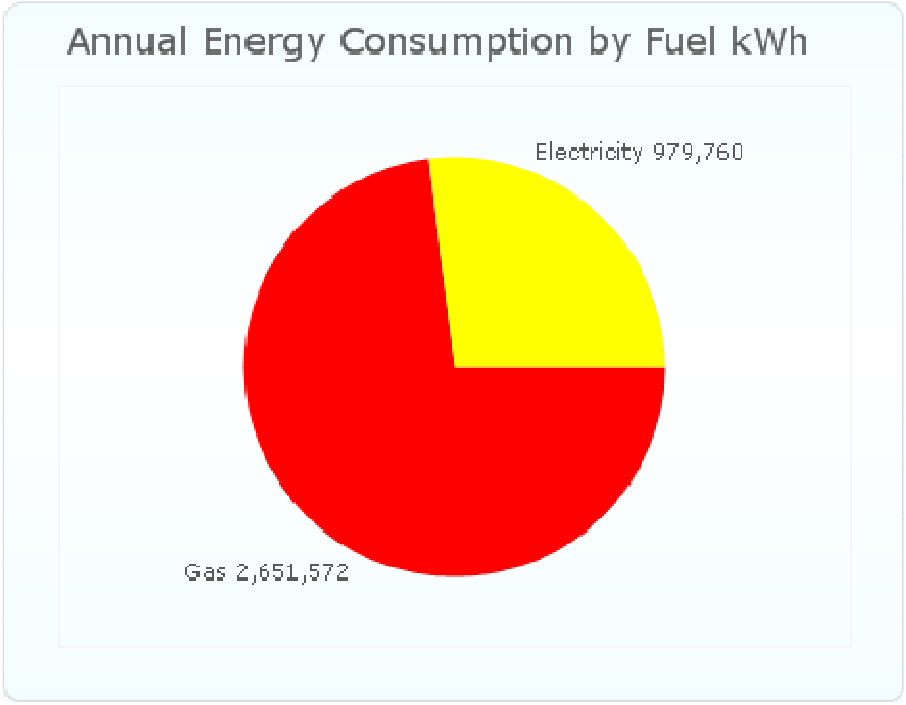


Figure 11

Figure 12 shows the estimated revised carbon dioxide emissions, incorporating the energy efficiency improvements, broken down by fuel.

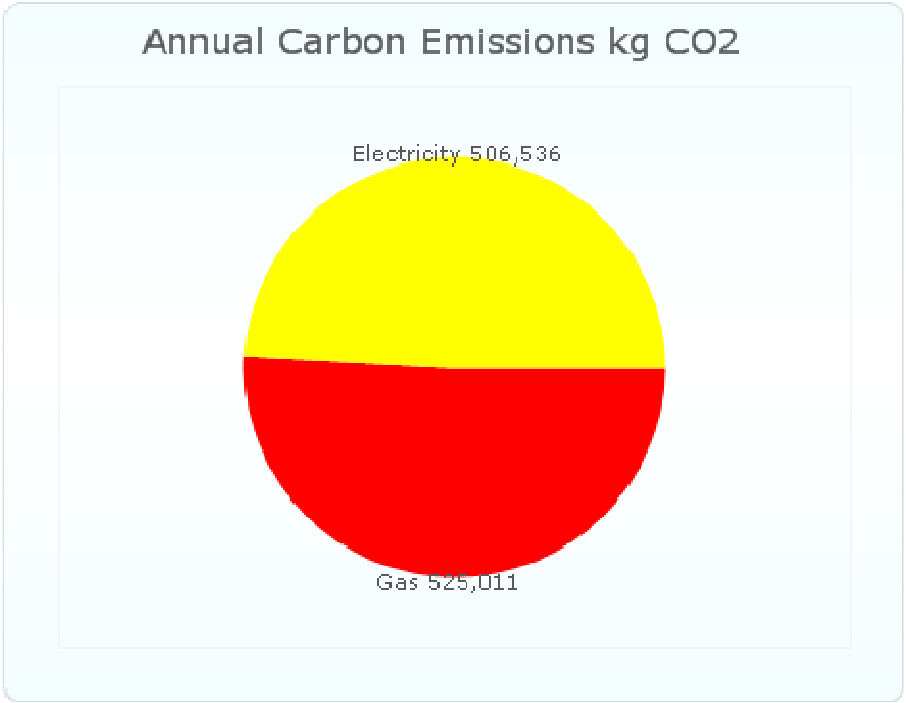


Figure 12

LOAD PROFILES

In order to analyse the performance of the potential low and zero carbon energy systems, monthly load profiles have been produced from the total estimated energy consumption figures. An hourly load profile has also been produced for a typical day for each of the four seasons of the year.

Figure 13 shows the estimated monthly energy profile for the building (incorporating the energy efficiency improvements).

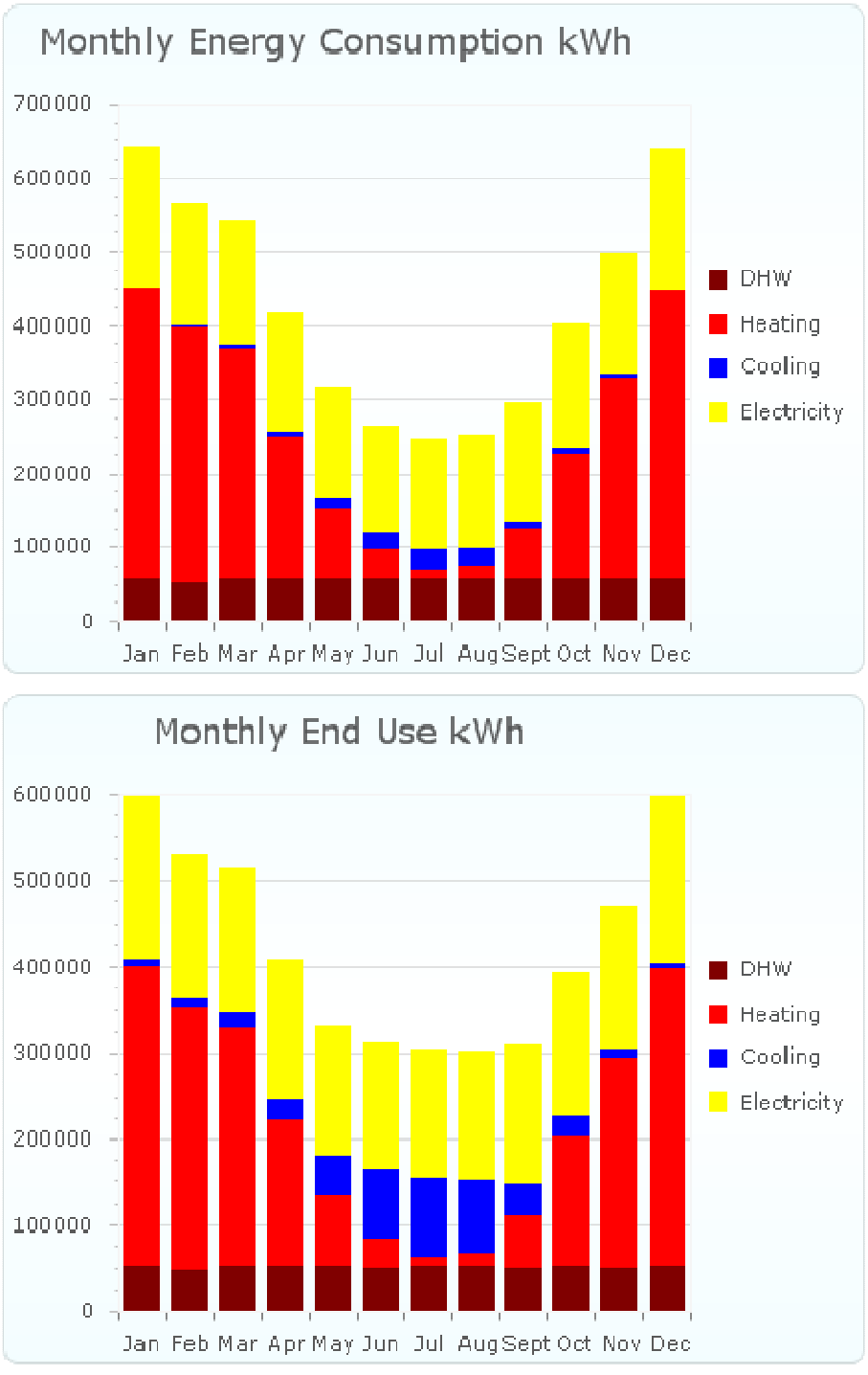
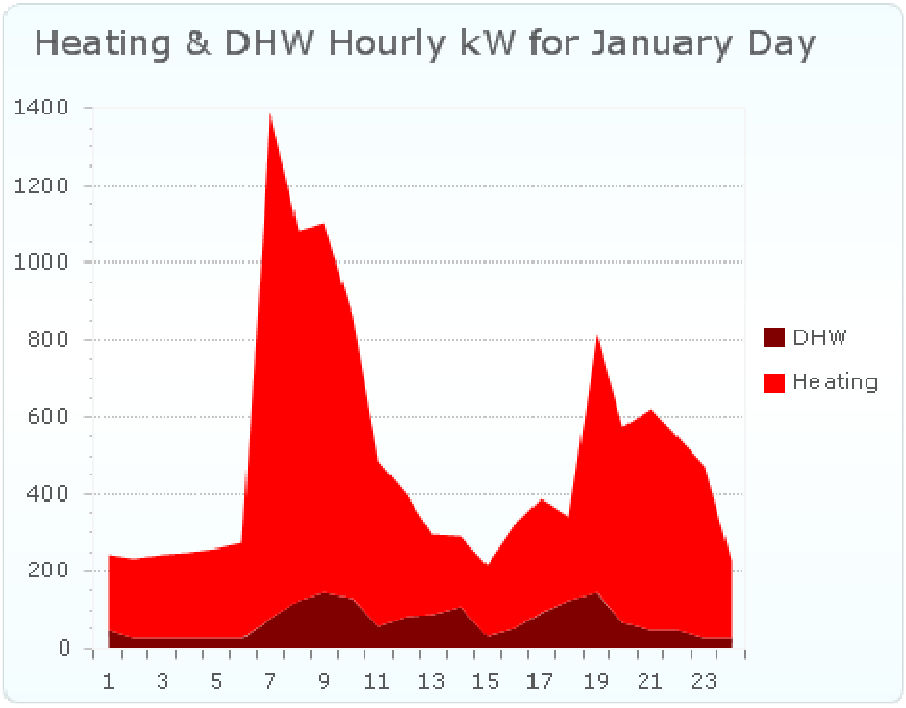
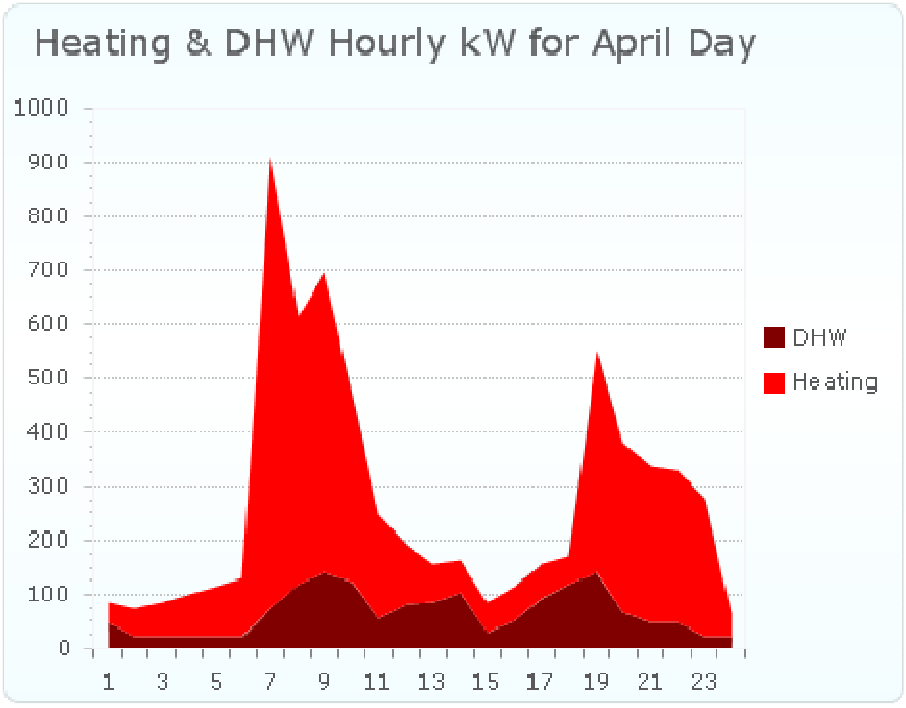


