SKELLY&COUCH

Energy and Sustainability Statement

Revision 1.0 - 04/06/2015 – Planning

Project

1279 - 22 Frognal Way

On behalf of:

Skelly and Couch Ltd

Skelly & Couch Ltd

Building Environmental & Services
Engineering Consultants

www.skellyandcouch.com

2nd Floor Studio
79 Fortess Road
London
NW5 1AG

Contents

1. **Executive Summary 3**
2. **Introduction 4**
   - 2.1. The Site 4
   - 2.2. Design Strategy 4
3. **Planning Policy Context 5**
   - 3.1. The London Plan (Including Further Alterations, FALP 2015) 5
   - 3.2. GLA Sustainable Design and Construction SPG (2014) 5
   - 3.3. Camden Council Development Policies - Core Policies related to Energy........ 5
   - 3.4. Camden Planning Guidance 3 - Sustainability 6
4. **Methodology and Computational Energy Modelling 7**
   - 4.1. Calculation Methodology........ 7
   - 4.2. Computational Energy Modelling 8
   - 4.3. Code for Sustainable Homes........ 9
5. **Baseline 10**
   - 5.1. Baseline / Notional Building Emissions........ 11
6. **Being Lean........ 12**
   - 6.1. Building Fabric Enhancements........ 12
   - 6.2. New Construction Philosophy........ 13
   - 6.3. Lean Savings........ 19
7. **Being Clean 20**
   - 7.1. Micro CHP 21
8. **Being Green........ 22**
   - 8.1. Photovoltaics (PV)........ 22
   - 8.2. Ground Source Heat Pump (Geothermal Piles)........ 24
   - 8.3. Renewables (Green) Saving 25
9. **Summary of Strategy and Conclusions 26**
10. **Water Efficiency 28**
11. **Climate Change Adaption 29**
    - 11.1. Flooding 29
    - 11.2. Drought........ 29
    - 11.3. Overheating........ 29
12. **Surface Water Run Off and Flooding........30**
13. **Materials Waste and Recycling........31**
14. **Pollution 32**
15. **Ecology 33**
16. **Whole Life Carbon Assessment........34**
    - 16.1. Embodied and Whole Life Carbon Report 34
    - 16.2. Baseline Whole Life Carbon Assessment 35
    - 16.3. Embodied Carbon Reduction Potentials 36
    - 16.4. Tender 37
    - 16.5. Construction........ 37
    - 16.6. Practical Completion 37

Appendix A – Planning Policy Extract........38
Appendix B – Building Usage Templates 39
Appendix C – SAP Worksheets........40
Appendix D – Building Fabric Constructions........41
Appendix E – Passivhaus 42
Appendix F – Renewables........43
Appendix G - Daylight Study........44

Audit History

Rev	Date of Issue	Status	Issued By	Checked By	Summary of Changes
1.0	04/06/2015	Planning	OH	MS	

1. Executive Summary

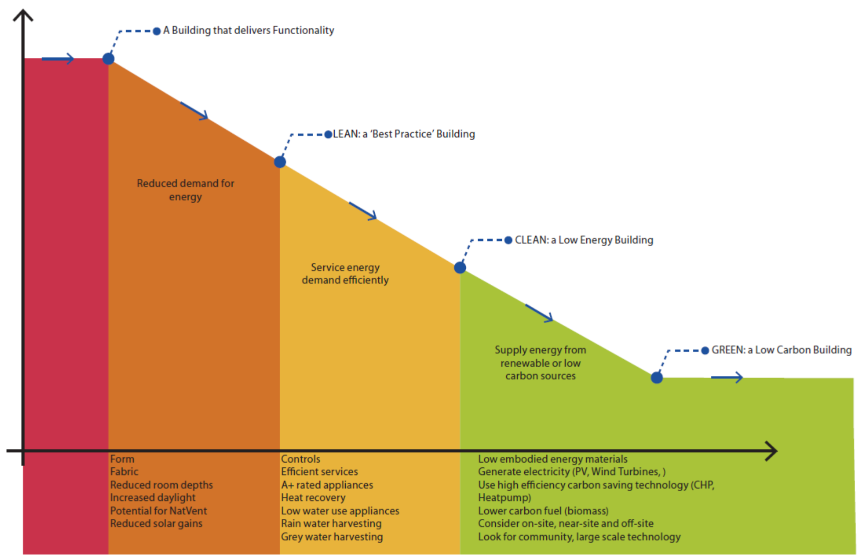
This report has been prepared by Skelly and Couch Ltd in support of the planning application for the proposed new building at 22 Frognal Way, Hampstead.

The new building will replace an existing building on the site, but has been designed to minimise its visual and environmental impact. The constrained site and innovative architectural solutions has inspired the design team to develop the scheme to have as low a zero carbon footprint as feasible.

Skelly and Couch have been appointed by KSR Architects as energy advisors. This document has been prepared to provide a formal analysis of the likely carbon emissions associated with the new build. Calculations have been undertaken to estimate carbon reductions under the energy hierarchy (Lean, Clean, Green) as per the London Plan, National Planning Policy Framework and Camden District Council guidance on preparing Energy Statements.

Carbon reduction measures and the scope and content of this report have been discussed with KSR. Using the Lean Clean Green methodology, the proposals given herein have been developed during a dynamic design process and the most appropriate solutions outlined and examined. The current conclusions drawn from this are outlined below with the most innovative and suitable technology, geothermal piles and integrated solar technology being proposed as the most sustainable method of delivering the brief.

The graph below demonstrates the methodology employed.



Energy Efficiency – Be Lean

The following items have been adopted within the proposals to reduce carbon use, regardless of the final clean / green energy options selected:

- 100% use of low energy fixed lighting within the dwelling
- Use of a balanced whole house mechanical ventilation with heat recovery:
  - Rigid duct work/Insulated duct
  - Specific fan power (S.F.P) 1.2 (max)
  - Heat recovery @ >85% efficiency
- A very low building air permeability rate based on a pressurization test result of 3 (m3/m2.h@50Pa)
- Building Fabric with improved U values and Medium – High Thermal Mass
  - Thermal Bridging averaged value of 0.04
  - Glazing g-value of 0.4
- A highly efficient hot water storage system
  - Efficient Hot water generation
- Total Water use of not more than 110 litres/person/day
- Primary Heating System incorporating:
  - Central heating system with under floor heating (in screed above insulation)
  - Time and temperature zone control
  - Weather compensator and boiler interlock
- Minimise overheating risk, and therefore minimize the need for cooing by use of mechanical ventilation.
- Use of night time ventilation to provide free cooling
- Heat recovery method from spaces providing heat to spaces requiring heat.
- Reducing heat gains by use of energy efficient lighting, and the control of solar gains with shading and high specification glazing
- Effective Building Energy Management System including sub metering and energy monitoring.
- Building user guide ensuring occupants apply and get the most from the low energy building

It is estimated that significant savings are available from energy efficiency "Lean" measures at 24%, with the various energy strategies examined providing greater carbon reductions as shown relative to the reductions each option gives.

CHP – Be Clean

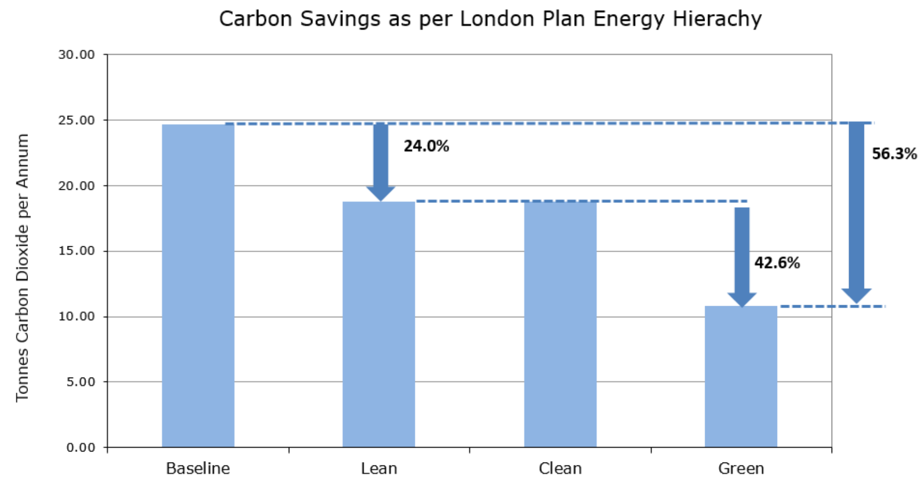
This "Clean" option uses combined heat and power (CHP) technology. Firstly, a micro CHP for the new dwelling was considered but the idea not pursued due to size of the dwelling base load and related carbon saving (12.8%). Connection to a decentralised network was not pursued.

Renewables – Be Green

The renewable options chosen for Frognal Way were Photovoltaics PVs and Ground Source Heat Pump (via geothermal Piles). It was found that the combination of these technologies, when applied with the Lean building principles met the carbon reduction targets.

The following chart highlights the savings associated with the energy saving measures applied at each process.

Loading	TCO2/year	% Improvement
Baseline Emissions	24.70	n/a
Savings from Energy Efficiency	5.9	24%
Savings from PV	5.0	20%
Savings from GSHP	3	12%
TOTAL SAVINGS	13.9	56%



A whole life carbon assessment has also been carried out by Sturgis Carbon Profiling and is included which demonstrates that a saving of approximately 10% of the building's whole life carbon footprint can be made.

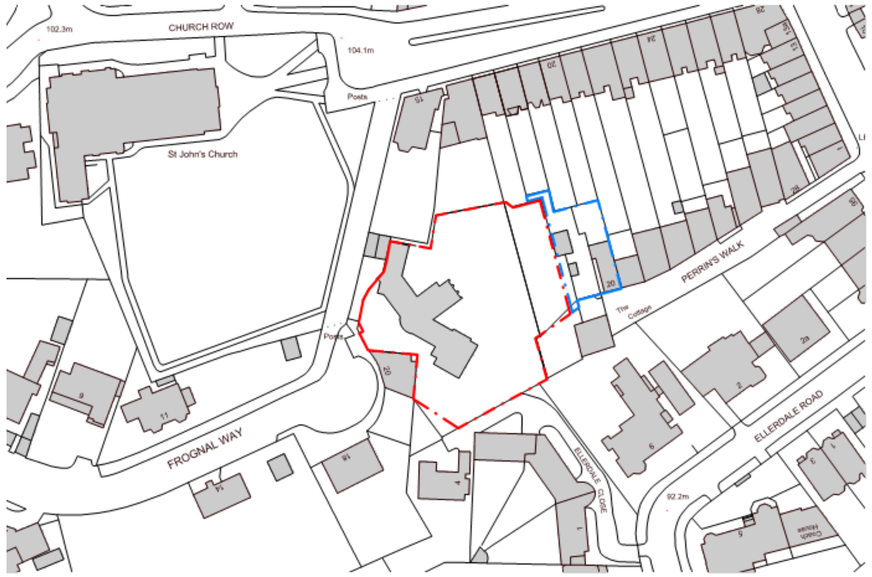
2. Introduction

Skelly and Couch have been appointed by KSR Architects to conduct an energy assessment for the proposed residential property at 22 Frognal Way, an innovative new dwelling in Hampstead located in London. The proposed residential development at Frognal Way aspires to be a low carbon project.

The approach chosen for this project was to identify the potential of the site and assess the latest innovative building services measures and processes, building methods and technologies available to achieve the most appropriate building for the clients brief. The sensitive nature of the site and the innovative architecture will be considered in order to propose the most subtle yet sustainable solution meeting both the client's requirements and the planning targets as set out by the local authority.

2.1. The Site

The site is in Hampstead and situated at 22 Frognal Way within a residential area between Perrins Walk, Ellerdale Close and Church Row.



The figures above show the sites mapped location and the figures below show the proposed building on the site.

The site has an existing building which shall be replaced by the new dwelling with no elements being retained so the brief is to design for a standalone building on the same plot.

2.2. Design Strategy

As this is a new building there are a myriad of options to deliver an energy strategy to suit the client, the design teams aspirations and the council's planning policy requirements. The key drivers thereof have been considered and within this report the development of the final solution can be seen.

It should be noted that the figures within this report are based on assumptions clearly outlined, and therefore provide only a suggestion of the predicted energy use and associated carbon emissions, so should not be used for predicted billing or final target energy ratings.

It should be noted that through the early stages of the deign process the solutions provided for the energy strategy have been developed to align with the requirements of the environmental strategy and clients aspirations.

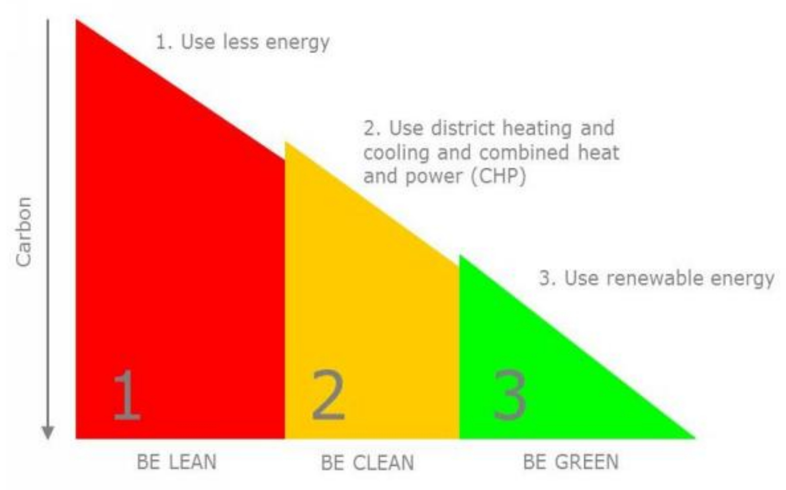
3. Planning Policy Context

Proposals at 22 Frognal Way will be in accordance with Camden Council planning guidance, as well as drawing from the Greater London Authority Policy. A summary of policies relating to sustainable development in Camden is provided below. Further details of each of the following policies and guides are shown in Appendix A.

3.1. The London Plan (Including Further Alterations, FALP 2015)

Policy 5.2 Minimising Carbon Dioxide Emissions

This policy within the London Plan contains an energy hierarchy for minimising carbon dioxide emissions: 'be Lean, be Clean, be Green'. This hierarchy outlines a framework under which the GLA requires energy efficient building design to be approached. Firstly looking to reduce the energy consumption of a building through passive measures (be Lean), then supplying energy efficiently via building services (be Clean), and finally through the use of renewable energy technologies that supplement conventional fuels (be Green)



Policy 5.2 also outlines specific targets for carbon dioxide reduction in buildings. These targets are expressed as minimum improvements over the Target Emission Rate (TER) calculated under the Building Regulations Part L. The targets for residential buildings are as follows:

Year	Improvement on 2010 Building Regulations
2010-2013	25% (Code for Sustainable Homes Level 4)
2013-2016	40%
2019-2031	Zero Carbon

Clause 5.2 states that where the targets for carbon dioxide emissions reduction cannot be fully achieved on site, the shortfall may be provided off site, but only in cases where there is an alternative proposal identified and delivery is certain.

Policy 5.6 Decentralised Energy Networks

This policy confirms that the mayor expects 25 percent of the heat and power used in London to be generated through the use of localised decentralised energy systems by 2025. In order to achieve this target the Mayor prioritises the development and area wide levels, including larger scale heat transmission networks.

The policy encourages developments to evaluate the feasibility of Combined Heat and Power (CHP) systems, and examine opportunities to extend systems beyond the site boundary to adjacent sites.

Policy 5.7 Renewable Energy

This policy confirms that the Mayor seeks to increase the proportion of the energy generated from renewable sources, and expects that the projections for installed renewable energy capacity outlines in the Climate Change Mitigation and Energy Strategy and in supplementary planning guidance will be achieved in London.

All renewable energy systems should be located and designed to minimise any potential adverse impacts on biodiversity, the natural environment and historical assets, and to avoid and adverse impacts on air quality.

3.2. GLA Sustainable Design and Construction SPG (2014)

This is supplementary planning guidance which published on behalf of the Greater London Authority (GLA) and informs the overriding method for this energy strategy.

3.3. Camden Council Development Policies - Core Policies related to Energy.

Alongside the London Plan, the Core Strategy for Camden sets out the key elements of the council's planning vision and strategy for the borough, directly related to the Local Development Framework (LDF). The Core strategies outlined therein relevant to sustainability are as follows:

CS13 – Tackling climate change through promoting higher environmental standards

This policy is further referred to in Camden's Development Policies Document.

DP22 – Promoting sustainable design and construction

DP23 – Water

3.4. Camden Planning Guidance 3 - Sustainability

Camden Planning Guidance (CPG) 3 supports the policies outlined in the LDF. The guidance is particularly relevant to the items discussed within this report and informs the structure of this report.

The following are the key sections relevant to this development.

3.4.1. The Energy Hierarchy

This section covers the requirements of the energy statement and the associated methods.

The energy hierarchy

KEY MESSAGES

- All developments are to be design to reduce carbon dioxide emissions
- Energy strategies are to be designed following the steps set out by the energy hierarchy

3.4.2. Energy Efficiency

This section covers how new buildings ensure they are as energy efficient as possible.

Energy efficiency: new buildings

KEY MESSAGES

All new developments are to be designed to minimise carbon dioxide emissions

The most cost-effective ways to minimise energy demand are through good design and high levels of insulation and air tightness.

3.4.3. Decentralised Energy Networks and Combined Heat and Power

This section covers the Clean section of the energy hierarchy to ensure developments have done all they can to obtain an efficient supply of energy.

KEY MESSAGES

Decentralised energy could provide 20% of Camden's heating demand by 2020.

Combined heat and power plants can reduce carbon dioxide emissions by 30-40% compared to a conventional gas boiler.

Where feasible and viable your development will be required to connect to a decentralised energy network or include CHP.

3.4.4. Renewable Energy

Renewable energy

KEY MESSAGES

There are a variety of renewable energy technologies that can be installed to supplement a development's energy needs

Developments are to target a 20% reduction in carbon dioxide emissions from on-site renewable energy technologies.

3.4.5. Water Efficiency

KEY MESSAGES

At least 50% of water consumed in homes and workplaces does not need to be of drinkable quality re-using water

All developments are to be water efficient

Developments over 10 units or 1000sq m should include grey water recycling

3.4.6. Sustainable Use of Materials

KEY MESSAGES

Reduce waste by firstly re-using your building, where this is not possible you should implement the waste hierarchy

The waste hierarchy prioritises the reduction, re-use and recycling of materials

Source your materials responsibly and ensure they are safe to health.

3.4.7. Sustainability Assessment Tools

KEY MESSAGES

A new build dwelling will have to be designed in line with the Code for Sustainable Homes

The creation of 5 or more dwellings from an existing building will need to be designed in line with EcoHomes

500sq m or more of non-residential floorspace will need to be designed in line with BREEAM

It should be noted that where the development will be designed to the sustainability criteria as outlined in CPG3, the Deregulation Bill 2015 has formally removed the requirement for residential schemes to comply with Code for Sustainable Homes.

The team will however attempt to show that the development would have met the criteria in any case.

3.4.8. Brown Roofs, Green Roofs and Green Walls

KEY MESSAGES

All developments should incorporate green and brown roofs

The appropriate roof or wall will depend on the development, the location and other specific factors

Specific information needs to be submitted with applications for green/brown roofs and walls

3.4.9. Flooding

KEY MESSAGES

All developments are required to prevent or mitigate against flooding

All developments are expected to manage drainage and surface water

There is a hierarchy you should follow when designing a sustainable drainage system

3.4.10. Adapting to Climate Change

KEY MESSAGE

All development should consider how it can be occupied in the future when the weather will be different

The early design stage is the most effective time to incorporate relevant design and technological measures.

3.4.11. Biodiversity

KEY MESSAGES

Proposals should demonstrate:

- how biodiversity considerations have been incorporated into the development;
- if any mitigation measures will be included; and
- what positive measures for enhancing biodiversity are planned.

3.4.12. Local Food Growing

KEY MESSAGE

We encourage food to be grown wherever possible and suitable

Rooftops and shared spaces such as gardens and parks provide opportunities for food growing

Note Sections 3.3.3 to 3.3.10 are covered in separate documentation.

4. Methodology and Computational Energy Modelling

4.1. Calculation Methodology

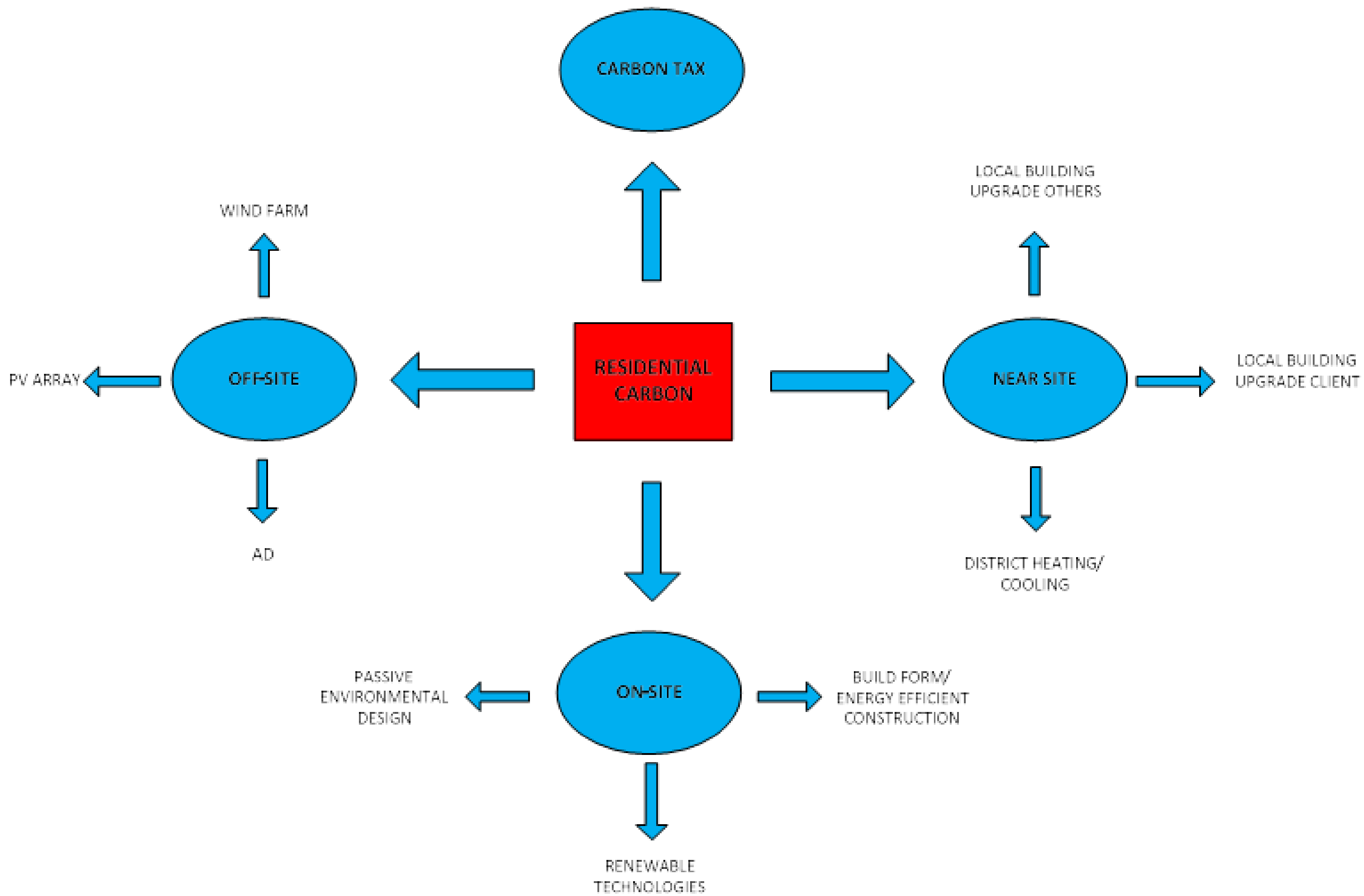
The calculation methodology used for presenting carbon emission reduction draws on the approach set out by Camden Council and the Greater London Authority under the National Planning Policy Framework. Predicted levels of carbon dioxide emissions have been assessed using the government's Standard Assessment Procedure (SAP) which forms part of Part L of the Building Regulations.

Before any procedures were cemented, the team assessed options to reduce the carbon associated with the new dwelling in a number of ways. The figure to the right gives a depiction of the offset criteria investigated

Despite the option of offsite generation and carbon tax being available under the planning framework, it was decided that the on-site or point of use reduction is the most honest and feasible for this project.

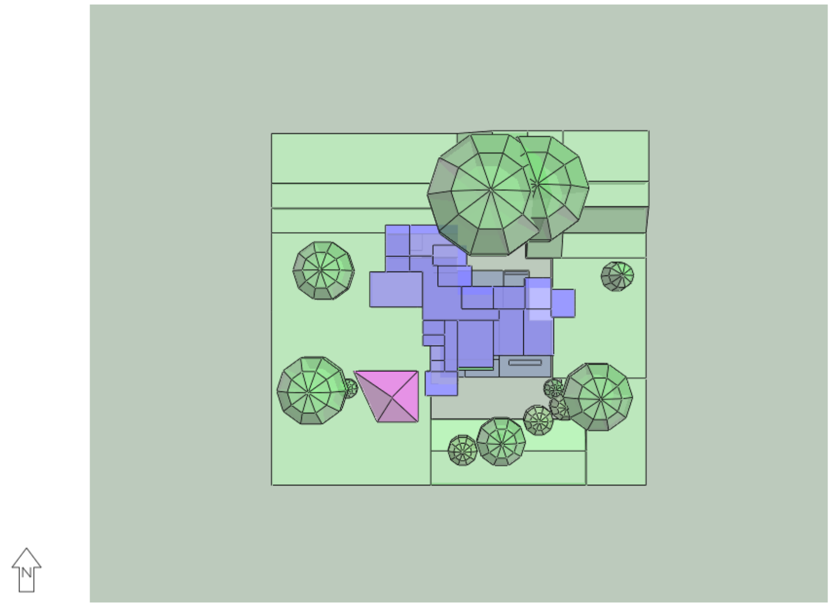
The calculations are based on the information provided by KSR Architects and the following drawings (received 10.04.15)

Drawing Number		
FGW-PP-080	FGW-PP-201	REVIT MODEL
FGW-PP-090	FGW-PP-301	FGW-Model_20150409
FGW-PP-100	FGW-PP-302	
FGW-PP-110	FGW-PP-303	

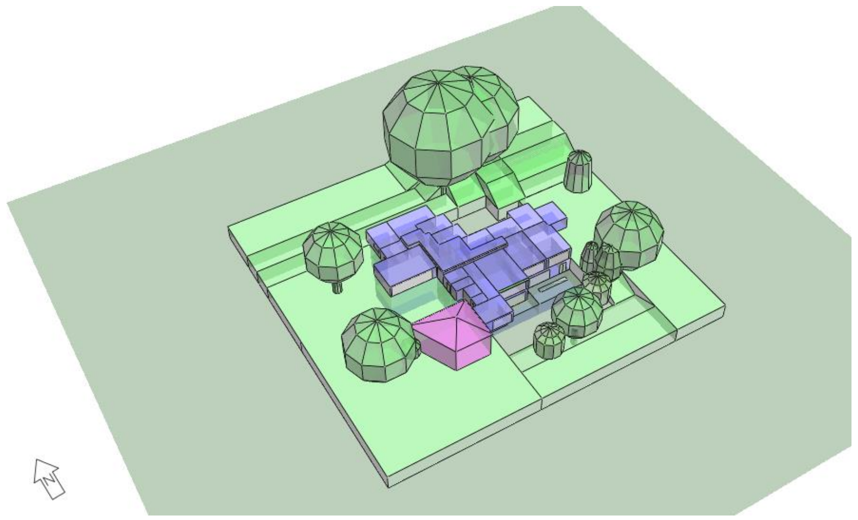


4.2. Computational Energy Modelling

A virtual computational model of proposals at Frognal Way has been created using IES Virtual Environment (Version 2014.2.1.0) based on plans and elevations from the architect. The model uses dynamic simulation to estimate annual energy consumption, which has been used to develop a low carbon strategy for the site.



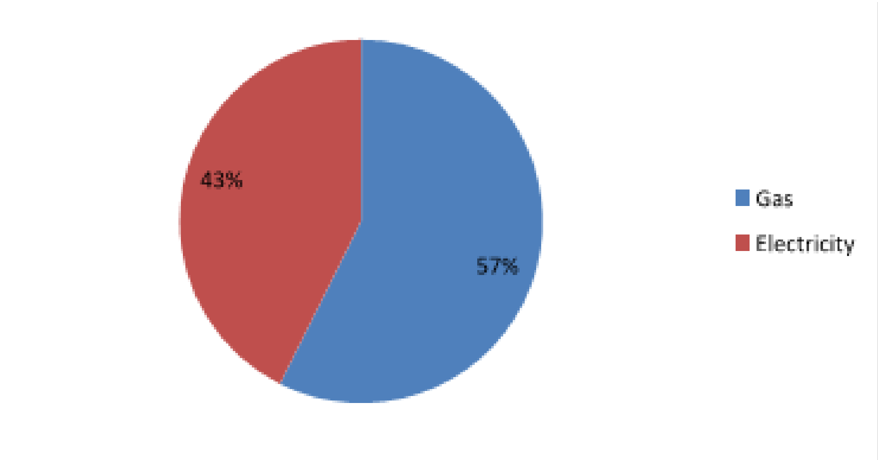
IES Model Plan

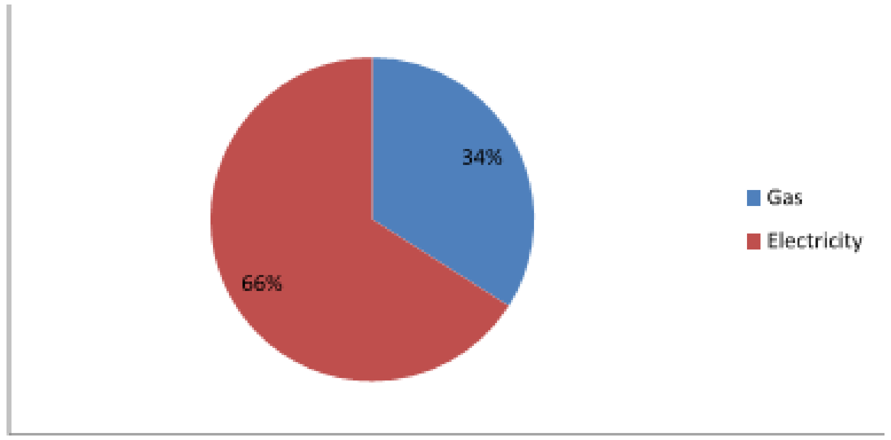


IES model South elevation

Within the model rooms have been grouped according to their activity, for example, bedrooms, circulation areas and living rooms and templates assigned based on the National Calculation Methodology (NCM) templates developed by the Building Research Establishment (BRE).