Figure 13

Figure 14 shows the estimated hourly heating and hot water load profiles for a typical winter, spring, summer and autumn day.





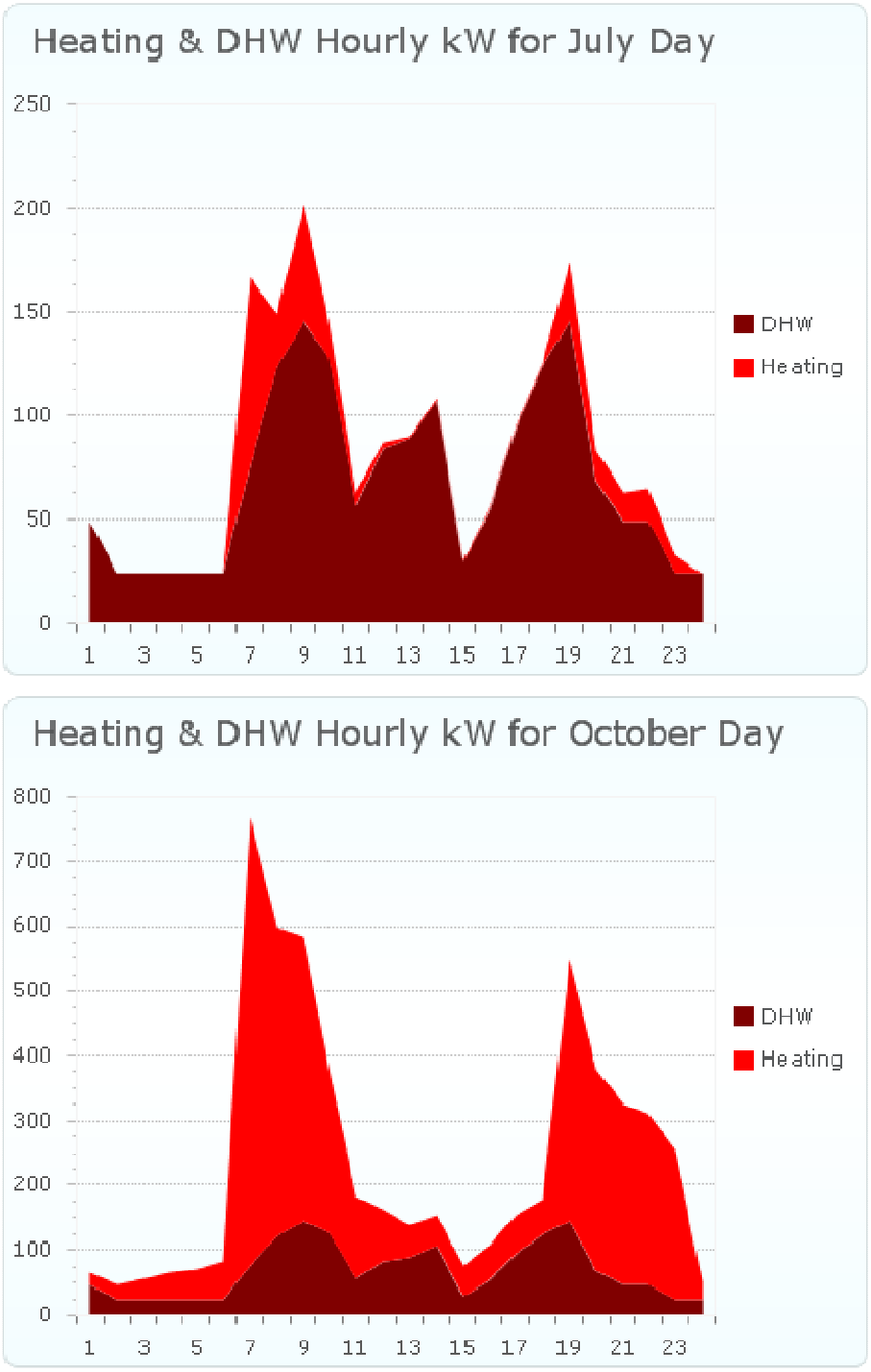
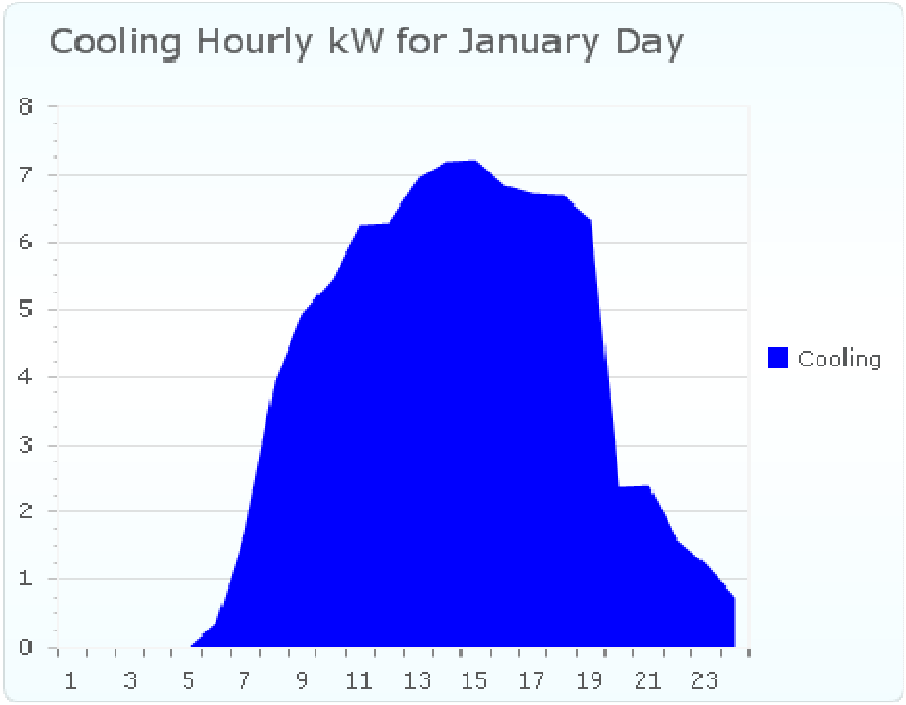
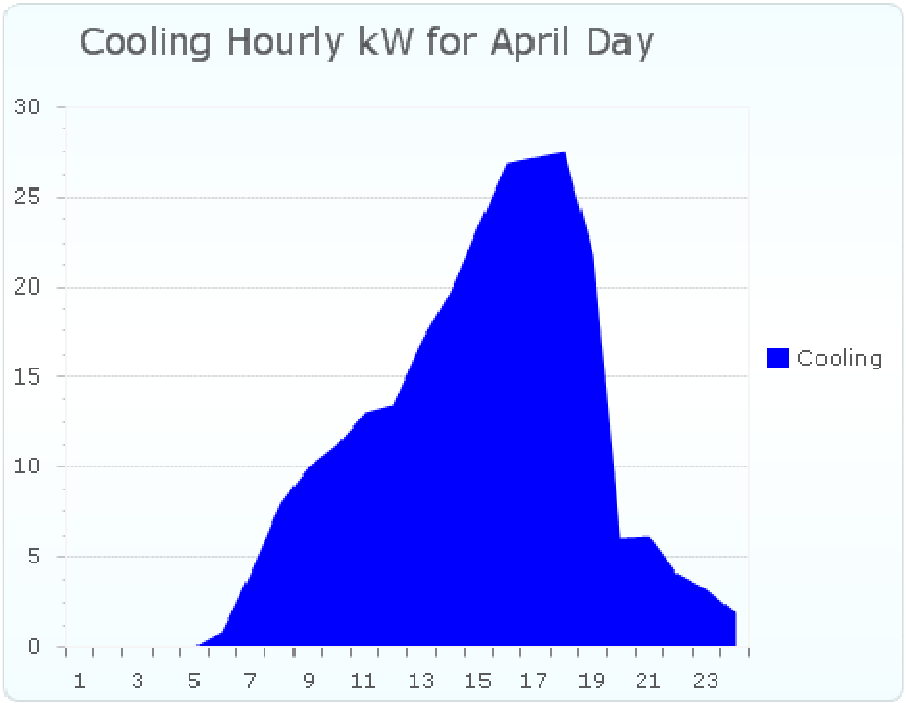

Heating & DHW Hourly kW for July Day
250
200
150
100
50
0
1 3 5 7 9 11 13 15 17 19 21 23
DHW
Heating
Heating & DHW Hourly kW for October Day
800
700
600
500
400
300
200
100
0
1 3 5 7 9 11 13 15 17 19 21 23
DHW
Heating

Figure 14

Figure 15 shows the estimated hourly cooling load profiles for a typical winter, spring, summer and autumn day.





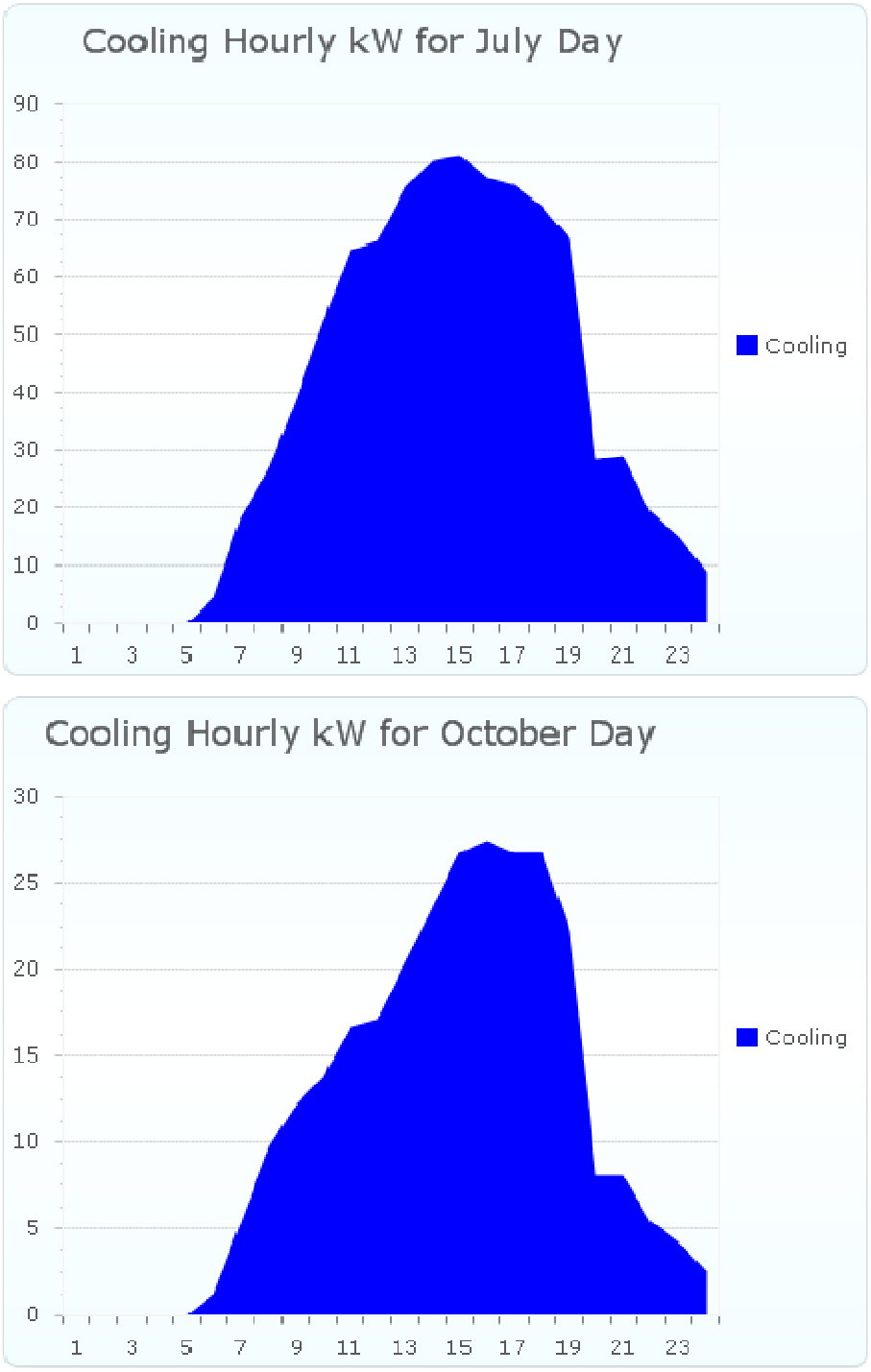

Cooling Hourly kW for July Day
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Cooling
Cooling Hourly kW for October Day
30
25
20
15
10
5
0
1
3
5
7
9
11
13
15
17
19
21
23
Cooling

Figure 15

4.0 COMBINED HEAT AND POWER

5.1 Gas-fired combined heat and power (CHP)

CHP uses a gas-fired reciprocating engine, connected to a generator to simultaneously generate both heat and power (electricity). Useable heat is generated by recovering the heat from the engine that, in a conventional generator, is rejected to atmosphere. In order to optimise the performance of the CHP engine it is important to provide consistent heating and electrical loads. For this reason, such a system would be supplemented by a gas fired boiler system and public electrical supply.

To ensure that CHP is financially viable it is essential that the unit is selected to meet the base heat load and that this load is maintained over a large proportion of the day (a figure of 17 hours per day is often quoted) to ensure that the additional costs (maintenance) associated with running a CHP unit can be recovered.

This need to run the CHP plant, as far as possible continuously makes the building load profile of prime importance when reviewing the viability of such solutions and in particular the summer time heat load profile. CHP systems only make financial sense to operate when the waste heat associated with generating the electricity is usefully used. To enable the CHP plant to run continuously when it is operating, a thermal store is often used so that excess CHP capacity can be used to generate hot water for use at a later time.

Table 6 shows the CHP selections made and results

Fuel Type	Natural Gas
kW Thermal	76
Thermal Efficiency %	46
Heat to Power Ratio	1.65
Assumed Daily Operating Hours	17
Eqv Operating Hours	6205
CHP Thermal Contribution %	19.98

Table 6 CHP Details

The CHP analysis is based on an electrical output of 51kWe and thermal output of 76 kWt.

All used input data are given by technical data sheets from a CHP supplier. It has been sized to cover 100% of the building's hotel area base domestic hot water load.

Figure 16 shows the CHP Contribution to the heating and hot water load on a monthly basis.