The usage profiles for these templates have been modified to more accurately represent the proposed operation of the building including the swimming pool templates. These can be found in appendix B. For example, designed ventilation rates and lighting loads have been assigned to provide more realistic figures. The relative estimated energy and carbon footprint for the site is shown below.





In order to show how much carbon is related to the energy used, there is a carbon factor associated to the generation of energy with each particular fuel. Currently the carbon factors are as below:

Fuel	Carbon factor (kgCO2/kWh)
Gas	0.216
Electricity	0.519
Biomass (wood logs)	0.019

These factors are taken from the latest Standard Assessment Procedure (SAP) 2012 documentation set by the Department for Energy and Climate Change (DECC) and are correct at the time of writing.

Due to these differing carbon factors relating to each of the associated fuels for energy uses, set here as gas and electricity for the baseline predictions, it can be seen that consideration needs to be given to every system consuming energy within the dwelling. A more detailed breakdown of the loads relating to the use is given in the baseline analysis.

These templates and related assumptions were kept the same for the baseline (worst case) run and for the various options studied making for a fair comparison of applied energy reduction measures.

4.3. Code for Sustainable Homes

Although this is no longer a planning requirement, the project will still aim to improve significantly on Code level 4. The fabric of the building will be designed to the highest performance standards to minimize operational emissions, with extensive use of renewable energy sources, within the constraints of the site, to achieve these goals.

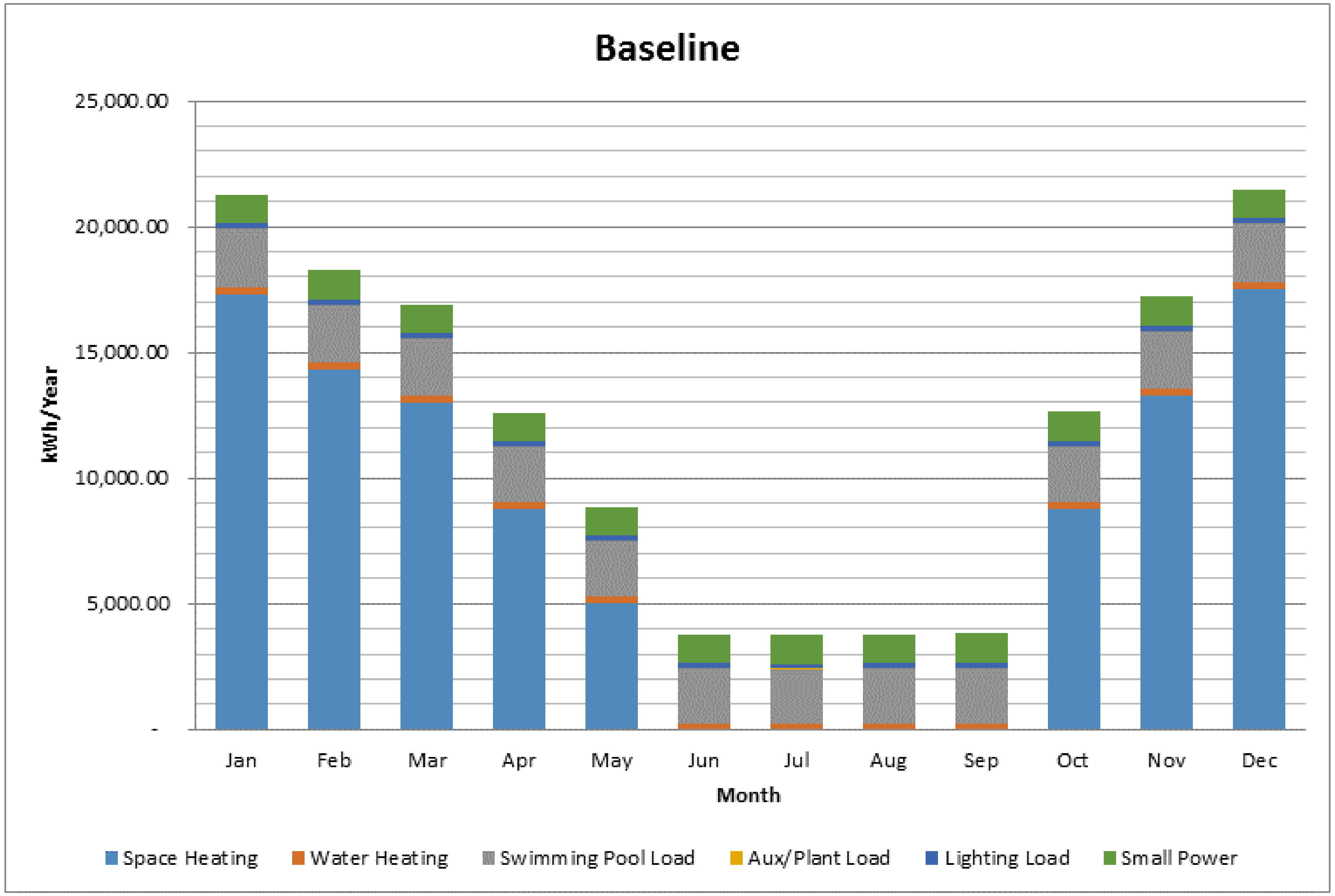
Regarding the regulated operational energy and water use, Camden have requested that at least 20% of the energy will be provided by renewables and the water usage will be below 110 litters per person per day. The proposed development will be designed to meet these sustainability targets.

5. Baseline

The predicted carbon baseline has been calculated as the energy consumption of the new dwelling, with no additional energy efficiency measures taken. Assumptions relating to the fabric and services have been determined form Part L 1A limiting parameters. This provides a baseline over which the energy efficiency improvements can be measured.

The estimated breakdown of the energy consumption can be seen in the figure to the right:

Space heating, including the swimming pool load and domestic hot water dominate the energy consumption of the building, with equipment and lighting becoming more important considerations when thinking about carbon reduction. The regulated loads (HVAC) and unregulated loads (cooking, external lighting etc) as set by the client's requirements are highlighted and show a profile favouring unregulated electrical loads.



5.1. Baseline / Notional Building Emissions

Compliance with the Criterions of Part L1A – Achieving an acceptable carbon emission rate can be assessed using the accredited software, IES and in conjunction JPA designer. The building is analysed using a relevant simulation method and results produced compare carbon emissions between the options related to the proposed building and a notional building.

The 'notional' building is intended to be an accurate representation of the intended design – the building as designed, but described within the limits of the government guidelines.

The notional building is a modified version of the proposed building, which has U-values, window sizes and service efficiencies determined by the 2002 Part L regulations. It is defined by the compliance software, and is not intended to be an accurate representation of the proposed building design but serves as a baseline against which the proposed improvement measures can be measured.

An annual simulation generates three carbon emission rates:

1) The NER – notional emission rating. This is the carbon emitted by the notional building, and is equivalent to a 2002 emission rate.

2) The TER – target emission rate. This is the carbon emission target for the building and is calculated by applying an improvement factor to the NER.

3) The BER – building emission rating. This is the figure generated by the actual building and must be lower than the TER for the building to comply and maybe subject to post construction testing.

IES VE has been used to model the proposed dwelling and the energy model imported into the BRE approved software JPA Designer (version 5.04a). SAP worksheets for the sample dwellings are provided in Appendix B.

The performance of the actual designed building is then simulated incorporating 'Lean, Clean and Green' proposals to demonstrate a percentage reduction in carbon emissions for each stage of the energy hierarchy.

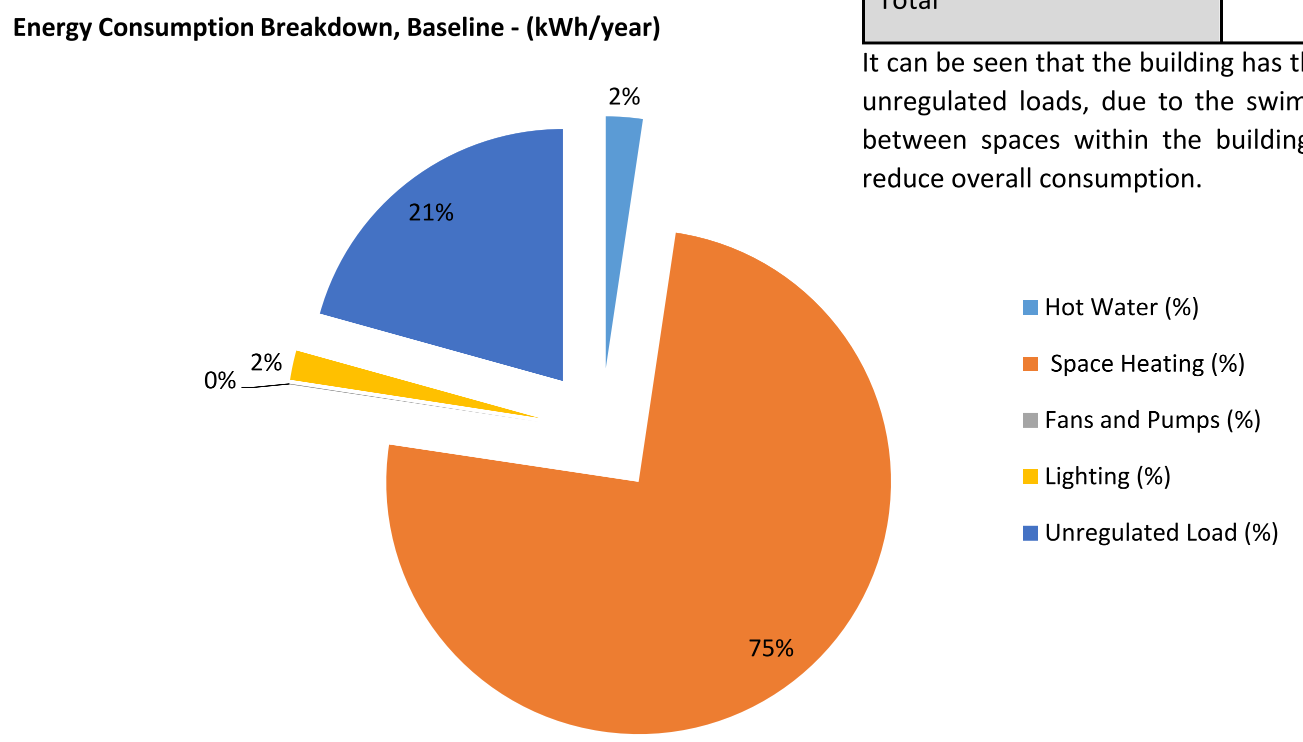
The predicted energy breakdown of the site can be seen in the figure below. The proportion of carbon related to each type of consumption indicates where savings can be targeted.

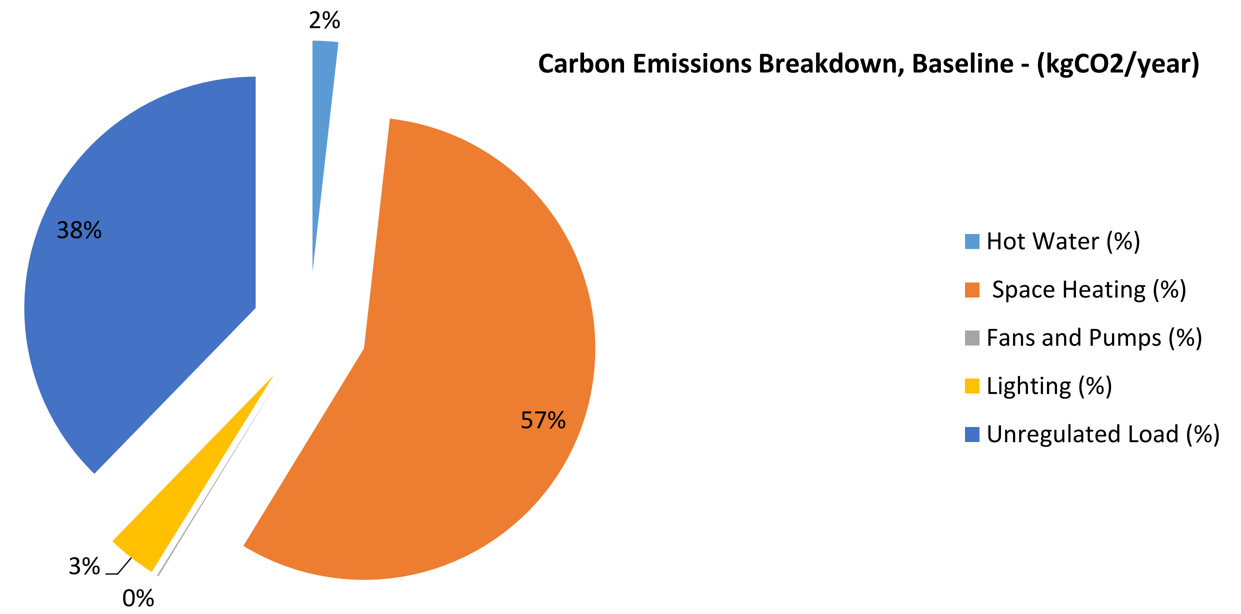
The breakdown of the results of the simulation carried out for the baseline study and be seen in figures to the right.

The results from the simulation show that the target baseline emissions 24.7 tonnes CO2 and 38.7 tonnes CO2 regulated and unregulated respectively. It is against this figure that all carbon reduction strategies will be compared as under the Greater London Authority (GLA) guidelines.

Loading	Regulated TCO2/year	Unregulated TCO2/year
Baseline Emissions	24.7	14.0
Total		38.7

It can be seen that the building has the potential for comparatively large unregulated loads, due to the swimming pool. The balance of energy between spaces within the building, shall be carefully considered to reduce overall consumption.





6. Being Lean

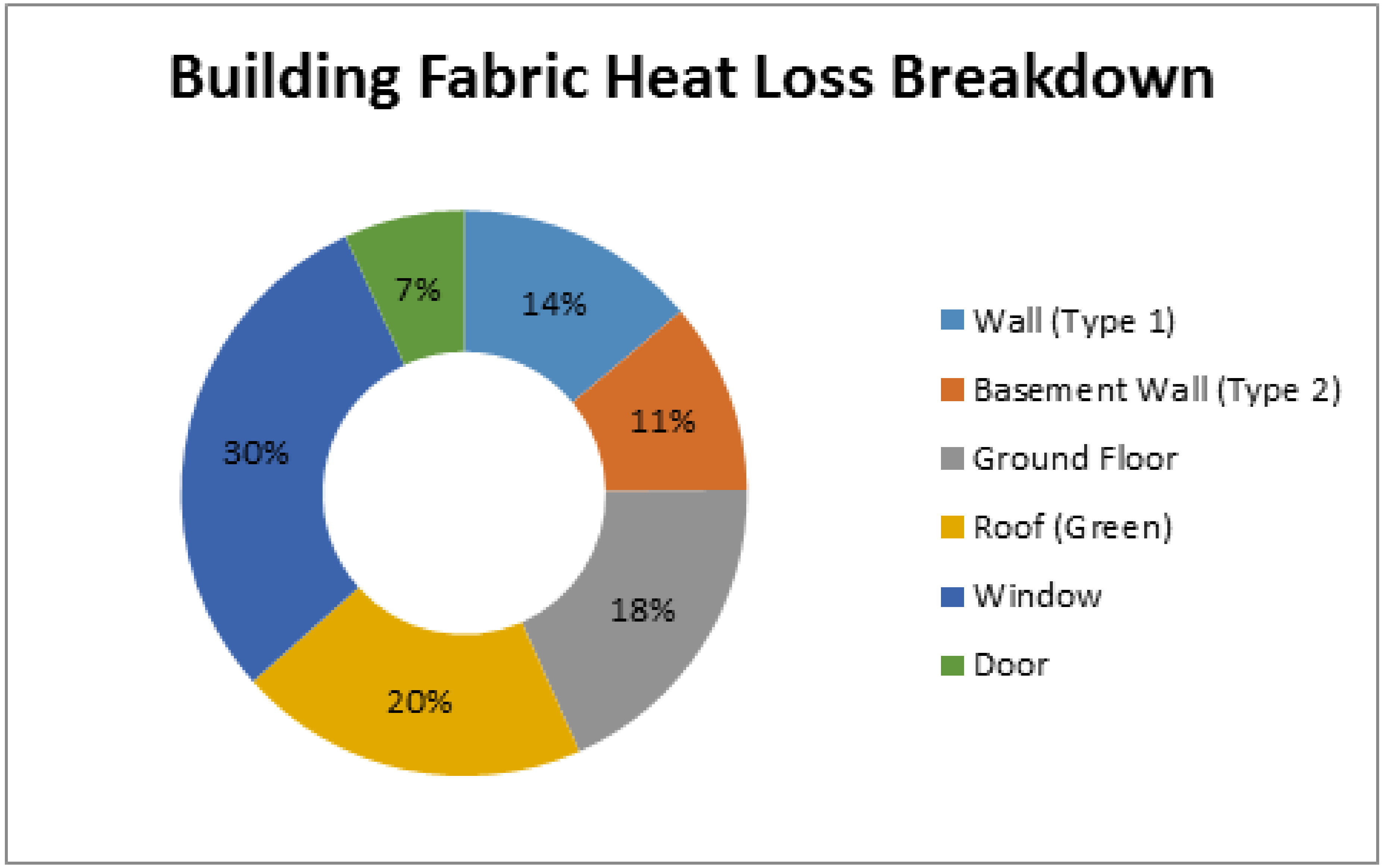
The first step in the energy hierarchy is to reduce the energy demand through passive design and efficient building services.

6.1. Building Fabric Enhancements

The proposed building fabric improvements are presented in the table below with key elements such as the green roof described in drawings in Appendix D.

Predicted fabric losses are shown in the figure to the right giving areas where improvements can be most effective.

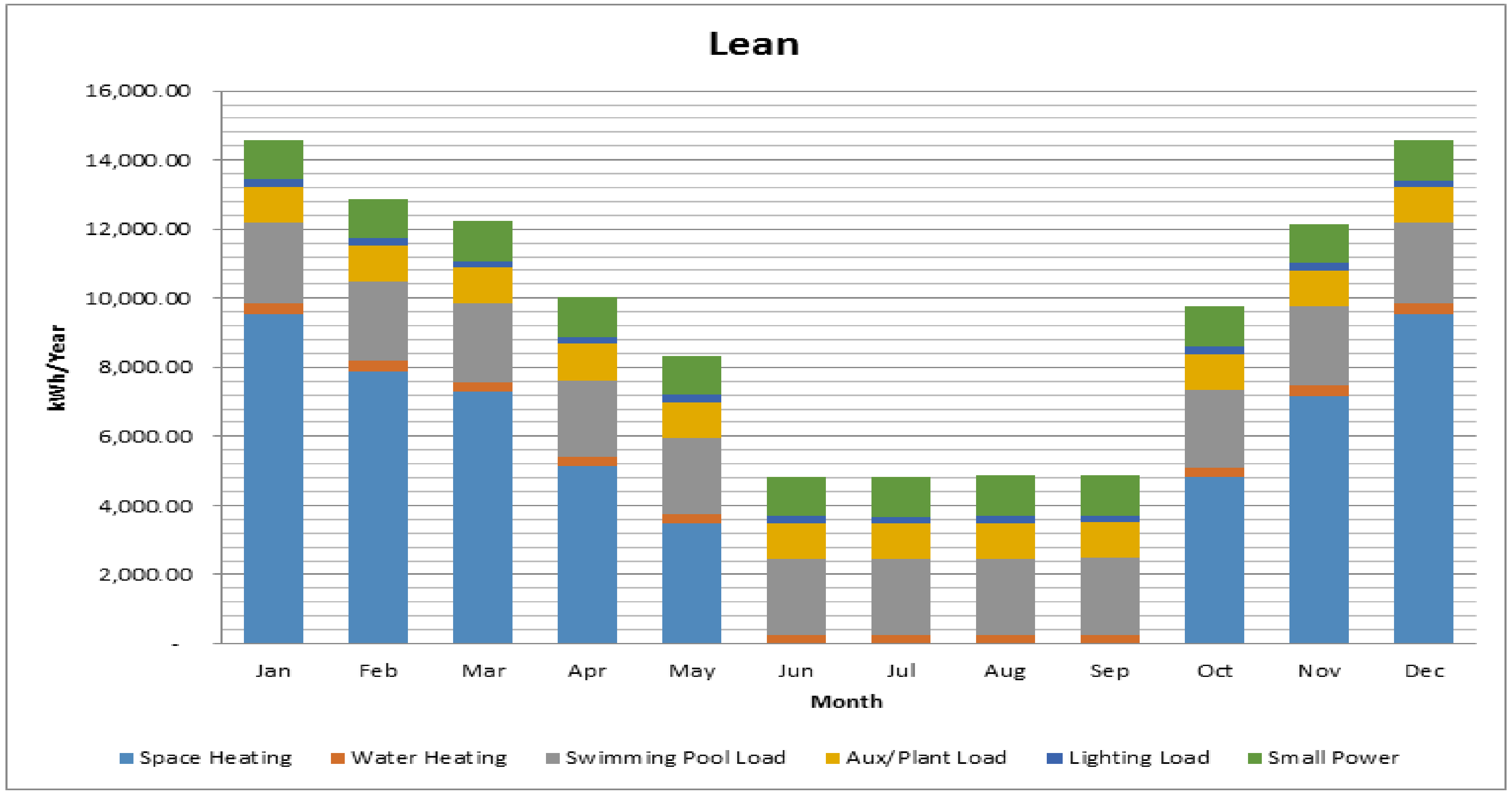
As can be seen the glazed element of the building has potential for savings.



6.2. New Construction Philosophy

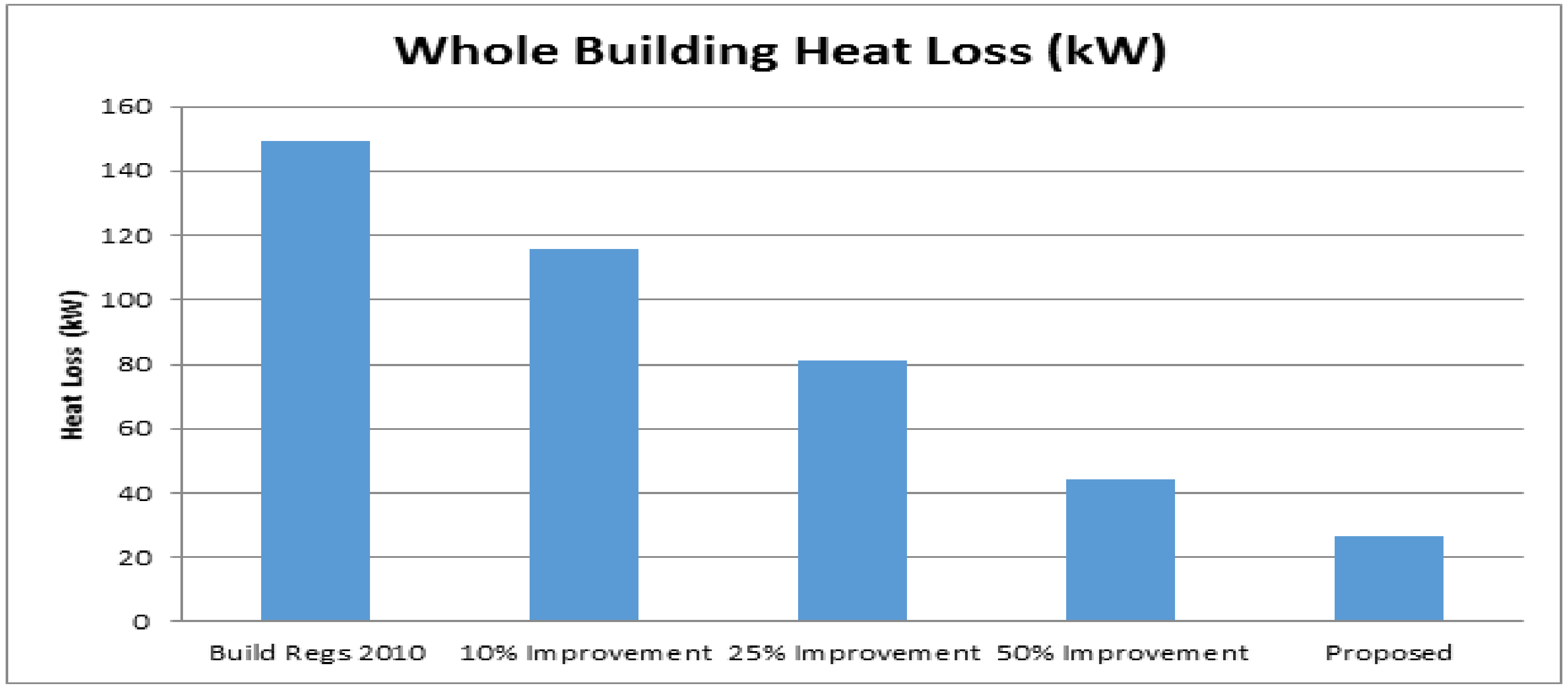
The new construction philosophy for Frognal Way goes beyond Building Regulation standards aiming for exemplary levels of performance.

Building Element	Lean Model (Proposed)	Baseline Model (Notional 2012)	Part L limiting value
	U-value (W/m².K)		
External Wall	0.125	0.18	0.3
Roof	0.12	0.13	0.2
External Glazing	0.7	1.4	2.0
Rooflight	1.2	1.4	2.0
Ground Floor	0.12	0.25	0.25
External Wall Below Ground	0.125	0.25	0.3
Swimming Pool Basin	0.15	0.25	0.25
Doors	0.5	1.0	2.0
Party Walls	0.0	0.0	1.5



The application of the building fabric improvements over Part L standard shifts the building loads as in the graph top right.

A method whereby the heat loss can be further reduced is by installing insulated external blinds as part of the window design. An example of this can be seen in the image below:



Other Passive design measures to reduce energy consumption included in the design development are described below.

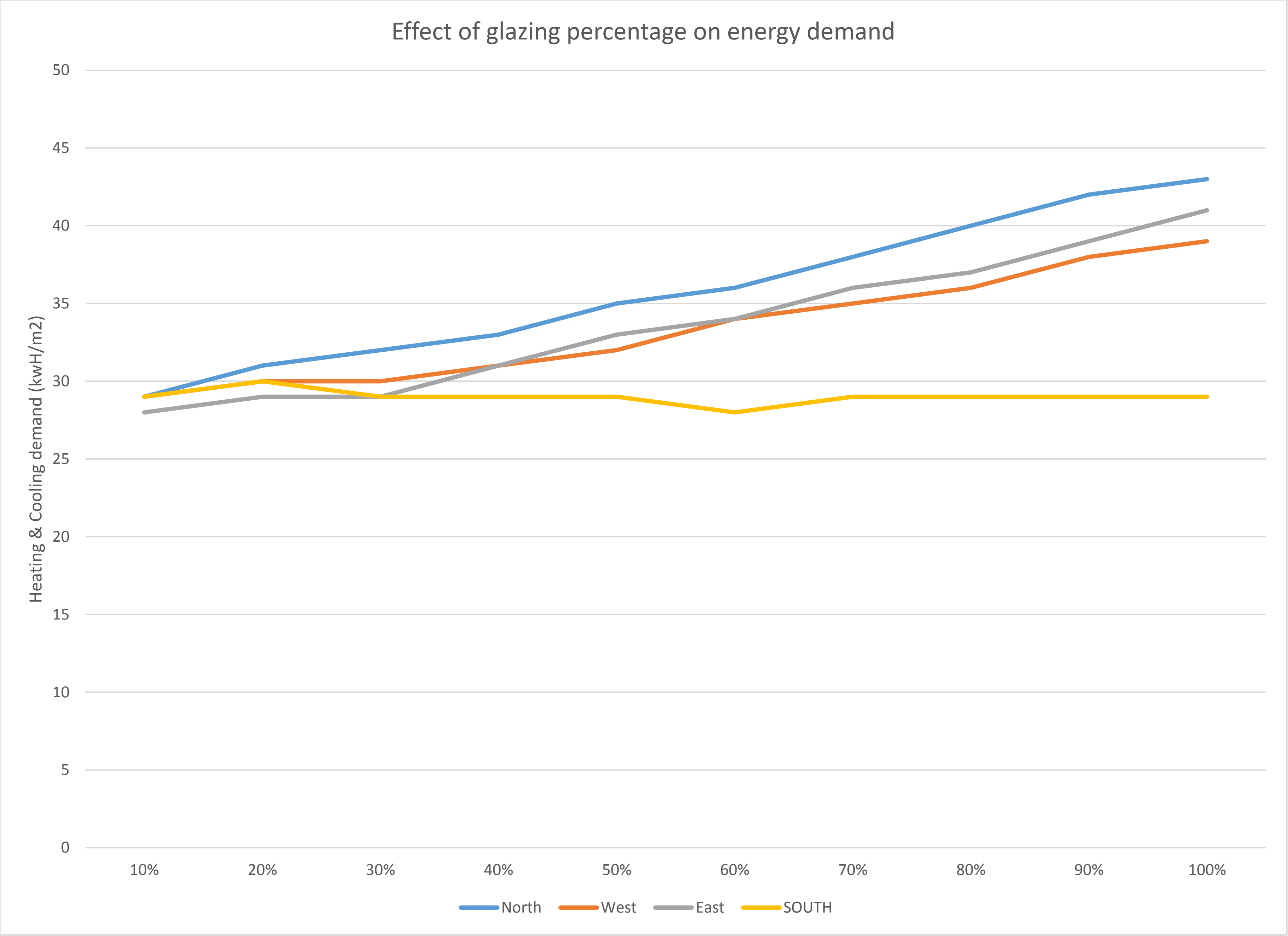
6.2.1. Passivhaus Aspirations

Whilst, despite the team having investigated the possibility, the building is unlikely to achieve full Passivhaus accreditation due to its nature (location, geometry and strategy), the standards for U-values, air permeability and thermal bridging are targeted.

Where the adoption of the principles of Passivhaus design have been possible on this project they have been applied.

A study governed by Passivhaus principles was carried out comparing impact of glazing % on energy demand when applied to the building's orientations.

The optimum glazing percentages for each orientation were discussed and a suitable ratio applied to balance function and energy efficient design. The process also enabled the team to minimise overheating and thermal losses. A more detailed breakdown of the study can be found in Appendix E.