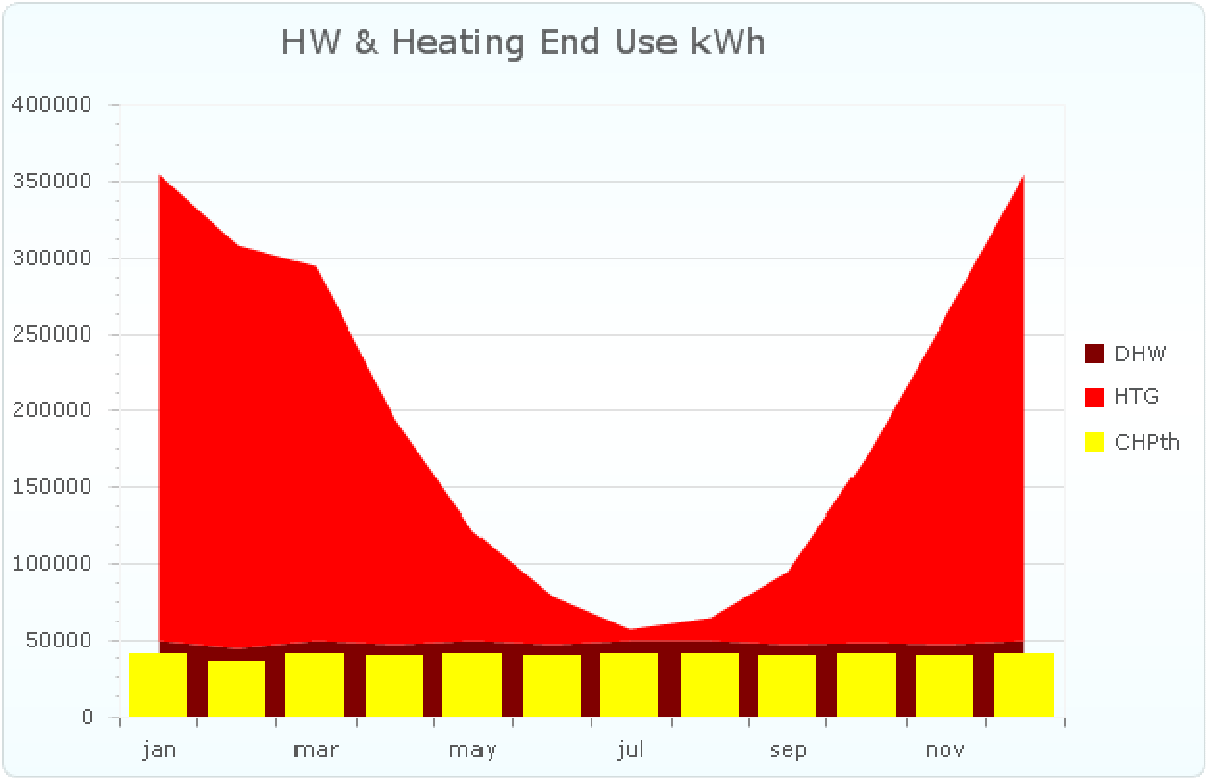
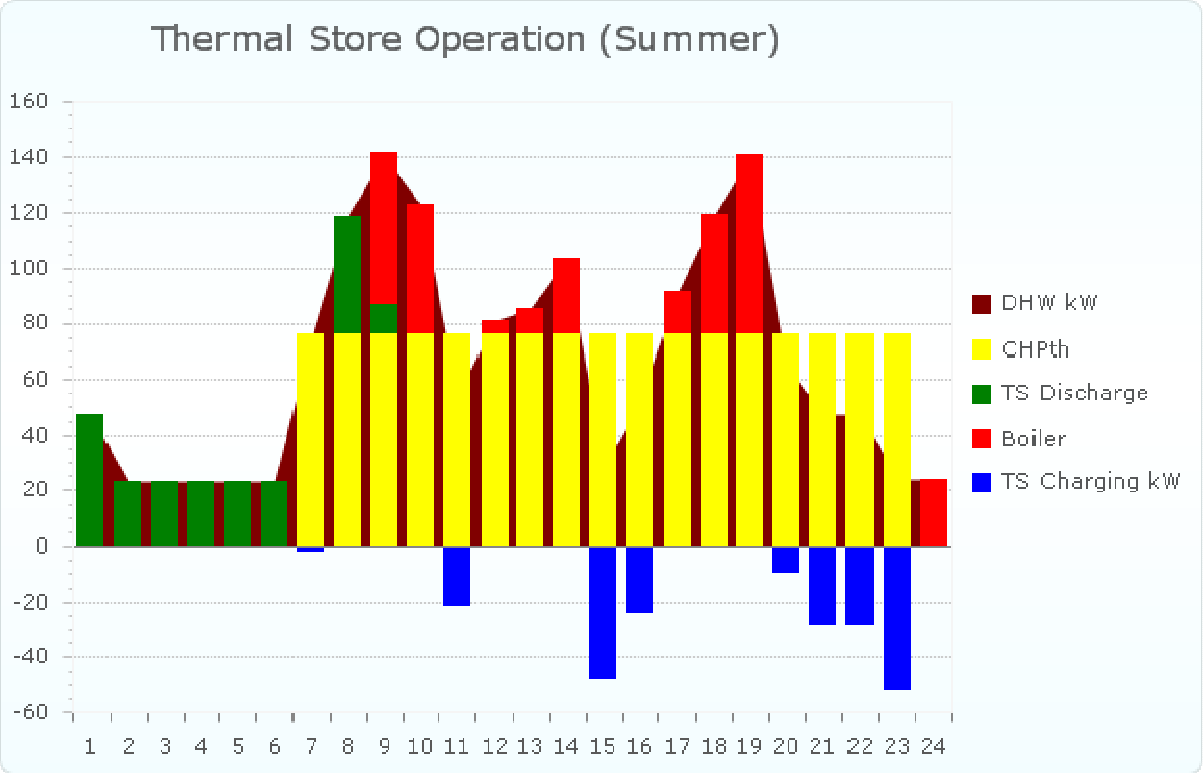


Figure 16

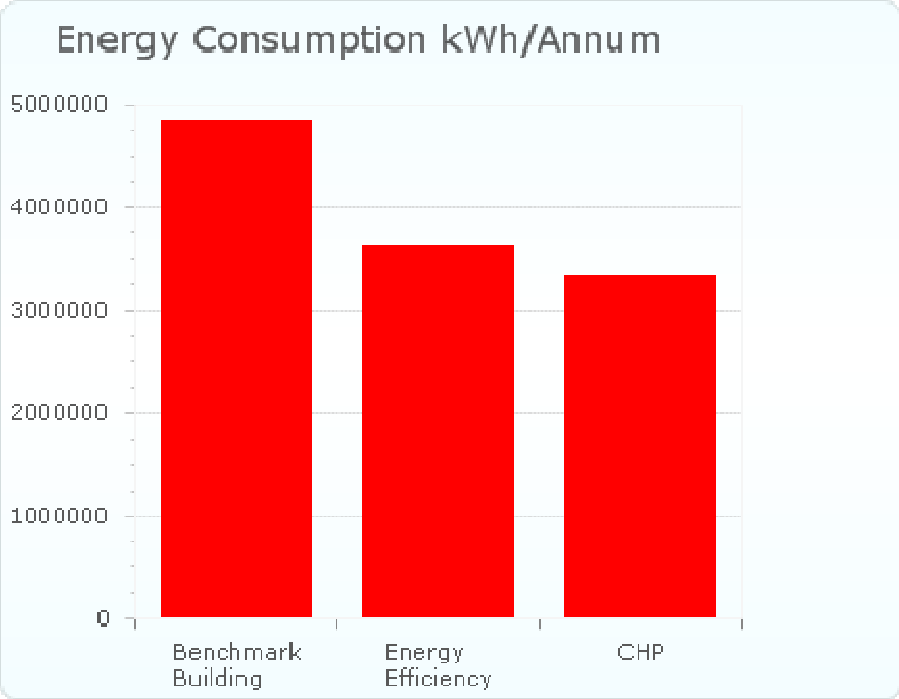
Figure 17 shows the hourly CHP thermal output and DHW load and charging/ discharging of the thermal store.



Delta T (K)	25	30	35	40	45
Thermal Store Capacity (Litres)	7,433.00	6,194.00	5,309.00	4,645.00	4,129.00

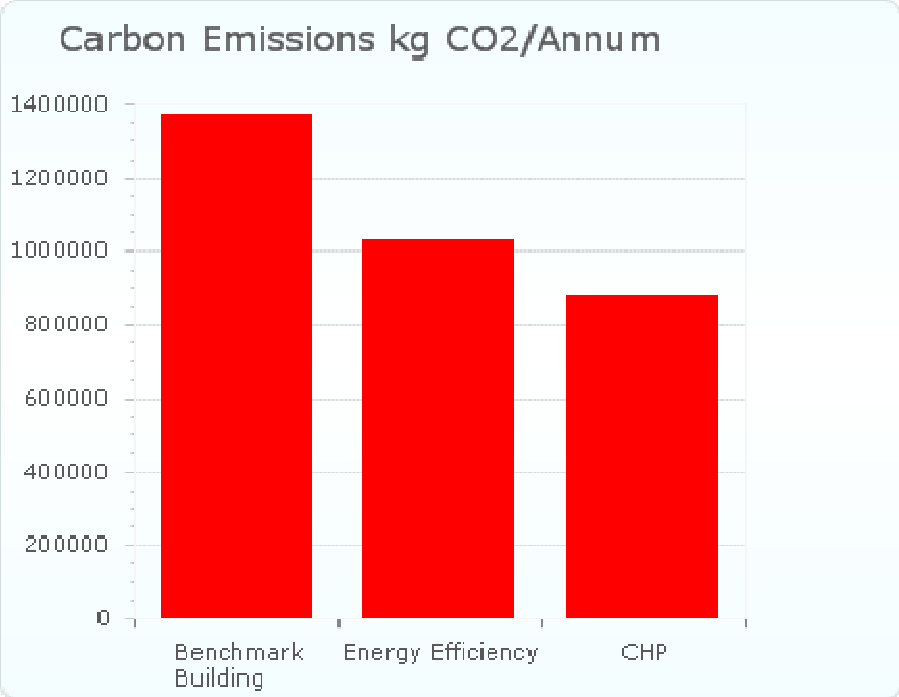
Figure 17

Figure 18 shows the revised estimated building energy consumption taking into account the contribution of CHP.



Energy Consumption kWh/Annum

		Gas	Electricity	Total
	Base Building	3,535,430	1,306,346	4,841,776
	Energy Efficiency	2,651,572	979,760	3,631,332
	Building Gas & Electricity Consumption	2,121,707	979,760	3,101,467
CHP	**CHP Gas Consumption & Displaced Electricity**	501,681	-285,806	501,681
	CHP Total Energy			3,317,342



Carbon Emissions kg CO2/Annum					
		Gas	Electricity	Total	Reduction %
	Base Building	700,015	675,381	1,375,396	
	Energy Efficiency	525,011	506,536	1,031,547	25.00
	Building Gas & Electricity Consumption	420,098	506,536	926,634	
CHP	CHP Gas Consumption & Displaced Electricity	99,333	-151,191	-51,859	
	CHP Total Energy			874,775	15.20

Figure 18

5.0 LOW AND ZERO CARBON ENERGY SYSTEMS

A number of technologies were appraised, in terms of technical and physical feasibility. Each technology was considered as an alternative option to CHP.

5.0 Option 1 Biomass heating boilers

A biomass boiler uses a natural fuel such as wood chips or wood pellets for combustion. Since it uses a natural resource that can be replanted it is considered as a renewable energy source. The carbon dioxide emitted from burning biomass is balanced by that absorbed during the fuel's production. Biomass heating therefore approaches a carbon neutral process.

The primary disadvantage is that it requires large amounts of fuel storage (which will need to be fed by deliveries of biomass fuel) and requires a suitable flue design.







Table 7**Error! Reference source not found.** shows the GSHP selections and results.

Biomass Boiler Size (kW)	200
Biomass Boiler Efficiency %	90
Thermal Contribution%	58.31

Table 7 Biomass Details

Figure 19 shows the thermal energy contribution from the biomass boiler and other sources

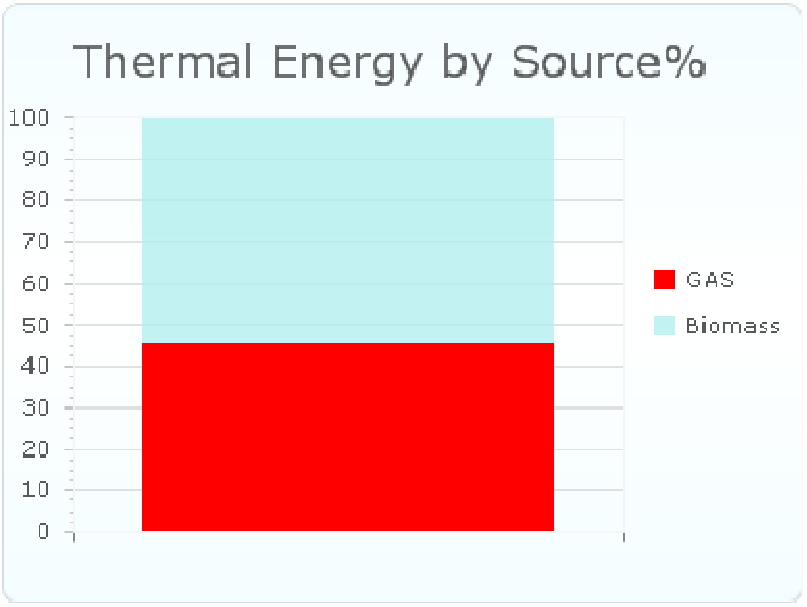
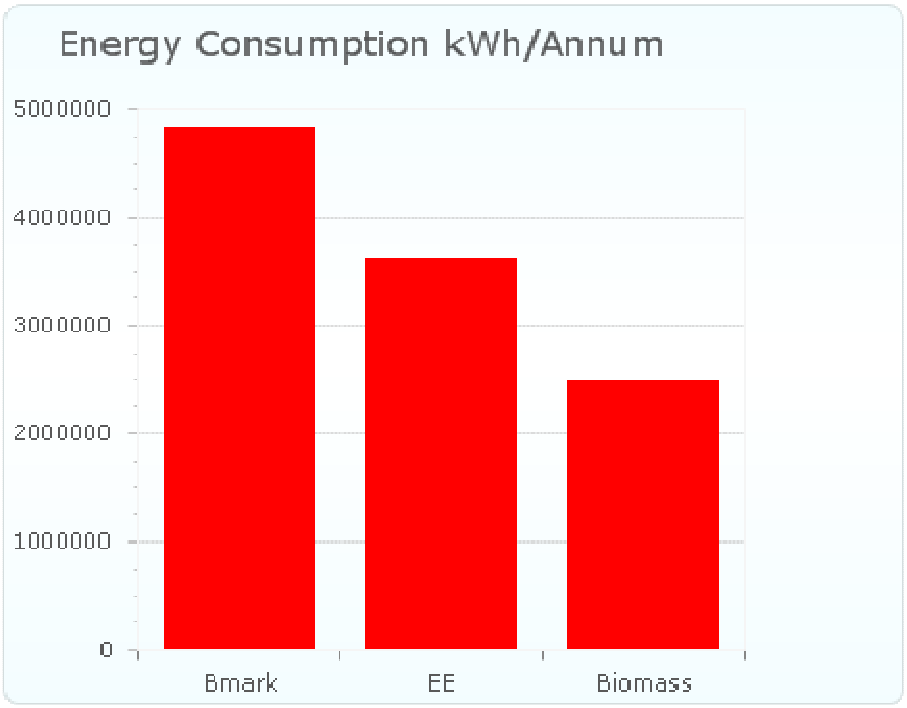
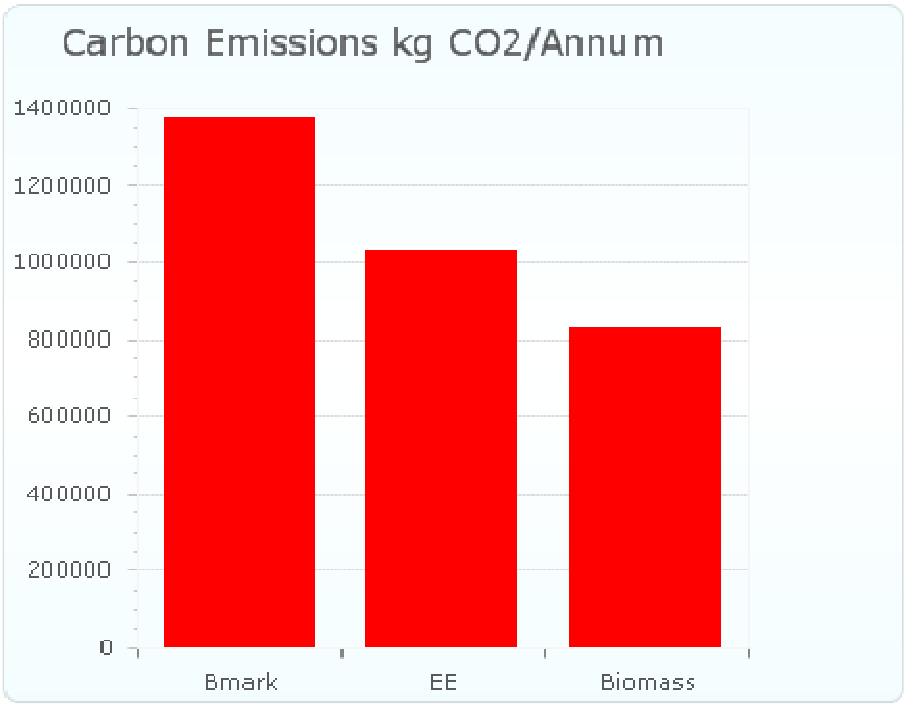


Figure 19

Figure 20 shows the estimated building energy consumption and carbon dioxide emissions, taking into account the contribution of the biomass boilers low and zero carbon (LZC) energy system options.