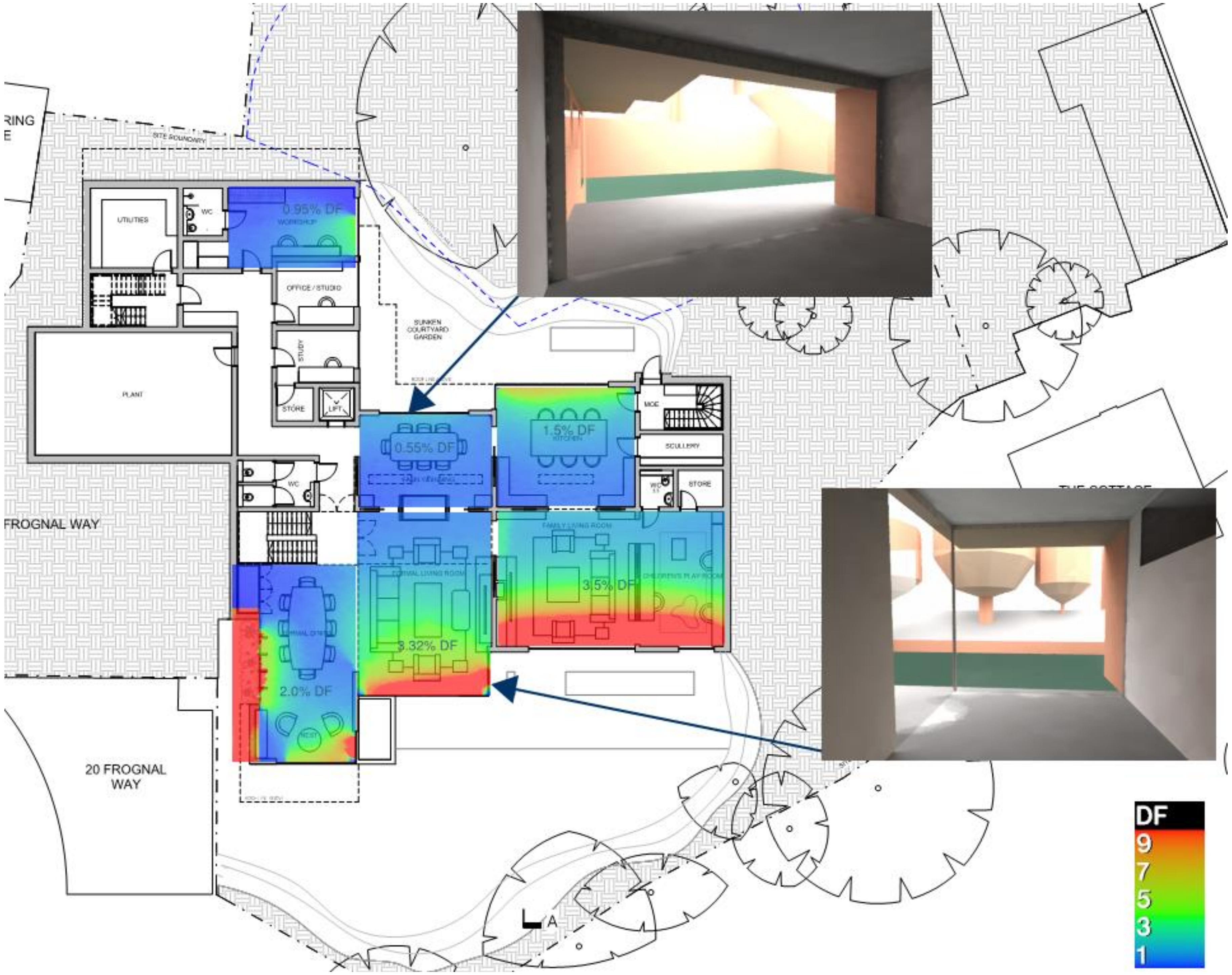


6.2.2. Daylighting Study

The nature of the building form, with there being a lower ground floor lead the team to carry out daylight analysis to enhance the potential for natural light dispersion throughout the building. This was co-ordinated with the need to optimise the quantity of glazing on the façade of the building. The daylight factors in key rooms of the house were assessed and light wells distributed where possible to enable optimum daylight levels. The figure to the right shows an example of the daylight study.

Results of other key rooms can be found in Appendix G.

The benefits of this include reducing the need for artificial lighting by showing that the daylight factor of each key space achieves in the region of 2% - 5%DF. This is considered to be well daylit and not requiring supplementary lighting for the majority of the day. (Camden Guidance)



6.2.3. Artificial Lighting Design

Energy consumption from lighting will be minimised via the following measures:

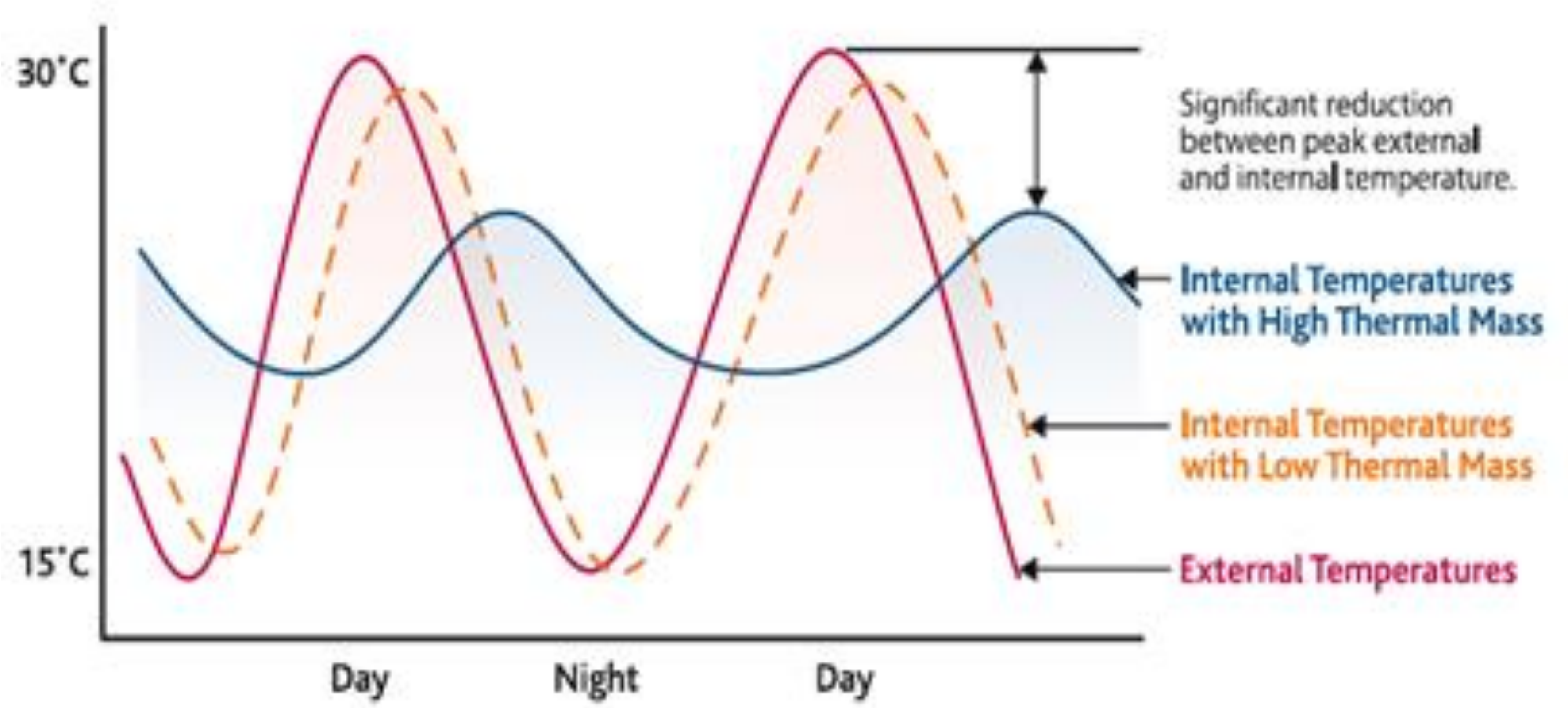
- Efficient lighting will be prioritised throughout, with a combination of compact fluorescent and LED fittings. 100% of all lighting will be energy efficient
- The target wattage across the total floor area of the dwelling shall be an average of 8W/m2
- Sophisticated controls will allow occupants to control and dim lighting on a room by room basis with the potential for daylight linking where appropriate
- In communal and circulation areas including externally, lighting will be controlled by timed switches
- Burglar Security lighting will have a maximum wattage of 150W, movement detection control devices (PIR) and daylight cu-off sensors
- Other security lighting with dedicated energy efficient fittings will be fitted with daylight cut-off sensors or timers

6.2.4. Thermal Mass Optimisation

Thermal mass will be optimised for the dwelling with a heavy concrete structure and blockwork employed. Materials with high thermal mass have been used wherever possible. This helps to reduce the heating and cooling loads by acting as a heat sink and source on hot and cold days respectively.

The graph below shows how on a summer day the thermal properties of the heavy weight materials help to smooth out the peaks and the troughs in internal temperature throughout the day. This strategy works well when employed with natural ventilation where the coolth of the night-time air can be stored in the building fabric to act as a heat sink during the following day.

Large areas such as the double height living space greatly benefit from the increased thermal mass.

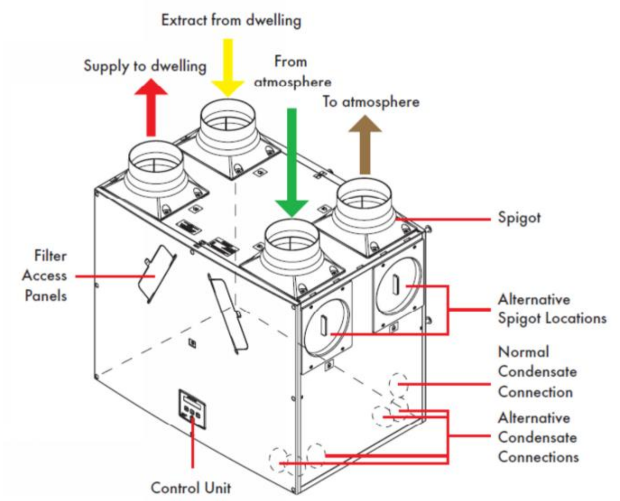


6.2.5. HVAC Systems and Controls

Energy consumption from heating, ventilation and air conditioning systems will be minimised via the following measures:

- All boilers will be high efficiency boilers (minimum 92% eff for gas condensing) the chosen technologies will be market leading
- All fans and pumps will operate on variable speed control
- Dwelling will have mechanical ventilation with heat recovery units, with a total unit specific fan power of no more than 1.2W/l/s and 85% heat recovery efficiency.
- Hot water pipes, tanks, calorifiers and ductwork will be insulated
- Electric sub metering will be installed to monitor energy use within the development. At least 95% of all gas and electrical use will be metered. All major items of plant will also be sub-metered including any cooling equipment, boilers, pumps and fans. The incoming gas and water mains will also be metered.
- All meters will provide pulsed output to the Building Energy Management System (BEMS) for automated metering and centralised monitoring of all water and energy use. The BMS will also ensure that the heating systems are highly responsive and operate at their optimal efficiency in maintaining internal comfort conditions.
- The metering strategy will be in alignment with CIBSE TM39
- High electric power factor will be specified at at least 0.95 efficiency

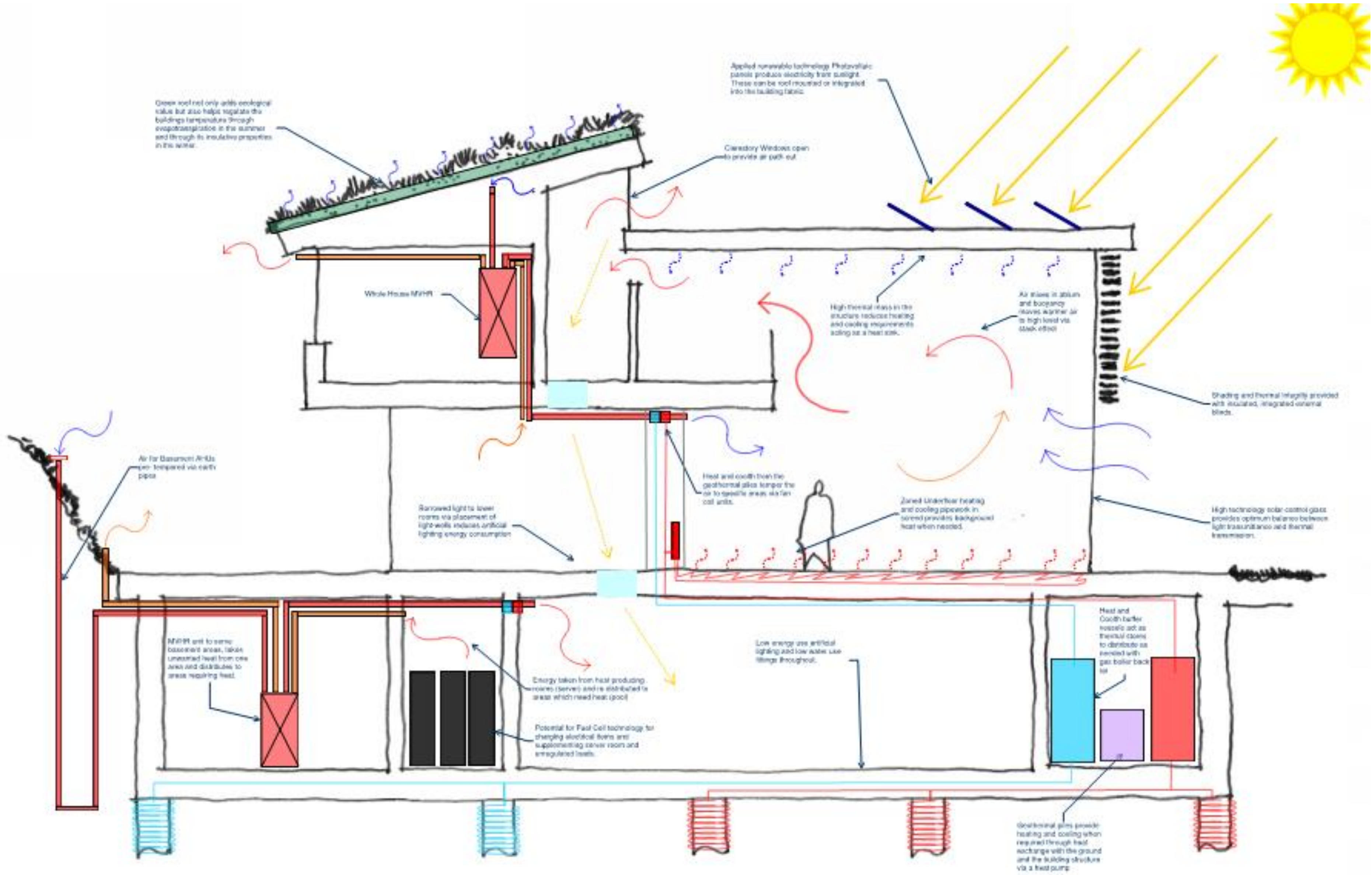
The proposed MVHR system for the dwelling at Frognal Way would make use of 3 units (1 per floor) similar to the type shown in the figure below.



The system would serve the whole house providing controlled ventilation. The management and control system of the ventilation is key to saving energy.

It should be noted that natural ventilation for the two upper floors is also possible for the majority of the year, when the external temperatures warrant the employment of opening the windows.

The image below shows the strategy highlighting where this approach is particularly relevant in the double height living area where the stack effect is employed.

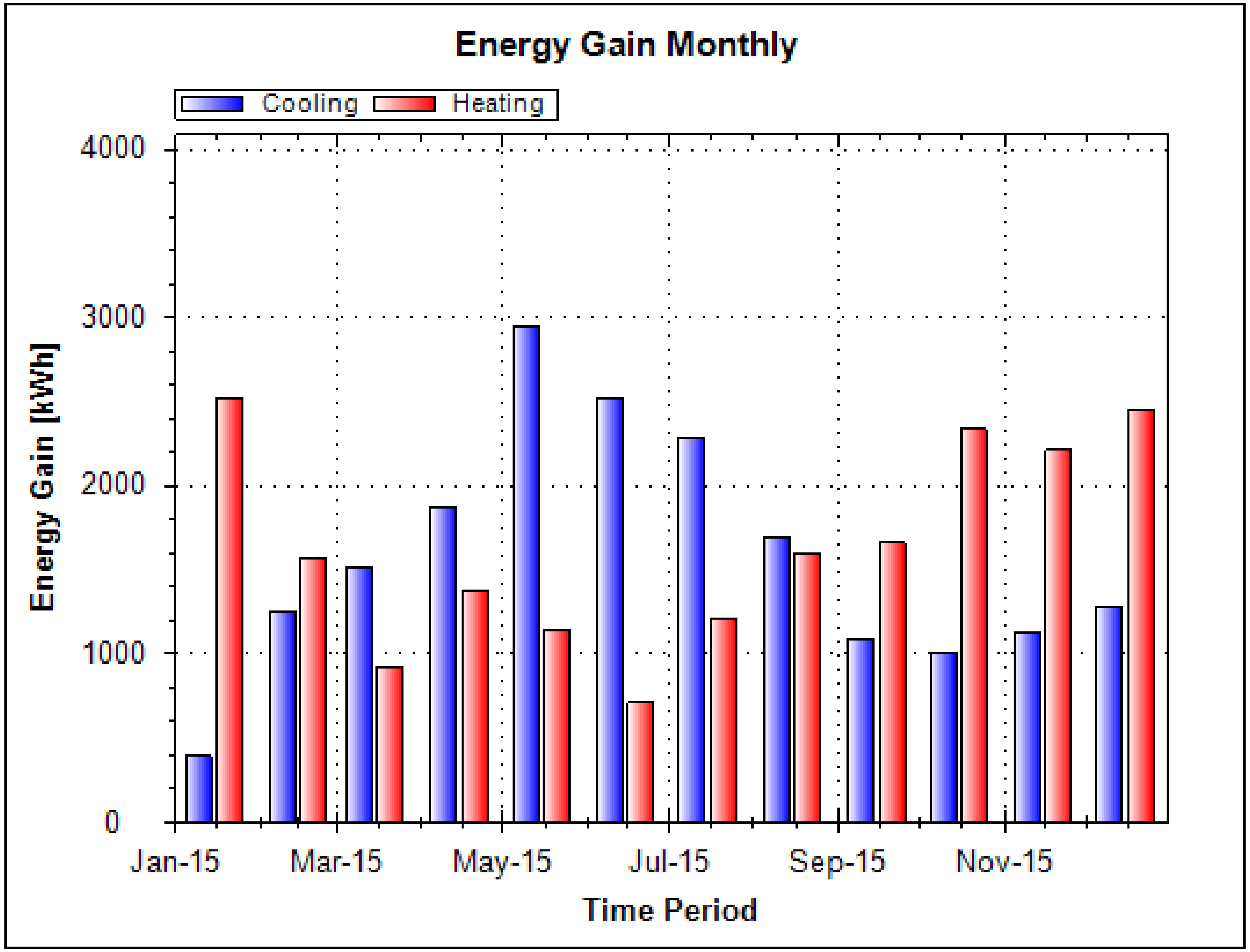


6.2.6. Earth Pipes

It is proposed that the MVHR system is combined with below ground earth tubes meaning further savings could be made. The proposal for Frognal Way would utilise 16 below Ground Heat transfer pipes located in the area as shown in the figure below:

The savings that can be expected from this arrangement of earth pipes can be seen in the graph to the right:

Earth pipes effectively temper the air form outside before it enters the building and so provides an energy saving as less heat is needed to heat the air.



6.2.7. Heat Distribution and Transfer

Within the proposed dwelling there are differing heat loads and requirements throughout the day. The potential for a server room for example which would be used constantly, provides a cooling load of around 10kW. It is here that a potential energy saving can be made. With the application of a heat pump (see section 8.2 for more detail) this heat, when it is not being directed to the ground piles, could be transferred and used to provide heat for the swimming pool for example. An estimated 2% saving over the regulated load is achievable. As the source is unregulated however, it is this saving that can only be applied to the overall carbon reduction.

6.2.8. Water Saving Measures

Other sustainable measures such as the application of rainwater harvesting and/or greywater recycling systems along with water recycling showers can further reduce the water use in the dwelling and can be assessed further in a site wide sustainability analysis.

The option of rainwater harvesting is currently proposed, along with low water use fittings, leak detection and metering as a method to help reduce the water use to the required 110litres/person per day.

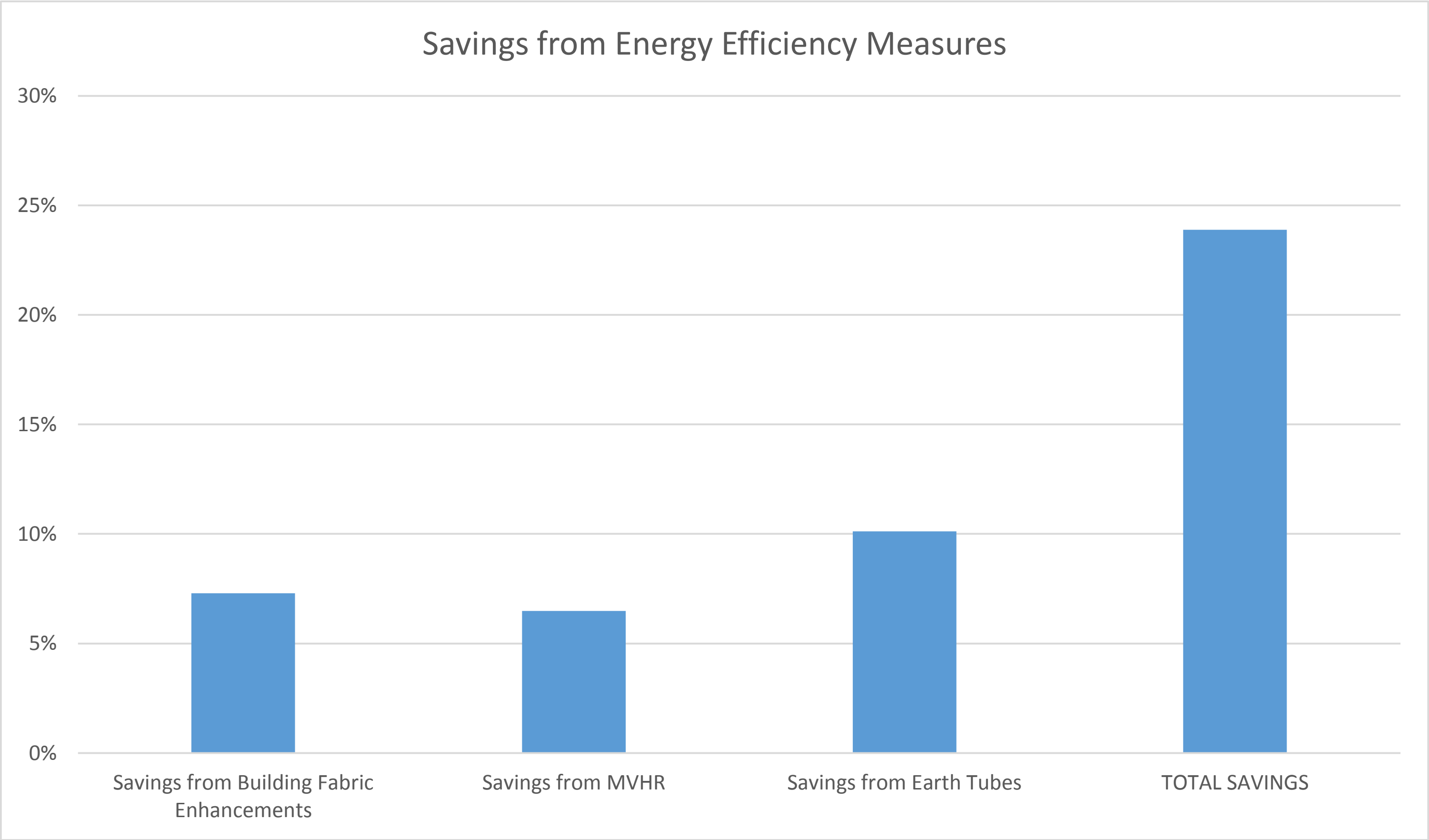
The water saving measures are explored in more detail in section 10.

6.3. Lean Savings

The table below demonstrates the savings to be expected from the applications of Lean methods:

Lean Savings	TCO2/year	% Improvement
Baseline Emissions	24.70	n/a
Savings from Building Fabric Enhancements	1.80	7%
Savings from MVHR	1.6	6%
Savings from Earth Tubes	2.5	10%
TOTAL SAVINGS	5.9	24%

Through the energy saving measures outlined, it is predicted the 'lean' measures proposed will reduce carbon emissions by 20% compared to the baseline building.



7. Being Clean

The second step of the energy hierarchy concerns itself with supplying energy efficiently.

The principle priority under the Camden guidelines is to establish CHP feasibility or connection to a de-centralised energy network.

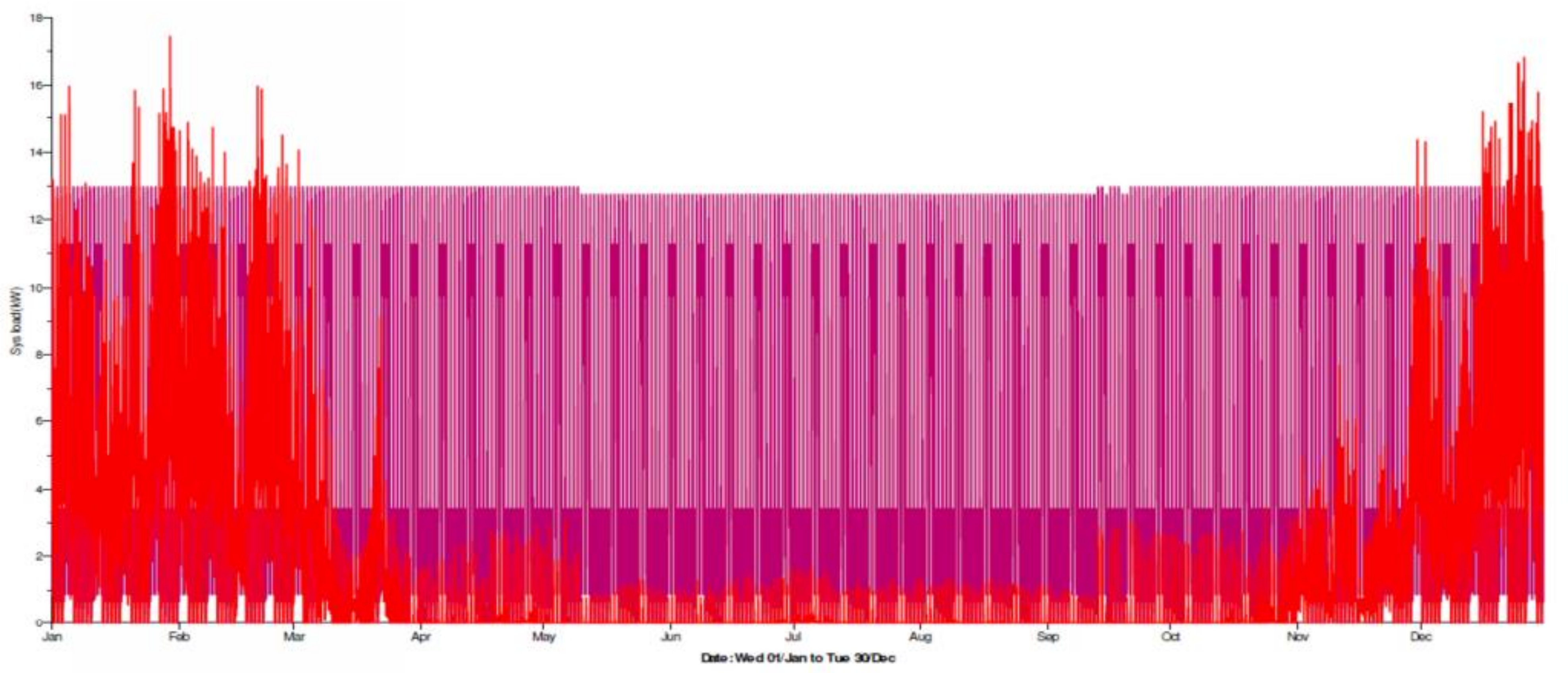
Through contact with a representative of Camden council it has been established that for a development of this scale there will be no need for this development to connect to or make provision for connection to any existing or emerging network. Notwithstanding this, the team has assessed the feasibility of micro CHP for the proposed development.

Combined Heat and Power (CHP) is the simultaneous generation of both usable heat and electrical power from the same source. In its simplest form, CHP employs a gas turbine or an engine to drive an alternator, and the resulting electricity can be used on-site. The heat produced during power generation is recovered, usually in a heat recovery boiler, and can be used to provide domestic hot water and/or space heating in buildings.

CHP requires predictable and relatively constant heat demand for good performance and needs to be assessed in terms of feasibility. There is no justification for over-sizing CHP systems, and the unit needs to be carefully matched to the demands of the development.

In order to size the CHP adequately and so give appropriate carbon savings figures, the load profile of the heating and domestic hot water needs to be established to identify the base load.

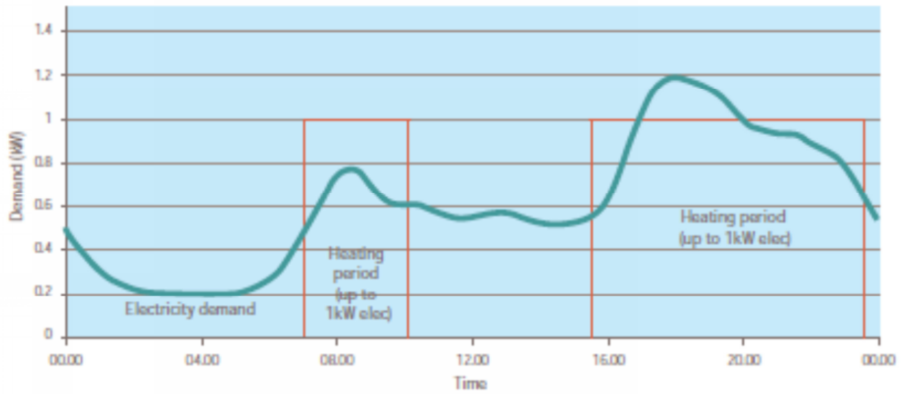
There are differences between weekday and weekend energy profiles and it is estimated that on weekdays the dwelling is occupied predominantly during the mornings and evenings, whereas at the weekends there is a more continuous occupancy.



Loading	Annual Energy (kWh/year)
Electrical Load (Including Unregulated Load)	14,903
Domestic Thermal Load	101,002
Swimming Pool Load	27,000

7.1. Micro CHP

The team have conducted an appraisal of the viability of employing a micro CHP unit within the dwelling. The new dwelling, due to the fact that it has a swimming pool, has a base heating load which made micro CHP a potential option.