Energy Consumption kWh/Annum				
		Gas	Electricity	Total
	Base Building	3,535,430	1,306,346	4,841,776
	Energy Efficiency	2,651,572	979,760	3,631,332
	LZC	1,495,953	979,760	2,475,713



Carbon Emissions kg CO2/Annum					
		Gas	Electricity	Total	Reduction%
	Base Building	700,015	675,381	1,375,396	
	Energy Efficiency	525,011	506,536	1,031,547	25.00
	LZC	325,089	506,536	831,625	19.38

Figure 20

Figure 21 shows the biomass boiler contribution to the heating and hot water load on a monthly basis

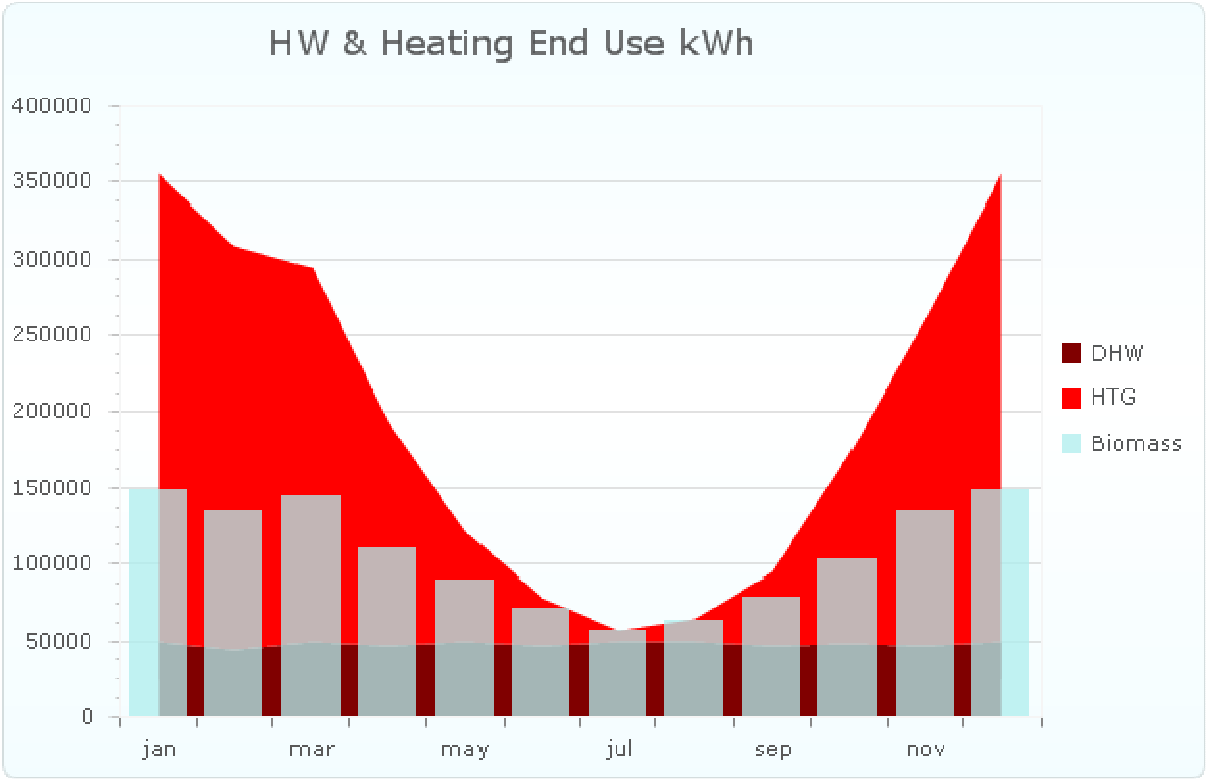


Figure 21

5.1 Option 2 Wind turbines

Wind turbines use the wind's lift forces to turn aerodynamic blades that turn a rotor thus generating electricity. There are three basic types to consider: horizontal axis (propeller type), vertical access (helical type) and building integrated (where the building design is adapted to suit the wind turbine). Building integrated systems are still at the development stage.



Table 8 shows preliminary equipment selections and results.

Terrain Type	Urban with average building height
Mean Annual Wind Speed (m/s)	6.00
Swept Area by Diameter	5.5
Hub Height (m)	15
Power (kW)	Small turbines < 80kW
Multiplier	2
Electricity Contribution%	1.39

Table 8 Wind Turbine Details

The Gateway House is located in the city of Manchester. It is likely that the benefits would be less because of the urban surroundings which cause turbulent air flow.

The analysis assumes that the mean annual wind speed is about 6 (m/s) and that two wind turbines will be placed on the roof top.

Figure 22 shows the electricity contribution from the wind turbines and other sources

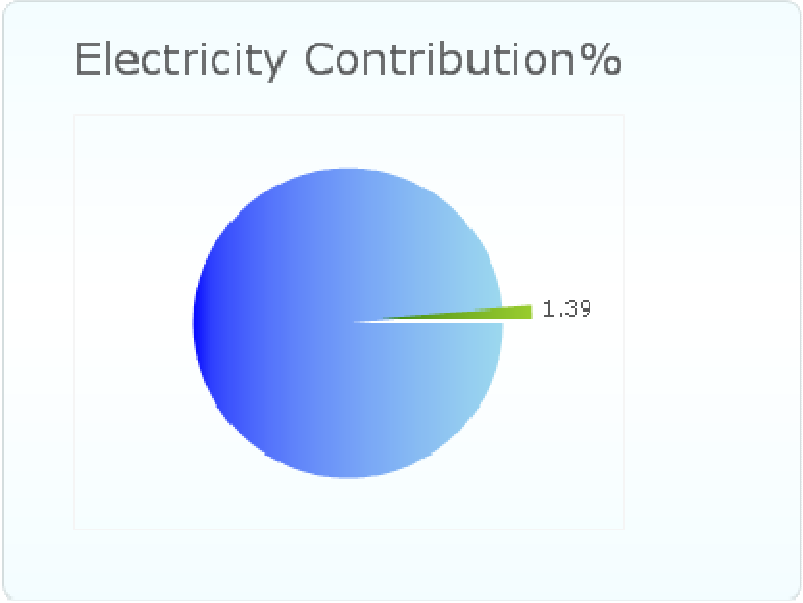
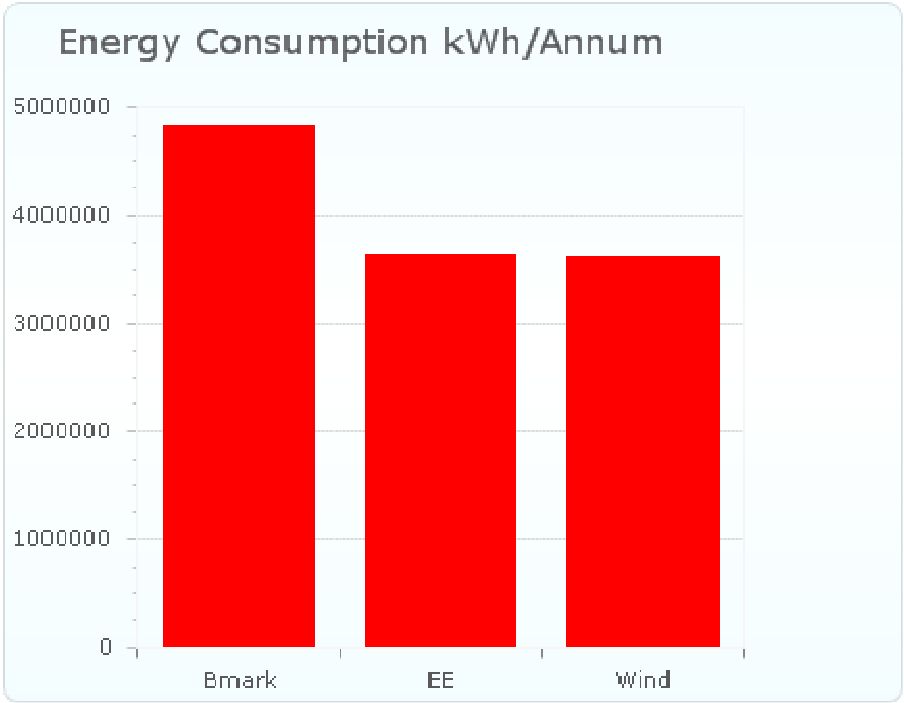
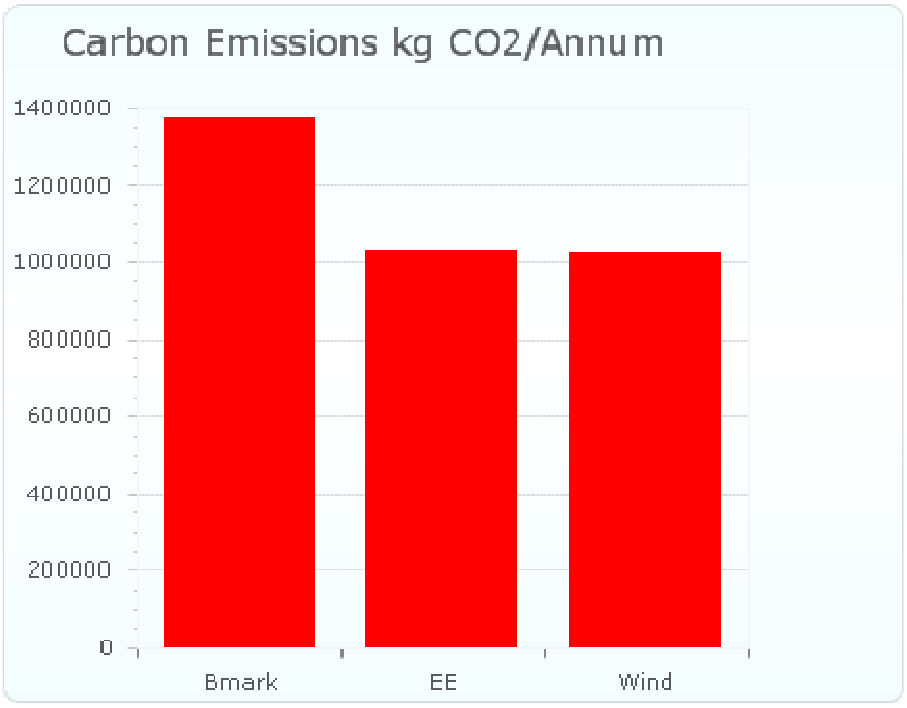


Figure 22

Figure 23 shows the estimated building energy consumption and carbon dioxide emissions, taking into account the contribution of the wind turbines low and zero carbon (LZC) energy system options.