The load profile of a Micro CHP unit

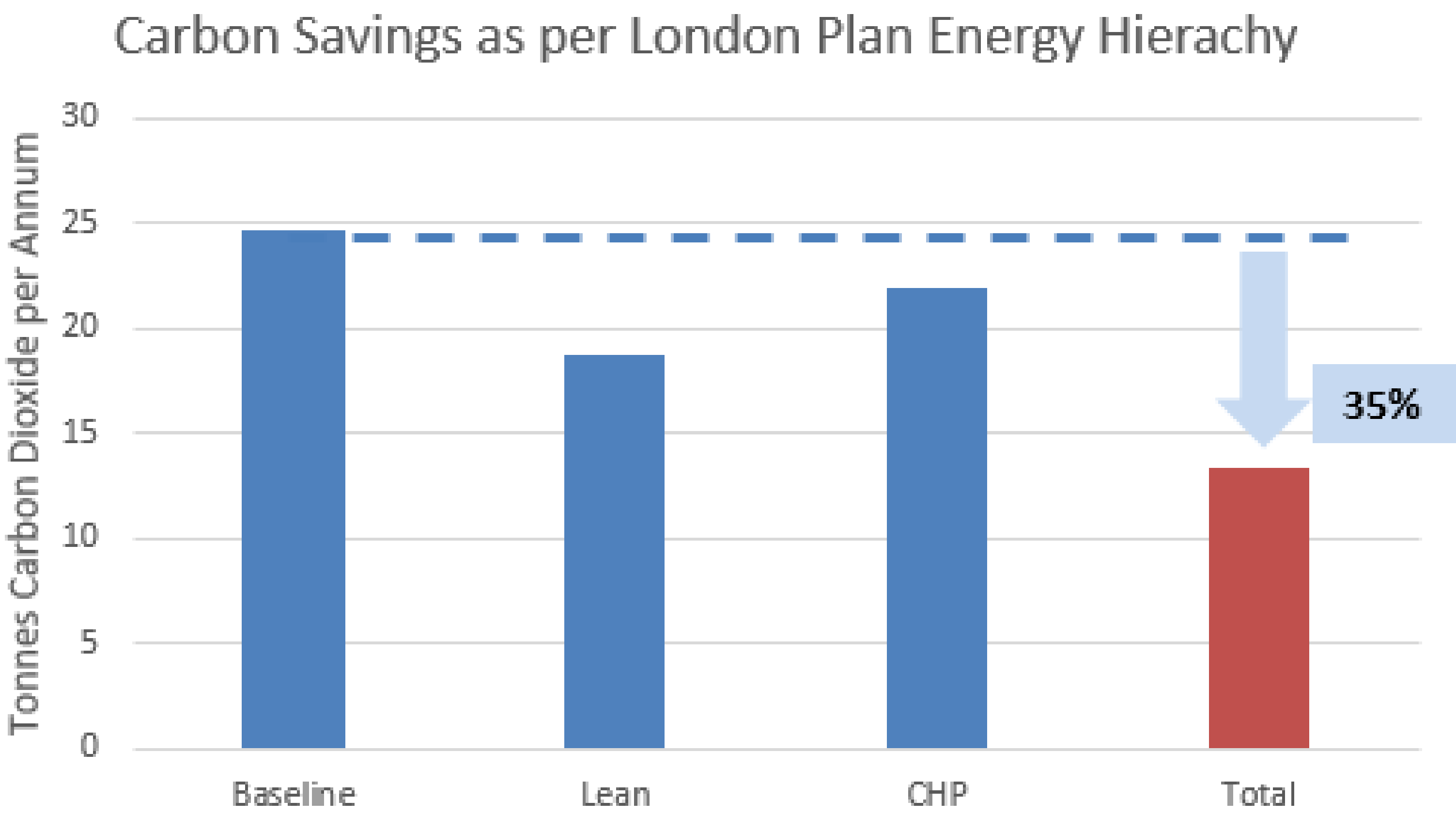
The potential micro CHP unit: Baxi EcoGen. This would be located in the plant room of the dwelling.

However, as the proposed excellent U-values of the fabric and glazing reduce the base load in the form of the space heating demand the savings from the efficiency of the CHP unit are reduced in scale.

Thermal profiles illustrate that on weekdays there is a high demand for hot water in the morning (approx 14kW) which then decreases during the day (approx 1kW) and then increases slightly during the evening. During weekends there is a continuous demand for hot water (approx 10kW).

As can be seen in the load profiles found in appendix H the erratic nature of the heating demand, despite the swimming pool load, along with the fact that it would not meet the carbon reduction criteria alone would make this option unfavourable for the project.

Loading	TCO2/year	% Improvement
Baseline Emissions	24.7	n/a
Savings from Energy Efficiency	5.9	24%
Savings from Micro CHP	2.7	11%
TOTAL SAVINGS	8.6	35%



8. Being Green

The third step of the energy hierarchy is to evaluate the potential for Low and Zero Carbon Technologies. (LZCTs). The table in Appendix F summarises the available technologies and their potential application at Frognal Way.

The predicted energy profile indicates that concentrating on space heating, domestic hot water and lighting loads will provide significant carbon savings.

Certain technologies can be dismissed without further investigation as they are simply inappropriate for the building or site. Being a visually sensitive site and relatively enclosed, wind turbines for example are unlikely to be approved.

The design team has favoured the use of PV, with the potential of being building integrated so this technology is being considered as a discrete solution.

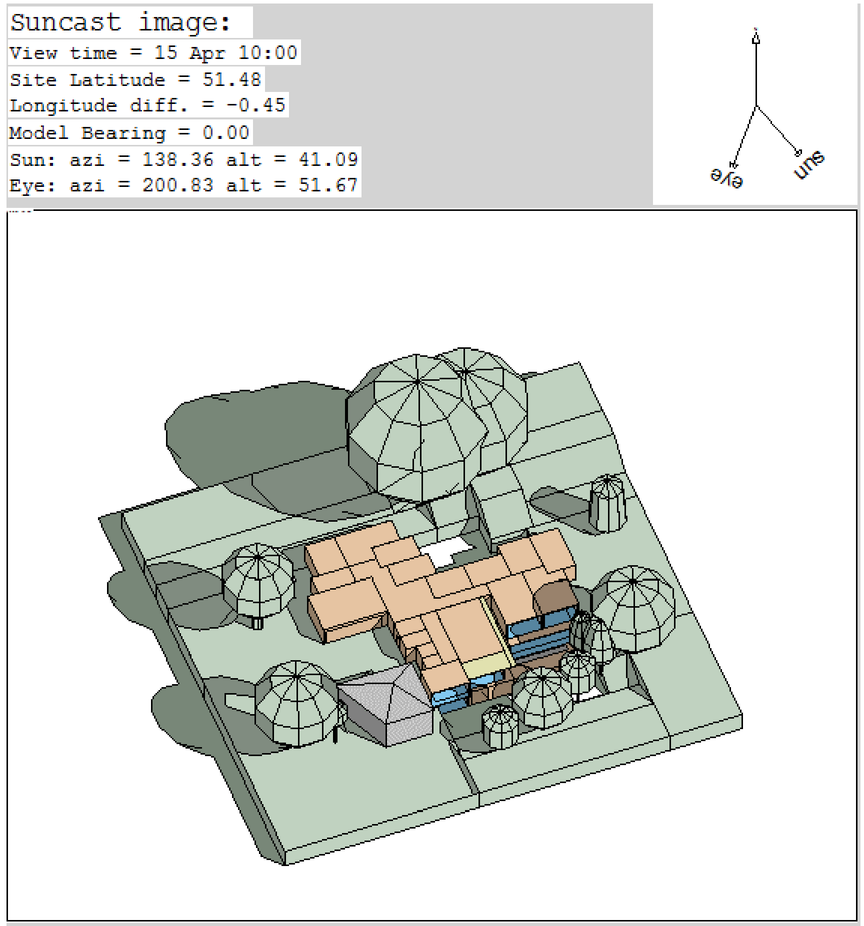
The use of a ground source heat pump coupled to the structural piles has been selected as the technology for Frognal Way due to the ground conditions being able to dissipate the heat effectively.

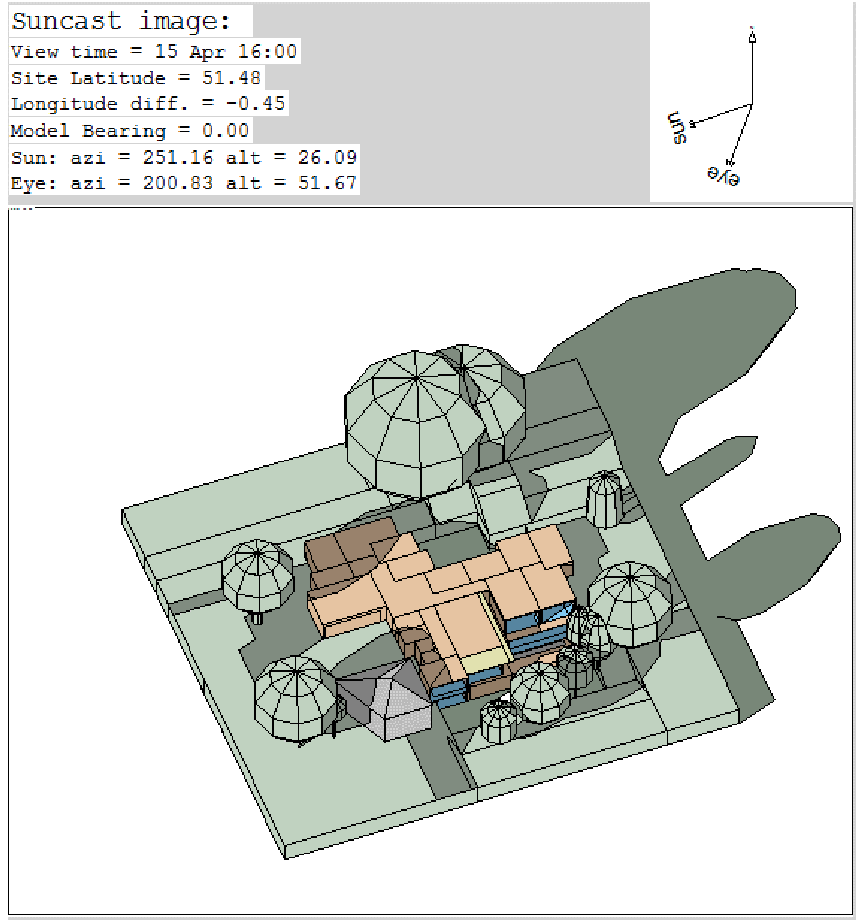
It shall be seen that these technologies alone combine to meet the carbon reduction requirements set out by Camden with the option of further reducing the carbon footprint by employing the most innovative technology, Hydrogen Fuel Cells.

These are explored further in the following sections.

8.1. Photovoltaics (PV)

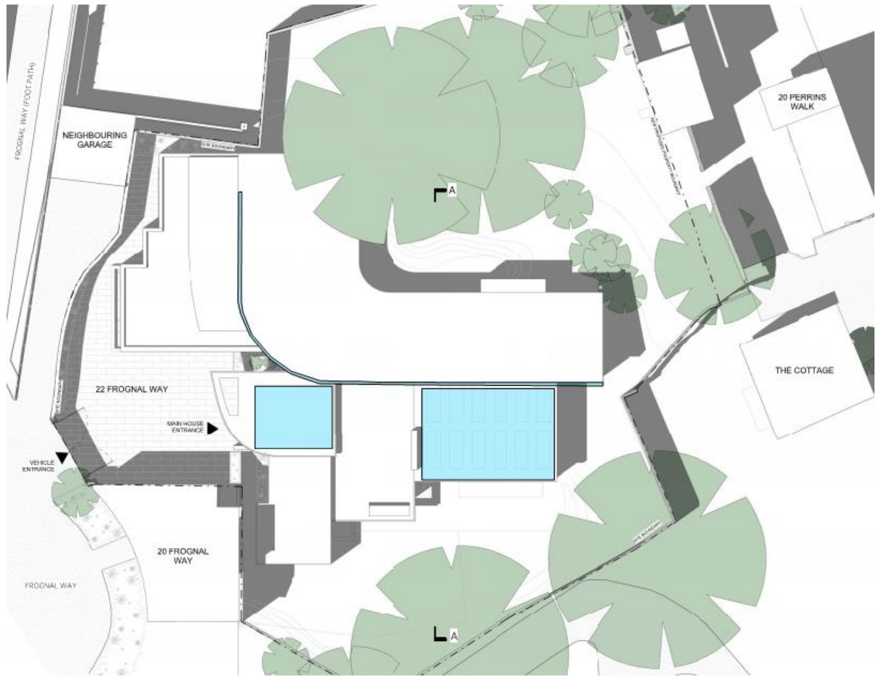
Photovoltaics is considered an appropriate renewable technology for the development. The roof areas proposed receives little over shading from neighbouring buildings or trees. The sunpath analysis carried out shows the amount of sunlight received. With a typical day in April AM and PM being displayed below.





The figure below shows the proposed locations of the PV arrays (in blue) as integrated on the proposed building including the lower roofs and integrated into the clerestory windows.

These locations are also considered to provide the least impact on visual amenity of the neighbours.

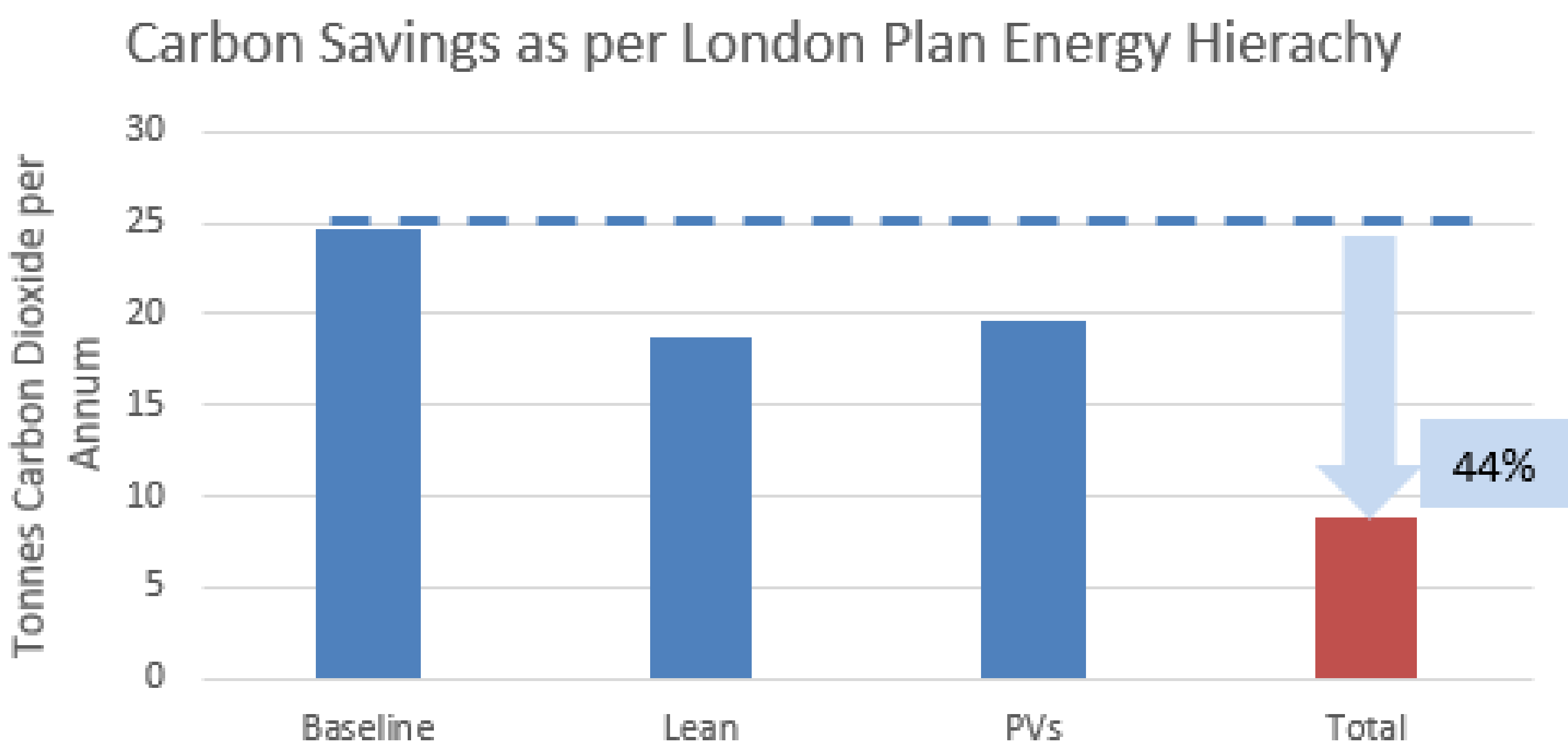


The Cells will be south facing, receiving annual solar radiation in the region of 850kWh/m2. The combined potential area for the PV's is approximately 120m2

An example of glazing integrated PV is shown in the image above (Romag)

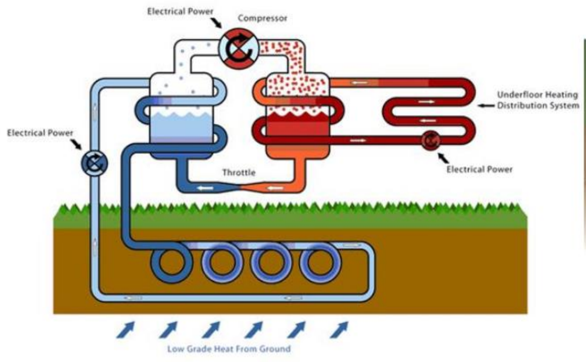
The integrated PV would save in the region of 5 Tonnes of CO2 per year.

Loading	TCO2/year	% Improvement
Baseline Emissions	24.70	n/a
Savings from Energy Efficiency	5.9	24%
Savings from PV	5.0	20%
TOTAL SAVINGS	10.9	44%

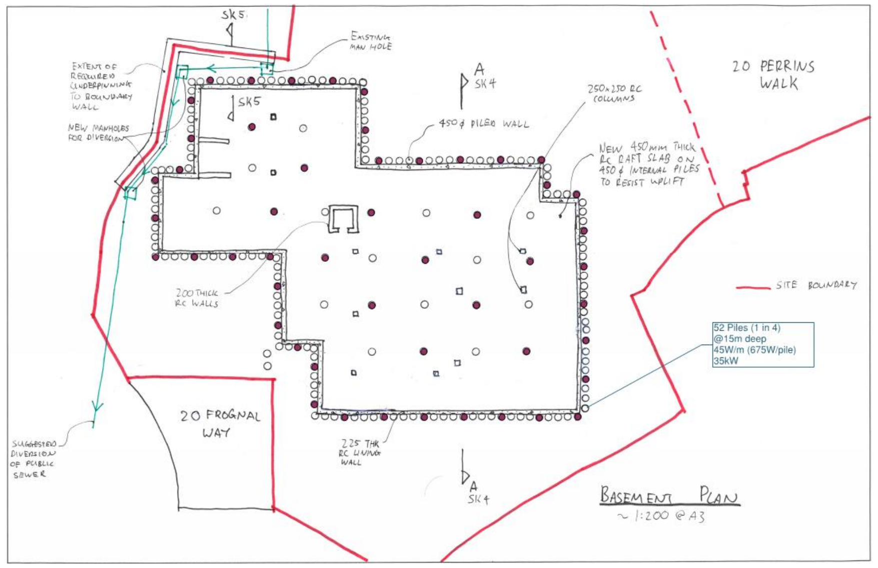


8.2. Ground Source Heat Pump (Geothermal Piles)

The inclusion of a ground source heat pump has been considered for Frognal Way due to the ground conditions favouring the technology through relatively good heat dissipation.



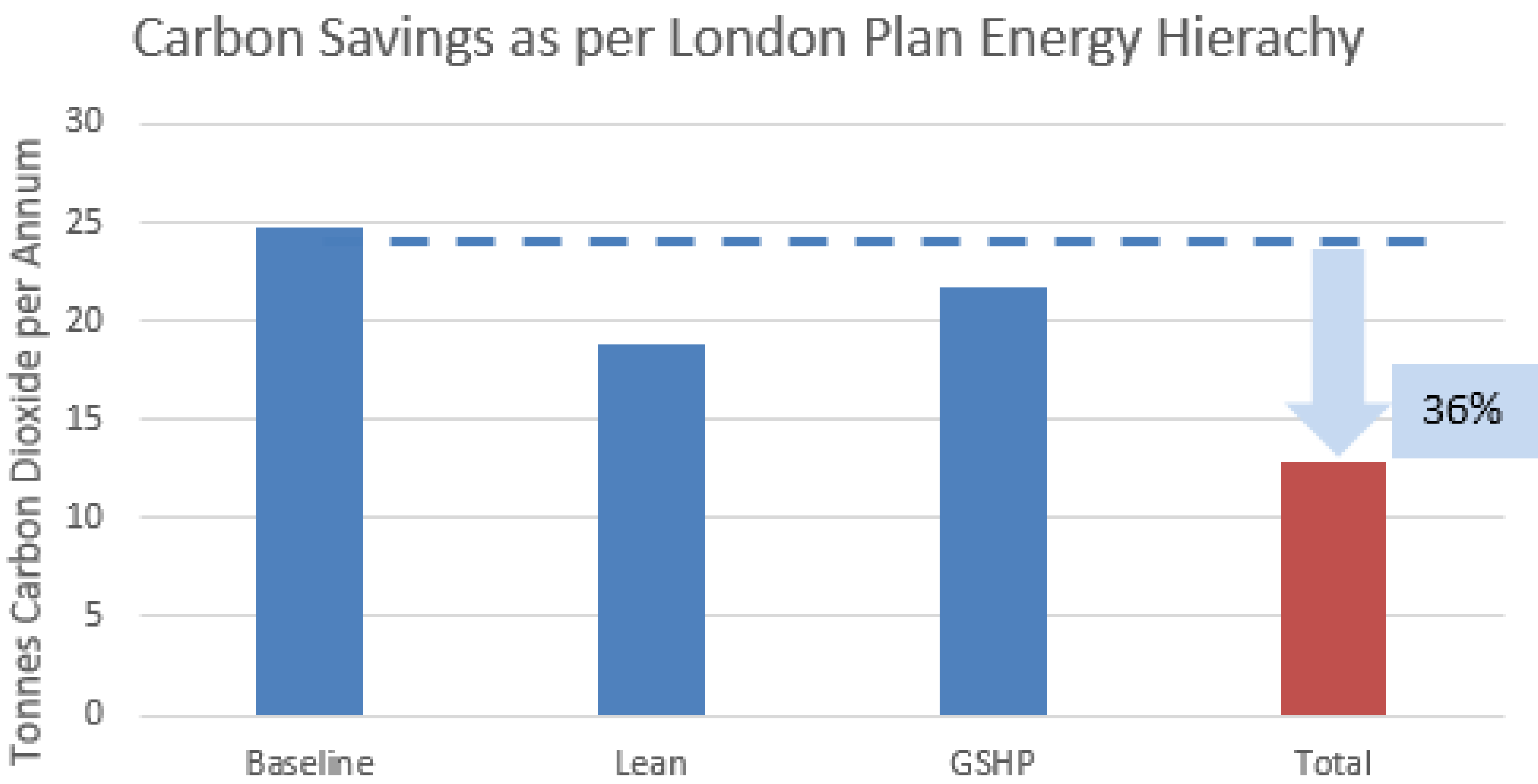
The image above shows the function of the heat pump in heating mode.



The proposed geothermal piling arrangement will be as shown in the figure above (provided by Price Myers – Structural Engineers) with the closed loop ground source pipework being placed within the concrete of every fourth pile. A COP of 3.5 is assumed. This will provide a peak output of around 35kW heating and 16 kW cooling if required.

The breakdown of savings are shown in the table below, where it can be seen that the 40% target cannot be met by GSHP geothermal piles alone and additional piles (150m) could be applied to produce the 20% minimum Camden requirement.

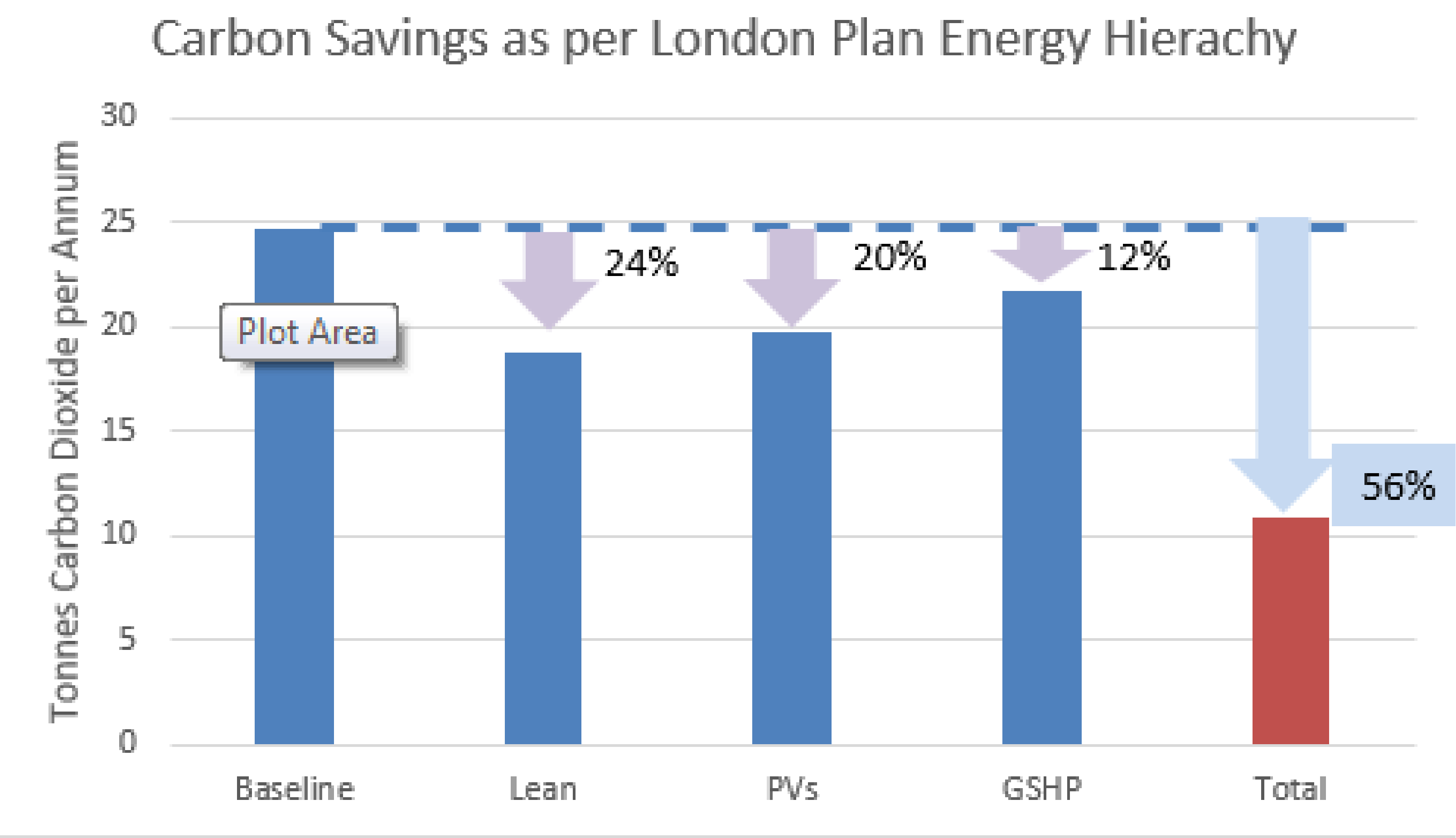
Loading	TCO2/year	% Improvement
Baseline Emissions	24.70	n/a
Savings from Energy Efficiency	5.9	24%
Savings from GSHP	3	12%
TOTAL SAVINGS	8.9	36%



8.3. Renewables (Green) Saving

The 'Green' proposal then for Frognal way is to combine these two renewable technologies within the building, to meet the 20% renewables target. The following table shows a breakdown of the savings.

Loading	TCO2/year	% Improvement
Baseline Emissions	24.70	n/a
Savings from Energy Efficiency	5.9	24%
Savings from PV	5.0	20%
Savings from GSHP	3	12%
TOTAL SAVINGS	13.9	56%



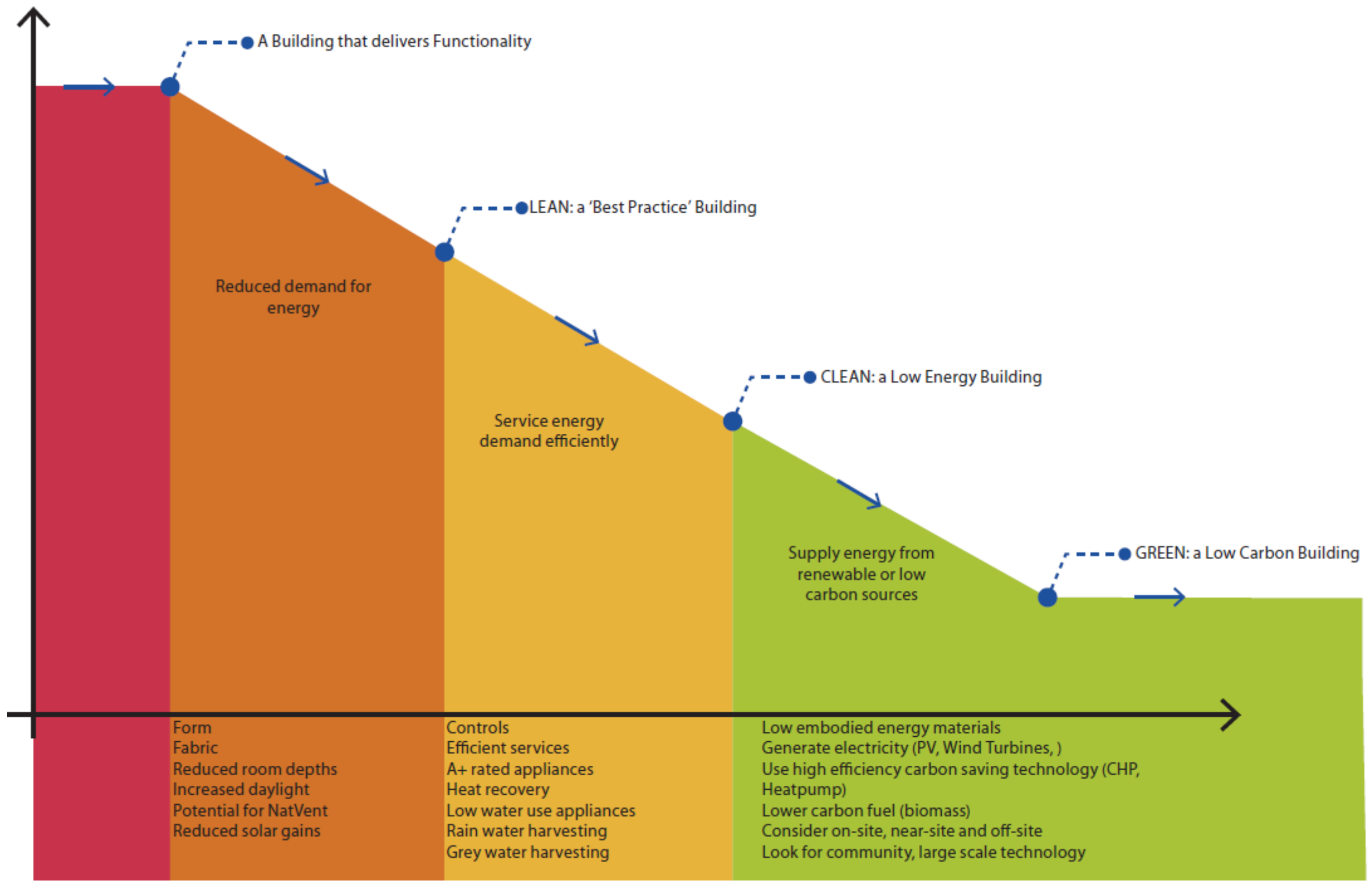
9. Summary of Strategy and Conclusions

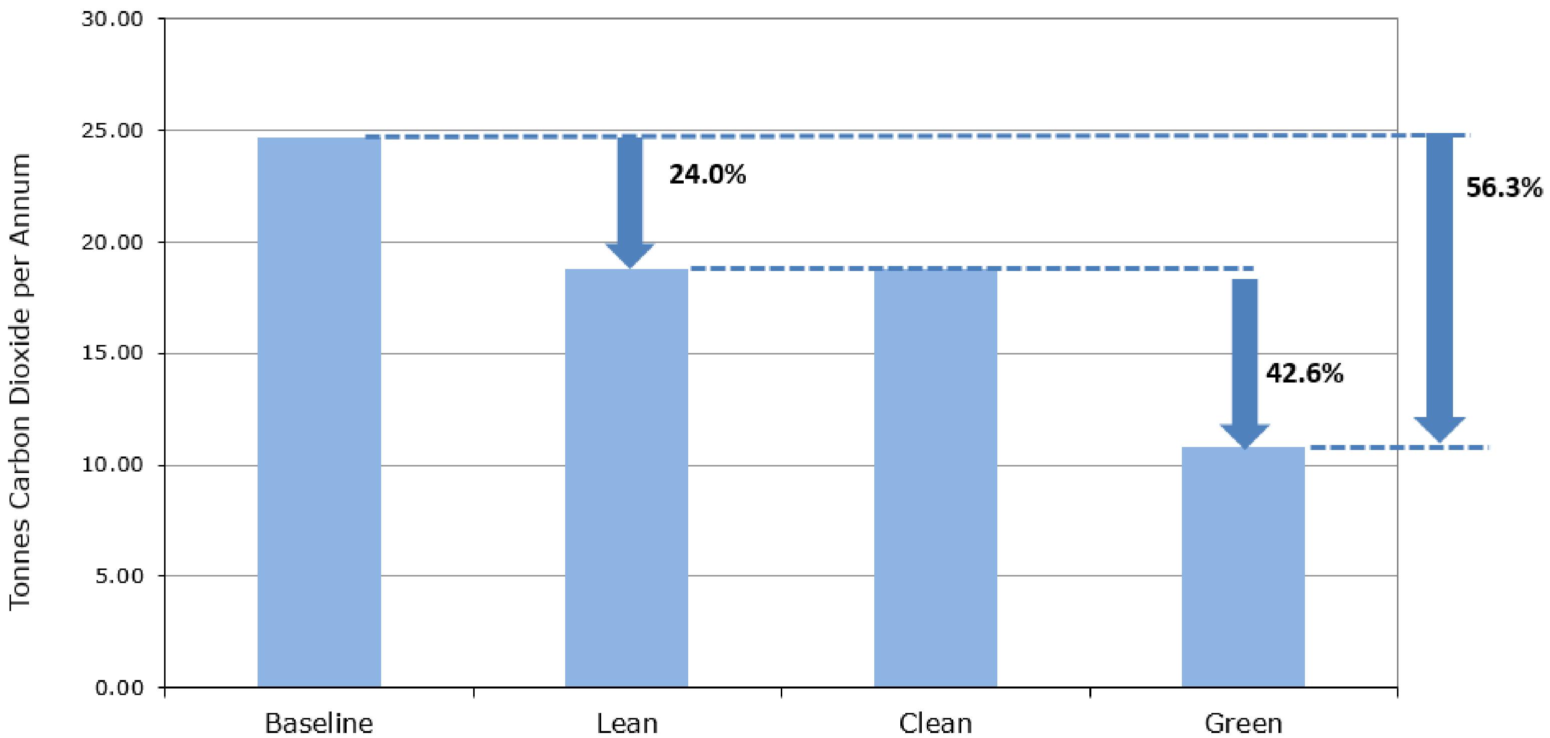
This report has provided an analysis of the likely energy consumption and carbon emissions associated with the new dwelling at 22Frognal Way. We have undertaken calculations as per the London Plan and the Camden Council Methodology in line with Part L and SAP, with baseline emissions estimated for the new dwelling.

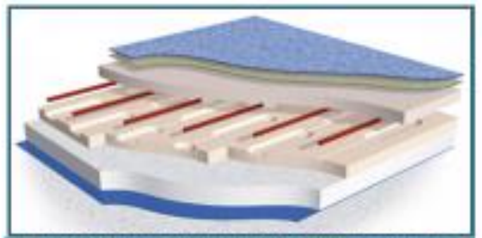
It has been shown that substantial carbon savings are achieved through 'Lean' measures: using building fabric constructions and designing in line with Passivhaus principles. This along with using plant with super-efficient systems, including earth tubes and energy efficient lighting and controls ensures that the building is as energy efficient as possible before applying the energy supply systems.

A heat pump utilising geothermal piles and careful positioning of PV's is proposed for the new dwelling with key technologies as shown in the figure below.

The Graph below shows the reduction measures for this project, which equate to a 56% carbon saving from the baseline position.





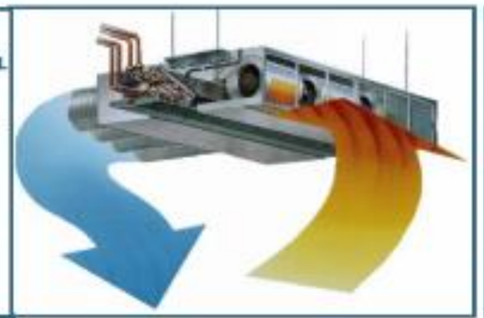


PIPEWORK COILS EMBEDDED IN THE SCREEDED FLOORS PROVIDE GENTLE HEATING AND ON HOT SUMMER DAYS, COOLING.
THIS IS PARTICULARLY EFFICIENT WHEN COMBINED WITH THE HEAT PUMP INSTALLATION WHICH PROVIDES HEATING/COOLING AT THE APPROPRIATE TEMPERATURE.
INSULATION PROVIDED UNDERNEATH TO PREVENT HEAT TRANSFER DOWNWARDS AND PROVIDE GOOD ACOUSTIC SEPARATION.

GREEN ROOFING NOT ONLY ADDS ECOLOGICAL VALUE BUT ALSO HELPS REGULATE THE BUILDINGS TEMPERATURE THROUGH EVAPOTRANSPIRATION IN THE SUMMER AND GOOD INSULATIVE PROPERTIES IN THE WINTER
THE NORTH FACING ROOF LENDS ITSELF WELL TO THIS TECHNOLOGY ON FROGNAL WAY

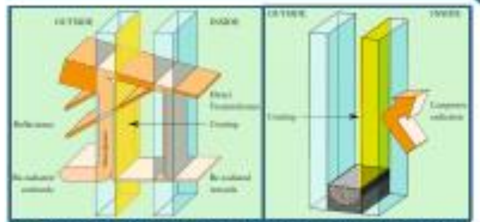
CERTAIN ROOMS FITTED WITH A CONCEALED FAN COIL UNIT TO PROVIDE ADDITIONAL COOLING SHOULD IT BE NEEDED DURING THE SUMMER.

THESE UNITS ARE ALSO FITTED IN THE BASEMENT TO PROVIDE HEATING AND COOLING.



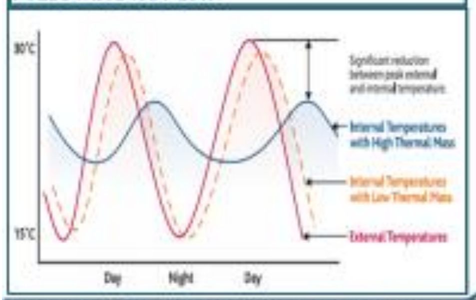
PHOTOVOLTAICS (PV) CONVERT SUNLIGHT INTO ELECTRICITY.

THIS RENEWABLE TECHNOLOGY WILL CONTRIBUTE TO A REDUCTION IN THE CARBON FOOTPRINT OF THE BUILDING BY BEING POSITIONED ON THE ROOF AND INTEGRATED INTO THE BUILDING FABRIC



HIGH TECHNOLOGY SOLAR CONTROL GLAZING ALLOWS 50% LIGHT TRANSMITTANCE AND ONLY 20% SOLAR HEAT TRANSMITTANCE WHILST REFLECTING INTERNAL WARMTH IN THE WINTER COUPLED WITH EXTERNAL SHUTTERS.

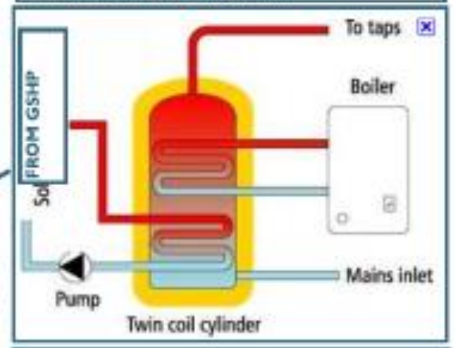
MATERIALS WITH HIGH THERMAL MASS HAVE BEEN USED WHEREVER POSSIBLE. THIS HELPS TO REDUCE HEATING AND COOLING LOADS BY ACTING AS A HEAT SINK AND SOURCE ON HOT AND COLD DAYS RESPECTIVELY.
THE GRAPH BELOW SHOWS HOW ON A SUMMER DAY THE THERMAL PROPERTIES OF THE HEAVY WEIGHT MATERIALS HELP TO SMOOTH OUT THE PEAKS AND TROUGHS THROUGHOUT THE DAY.
THIS STARTGEY WORKS WELL WITH NATURAL VENTILATION WHERE THE COOLTH OF NIGHTIME AIR CAN BE STORED IN THE BUILDING FABRIC TO ACT AS A HEAT SINK DURING THE FOLLOWING HOT DAY.

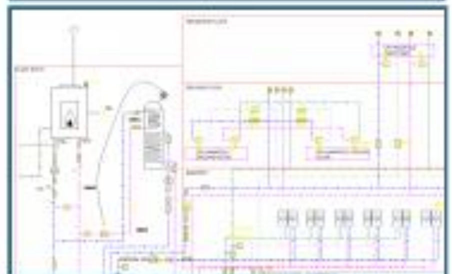


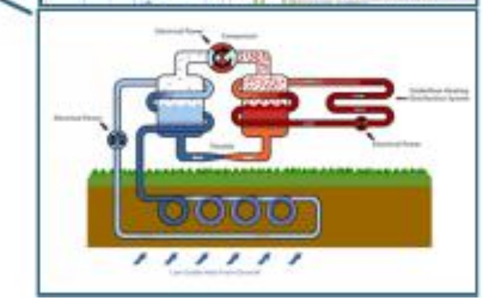
PART OF THE BUILDINGS TOTAL HEATING, COOLING AND HOT WATER IS PROVIDED BY THE HEAT PUMP INSTALLATION. THIS RESULTS IN AN ANNUAL CARBON AND COST SAVING.

THE SYSTEM USES ELECTRICAL ENERGY TO COMPRESS THE LOW GRADE HEAT FROM THE GROUND TO PRODUCE HIGHER GRADE HEAT FOR SPACE HEATING, HOT WATER OR COOLING.

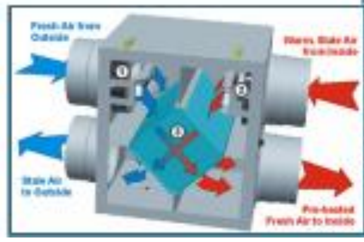
COOLING IS PROVIDED BY THIS INSTALLATION, MEANING THAT NO UNSIGHTLY AND NOISY EXTERNAL CONDENSERS ARE REQUIRED.







PIPEWORK COILS ARE EMBEDDED IN THE PILES WHICH EXTEND TO ~15M BELOW BASEMENT LEVEL. WATER IS CIRCUATED THROUGH THE PIPEWORK AND THE GROUND IS USED AS A HEAT SOURCE AND HEAT SINK. THIS APPLICATION IS PARTICULARLY SUITED TO 22 FROGNAL WAY WHICH HAS A HIGH WATER TABLE WITH WATER MOVEMENT FROM HAMPSTEAD HEATH RESULTING IN HEAT BEING DISSIPATED QUICKLY.



A WHOLE HOUSE MECHANICAL VENTILATION SYSTEM WITH HEAT RECOVERY (MVHR) SUPPLIES FRESH AIR TO THE OCCUPANTS WITHIN THE BUILDING WHILE RECOVERING HEAT FROM AIR EXTRACTED FROM THE BUILDING. THIS IS DONE VIA A HEAT EXCHANGER.
AROUND 80% OF THE HEATING ENERGY CAN BE SAVED BY THIS METHOD OF VENTILATION.
THE OPTION OF FULL NATURAL VENTILATION VIA OPENABLE WINDOWS IS AVAILABLE CONCURRENLTY

10. Water Efficiency

The planning guidance on water use specifies that the dwelling shall not use more than 110litres per person per day.

Water saving technologies will be incorporated into the sanitaryware in order to reduce domestic water consumption to achieve this standard. The following design features will be considered in order to ensure that the dwelling uses water efficiently to achieve this:

- Rainwater harvesting/Greywater recycling (from pool backwash)
- Reduced construction water use
- Recycling Showers
- Low flow non-concussive taps
- Low flow dual flush WCs
- Flow limiters on appliances
- Sanitary shut off linked to PIR on WC water supplies
- A leak detection system on the incoming main supply.
- Metering to the following:
- The main incoming cold water supply
- Cold Water Supply to the main hot water calorifer.

11. Climate Change Adaption

This section describes what considerations have been given to ensuring that the development will be capable of adapting to the future impacts of climate change.

This response will also incorporate the requirements as set out in the new draft Local Plan under policy CC1 Planning for Climate Change Adaptation which include the following:

11.1. Flooding

See section 12

11.2. Drought

See section 10

11.3. Overheating

This section summarises how the proposals mitigate overheating in possible future climates and are able to provide adequate conditions without the need for active cooling.

The building is designed as a domestic property and the use of the dwelling is not expected to change throughout the lifetime of the building. The structure/building fabric shall be designed to withstand the burden of weather / increase pressure/hazards associated with climate change including:

- Solar radiation
- Temperature variation
- Water/Moisture
- Wind
- Precipitation (rain and snow)
- Extreme weather conditions: high wind, flooding, driving rain, snow, rainwater ponding)
- Subsidence/ground movement.

11.3.1. Design Features

The development is designed to be resilient to, and adapt to the future impacts of, climate change through the inclusion of the following adaptation measures:

- the layout, building orientation, construction techniques and materials and natural ventilation methods used mitigate against rising temperatures;
- the use of multi-functional green infrastructure including internal and external planting for urban cooling
- Use of passive and active design methods in line with the cooling hierarchy including:
  - Using high performance glazing that lets in a high proportion of daylight but cuts out a significant portion of the sunlight
  - Using overhangs and deep reveals to the windows on the south façade to provide some natural shading
  - A well-insulated and air tight building envelope
  - Exposed thermal mass
  - Energy efficient lighting and equipment
  - The capability of using outside air via opening windows
  - Maximising cross ventilation
  - Using night-time ventilation through secure and effective openings
  - Planting and making use of the natural vegetation around the building

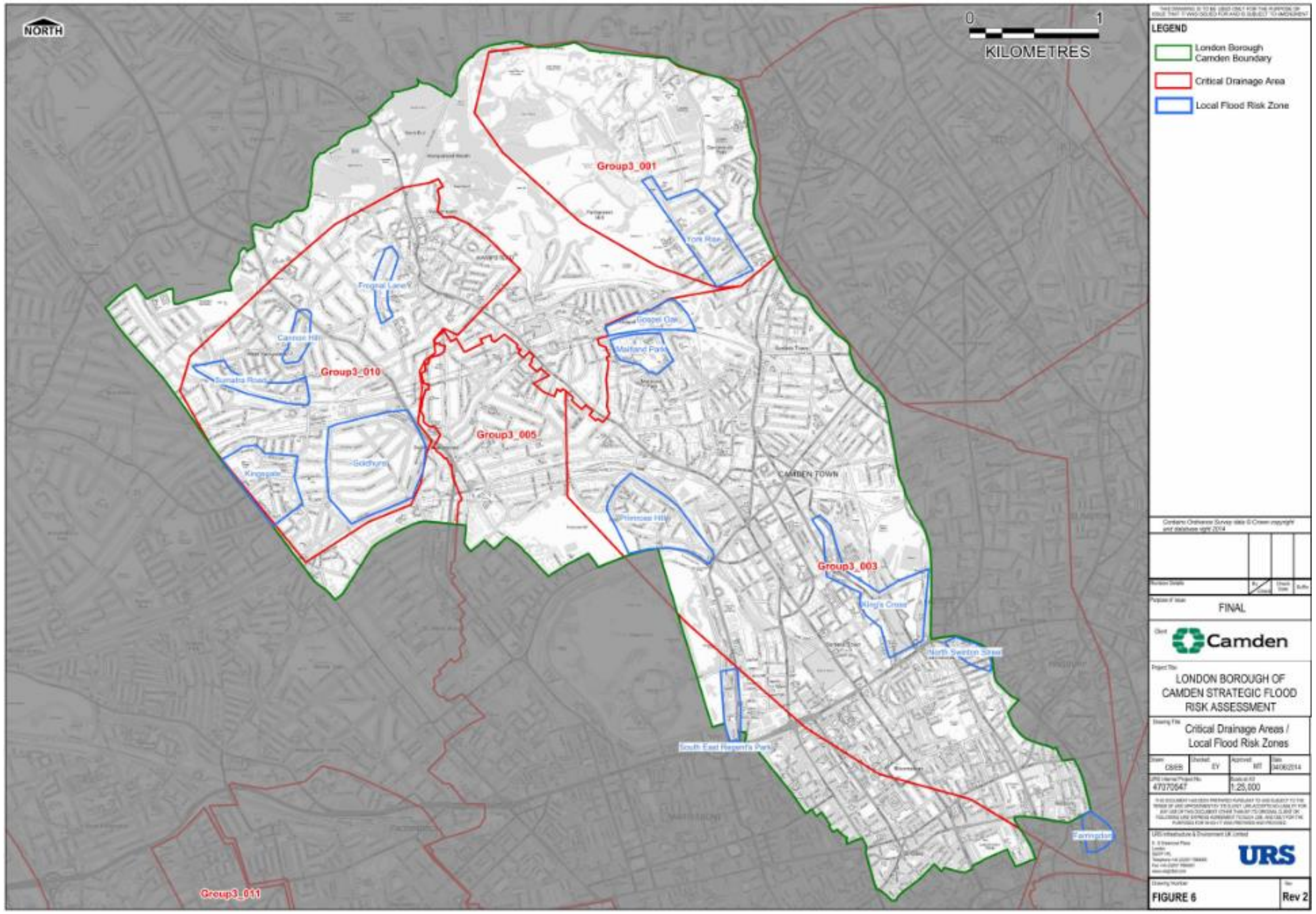
With the application of thermal mass and the versatile ventilation strategies, coupled to earth pipes and a ground source heat pump, the environmental conditions within the building is not anticipated to fluctuate outside acceptable limits. The anticipated change in global temperatures will have limited impact on the energy consumption of the building as the building fabric and control strategies linked to the heating and cooling systems shall be designed to compensate any dramatic variations.

12. Surface Water Run Off and Flooding

In accordance with national policy (PPS25, Building Regulations 2000 (Part H) and CIRIA C697) and regional policy (Camden Development Policy DP23), the management of surface water has also been considered as part of this FRA to mitigate against any increase in surface water runoff from the development proposals.

For more information refer to the flood risk assessment submitted as a separate report within the submission.

The map to the right shows that the Frognal Way site is not in a local flood risk zone.



13. Materials Waste and Recycling

The design teams shall specify that the building contractor source their materials from responsibly sourced supplier and encourage them to provide EMS and timber certification certificates for the main building components. The contractor will be encouraged to adopt a site waste management plan and divert as much waste as feasible from landfill. In addition, consideration should be given to:

- Use of recycled materials
- Embodied energy
- Life cycle of materials and components

14. Pollution

The mitigation of all forms of pollution, from or existing, influencing the site will be considered in the design. This will include but not be limited to:

- Contaminated Land assessment,
- Keeping noise levels within standard ranges,
- Limiting plant noise,
- Reducing light pollution,
- Low-GWP insulation,
- Low-GWP refrigerants with recovery and leak detection,
- Air quality assessment,
- Clean MV air supply, fine air filtering for NV,
- CO_2 monitoring.

15. Ecology

Frognal Way's ecological value can be improved with the sensitive application of good landscaping and vegetation to improve biodiversity.

Nesting birds, if present on site, could potentially be affected so vegetation clearance should be undertaken outside the main UK nesting bird season. An invasive plant check should be carried out prior to works starting as colonisation of some species is relatively quick.

16. Whole Life Carbon Assessment

16.1. Embodied and Whole Life Carbon Report

16.1.1. Summary:

In order to optimize carbon emissions reductions for this proposed development, the client commissioned Sturgis Carbon Profiling (SCP) to work with the design team to identify the potential for embodied and whole life carbon emissions reductions.

This report sets out the methods, metrics, standards and process up to submission, and outlines the subsequent steps through to Practical Completion for optimizing the delivery of the anticipated emissions reductions.

We assess carbon emissions as follows:

Embodied Carbon emissions up to Practical Completion (PC). These are the carbon emissions derived from the sourcing and fabrication of materials, their transport, and assembly into the final building, including all site emissions associated with the construction process.

'Whole Life' Carbon emissions. This includes: embodied emissions up to PC and over 60 years, i.e. to include the maintenance and replacement of materials over that period, and their ultimate disposal, together with regulated (Part L) and unregulated operational emissions over the same period.

16.1.2. Methodology and Metrics:

The 'whole life' carbon emissions assessment is done in accordance with BS EN 15978:2011, BS EN 15804:2012 and associated British Standards. These cover four main carbon assessment stages that accrue over the life of a building: Product Manufacture, Construction Stage, In Use, and End of Life. These in turn are split down into a further sub categories relating to the individual emission sources from each category, for instance, transport emissions or emissions from construction site based activities.

Other standards, principally PAS 2050, and ISO 14000 series are also relevant.

Lifespan Data is from or derived from RICS/BCIS Life Expectancy of Building Components.

The product data used is from or in accordance with the Bath ICE Database, and published EPD's.

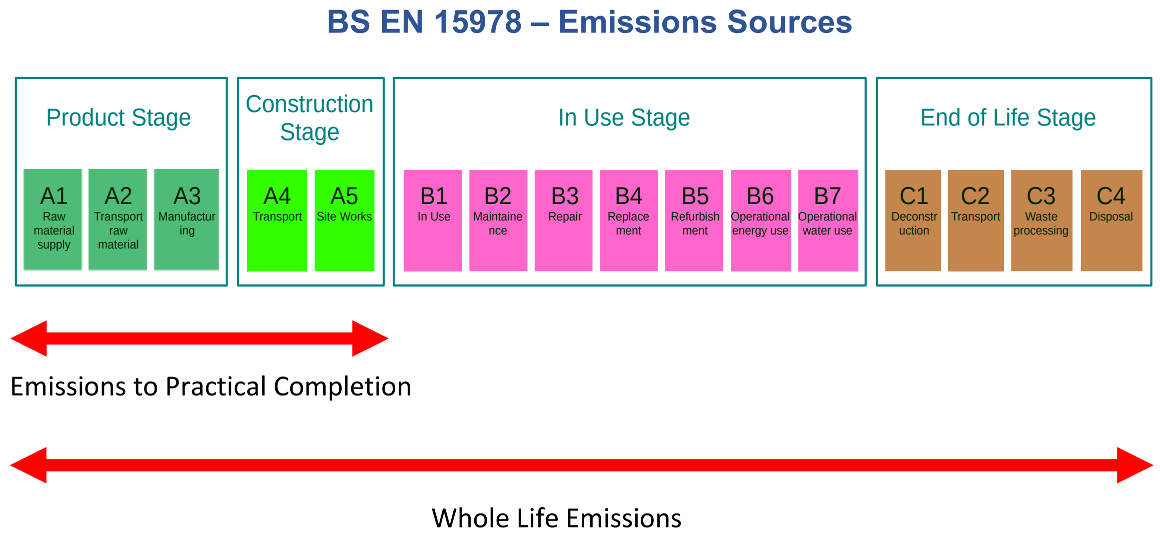
16.1.3. Process:

The first stage of the assessment was to create a 'Baseline' Whole Life Carbon assessment, using the information available from the current design of structure, services, external envelope and internal fixtures and finishes.

After the planning submission, the design team will then explore 'options to reduce' through a series of workshops, assessing all aspects of the structural, architectural and services design as per the new revised scheme, to identify lower carbon options compared to the Baseline scheme.

The outcome of this process was to produce the 'Carbon Budget'. This would identify carbon emission savings opportunities and these savings are therefore built into the design. In addition further savings have also been identified that would be targeted during the procurement, tender and construction phases.

Source: Sturgis Carbon Profiling



16.2. Baseline Whole Life Carbon Assessment

16.2.1. Carbon at different stages:

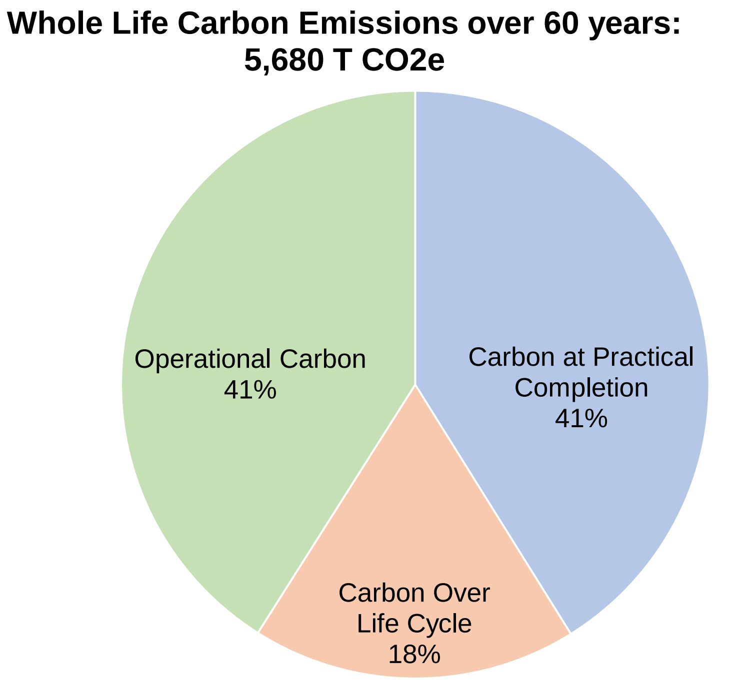
The initial analysis indicates that the combined embodied emissions to practical completion are about 2,340 tonne CO2e, and are mainly from construction of building structure and internal finishes (approx. 75% in combination). The materials related embodied carbon of over the life cycle of the building are over 1,010 tonnes and are mainly due to replacement of internal finishes and building service equipment.

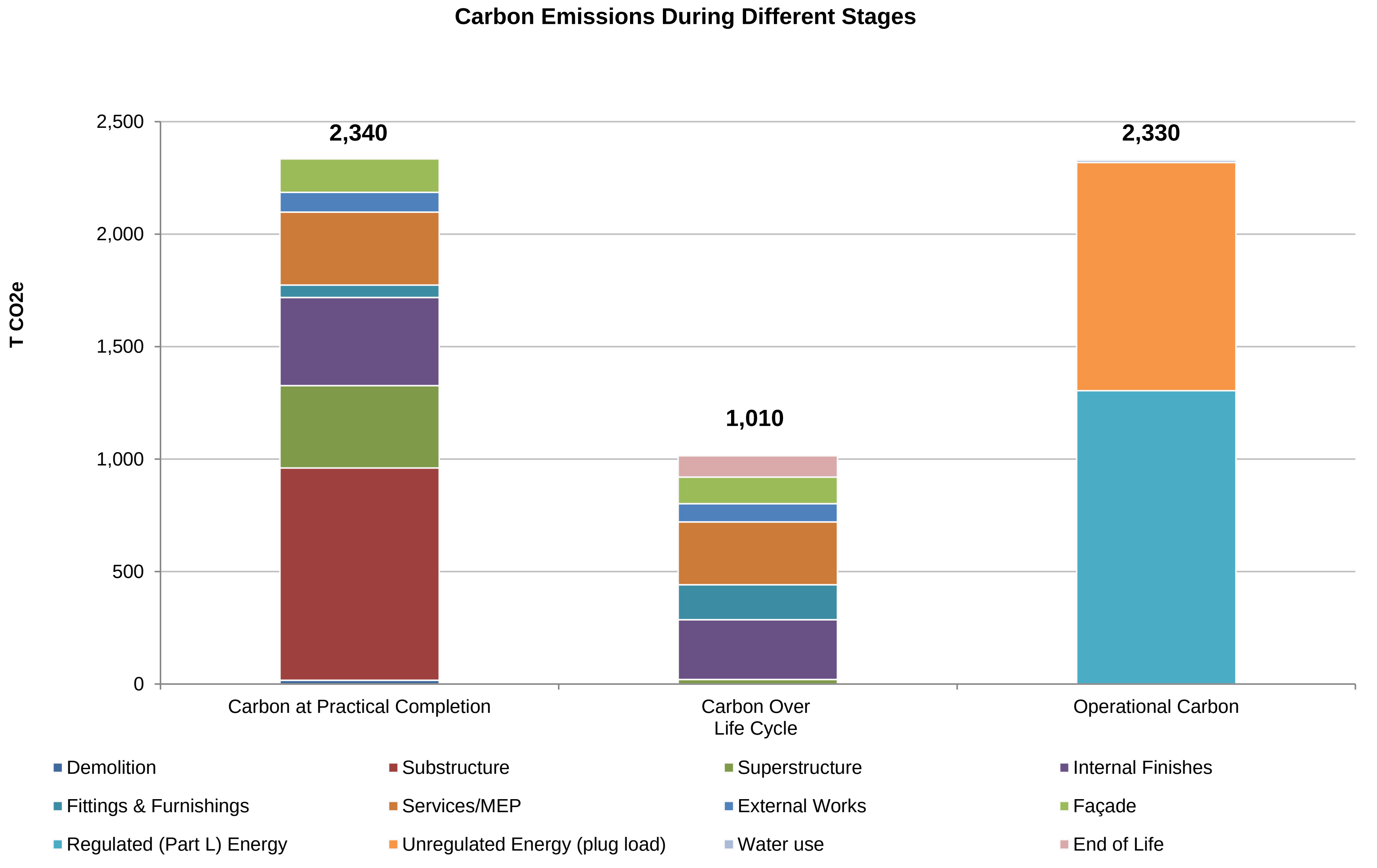
Life cycle emissions from both regulated operational energy (part L), unregulated energy (plug load) and water usage are 2,330 tonnes. This has taken into the consideration of grid decarbonization.

16.2.2. Whole Life Carbon Analysis

The overall Whole Life Carbon emissions of 22 Frognal Way project is about 5,680 Tonne CO2e, the choice of building material is making a greater impact on the building's carbon footprint as about 60% of the emissions are from building materials during construction process or repair and replacement during in-use stage. Using materials with low carbon footprint will deliver great environmental benefit for the development.