Energy Consumption kWh/Annum				
		Gas	Electricity	Total
	Base Building	3,535,430	1,306,346	4,841,776
	Energy Efficiency	2,651,572	979,760	3,631,332
	LZC	2,651,572	966,141	3,617,713



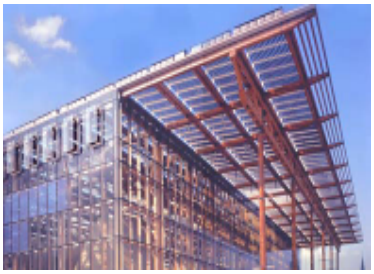
Carbon Emissions kg CO2/Annum					
		Gas	Electricity	Total	Reduction%
	Base Building	700,015	675,381	1,375,396	
	Energy Efficiency	525,011	506,536	1,031,547	25.00
	LZC	525,011	499,331	1,024,343	0.7

Figure 23

5.2 Option 3 Photovoltaic (PV) modules for electricity generation

This option uses an array of photovoltaic (PV) solar cells to generate electricity. Solid PV cells can be either roof or façade mounted (although solar modules fitted on a south facing façade have only 75% the output of roof mounted modules). Thin film PV types are more flexible; they can be curved or flat and can be integrated into a roof or cladding system. PV cells can also be integrated into glazing; the gaps around the PV cells allow some daylight penetration. This can be used for partial shading in a glazed roof.



Error! Reference source not found. Table 9 shows the photovoltaic selections and results.

Watt Peak Type	Polocrystaline Silicon
Orientation	South
Inclination (deg)	30
Area (m2)	400
Electricity Contribution%	3.83

Table 9 Photovoltaic Details

The roof of the Gateway House has got a total area of approximately 2000 m2. Therefore it would be reasonable to assume that about 400 m2 (20% of total roof area) can be used for the installation of PV's to ensure enough workspace for maintenance and the space requirements of plant.

The PVs should be mounted on the South-West of the roof to rule out possible shadowing by nearby buildings. Lower lying areas e.g. the roof of new buildings are not recommended because of shadowing.

In comparison with case studies an installation within the façade is not recommended due to the high capital and maintenance costs.

Preliminary calculations suggest that the installation of PV panels is an opportunity to reduce the CO_2 emissions of the Gateway House by approximately 2%.

The feed-in-tariffs make a small PV installation potentially commercially viable (subject to further financial analysis)

Figure 24 shows the electricity contribution from the photovoltaics

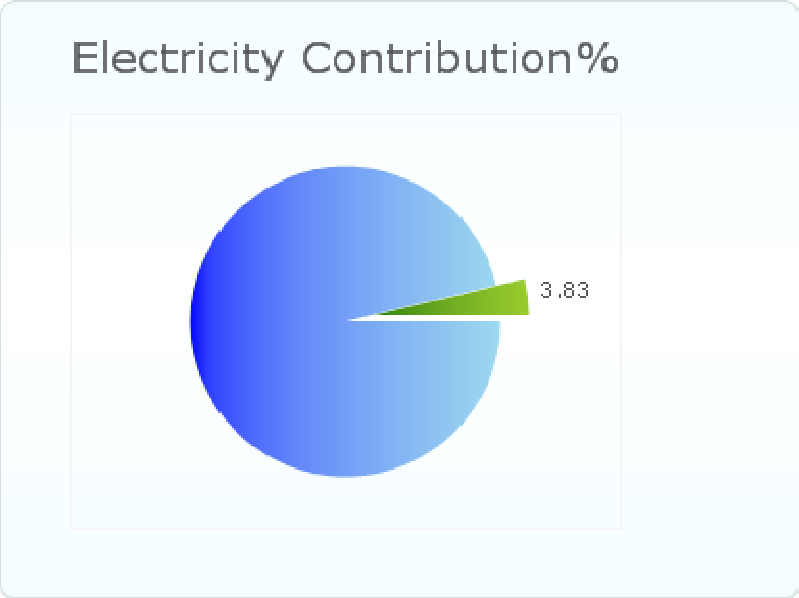
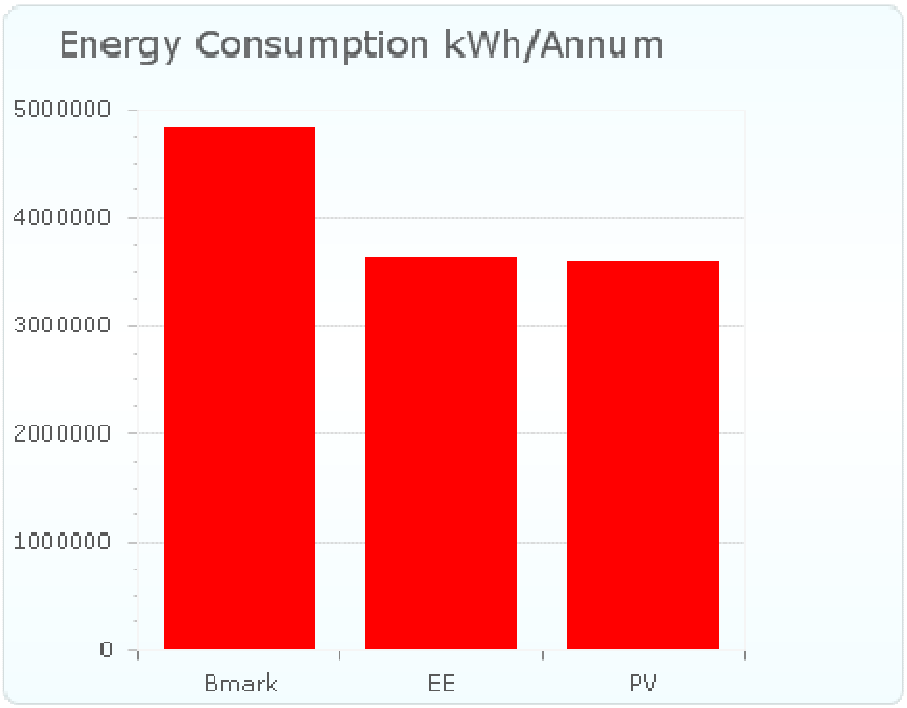


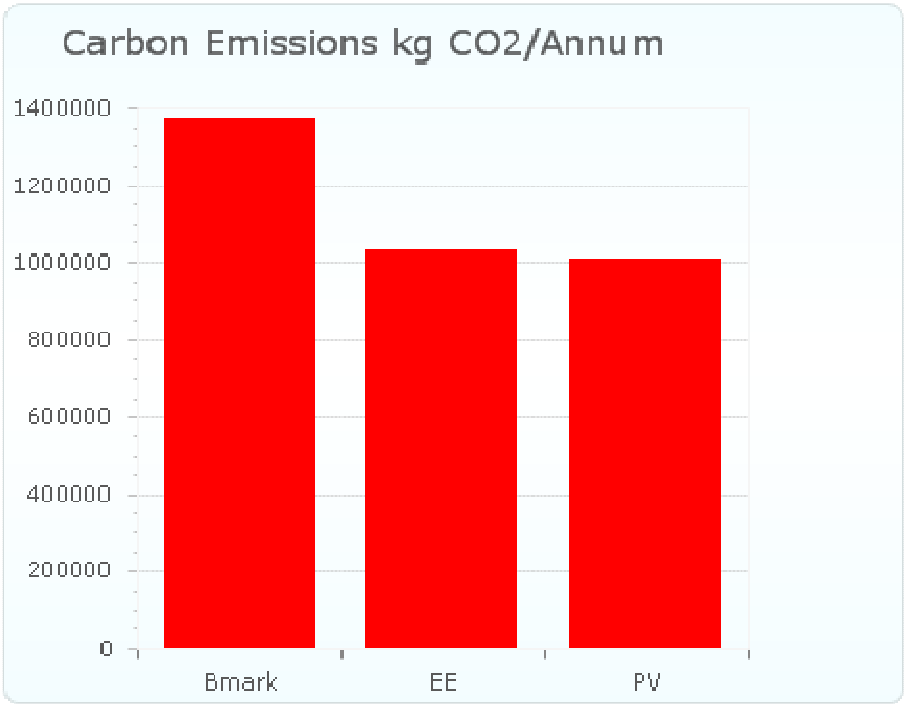
Figure 24

Figure 25 shows the estimated building energy consumption and carbon dioxide emissions, taking into account the contribution of the photovoltaics.



Energy Consumption kWh/Annum

		Gas	Electricity	Total
	Base Building	3,535,430	1,306,346	4,841,776
	Energy Efficiency	2,651,572	979,760	3,631,332
	LZC	2,651,572	942,235	3,593,807



Carbon Emissions kg CO2/Annum					
		Gas	Electricity	Total	Reduction%
	Base Building	700,015	675,381	1,375,396	
	Energy Efficiency	525,011	506,536	1,031,547	25.00
	LZC	525,011	486,685	1,011,696	1.92

Figure 25

5.3 Option 4 Solar water heating panels

Solar water heating systems use heat from the sun to pre-heat domestic hot water. The system requires solar panels on the roof, ideally south facing, linked to hot water storage cylinders.