Source: Sturgis Carbon Profiling





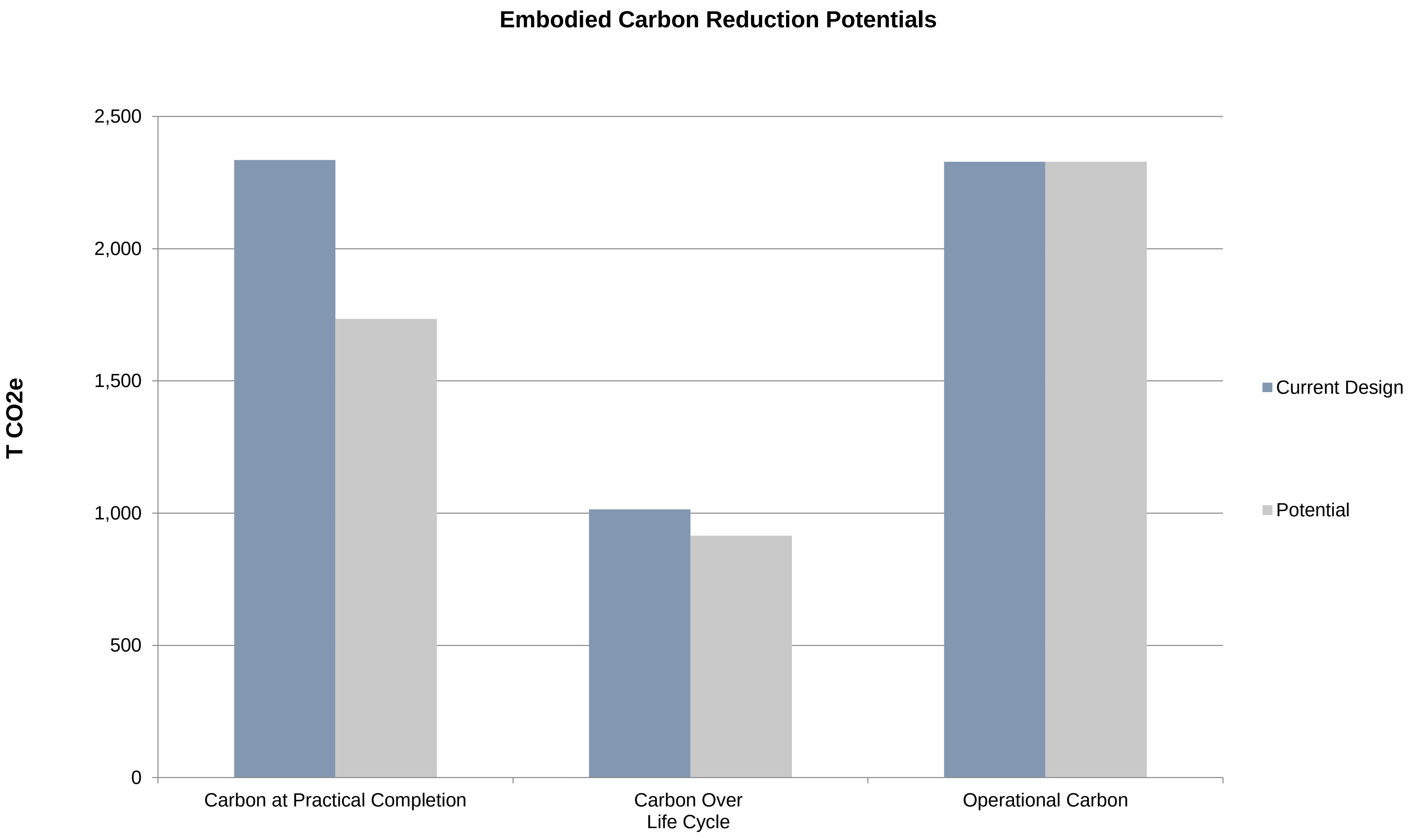
16.3. Embodied Carbon Reduction Potentials

The following potential savings have been outlined, those need to be investigated and expanded further through design and specification up to tender:

- The use of a proportion of cement replacements in all concrete (i.e. GGBS) of between 30-70% (depending on super/sub structure design requirement etc.).
- Recycled content in reinforcing steel, up to 100%.
- Recycled content in aluminium, say between 50-80%.
- Local sourcing of materials generally, i.e. reducing emissions during transportation
- Selection and disposal of formwork for concrete to reduce methane from landfill
- Recycled content carpets and other finishes.
- Minimization and efficient disposal of site waste, ie reduced HGV traffic.
- Improved lifespan of systems achieved through detailed design.

If most of the above options could be implemented through the detailed design, specifications for tender, and efficient operations on site, this would lead to approximately 10% saving of building's Whole Life Carbon footprint, more than 25 years' carbon emissions from part L regulated energy (heating, lighting hotwater etc.).

Source: Sturgis Carbon Profiling



16.4. Tender

1.1 To achieve optimum carbon emissions reductions it is necessary for those reduction options agreed by the Design Team to be delivered firstly during the procurement process and secondly during construction.

1.2 The specifications are therefore tailored to ensure that the identified reduction options are delivered during the procurement process.

1.3 The Environmental Policies of prospective tenderers are reviewed.

1.4 The main contractor and all subcontractors down the supply chain provide energy and emissions data at tender. SCP review and monitor this data.

16.5. Construction

1.5 At the outset of the construction process, the Initial Carbon Budget is revised in the light of the received tenders and updated to form the 'Contract Carbon Budget'.

1.6 Temporary works, waste, use of power and movement of vehicles are all logged and monitored during construction

1.7 During construction the contractor reports and is monitored against the Contract Carbon Budget.

16.6. Practical Completion

Post Practical Completion the 'as built' scheme is assessed against the initial Carbon Budget and a Certificate is issued detailing the final carbon footprint of the building.

Appendix A – Planning Policy Extract

Appendix A – Planning Policy Extracts

3.2. GLA Sustainable Design and Construction SPG (2014)

5.3 Completion of the following tables must be undertaken to demonstrate compliance with the energy hierarchy. Note: unregulated emissions are likely to be the same after the first stage of the energy hierarchy.

[6] This is available from www.london.gov (from April 2014)

Table 1: Carbon Dioxide Emissions after each stage of the Energy Hierarchy

	Carbon dioxide emissions (Tonnes CO_2 per annum)	
	Regulated	**Unregulated**
Baseline: Part L 2013 of the Building Regulations Compliant Development	A	
After energy demand reduction	B	
After CHP	C	
After renewable energy	D	

Table 2: Regulated carbon dioxide savings from each stage of the Energy Hierarchy

	Regulated Carbon dioxide savings	
	(Tonnes CO_2 per annum)	**(%)**
Savings from energy demand reduction	A - B	(A – B)/A * 100
Savings from CHP	B- C	(B – C)/B * 100
Savings from renewable energy	C - D	(C – D)/C*100
Total Cumulative Savings	**A - D = E**	**(A – D)/A*100**
Total Target Savings	**[A * 0.35] = F**	**35%**
Annual Surplus	**E - F**	

6.3 *Calculating regulated CO_2 emissions at each stage of the energy hierarchy*

Regulated emissions, which include the energy consumed in the operation of the space heating/cooling and hot-water systems, ventilation, internal lighting, must be calculated. Separately, unregulated emissions i.e. those relating to cooking and all electrical appliances and other small power, should be calculated.

Emissions for **dwellings** must establish:

- a Dwelling CO_2 Emissions Rate (DER) calculated through the Part L 2013 of the Building Regulations methodology SAP 2012[8]. This is multiplied by the cumulative floor area for the particular dwelling type in question to give the related CO_2 emissions

The CO_2 emissions for each building and dwelling type must then be summed to give the total regulated emissions and expressed in tonnes per annum.

After calculating the regulated emissions at each stage of the energy hierarchy, the percentage savings in regulated emissions over a Part L 2013 of the Building Regulations compliant development must be provided (as shown in Table 2 above).

3.3. Camden Council Development Policies - Core Policies related to Energy.

3.3.1. CS13 – Tackling climate change through promoting higher environmental standards

CS13 - Tackling climate change through promoting higher environmental standards

Reducing the effects of and adapting to climate change

The Council will require all development to take measures to minimise the effects of, and adapt to, climate change and encourage all development to meet the highest feasible environmental standards that are financially viable during construction and occupation by:

a) ensuring patterns of land use that minimise the need to travel by car and help support local energy networks;
b) promoting the efficient use of land and buildings;
c) minimising carbon emissions from the redevelopment, construction and occupation of buildings by implementing, in order, all of the elements of the following energy hierarchy:
  - ensuring developments use less energy,
  - making use of energy from efficient sources, such as the King's Cross, Gower Street, Bloomsbury and proposed Euston Road decentralised energy networks;
  - generating renewable energy on-site; and
d) ensuring buildings and spaces are designed to cope with, and minimise the effects of, climate change.

The Council will have regard to the cost of installing measures to tackle climate change as well as the cumulative future costs of delaying reductions in carbon dioxide emissions

Local energy generation

The Council will promote local energy generation and networks by:

e) working with our partners and developers to implement local energy networks in the parts of Camden most likely to support them, i.e. in the vicinity of:
  - housing estates with community heating or the potential for community heating and other uses with large heating loads;
  - the growth areas of King's Cross, Euston; Tottenham Court Road; West Hampstead Interchange and Holborn;
  - schools to be redeveloped as part of Building Schools for the Future programme;
  - existing or approved combined heat and power/local energy networks (see Map 4);

  and other locations where land ownership would facilitate their implementation.
f) protecting existing local energy networks where possible (e.g. at Gower Street and Bloomsbury) and safeguarding potential network routes (e.g. Euston Road);

Water and surface water flooding

We will make Camden a water efficient borough and minimise the potential for surface water flooding by:

g) protecting our existing drinking water and foul water infrastructure, including Barrow Hill Reservoir, Hampstead Heath Reservoir, Highgate Reservoir and Kidderpore Reservoir;
h) making sure development incorporates efficient water and foul water infrastructure;
i) requiring development to avoid harm to the water environment, water quality or drainage systems and prevents or mitigates local surface water and down-stream flooding, especially in areas up-hill from, and in, areas known to be at risk from surface water flooding such as South and West Hampstead, Gospel Oak and King's Cross (see Map 5).

Camden's carbon reduction measures

The Council will take a lead in tackling climate change by:

j) taking measures to reduce its own carbon emissions;
k) trialling new energy efficient technologies, where feasible; and
l) raising awareness on mitigation and adaptation measures.

3.3.1. DP22 – Promoting sustainable design and construction

Policy DP22 - Promoting sustainable design and construction

The Council will require development to incorporate sustainable design and construction measures. Schemes must:

a) demonstrate how sustainable development principles, including the relevant measures set out in paragraph 22.5 below, have been incorporated into the design and proposed implementation; and
b) incorporate green or brown roofs and green walls wherever suitable.

The Council will promote and measure sustainable design and construction by:

c) expecting new build housing to meet Code for Sustainable Homes Level 3 by 2010 and Code Level 4 by 2013 and encouraging Code Level 6 (zero carbon) by 2016.
d) expecting developments (except new build) of 500 sq m of residential floorspace or above or 5 or more dwellings to achieve "very good" in EcoHomes assessments prior to 2013 and encouraging "excellent" from 2013;
e) expecting non-domestic developments of 500sqm of floorspace or above to achieve "very good" in BREEAM assessments and "excellent" from 2016 and encouraging zero carbon from 2019.

The Council will require development to be resilient to climate change by ensuring schemes include appropriate climate change adaptation measures, such as:

f) summer shading and planting;
g) limiting run-off;
h) reducing water consumption;
i) reducing air pollution; and
j) not locating vulnerable uses in basements in flood-prone areas.

3.3.2. DP23 – Water

Policy DP23 - Water

The Council will require developments to reduce their water consumption, the pressure on the combined sewer network and the risk of flooding by:

a) incorporating water efficient features and equipment and capturing, retaining and re-using surface water and grey water on-site;
b) limiting the amount and rate of run-off and waste water entering the combined storm water and sewer network through the methods outlined in part a) and other sustainable urban drainage methods to reduce the risk of flooding;
c) reducing the pressure placed on the combined storm water and sewer network from foul water and surface water run-off and ensuring developments in the areas identified by the North London Strategic Flood Risk Assessment and shown on Map 2 as being at risk of surface water flooding are designed to cope with the potential flooding;
d) ensuring that developments are assessed for upstream and downstream groundwater flood risks in areas where historic underground streams are known to have been present; and
e) encouraging the provision of attractive and efficient water features.

3.4. Camden Planning Guidance 3 – Sustainability

3.4.1. The Energy Hierarchy

The energy hierarchy

KEY MESSAGES

- All developments are to be design to reduce carbon dioxide emissions
- Energy strategies are to be designed following the steps set out by the energy hierarchy

Developments involving 5 or more dwellings and/or 500sq m (gross internal) floorspace or more are required to submit an energy statement which demonstrates how carbon dioxide emissions will be reduced in line with the energy hierarchy (see below for more details on what to include in an energy statement).

3.4.2. Energy Efficiency

Energy efficiency: new buildings

KEY MESSAGES

All new developments are to be designed to minimise carbon dioxide emissions

The most cost-effective ways to minimise energy demand are through good design and high levels of insulation and air tightness.

WHAT WILL THE COUNCIL EXPECT?

All new developments are to be designed to minimise carbon dioxide emissions by being as energy efficient as is feasible and viable

WHAT INFORMATION DOES THE COUNCIL REQUIRE?

- A full model of the building should be carried out to ensure the building design optimises solar gain and daylight without resulting in overheating for developments comprising 5 dwellings or more or 500sq m or more of any floorspace
- Consider maximising the use of natural systems within buildings before any mechanical services are considered

WHAT INFORMATION DOES THE COUNCIL REQUIRE?

- Any development proposing electric heating (including heat pumps) will need to demonstrate the carbon efficiency of the proposed heating system. Specifications of the electric heating system and calculations will need to be provided to demonstrate that the proposed electric heating system would result in lower carbon dioxide emissions than an efficiency gas fuelled heating system.

3.4.1. Decentralised Energy Networks and Combined Heat and Power

KEY MESSAGES

Decentralised energy could provide 20% of Camden's heating demand by 2020.

Combined heat and power plants can reduce carbon dioxide emissions by 30-40% compared to a conventional gas boiler.

Where feasible and viable your development will be required to connect to a decentralised energy network or include CHP.

5.17 Developments which fall within proposed within 1km of an existing decentralised energy network, or one that is likely to be operational within 3 years of occupation of the development, should assess the feasibility of connecting to the network. See figure 4 below for a map of existing and emerging networks. Further information on the networks can be found in Camden's or other provider's decentralised energy strategies. A connection should be made unless it can be clearly demonstrated that it would not be viable. Where no connection is made, a financial contribution will be sought. See paragraph 5.24 for more information on financial contributions.

5.18 Developments which are proposed within 500m of a potential network (see figure 5 below) which have no timetable for delivery should ensure that the development is capable of connecting to a network in the future. A financial contribution will be sought to fund the future expansion of the network, unless on-site CHP is feasible and included as part of the development.

3.4.2. Renewable Energy

Renewable energy

KEY MESSAGES

There are a variety of renewable energy technologies that can be installed to supplement a development's energy needs

Developments are to target a 20% reduction in carbon dioxide emissions from on-site renewable energy technologies.

WHAT DOES THE COUNCIL EXPECT?

All developments are to target at least a 20% reduction in carbon dioxide emissions through the installation of on-site renewable energy technologies. Special consideration will be given to heritage buildings and features to ensure that their historic and architectural features are preserved.

When assessing the feasibility and viability of renewable energy technology, the Council will consider the overall cost of all the measures proposed and resulting carbon savings to ensure that the most cost-effective carbon reduction technologies are implemented in line with the energy hierarchy.

3.4.3. Water Efficiency

KEY MESSAGES

At least 50% of water consumed in homes and workplaces does not need to be of drinkable quality re-using water

All developments are to be water efficient

Developments over 10 units or 1000sq m should include grey water recycling

WHAT DOES THE COUNCIL EXPECT?

The Council expects all developments to be designed to be water efficient by minimising water use and maximising the re-use of water. This includes new and existing buildings.

WHAT WILL THE COUNCIL EXPECT?

The Council will require buildings with gardens or landscaped areas that require regular maintenance to be fitted with water butts.

The Council will require developments over 10 units or 1000sq m and/or intense water use developments, such as hotels, hostels, student housing etc to include a grey water harvesting system, unless the applicant demonstrates to the Council's satisfaction that this is not feasible.

3.4.4. Sustainable Use of Materials

KEY MESSAGES

Reduce waste by firstly re-using your building, where this is not possible you should implement the waste hierarchy

The waste hierarchy prioritises the reduction, re-use and recycling of materials

Source your materials responsibly and ensure they are safe to health.

WHAT WILL THE COUNCIL EXPECT?

All developments should aim for at least 10% of the total value of materials used to be derived from recycled and reused sources. This should relate to the WRAP Quick Wins assessments or equivalent as (highlighted in the waste hierarchy information section below). Special consideration will be given to heritage buildings and features to ensure that their historic and architectural features are preserved.

Major developments are anticipated to be able to achieve 15-20% of the total value of materials used to be derived from recycled and reused sources.

3.4.5. Sustainability Assessment Tools

KEY MESSAGES

A new build dwelling will have to be designed in line with the Code for Sustainable Homes

The creation of 5 or more dwellings from an existing building will need to be designed in line with EcoHomes

500sq m or more of non-residential floorspace will need to be designed in line with BREEAM

3.4.6. Brown Roofs, Green Roofs and Green Walls

KEY MESSAGES

All developments should incorporate green and brown roofs

The appropriate roof or wall will depend on the development, the location and other specific factors

Specific information needs to be submitted with applications for green/brown roofs and walls

WHAT WILL THE COUNCIL EXPECT?

The Council will expect all developments to incorporate brown roofs, green roofs and green walls unless it is demonstrated this is not possible or appropriate. This includes new and existing buildings. Special consideration will be given to historic buildings to ensure historic and architectural features are preserved.

WHAT INFORMATION WILL THE COUNCIL EXPECT?

- a statement of the design objectives for the green or brown roof or green wall
- details of its construction and the materials used, including a section at a scale of 1:20
- planting details, including details of the planting technique, plant varieties and planting sizes and densities.
- a management plan detailed how the structure and planting will be maintained

3.4.7. Flooding

KEY MESSAGES

All developments are required to prevent or mitigate against flooding

All developments are expected to manage drainage and surface water

There is a hierarchy you should follow when designing a sustainable drainage system

WHAT DOES THE COUNCIL EXPECT?

Developments must not increase the risk of flooding, and are required to put in place mitigation measures where there is known to be a risk of flooding.

Within the areas shown on Core Strategy Map 5 (Development Policies Map 2) we will expect water infrastructure to be designed to cope with a 1 in 100 year storm event in order to limit the flooding of, and damage to, property.

WHAT DOES THE COUNCIL EXPECT?

All developments are expected to manage drainage and surface water on-site or as close to the site as possible, using Sustainable Drainage Systems (SUDS) and the hierarchy set out below.

The Council will expect plans and application documents to describe how water will be managed within the development, including an explanation of the proposed SUDS, the reasons why certain SUDS have been ruled out and detailed information on materials and landscaping.

The Council will expect developments to achieve a greenfield surface water run-off rate once SUDS have been installed. As a minimum, surface water run-off rates should be reduced by 50% across the development.

3.4.8. Adapting to Climate Change

KEY MESSAGE

All development should consider how it can be occupied in the future when the weather will be different

The early design stage is the most effective time to incorporate relevant design and technological measures.

WHAT WILL THE COUNCIL EXPECT?

All development is expected to consider the impact of climate change and be designed to cope with the anticipated conditions.

3.4.9. Biodiversity

KEY MESSAGES

Proposals should demonstrate:

- how biodiversity considerations have been incorporated into the development;
- if any mitigation measures will be included; and
- what positive measures for enhancing biodiversity are planned.

3.4.10. Local Food Growing

KEY MESSAGES

We encourage food to be grown wherever possible and suitable

Rooftops and shared spaces such as gardens and parks provide opportunities for food growing

Appendix B – Building Usage Templates

Appendix B – Building Usage Templates

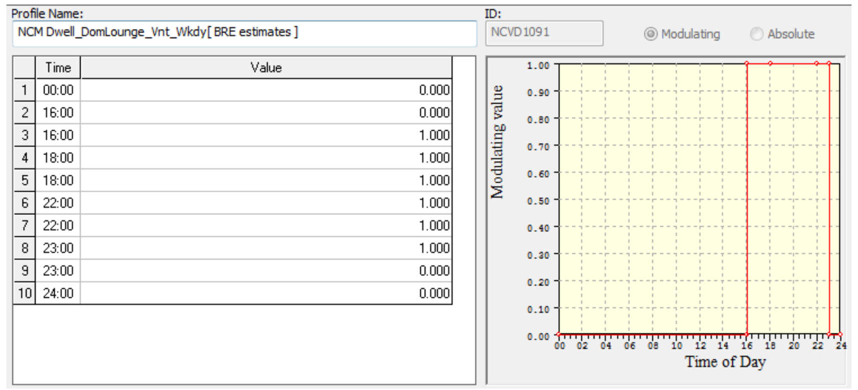


Figure 1: Occupancy Profile-Lounge Weekday

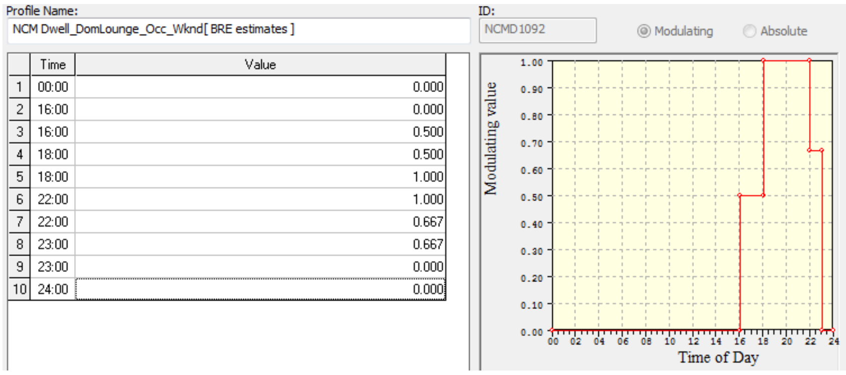


Figure 2: Occupancy Profile-Lounge Weekend

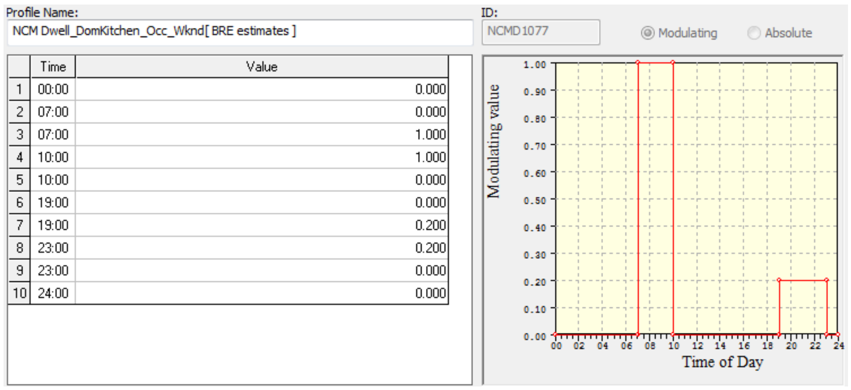


Figure 3: Occupancy Profile-Kitchen Weekday/Weekend

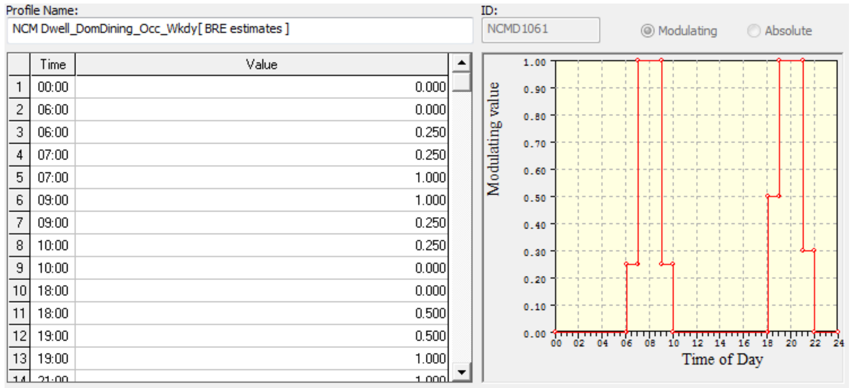


Figure 4: Occupancy Profile-Dining Weekday/Weekend

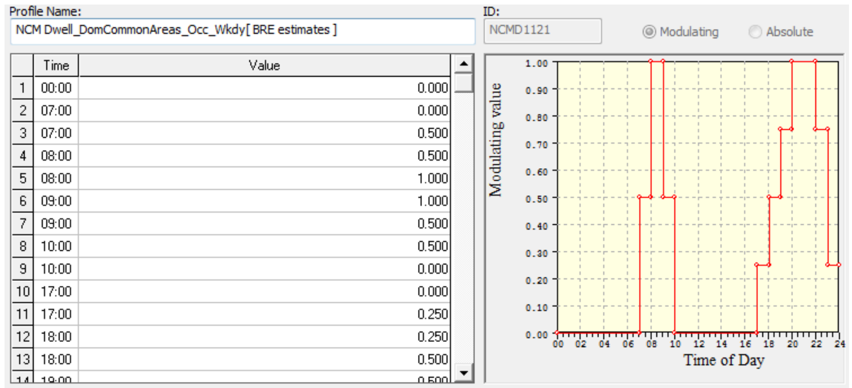


Figure 5: Occupancy Profile-Common Areas Weekday

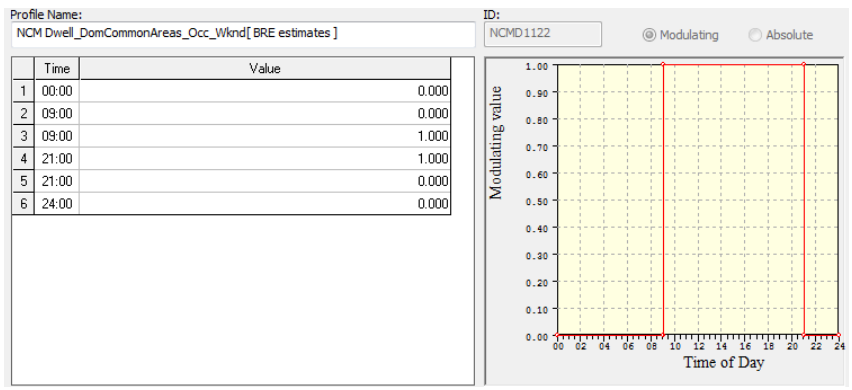


Figure 6: Occupancy Profile-Common Areas Weekend

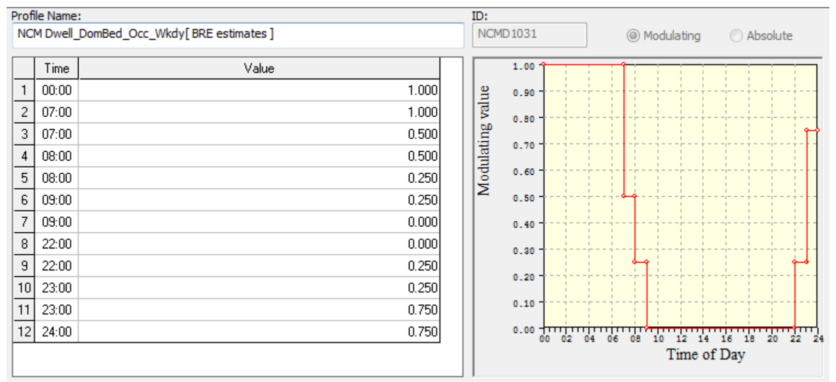


Figure 7: Occupancy Profile-Bedrooms Weekday/Weekend

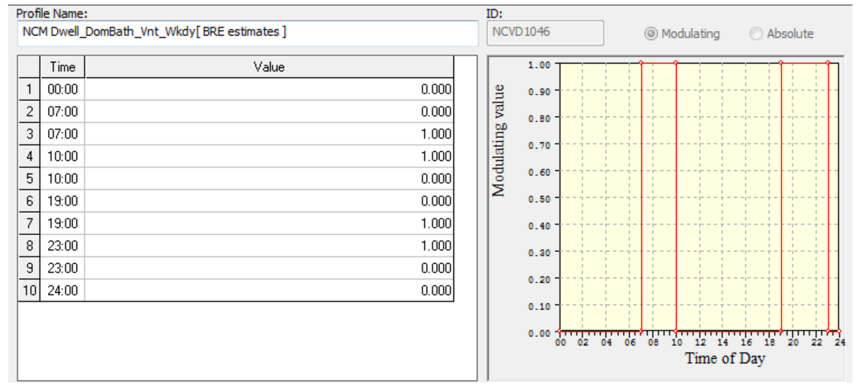


Figure 8: Occupancy Profile-Bathrooms Weekday/Weekend

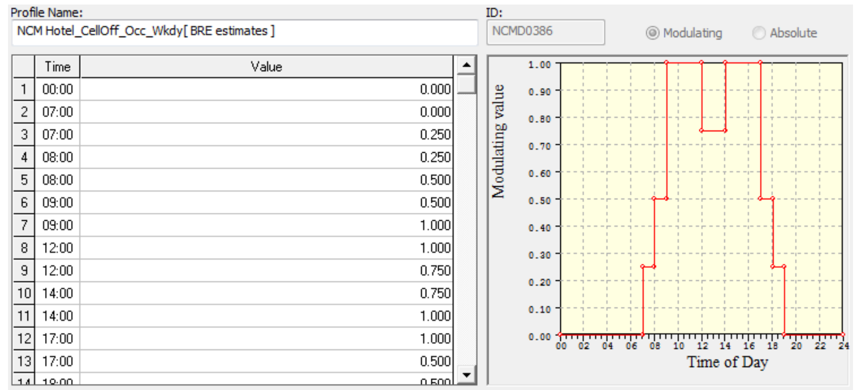


Figure 9: Occupancy Profile-Office Space Weekday/Weekend

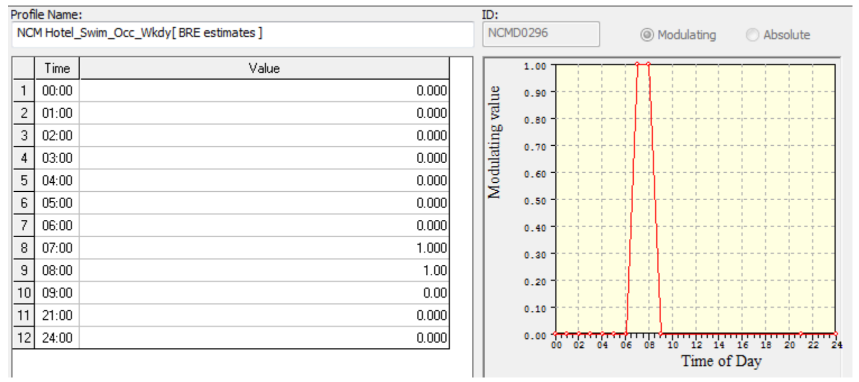


Figure 10: Occupancy Profile – Swimming Pool Weekday

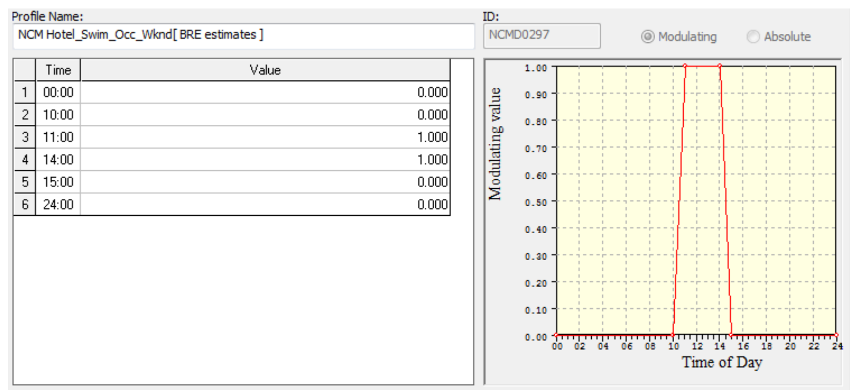


Figure 11: Occupancy Profile Swimming Pool Weekend

Appendix C – SAP Worksheets

Appendix C – SAP Worksheets

(Full worksheets available on request)

Baseline

SAP 2012 worksheet for notional dwelling - calculation of target emissions

2. Ventilation rate

	main + seondary + other heating		m³ per hour	
Number of chimneys	0 + 0 + 0	x 40	0.00	(6a)
Number of open flues	0 + 0 + 0	x 20	0.00	(6b)
Number of intermittent fans	4	x 10	40.00	(7a)
Number of passive vents	0	x 10	0.00	(7b)
Number of flueless gas fires	0	x 40	0.00	(7c)

		Air changes per hour	
Infiltration due to chimneys, fans and flues		0.01	(8)
Pressure test, result q50	5.00		(17)
Air permeability		0.26	(18)
Number of sides on which sheltered		3.00	(19)
Shelter factor		0.78	(20)
Infiltration rate incorporating shelter factor		0.20	(21)

Infiltration rate modified for monthly wind speed

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.10	5.00	4.90	4.40	4.30	3.80	3.80	3.70	4.00	4.30	4.50	4.70

52.50 (22)

Wind Factor

1.27	1.25	1.23	1.10	1.08	0.95	0.95	0.93	1.00	1.08	1.13	1.18

13.13 (22a)

Adjusted infiltration rate (allowing for shelter and wind speed)

0.25	0.25	0.24	0.22	0.21	0.19	0.19	0.18	0.20	0.21	0.22	0.23

2.61 (22b)

Ventilation : natural ventilation, intermittent extract fans

Effective air change rate

0.53	0.53	0.53	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.53	0.53

(25)

12a. Carbon dioxide emissions

	Energy kWh/year	Emission factor kg CO2/kWh	Emissions kg CO2/year	
Space heating, main system 1	104733.61	0.216	22622.46	(261)
Space heating, main system 2	0.00	0.000	0.00	(262)
Space heating, secondary	0.00	0.519	0.00	(263)
Water heating	3537.05	0.216	764.00	(264)
Space and water heating			23386.46	(265)
Electricity for pumps and fans	75.00	0.519	38.93	(267)
Electricity for lighting	2466.56	0.519	1280.14	(268)
Electricity generated - PVs	0.00	0.519	0.00	(269)
Electricity generated - µCHP	0.00	0.000	0.00	(269)
Appendix Q -				
Energy saved ():	0.00	0.000	0.00	(270)
Energy used ():	0.00	0.000	0.00	(271)
Total CO2, kg/year			24705.53	(272)

	kg/m²/year	
Emissions per m² for space and water heating	**12.57**	(272a)
Emissions per m² for lighting	**0.69**	(272b)
Emissions per m² for pumps and fans	**0.02**	(272c)
Target Carbon Dioxide Emission Rate (TER)	**13.28**	(273)

= (12.5699 x 1.00) + 0.6881 + 0.0209

Lean

SAP 2012 worksheet for New dwelling as designed - calculation of dwelling emissions

2. Ventilation rate

	main + seondary + other heating		m³ per hour	
Number of chimneys	0 + 0 + 0	x 40	0.00	(6a)
Number of open flues	0 + 0 + 0	x 20	0.00	(6b)
Number of intermittent fans	0	x 10	0.00	(7a)
Number of passive vents	0	x 10	0.00	(7b)
Number of flueless gas fires	0	x 40	0.00	(7c)

		Air changes per hour	
Infiltration due to chimneys, fans and flues		0.00	(8)
Pressure test, result q50	3.00		(17)
Air permeability		0.15	(18)
Number of sides on which sheltered		2.00	(19)
Shelter factor		0.85	(20)
Infiltration rate incorporating shelter factor		0.13	(21)

Infiltration rate modified for monthly wind speed

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.10	5.00	4.90	4.40	4.30	3.80	3.80	3.70	4.00	4.30	4.50	4.70

52.50 (22)

Wind Factor

1.27	1.25	1.23	1.10	1.08	0.95	0.95	0.93	1.00	1.08	1.13	1.18

13.13 (22a)

Adjusted infiltration rate (allowing for shelter and wind speed)

0.16	0.16	0.16	0.14	0.14	0.12	0.12	0.12	0.13	0.14	0.14	0.15

1.67 (22b)

air change rate through system	0.50	(23a)
efficiency in % allowing for in-use factor	72.25	(23c)

Ventilation : balanced whole house mechanical with heat recovery

Effective air change rate

0.30	0.30	0.29	0.28	0.28	0.26	0.26	0.26	0.27	0.28	0.28	0.29

(25)

12a. Carbon dioxide emissions

	Energy kWh/year	Emission factor kg CO2/kWh	Emissions kg CO2/year	
Space heating, main system 1	58700.69	0.216	12679.35	(261)
Space heating, main system 2	0.00	0.000	0.00	(262)
Space heating, secondary	0.00	0.519	0.00	(263)
Water heating	3928.40	0.216	848.54	(264)
Space and water heating			13527.89	(265)
Electricity for pumps and fans	12508.05	0.519	6491.68	(267)
Electricity for lighting	2395.65	0.519	1243.34	(268)
Electricity generated - PVs	0.00	0.519	0.00	(269)
Electricity generated - µCHP	0.00	0.000	0.00	(269)
Appendix Q -				
Energy saved ():	0.00	0.000	0.00	(270)
Energy used ():	0.00	0.000	0.00	(271)
Total CO2, kg/year			21262.91	(272)

	kg/m²/year	
Dwelling Carbon Dioxide Emission Rate (DER)	**11.43**	(273)

Clean CHP

SAP 2012 worksheet for New dwelling as designed - calculation of dwelling emissions

2. Ventilation rate

	main + seondary + other heating		m³ per hour	
Number of chimneys	0 + 0 + 0	x 40	0.00	(6a)
Number of open flues	0 + 0 + 0	x 20	0.00	(6b)
Number of intermittent fans	0	x 10	0.00	(7a)
Number of passive vents	0	x 10	0.00	(7b)
Number of flueless gas fires	0	x 40	0.00	(7c)

		Air changes per hour	
Infiltration due to chimneys, fans and flues		0.00	(8)
Pressure test, result q50	3.00		(17)
Air permeability		0.15	(18)
Number of sides on which sheltered		2.00	(19)
Shelter factor		0.85	(20)
Infiltration rate incorporating shelter factor		0.13	(21)

Infiltration rate modified for monthly wind speed

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.10	5.00	4.90	4.40	4.30	3.80	3.80	3.70	4.00	4.30	4.50	4.70

52.50 (22)

Wind Factor

1.27	1.25	1.23	1.10	1.08	0.95	0.95	0.93	1.00	1.08	1.13	1.18

13.13 (22a)

Adjusted infiltration rate (allowing for shelter and wind speed)

0.16	0.16	0.16	0.14	0.14	0.12	0.12	0.12	0.13	0.14	0.14	0.15

1.67 (22b)

air change rate through system	0.50	(23a)
efficiency in % allowing for in-use factor	72.25	(23c)

Ventilation : balanced whole house mechanical with heat recovery

Effective air change rate

0.30	0.30	0.29	0.28	0.28	0.26	0.26	0.26	0.27	0.28	0.28	0.29

(25)

12a. Carbon dioxide emissions

	Energy kWh/year	Emission factor kg CO2/kWh	Emissions kg CO2/year	
Space heating, main system 1	58609.12	0.216	12659.57	(261)
Space heating, main system 2	0.00	0.000	0.00	(262)
Space heating, secondary	5863.87	0.519	3043.35	(263)
Water heating	0.00	0.216	0.00	(264)
Space and water heating			15702.92	(265)
Electricity for pumps and fans	12463.05	0.519	6468.32	(267)
Electricity for lighting	2395.65	0.519	1243.34	(268)
Electricity generated - PVs	0.00	0.519	0.00	(269)
Electricity generated - µCHP	-2811.09	0.519	-1458.96	(269)
Appendix Q -				
Energy saved ():	0.00	0.000	0.00	(270)
Energy used ():	0.00	0.000	0.00	(271)
Total CO2, kg/year			21955.63	(272)

	kg/m²/year	
Dwelling Carbon Dioxide Emission Rate (DER)	**11.80**	(273)

Green GSHP

SAP 2012 worksheet for New dwelling as designed - calculation of dwelling emissions

2. Ventilation rate

	main + seondary + other heating		m³ per hour	
Number of chimneys	0 + 0 + 0	x 40	0.00	(6a)
Number of open flues	0 + 0 + 0	x 20	0.00	(6b)
Number of intermittent fans	0	x 10	0.00	(7a)
Number of passive vents	0	x 10	0.00	(7b)
Number of flueless gas fires	0	x 40	0.00	(7c)

		Air changes per hour	
Infiltration due to chimneys, fans and flues		0.00	(8)
Pressure test, result q50	3.00		(17)
Air permeability		0.15	(18)
Number of sides on which sheltered		2.00	(19)
Shelter factor		0.85	(20)
Infiltration rate incorporating shelter factor		0.13	(21)

Infiltration rate modified for monthly wind speed

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.10	5.00	4.90	4.40	4.30	3.80	3.80	3.70	4.00	4.30	4.50	4.70

52.50 (22)

Wind Factor

1.27	1.25	1.23	1.10	1.08	0.95	0.95	0.93	1.00	1.08	1.13	1.18

13.13 (22a)

Adjusted infiltration rate (allowing for shelter and wind speed)

0.16	0.16	0.16	0.14	0.14	0.12	0.12	0.12	0.13	0.14	0.14	0.15

1.67 (22b)

air change rate through system 0.50 (23a)
efficiency in % allowing for in-use factor 72.25 (23c)
Ventilation : balanced whole house mechanical with heat recovery
Effective air change rate

0.30	0.30	0.29	0.28	0.28	0.26	0.26	0.26	0.27	0.28	0.28	0.29

(25)

12a. Carbon dioxide emissions

	Energy kWh/year	Emission factor kg CO2/kWh	Emissions kg CO2/year	
Space heating, main system 1	29360.84	0.216	6341.94	(261)
Space heating, main system 2	12207.51	0.519	6335.70	(262)
Space heating, secondary	0.00	0.519	0.00	(263)
Water heating	3666.14	0.216	791.89	(264)
Space and water heating			13469.53	(265)
Electricity for pumps and fans	10380.86	0.519	5387.67	(267)
Electricity for lighting	2395.65	0.519	1243.34	(268)
Electricity generated - PVs	0.00	0.519	0.00	(269)
Electricity generated - µCHP	0.00	0.000	0.00	(269)
Appendix Q -				
Energy saved ():	0.00	0.000	0.00	(270)
Energy used ():	0.00	0.000	0.00	(271)
Total CO2, kg/year			20100.54	(272)
			kg/m²/year	
Dwelling Carbon Dioxide Emission Rate (DER)			**10.80**	(273)

Green PVs

SAP 2012 worksheet for New dwelling as designed - calculation of dwelling emissions

2. Ventilation rate

	main + seondary + other heating		m³ per hour	
Number of chimneys	0 + 0 + 0	x 40	0.00	(6a)
Number of open flues	0 + 0 + 0	x 20	0.00	(6b)
Number of intermittent fans	0	x 10	0.00	(7a)
Number of passive vents	0	x 10	0.00	(7b)
Number of flueless gas fires	0	x 40	0.00	(7c)

		Air changes per hour	
Infiltration due to chimneys, fans and flues		0.00	(8)
Pressure test, result q50	3.00		(17)
Air permeability		0.15	(18)
Number of sides on which sheltered		2.00	(19)
Shelter factor		0.85	(20)
Infiltration rate incorporating shelter factor		0.13	(21)

Infiltration rate modified for monthly wind speed

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.10	5.00	4.90	4.40	4.30	3.80	3.80	3.70	4.00	4.30	4.50	4.70

52.50 (22)

Wind Factor

1.27	1.25	1.23	1.10	1.08	0.95	0.95	0.93	1.00	1.08	1.13	1.18

13.13 (22a)

Adjusted infiltration rate (allowing for shelter and wind speed)

0.16	0.16	0.16	0.14	0.14	0.12	0.12	0.12	0.13	0.14	0.14	0.15

1.67 (22b)

air change rate through system 0.50 (23a)
efficiency in % allowing for in-use factor 72.25 (23c)
Ventilation : balanced whole house mechanical with heat recovery
Effective air change rate

0.30	0.30	0.29	0.28	0.28	0.26	0.26	0.26	0.27	0.28	0.28	0.29

(25)

12a. Carbon dioxide emissions

	Energy kWh/year	Emission factor kg CO2/kWh	Emissions kg CO2/year	
Space heating, main system 1	58700.69	0.216	12679.35	(261)
Space heating, main system 2	0.00	0.000	0.00	(262)
Space heating, secondary	0.00	0.519	0.00	(263)
Water heating	3928.40	0.216	848.54	(264)
Space and water heating			13527.89	(265)
Electricity for pumps and fans	10250.86	0.519	5320.20	(267)
Electricity for lighting	2395.65	0.519	1243.34	(268)
Electricity generated - PVs	-9829.64	0.519	-5101.58	(269)
Electricity generated - µCHP	0.00	0.000	0.00	(269)
Appendix Q -				
Energy saved ():	0.00	0.000	0.00	(270)
Energy used ():	0.00	0.000	0.00	(271)
Total CO2, kg/year			14989.84	(272)
			kg/m²/year	
Dwelling Carbon Dioxide Emission Rate (DER)			**8.06**	(273)

Lean + Green (PVs & GSHP)

2. Ventilation rate

	main + seondary + other heating		m³ per hour	
Number of chimneys	0 + 0 + 0	x 40	0.00	(6a)
Number of open flues	0 + 0 + 0	x 20	0.00	(6b)
Number of intermittent fans	0	x 10	0.00	(7a)
Number of passive vents	0	x 10	0.00	(7b)
Number of flueless gas fires	0	x 40	0.00	(7c)

		Air changes per hour	
Infiltration due to chimneys, fans and flues		0.00	(8)
Pressure test, result q50	3.00		(17)
Air permeability		0.15	(18)
Number of sides on which sheltered		2.00	(19)
Shelter factor		0.85	(20)
Infiltration rate incorporating shelter factor		0.13	(21)

Infiltration rate modified for monthly wind speed

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.10	5.00	4.90	4.40	4.30	3.80	3.80	3.70	4.00	4.30	4.50	4.70

52.50 (22)

Wind Factor

1.27	1.25	1.23	1.10	1.08	0.95	0.95	0.93	1.00	1.08	1.13	1.18

13.13 (22a)

Adjusted infiltration rate (allowing for shelter and wind speed)

0.16	0.16	0.16	0.14	0.14	0.12	0.12	0.12	0.13	0.14	0.14	0.15

1.67 (22b)

air change rate through system 0.50 (23a)
efficiency in % allowing for in-use factor 72.25 (23c)
Ventilation : balanced whole house mechanical with heat recovery
Effective air change rate

0.30	0.30	0.29	0.28	0.28	0.26	0.26	0.26	0.27	0.28	0.28	0.29

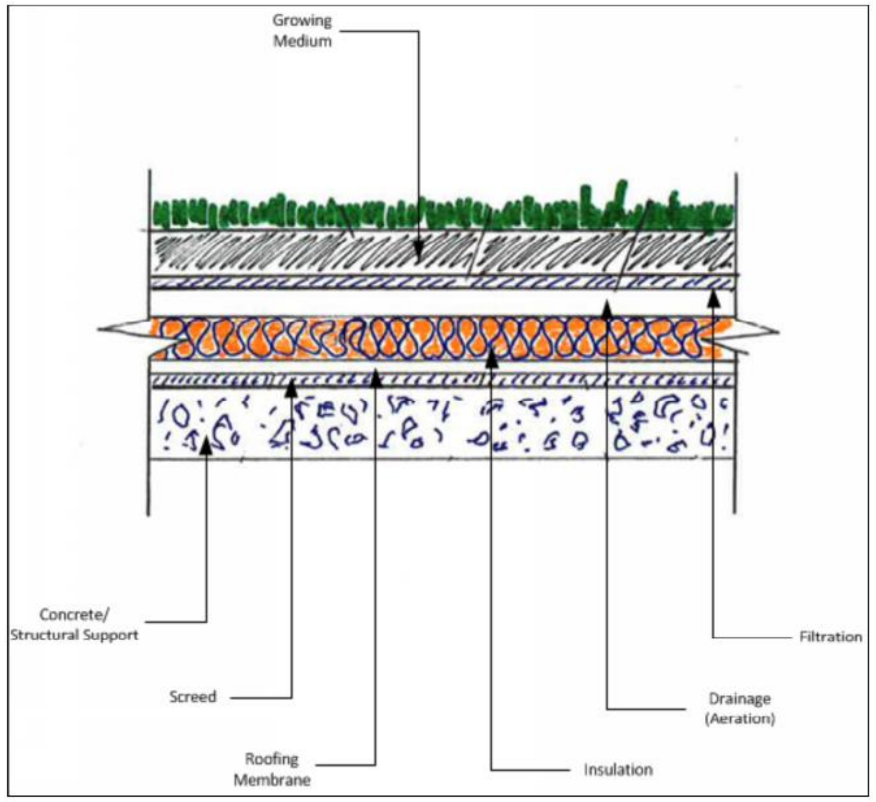
(25)

12a. Carbon dioxide emissions

	Energy kWh/year	Emission factor kg CO2/kWh	Emissions kg CO2/year	
Space heating, main system 1	58731.34	0.216	12685.97	(261)
Space heating, main system 2	0.00	0.000	0.00	(262)
Space heating, secondary	0.00	0.519	0.00	(263)
Water heating	3502.98	0.216	756.64	(264)
Space and water heating			13442.61	(265)
Electricity for pumps and fans	10380.86	0.519	5387.67	(267)
Electricity for lighting	2395.65	0.519	1243.34	(268)
Electricity generated - PVs	-9829.64	0.519	-5101.58	(269)
Electricity generated - µCHP	0.00	0.000	0.00	(269)
Appendix Q -				
Energy saved ():	0.00	0.000	0.00	(270)
Energy used ():	0.00	0.000	0.00	(271)
Total CO2, kg/year			14972.04	(272)
			kg/m²/year	
Dwelling Carbon Dioxide Emission Rate (DER)			**8.05**	(273)

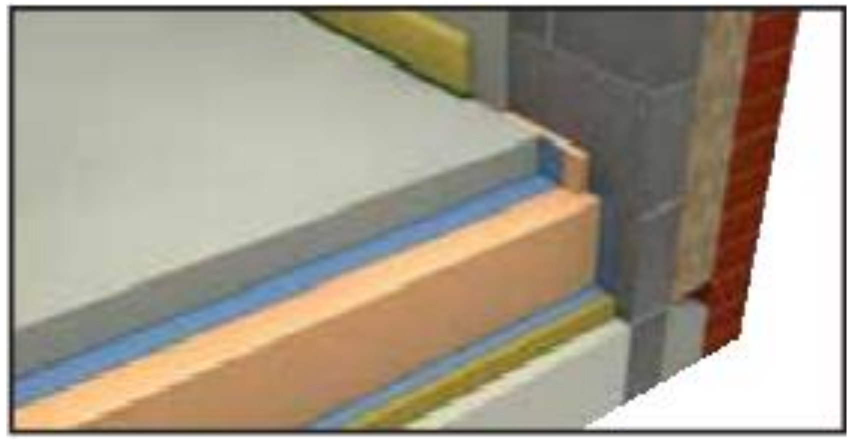
Appendix D – Building Fabric Constructions

Appendix D – Building Fabric Constructions

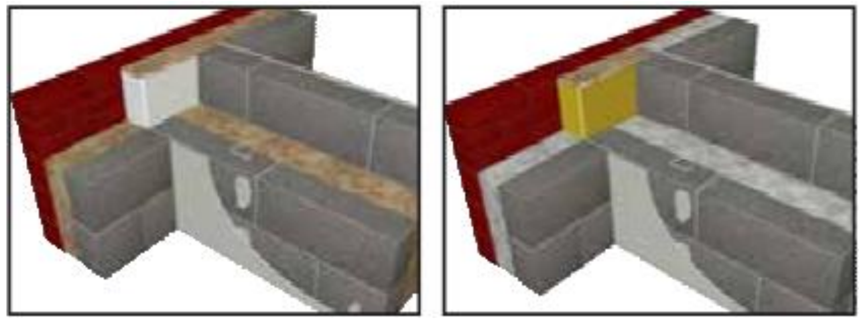


Green Roof Construction Example

Triple Glazing Example (Internorm) 0.7 U-Value



Ground bearing concrete floor (Knauf) 0.125 U-Value



Masonry Party Wall – fully filled (Knauf) Effective U-Value of Zero

Appendix E – Passivhaus

Appendix E - Passivhaus Principles Study

The basic principles of Passivhaus are:

- High levels of thermal insulation both for the opaque and transparent element
- Whole house mechanical ventilation with heat recovery
- Air tight construction
- Elimination of thermal bridges

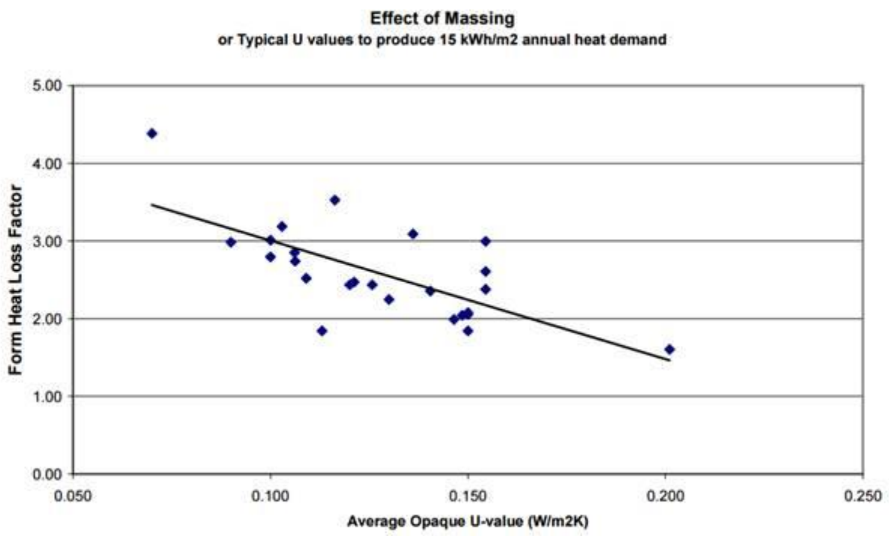
The proposed constructions for Frognal Way have U values equal or lower than the ones required for Passivhaus schemes. However, as it will be explained later this often is not adequate to meet Passivhaus targets which in terms of heating requirements is 15kWh/m^2/year.

Building Form

'Form Factor' is a figure that describes the relationship between the external surface area (A) and the internal Treated Floor Area (TFA). Values of heat loss Form Factors ≤3 is a useful benchmark for small Passivhaus buildings.

Buildings with complex form usually have an increased surface area for the same useful area which leads to additional insulation required to maintain the same heating demand with a building with same orientation and useful area but more compact form.

The graph below illustrates the relationship between heat loss form factor and average U values of the opaque elements of the building in order to meet the 15kWh/m^2 criterion which is required for passivhaus accreditation.



The calculated 'Form Factor' for Frognal way is 2 which in cases of small houses would mean that the Passivhaus standards would be achievable.

Another similar to the heat loss factor which is indicative of how easily passivaus standards can be met is the surface area to volume ration (A/V). A favourable compactness ration is considered to be one were the A/V ratio ≤ 0.7 m^2/m^3.

For Frognal Way this figure is 0.9, slightly higher than the benchmark value.

Despite the proposed U-Values being equivalent to Passivhaus standards, and the 'Form Factor' is lower than the benchmark value, the SAP analysis indicates that the energy required for heating is almost double than the 15kWh/m^2 threshold (29kWh/m^2).

It is envisaged that the main reasons for this is are the high proportion of glazed areas on the facades and the increased heat losses due to thermal bridges which are encountered at geometric junctions and connections between the elements. For Buildings with complex shape such as the proposed, the elimination of thermal bridges is difficult to be achieved.

Appendix F – Renewables

Appendix F – Renewables Optioneering

Technology	Design Considerations	Initial Feasibility Status		
Absorption cooling	High cooling load required.	Not suitable for Frognal Way as cooling may only be required in certain spaces e.g. Server Room and domestic load insufficient	✗	
Anaerobic Digestion	Need good supply of highly organic waste materials e.g. food waste, manure. Can collaborate with nearby farm / hotel waste if rural site. Location of large plant to be considered and deliveries / management regime.	Initial feasibility of current waste streams at Frognal Way indicated that system not viable. Solution not to be pursued due to site restrictions, high capital costs, long payback period and variability of waste streams across typical year. .	✗	
Biomass	Large areas of woodland on site can be used as fuel in conjunction with a tree station (chipper and storage for drying). Promotes management of woodland areas. Fuel storage space required for boiler – above or below ground.	Biomass resource and fuel deliveries may be prohibitive in London and at Frognal way. Fuel storage not currenly designed. This technology has a potential to achieve carbon savings however if wood burners with heat recovery to LTHW system are employed.	✗	
CHP	Requirement for a continual annual heat load to ensure Good Quality CHP installation (based on annual hours running time). Relatively large plant room requirement. District connected scheme to be explored – London Heat Map.	House has swimming pool and which would provide suitable base load for CHP system. Camden guidance refers to CHP as a key consideration before other renewable alternatives. No District Heating CHP scheme available. Stand-alone small scale application to be investigated but may not be feasible alongside other technologies. And unlikely to reach carbon target as sole LZCT.	✗	
Fuel cells	Technology is currently at very early stage of production and requires significant capital investment.	Potential for Frognal Way as small scale H2 only. For unregulated electrical loads Can be assessed at next stage.	✗	
Ground source systems – air	The Rehau Awadukt system provides useful savings for buildings which require high ventilation rates. Suitable where large area of ground works being undertaken close to new building.	Could be installed under new garden areas or around perimeter. Solution to be pursued for building.	✓	Carbon emissions offset: 2.79 tonnes CO_2/year 11% improvement over baseline emissions **NOTE**: The above figures based on a 25kW system. If a 35kW system is employed the above figures will be 3.9 tonnes CO_2/year and 19.5% improvement respectively.
Ground source systems – open loop heat pump	The Environment Agency rarely grant permission for proposals looking to withdraw and return to the local aquifer – closed loop preferable.	There appears to be various groundwater potential around. i.e. 200m from the proposed building; however the complexity and costs associated with permits are considered too great to pursue this option.	✗	
Ground source systems – closed loop heat pump (boreholes)	Boreholes typically 100-150m deep) Output: 3.6kW in clay, 6.6kW in saturated stone Area requirements: 9-10m grid for heating only. 6-7m grid for heating and cooling system. Must be integrated with the piling system design and programme.	A number of boreholes will be required across the site to make significant savings, which will involve high capital costs. Boreholes not considered. Energy /geothermal piles for new building could generate a proportion of required carbon reduction.	✓	From Site Analysis a geothermal Pile system could generate around 35kW heating energy. (COP 3.5 assumed)

	Output: 1-1.5kW per pile. Relatively small plant room space required.			
Ground source systems – closed loop heat pump (horizontal)	Similar plant considerations as above. Much larger ground area required compared to borehole system – quick comparison: vertical 500 W/m² / horizontal 30 W/m² of ground area. May lower ground temperatures over time, potentially damaging for plant life and grass unless used for cooling in summer months	As there are not extensive horizontal ground works planned at Frognal Way– other than driveway – it is unlikely horizontal closed loop GSHP could make significant carbon savings. This option could only be explored as a combination of technologies.	✗	
Air Source Heat Pump	Noise associated with systems to be considered. Gas and Electricity based systems commercially available. Beneficial in spaces where there is a heating load in summer months and cooling load in winter months, as reversible, with good COP in heating mode. Winter COPs to be considered.	Could be installed to serve specialist areas which require cooling in new building. Due to the issues with winter COP, and building load profile not considered appropriate.	✗	
Micro-Hydroelectric	Relatively large volume of water and sufficient head required for appropriate application. Large scale earthworks needed. The Environment Agency would likely need to be contacted for permission for proposals looking to withdraw and return to the local aquifer	Site has potential due to initial indications of high groundwater table and sloping site, however, small chance of application. Not currently considered unless ground/water report suggests otherwise.	✗	
Photovoltaics	Integration with other roof mounted plant to be considered. If applying to a green roof – lower ambient temperature can improve efficiency of panel. Can be façade/glazing mounted.	PV panels could be installed on various roofs on Frognal Way. Also potential for glazing integrated cells on the south façade clerestory windows.	✓	Carbon emissions offset: 5 tonnes CO_2/year 20% improvement over baseline emissions
Solar cooling	High cooling load required.	Not suitable for Frognal as cooling only required in specialist spaces e.g. server rooms.	✗	
Solar water heating	Suitable in areas with high hot water load e.g. sports facilities. Integration with other heat generating technology, e.g. biomass/CHP, which would also supply the base load hot water needs considering.	Likely to be a small amount of solar thermal included at new development The hot water use and the potential to connect to a hybrid heat station means this is a viable solution	✗	
Surface water cooling	High cooling load required.	Not suitable for Frognal as cooling only required in specialist spaces e.g. server room.	✗	
Wind (building mounted)	Studies (e.g. Warwick wind trials) have indicated that the wind resource for building mounted turbines is even lower than predictions due to effects of turbulence effects. Effects of vibrations on structure, visual impact and acoustics need considering. High visibility technology – aid as a teaching tool. Size of kit that accompanies turbine must	Average wind speed for the site is average/turbulent. Technology wouldn't integrate well due to urban environment and surrounding existing buildings. Visible impact would be detrimental to planning. Not acceptable.	✗	

	not be forgotten and accommodated in the plant room.			
Wind (stand alone)	Effects of visual impact and acoustics need considering. High visibility technology Kit that accompanies turbine must be accommodated in plant room.	Proximity to neighbouring buildings and residential areas may mean that noise and flicker are problematic. Wind speeds not appropriate for function. Council planning highly unlikely to accept a wind turbine due to visual impact. Not acceptable	✗	

PHOTOVOLTAICS

Photovoltaics (PV) generate electrical energy from sunlight. There are three main types of photovoltaic system available and some hybrid systems:

Monocrystalline Silicon Cells

- these are a single crystal of electronically pure silicon.
- they have high costs but also have a high efficiency (14 - 15%).
- these perform badly under part load and very badly if any part of the array becomes shaded.
- cost approx. £600-£700/m^2

Polycrystalline Cells

- these are formed from shards of silicon cells.
- these are still highly efficient but are cheaper than monocrystalline cells.
- 12 – 13% efficiency.
- these perform badly under part load and the output from the whole array is greatly reduced if any part of the array becomes shaded.
- cost approx. £500 - 600/m^2

Thin Film/Amorphous Cell

- these are formed by an amorphous layer of silicon being deposited on a substrate. This allows for the production of flexible/semi-transparent cells (solar transmittance is approx. 10%).
- their efficiency is the worst of the silicon PV cell types and is typically in the region of 5%.
- although their peak efficiencies are lower than the other two, the part load efficiency is good and shading only reduces the output on the part that is shaded.
- the yearly output is often the same as for the other two types depending on the site.
- can be used as shades to stop glare and overheating in place of brise soleil or expensive high performance glazing.
- These cells can be added to ETFE cushions
- cost approx. £400/m^2

The cost analysis currently shows that the payback of Monocrystalline cells is slightly more beneficial than the other types.