Table 10 shows the solar hot water selections and results

Orientation	South
Inclination (deg)	30
Area (m^2)	400.00
Gross/ Aperture	Gross
Type	Evacuated Tube
Thermal Contribution %	4.29

Table 10 Solar Water Details

Figure 26 shows the thermal energy contribution from the solar hot water system and other power

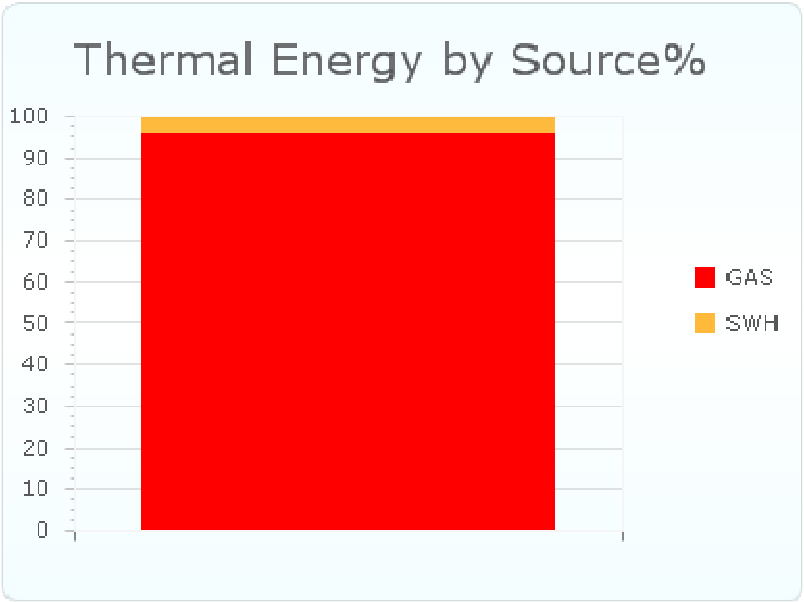
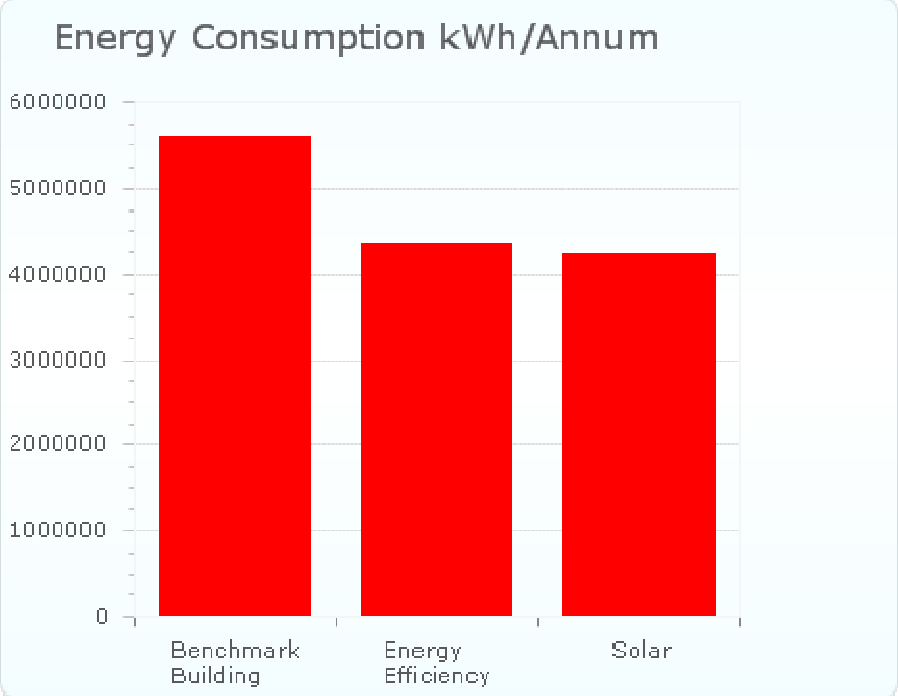


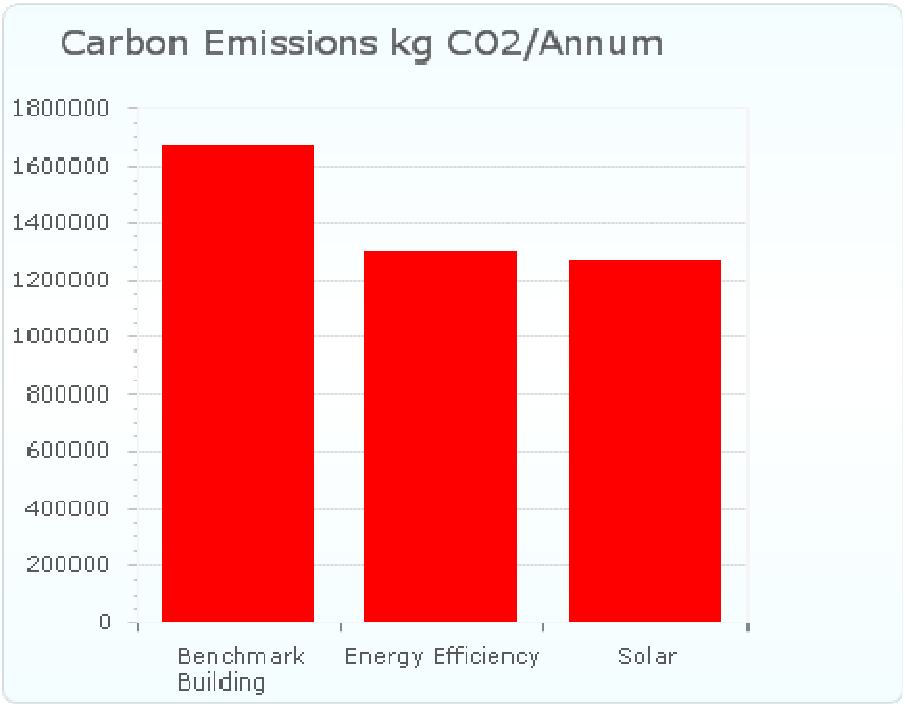
Figure 26

Figure 27 shows the estimated building energy consumption and carbon dioxide emissions, taking into account the contribution of the solar hot water low and zero carbon (LZC) energy system options.



Energy Consumption kWh/Annum

		Gas	Electricity	Total
	Base Building	3,837,652	1,759,872	5,597,524
	Energy Efficiency	2,987,047	1,359,736	4,346,782
	LZC	2,858,788	1,359,736	4,218,523



Carbon Emissions kg CO2/Annum

		Gas	Electricity	Total	Reduction%
	Base Building	759,855	909,854	1,669,709	
	Energy Efficiency	591,435	702,983	1,294,419	22
	LZC	566,040	702,983	1,269,023	1

Figure 27

Figure 28 shows the solar hot water contribution to the heating and hot water load on a monthly basis.

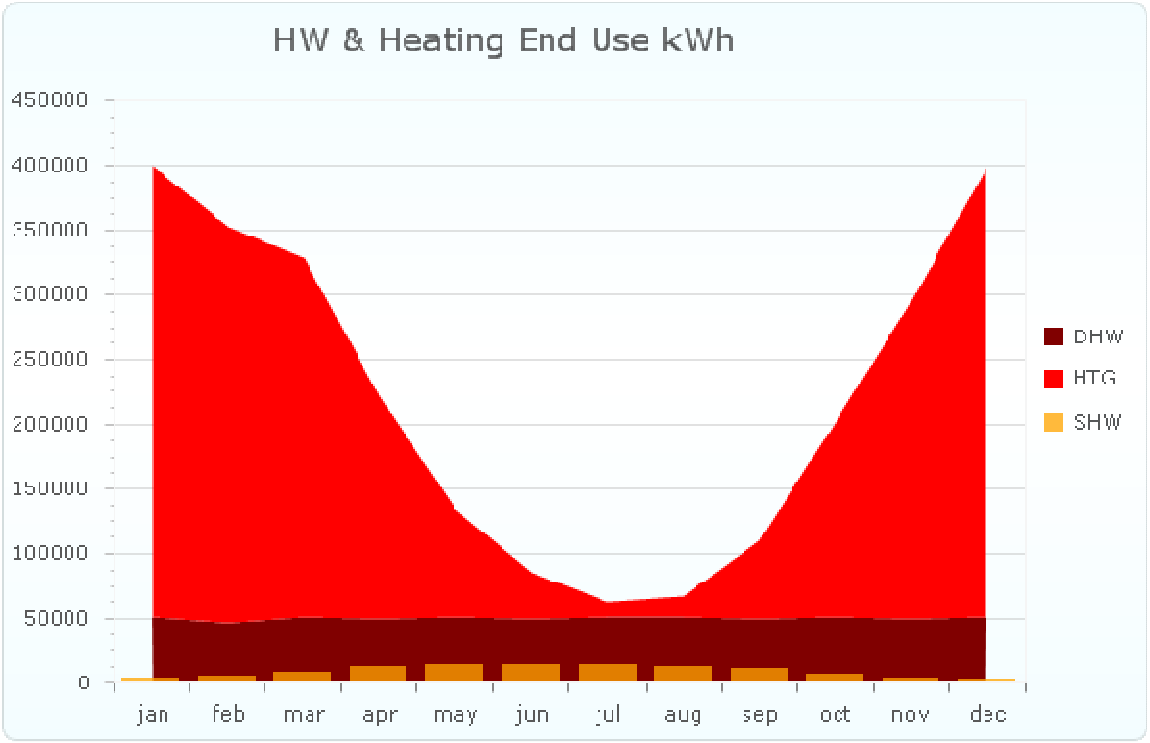


Figure 28