Inverters and protection devices are required to connect the PV panels to the building electrical distribution system. Any excess power may be transferred to the grid to generate extra income however it is not worth over sizing the system with this in mind as the price paid for exported power is considerably lower than the cost of imported power and the cost of the meter.

Advantages

- Produces clean (pollution free) renewable electrical energy
- High visibility, therefore excellent educational and PR value
- Once built the energy is virtually free.
- Mechanically simple, no moving parts, therefore low maintenance requirements and operating costs and long life
- Architecturally pleasing
- High public acceptance
- May offset the cost of roof or cladding
- Modular in nature so easy to size appropriately and extend
- Easy to integrate with battery storage
- Good safety record
- Can be integrated into new or existing buildings
- Attract Feed-in Tariffs

Disadvantages

- Need sunlight to work effectively, don't produce energy at night, and output reduced in overcast conditions
- Solar energy is not constant and is difficult to predict.
- May require planning permission in conservation areas (not applicable here)
- Risk of future overshadowing
- PV's cell produce DC electricity which must be converted to AC
- Efficiency drops as temperature rises
- Low-voltage output can be difficult to transmit
- Poor reliability of auxiliary (balance of system) components and storage devices.
- Long Paybacks as inefficient and still relatively expensive.
- Require large area compared to other technologies.
- Some materials used in the PV production process are toxic like cadmium and arsenic.
- Renewable technologies tend to require a high initial capital investment that often falls outside capital budgets.

Thin Film Panels installed on the Nation Trust HQ Building in Swindon

Thin Film Technology Integrated onto an ETFE roof

PV Cells laminated into glass panels and acting as a solar

Application

Both types of system perform best when located on an unshaded south facing rooftop inclined at approx 30deg. The chart below shows the effect of orientation and tilt on the peak output of a PV panel. This demonstrates the importance of the correct orientation for what is already a relatively inefficient technology.

Effect of orientation and tilt on percentage of peak output

		West	SW		South	SE		East
		270˚	240˚	210˚	180˚	150˚	120˚	90˚
Vertical	90˚	56	64	69	71	71	65	58
	80˚	63	72	77	80	79	74	65
	70˚	69	78	85	87	86	80	70
Roof	60˚	74	84	90	93	92	86	76
Pitch	50˚	78	88	95	97	96	89	80
[Deg]	40˚	82	90	97	100	98	92	84
	30˚	86	93	98	100	98	94	86
	20˚	87	93	97	98	97	94	88
	10˚	89	92	95	96	95	93	90
Horiz	0˚	90	90	90	90	90	90	90

Photovoltaic Option Summary

The figure opposite is based on the energy model results for the proposed building. The areas used take into account horizontal and vertical PVs as integrated to the building.

		Frognal Way
LZC Proportion	%	25%
Carbon Offset Required	kgCO2/yr	4,981
Size of Installation	kWp	17.0
Area of PV Required	m^2	119.9
Area of Roof Required	m^2	149.9
Proportion of Roof	%	-
Capital Cost	£	£ 47,156.11
Service Life	years	25
Feed in Tarrif	£/kWh	0.13
Annual Running Costs	£/year	£ 346.04
Cost Efficiency (Life)	£/kgCO2/yr	£ 9.47
Net Income over Life	£	£ 16,878.56
Payback	Years	18.3

GROUND SOURCE HEAT PUMPS

Ground Source Technologies

Introduction

Ground source heating involves extracting heat from the ground to heat the building, by circulating water through buried pipes. The length of the pipe depends on the buildings energy requirements.

The low grade heat extracted from the ground is passed through a heat pump, which provides high grade heat (in the form of hot water) to the building. The system can also be used in reverse to provide cooling in summer. By coupling the heat pump with the ground, a much higher Coefficient of Performance (COP) is achieved than the air coupled heat pumps commonly used in cooling systems.

The ground's temperature at around 2m deep remains at a steady 11°C. In the winter, this relatively high temperature can be taken advantage of as a heat source.

Heat pumps can be a very efficient way of obtaining heat. A typical COP is 3, which means for every kW of electricity used in the heat pump 3 kW of heat will be transferred to the building. The system must be designed to optimise the heat pump, best efficiencies for heat pumps are achieved when the difference in temperature between the heated water and the ground are lowest. Therefore heat pump technology is especially suited to low temperature heating systems such as under floor heating. A COP of 4 can be achieved where the required temperature is 35 deg, but drops to 3 where the required temperature is 45deg.

Types of Ground Source Array or Collector

There are four basic types of ground loop systems:

- Horizontal (slinky)
- Vertical
- Pond/Lake
- Open Loop

Three of these—horizontal, vertical, and pond/lake—are closed-loop systems. The fourth type of system is the open-loop option. Which one of these is best depends on the climate, soil conditions, available land, and local installation costs at the site. All of these approaches can be used for residential and commercial building applications.

The Advantages and Disadvantages

The advantages of ground source heat pumps include:

- Unobtrusive
- Despite using electricity (which has a higher carbon content than gas) their efficiency means that they are lower carbon emitters than gas boilers.
- There is the option of not providing gas or oil infrastructure to the building.
- If a reversible unit is used the heat pump can be used to provide both heating in the winter and cooling in the summer.
- The use of the low grade heat with either under-floor heating or warm air heaters mean that the plumbing is less obtrusive.

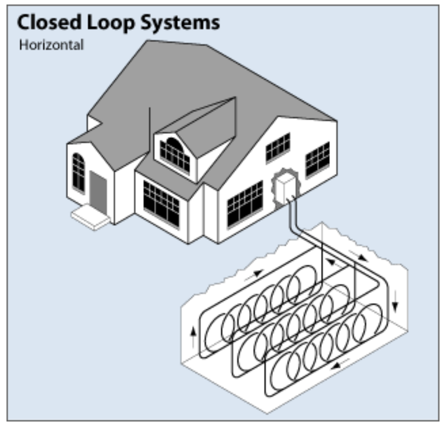
Disadvantages include:

- Low-grade heat is produced which means that heat emitters must be larger and hot water generation difficult.
- Requires electrical energy, which is rising in cost and thus this affects paybacks
- Storage vessel is required, to prevent heat pump cycling too often.
- They are complex pieces of machinery and maintenance engineers are not as readily available as with boilers
- Maintenance costs are higher than compared to boilers
- Water in closed loop circuits need to contain glycol which is a hazardous substance.
- They can be noisy.
- They are not very visible and thus have limited marketing potential.

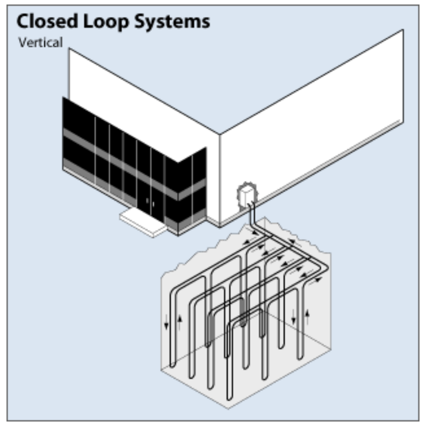
Picture of a Ground Source Heat Pump

Different Types of Ground Source Heat Types

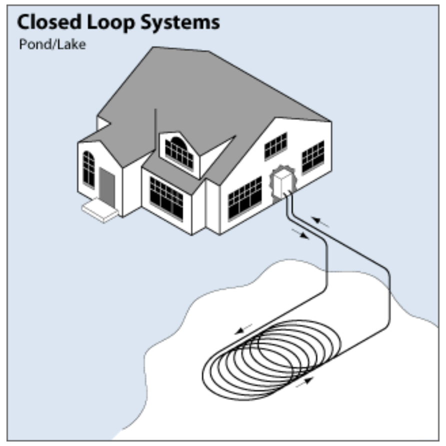
Geothermal Piles



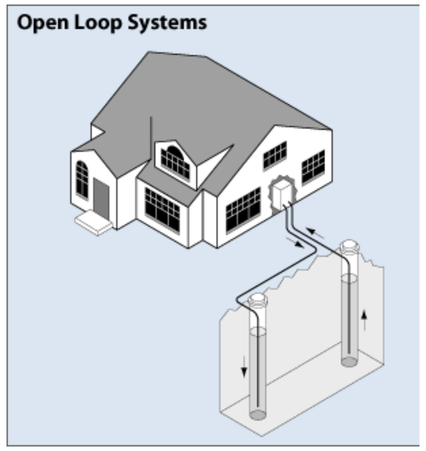
Horizontal (Slinky)



Vertical



Pond/lake



Open Loop

Ground and Surface Water

The environment agency maps show that there is not significant ground water in the area that would make an open loop ground source system viable.

Also no open surface water sources are available.

Therefore open loop and pond sources have been discounted.

Operation and Maintenance

Closed loop ground source heat pump systems use a water/glycol mix is used for the heat transfer medium. Some forms of glycol are toxic and care should be taken to specify a benign glycol mixture.

In order to install a ground loop, we show the Environment Agency that the construction of the ground loops will not result in contaminants from the surface soil layer reaching the water table. Having spoken to several ground loop installers though, we are confident that this will not present a significant obstacle.

Once the vertical ground pipes are installed, if there are any leaks detected, no remedial work is possible and the vertical pipe must be isolated to prevent further contamination. Such an action reduces the capacity of the installation.

Analysis

The analysis was undertaken for a horizontal slinky heat pump installation and a vertical closed loop borehole installation. The results of the analysis are summarised in the table opposite. Although a horizontal sinky pump installation seems to be a better option, the required area for the installation of 745 m^2, makes it not feasible for the site. A vertical closed loop borehole installation is an option if more renewable energy is required due to specific site ground conditions. The chosen application however for GSHP is with geothermal piles as the site constraints and conditions warrant this approach giving good energy output.

		Horizontal Slinkies	Vertical Piles
LZC Proportion	%	14%	14%
Carbon Offset	$kgCO_2/yr$	2,790	2,790
Area of Slinky or Number of 100m deep piles		745	4
Capital Cost	£	£ 24,845.45	£ 49,690.91
Service Life	years	0	0
Renewable Heat Incentive	£/kWh	£ 0.09	£ 0.09
Annual Running Costs	£/year	£ 649.40	£ 1,298.80
Cost Efficiency (Life)	£/$kgCO_2/yr$	£ 8.91	£ 17.81
Net Income over Life	£	£ 25,379.39	none
Payback	Years	11	never

Table 1: Analysis based on two types of ground source heat pumps

WIND TURBINES

Introduction

A wind turbine harnesses the power of the wind to produce electricity. The power of the wind is proportional to the cube of the wind speed thus higher wind speeds significantly increase the power output.

The turbine rotor converts linear air movement to rotation, which drives a generator. The most common rotor design is for three blades mounted on a horizontal axis but many types are available:

Types of Wind Turbines

Wind turbines are available in a wide range of sizes, from large 'wind-farm' scale turbines to small domestic roof-mounted versions. The output of a turbine is proportional to the area swept by the rotor, and therefore to the square of rotor diameter, so larger turbines can produce a lot more power.

Horizontal Axis Wind Turbines

Horizontal-axis wind turbines (HAWT) have the main rotor shaft and electrical generator at the top of a tower, and must be pointed into the wind. Small turbines are pointed by a simple wind vane, while large turbines generally use a wind sensor coupled with a servo motor. Most have a gearbox, which turns the slow rotation of the blades into a quicker rotation that is more suitable to drive an electrical generator.

Since a tower produces turbulence behind it, the turbine is usually pointed upwind of the tower. Turbine blades are made stiff to prevent the blades from being pushed into the tower by high winds. Additionally, the blades are placed a considerable distance in front of the tower and are sometimes tilted up a small amount.

Downwind machines have been built, despite the problem of turbulence, because they don't need an additional mechanism for keeping them in line with the wind, and because in high winds, the blades can be allowed to bend which reduces their swept area and thus their wind resistance. Since turbulence leads to fatigue failures, and reliability is so important, most HAWTs are upwind machines.

Vertical Axis Wind Turbines

Vertical-axis wind turbines (or VAWTs) have the main rotor shaft arranged vertically. Key advantages of this arrangement are that the turbine does not need to be pointed into the wind to be effective. This is an advantage on sites where the wind direction is highly variable. VAWTs can utilize winds from varying directions, and are thus able to deal with more turbulent conditions

The electricity generated can be used directly, stored in batteries or fed to the grid. The electricity may be sold to the grid when not used on site.

The safety requirements are laid out in document G83 for small-scale turbines and G59 for larger scale.

Advantages

- Produces clean (pollution free) renewable electrical energy
- High visibility, therefore excellent educational and PR value
- Its relatively abundant (UK one of the windiest countries in Europe), plus windier in winter when demand is higher.
- Good payback periods where wind exposure is high and consistent
- Once built the energy is virtually free.
- Wind turbines come in many sizes, from small domestic turbines to large commercial turbines.
- Requires smaller area in plan per kwh of energy produced compared to most other renewable technologies, but more area than traditional power stations.

Disadvantages

- Considered by some to have a negative visual impact.
- Require Planning permission
- Generate noise
- Require negotiations with wildlife groups (birds and insects)
- Wind energy is not constant and is difficult to predict. Also the storage of energy is difficult.
- Wind energy is often better in more remote locations and is less appropriate in urban environments.
- Turbines can cause slight electromagnetic interference that can affect television or radio signals and other communications equipment if within the line of sight.
- Wind turbines require specialist maintenance that can be costly.
- The rotation of the turbine blades can cause shadow flicker
- Renewable technologies tend to require a high initial capital investment that often falls outside capital based build projects.
- Although the probability is small, there is a risk of catastrophic failure

A Horizontal Axis Wind Turbine

Figure 1: Different types of Wind Turbines

Drawbacks that need to be addressed

In addition to the high visual impact of wind turbines (people tend to either love them or hate them), there are a number of issues that need to be addressed.

Planners should be approached to determine how they would be met on application for permission. The major areas of concern are with visual impact, noise output, implications to wild life groups and issues of reflected light and shadow flicker. Maintenance and management should also be addressed.

Building-integrated or free standing

In order to generate a useful amount of energy, a wind turbine must be mounted a significant height above the surrounding urban fabric. What this 'significant' height is depends on the scale of the surrounding buildings. On this site, a hub height of at least 30m is required to lift the turbines out of the shelter of surrounding trees and buildings.

The mast of a large turbine would be sufficiently tall to lift the hub above this level, and therefore a large turbine could be a free-standing structure, which avoids issues of transmitting vibration to the building fabric, and placing additional loads on the structure. Smaller turbines could also be mounted on free-standing masts, but it may make more sense economically and architecturally to mount them on top of the building and use shorter (15m) masts. In this case the structure would need to be designed to accommodate the additional load.

Noise

The level of noise produced by a turbine depends on the type of turbine and the speed of rotation. A detailed study will be carried out to accompany the planning application, using manufacturer's noise data.

Shadow flicker

When a turbine rotates, the blades cast an intermittent shadow that can be irritating if it crosses windows into dwellings or places of work. This is known as shadow flicker, and is only a problem for large turbines. The area affected depends on the local topography and time of year.

Electromagnetic Interference

Wind turbines can interfere with electromagnetic transmissions (radio, TV, mobile phone etc) if they are located within, or close to, the line of sight of the transmission.

Catastrophic failure

The potential consequences of catastrophic failure of a wind turbine (i.e. falling over or losing a blade) are clearly much more serious in an urban location than at a typical rural wind farm. However, the risk of such an accident is extremely small. It has been estimated that the risk of catastrophic failure of a turbine over its lifetime, if maintained properly, is 10-5 (1 in 100,000). Assuming a 20-year period of operation, the risk of failure in any single year is 5 x 10-7. To put this in context, this is the same as the risk of death from being struck by lightning in a single year, and orders of magnitude smaller than the risk of death by poisoning (1 x 10-5 in each year) and traffic accidents (1.3 x 10-4 in each year). We would minimise the risk of failure by selecting a turbine type that has no record of failure. According to ODPM's Planning Policy Statement 22 on renewable energy, all recorded accidents involving wind turbines have been as a result of failure to maintain and operate the machine in accordance with manufacturer's recommendations, and no accidents have ever involved a member of the public.

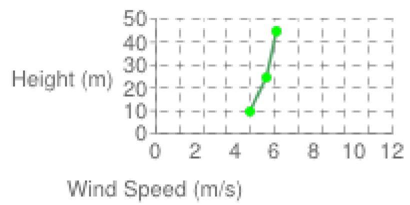
Specific Site Conditions

Determining the wind speed of the site is critical to the viability. The wind environment in cities is generally poor, with low average wind speeds and intense turbulence. A large-scale turbine in an urban context is expected to run at about 5% capacity factor, whereas a turbine in a commercial wind farm would be at more like 30%.

Interference from ground obstructions is reduced with height and as a result the average wind speed on a site increases with height.

The only definitive method to determine the wind speed on site is to collect real time information. Where impractical to gather real time data, the NOABL wind speed database (www.bwea.org.uk) provides average wind speed data for co-ordinate points. The NOABL wind speed for this site is outlined below, but the actual wind speed will depend of the topology of the chosen site.

Height Above Ground	Wind Speed
At 10 meters	4.8 m/s 10.7 mph
At 25 meters	5.6 m/s 12.5 mph
At 45 meters	6.1 m/s 13.6 mph



The wind speed data for the site suggests that the wind speeds are not higher than average and therefore no specific benefit would be gained by adopting wind turbine technology over other technology.

Locating a Turbine on the Site

Planners often apply a rule of thumb to wind turbines that state that small wind turbines, should not be located within 100m of a residential property and large commercial wind turbines should not be located within 450m. No part of the site is more than 100m from a residential property therefore wind is not deemed suitable for this site.

Analysis - Turbine Options

The power available in the wind, for conversion by the turbine, is proportional to the swept area of the blades and the wind speed cubed. How much of this energy can actually be converted into electricity depends on the turbine itself. There is a theoretical upper limit on turbine efficiency (known as the Betz limit) of 59% of the energy that flows through the rotor area, regardless of turbine type. Recent research has shown that a propeller-type horizontal axis turbine can at best extract 30% of the wind's energy, whereas a vertical axis helical-type turbine can in theory extract up to 35%.

In practice however, commercially-available turbines do not achieve these efficiencies even in ideal conditions – 10-20% is more usual. There is no general rule that horizontal axis turbines perform better than vertical, or vice versa. The output depends on the geometry and construction of the turbine, and manufacturers data must be used to assess the likely performance of any particular model of turbine in a given wind environment.

Vertical axis turbines have been around for some time, but have not seen as much commercial development as the horizontal axis turbine. As a result, the vertical axis turbine designs are not as standardised as horizontal axis models. Manufacturers of vertical axis wind turbines claim that they are better suited to the urban environment, because they are less affected by turbulence, and generate less noise due to lower blade tip speeds. While these claims seem reasonable (at least with regard to the noise and influence of changing wind direction), they are largely unproven because the first commercially-available vertical axis turbines for the urban environment are only just emerging on the market. In addition, VAWTs are relatively inefficient compared to HAWTs.

We have carried out this assessment using three Wind Turbines with outputs of 11kW, 6kW and 8.5kW.

This option looks attractive but usually presents a planning risk and needs to be tested against real wind speed data.

The table below summarises the results of the analysis based on two horizontal turbines and a vertical turbine.

		Gaia 11kW	Proven 6kW	Quiet Rev 8.5kW
LZC Proportion	%	63%	21%	11%
Carbon Offset	kgCO2/yr	12,550	4,267	2,108
Capital Cost	£	£ 60,000.00	£ 25,000.00	£ 40,000.00
Service Life	years	20	20	20
Feed in Tarrif	£/kWh	£ 0.22	£ 0.22	£ 0.22
Annual Running Costs	£/year	£ 3,000.00	£ 3,000.00	£ 3,000.00
Cost Efficiency (Life)	£/kgCO2/yr	£ 4.78	£ 5.86	£ 18.97
Net Income over Life	£	£ 71,744.21	£ 106,744.21	£ 91,744.21
Payback	Years	10.7	4.9	7.5

Table 2: Analysis based on three types of wind turbines based on average wind speeds of 5.25 m/s

SOLAR THERMAL

Introduction

Solar thermal collectors use heat from the sun to warm up water, thus helping provide hot water for the building.

A conventional system uses a mains powered circulation pump to couple a hot water storage tank with the solar panels. The storage tank is placed inside the building, and thus requires a controller that measures when the water is hotter in the panels than in the tank.

Types of Solar Thermal Panels
There are two types of Solar Thermal Water Heating Panels:

Evacuated Tubes
Evacuated tube collectors are made of a series of modular tubes, mounted in parallel, whose number can be added to or reduced as hot water delivery needs change. This type of collector consists of rows of parallel transparent glass tubes, each of which contains an absorber tube (in place of the absorber plate to which metal tubes are attached in a flat-plate collector). The tubes are covered with a special light-modulating coating. In an evacuated tube collector, sunlight passing through an outer glass tube heats the absorber tube contained within it.

Evacuated tube panels are generally more expensive but suffer less with heat loses and are less effected by some parts of the panel being shaded and are therefore more efficient.

Panel Collectors

A flat plate collector consists of a thin absorber sheet (of thermally stable polymers, aluminium, steel or copper, to which a black or selective coating is applied) backed by a grid or coil of fluid tubing and placed in an insulated casing with a glass or polycarbonate cover.

The Advantages and Disadvantages

The advantages of solar thermal include:

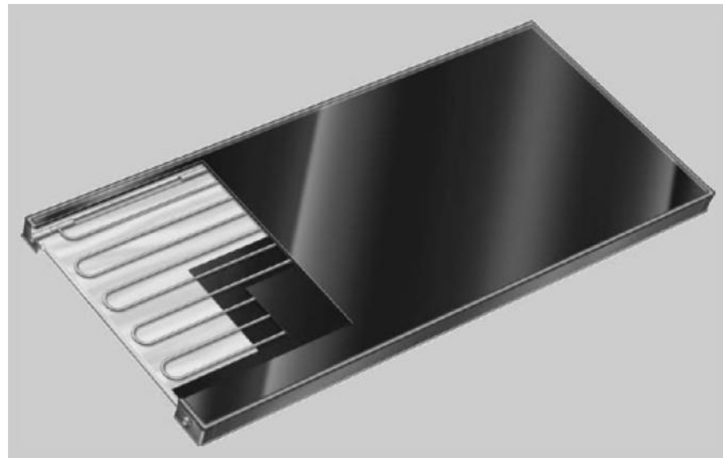
- Produces clean (pollution free) renewable heat energy
- High visibility, therefore excellent educational and PR value
- Once built the energy is virtually free.
- Low maintenance and operating costs
- High public acceptance
- Unobtrusive plumbing
- May offset the cost of roof or cladding
- Modular in nature so easy to size appropriately and extend
- Good safety record
- Can be integrated into new or existing buildings

Disadvantages include:

- Need sunlight to work effectively, don't produce energy at night, and output reduced in overcast conditions
- Solar energy is not constant and is difficult to predict.
- May require planning permission in conservation areas (not applicable here)
- Risk of future overshadowing
- Low grade heat produced
- Water may require softening
- Requires an electrical pump
- Storage is required, as solar source does not often match hot water requirement
- Limited by Hot Water demand in Summer
- Does not like being unused in summer.
- Require large area compared to other technologies.
- Renewable technologies tend to require a high initial capital investment that often falls outside capital budgets.

Different Types of Solar Thermal Panel

Evacuated Solar Tube Collector



Flat Panel Solar Collector

Application

As with PVs, both types of system perform best when located on an unshaded south facing rooftop inclined at approx 30-40 deg.

The Analysis

The amount of solar thermal that can be incorporated into the scheme is a function of the hot water load.

The predicted carbon emissions related to domestic hot water production have been estimated to 728 kg CO_2/year. Consequently, the maximum offset that can be achieved assuming a utilization factor of 40% is about 1.5% which equates to 291.1 kgCO_2/year. This along with the aesthetic of building mounted solar thermal make this technology unsuitable for the site.

The cost and life cycle costs of the system have led to the conclusion that solar thermal technologies are not the most attractive technology available for this application.

Analysis based on Flat Panel Collector

LZC Proportion	%	1.5%
Carbon Offset Required	kgCO2/yr	728
Area of Solar Thermal Required	m²	10
Area of Roof Required	m²	12
Capital Cost	£	£8,000
Service Life	years	20
Renewable Heat Incentive	£/kWh	0.10
Annual Running Costs	£/year	£310
Cost Efficiency (Life)	£/kgCO2/yr	1.89
Net Income over Life	£	£43,247
Payback	Years	4

AIR SOURCE HEAT PUMPS

Introduction

Air-source heat pumps are similar in operation to ground-source heat pumps, except that heat is extracted from the external air rather than the ground. Air-source heat pumps are classified as either air-to-air or air-to-water depending on whether the heat distribution system in the building uses air or water.

. It can extract heat from the air even when the outside temperature is as low as minus 15° C. Heat pumps have some impact on the environment as they need electricity to run, but the heat they extract from the air is constantly being renewed naturally.

Unlike gas boilers, heat pumps deliver heat at lower temperatures over much longer periods. This means that during the winter they may need to be left on longer to work efficiently.

Types of Air Source Heat Pump

There are two main types of air source heat pump system:

- An air-to-water system distributes heat via the wet central heating system. Heat pumps work much more efficiently at a lower temperature than a standard boiler system would. So they are more suitable for underfloor heating systems or larger radiators, which give out heat at lower temperatures over longer periods of time.
- An air-to-air system produces warm air which is circulated by fans to heat. They will not provide hot water as well.

Heat from the air is absorbed into a fluid which is pumped through a heat exchanger in the heat pump. Low grade heat is then extracted by the refrigeration system and, after passing through the heat pump compressor, is concentrated into a higher temperature useful heat capable of heating water for the heating and hot water circuits. For cooling, this cycle works in reverse.

Advantages and Disadvantages

The advantages of air source heat pumps include:

- Much cheaper option than ground source
- Provides cooling as well as heating. This makes the system much more efficient.
- Less risky than ground source systems
- No gas supply required
- No ground works required
- No local emissions
- Relatively long life

The disadvantages include:

- COP must be 3 or better to be more efficient than a gas boiler. This means the external temperature needs to be above 10 degC which only occurs 15% of the occupied period during the heating season (resultant COP for calculations is 2.3)
- Can be noise issues
- Lower rates on the RHI as it can barely be regarded as a renewable
- Uses significant amounts of electric if not operating at optimum conditions
- More suited to smaller installations where smaller loads and lower flow temperatures are acceptable
- Not well suited to AHU heating/cooling which requires high grade heat/coolth
- They are complex pieces of machinery and maintenance engineers are not as readily available as with boilers
- Storage vessel often required, to prevent heat pump cycling too often
- Often does not meet Planning requirements for carbon saving.

Performance issues

A potential downside of using air as a heat source is the heat pump's coefficient of performance (COP). During the heating season the outside air temperature is often less than the ground temperature (at a depth at which heat is extracted by a ground-source heat pump). This lower temperature has the effect of reducing the COP.

Some manufacturers of air-source heat pumps quote COPs of four or more, but this data should be treated with caution. The relevant test standard for most packaged heat pumps is BS EN 14511. For an air-to-water heat pump the standard specifies test conditions of 7°C outdoor air temperature (source temperature). At external air temperatures lower than this, the COP will fall, as will the heating output of the heat pump. Depending on the application this reduction may be significant, such as during a cold winter morning when building pre-heat is needed.

A further factor influencing the COP of a heat pump is the sink temperature (the temperature of the supplied heated air or circulated water within the building). For an air-to-water heat pump BS EN 14511 specifies a return and flow temperature of 40oC and 45oC respectively.

At temperatures higher than these the COP (and heat output) will fall. This means that heat pumps, although potentially suited to low temperature heating systems (such as underfloor heating), have poor COPs when used with conventional hydronic heating systems with high circulation temperatures, such as 60oC or higher. High flow temperatures will result in a lower heat pump COP, while lower flow temperatures will require greater radiator surface area.

Test conditions (and hence manufacturers' quoted COP data) can therefore differ significantly from actual design and operating conditions.

Analysis

Our analysis shows that an ASHP system sized to do 50% of the peak load (75 kW) and 90% of the annual load will offset 17% of the carbon emissions, at a cost of £17,000. Although this looks as an attractive option, as mentioned earlier in the report issues with winter COP in conjunction with the building load profile make an ASHP system not appropriate.

BIOMASS AND BIOFUEL TECHNOLOGIES

Introduction

Biomass refers to living or recently living biological material which can be used to fuel energy production. Biomass can consist of wood products or non-wood products which include bio-degradables. Biomass can only be considered as a renewable energy if it comes from a sustainable source.

You can convert biomass into useful electricity or heat using generator and boiler technologies. The electricity generating technologies associated with biomass are still relatively unproven therefore in this section we are going to discuss burning biomass to create heat.

Figure 4.15: - Section through a Biomass Boiler

Types of Biomass Fuel
There are five basic categories of material:

- *Virgin wood*, from forestry, arboricultural activities or from wood processing
- *Industrial waste and co-products* from manufacturing and industrial processes.
- *Energy crops*: high yield crops grown specifically for energy applications (not considered sustainable in UK due to need to grow food).
- *Agricultural residues*: residues from agriculture harvesting or processing
- *Food waste*, from food and drink manufacture, preparation and processing, and post-consumer waste

In the case of this development, the first two options should be considered as possible sustainable fuel supplies, suitable for burning in a biomass boiler.

Woodchip

The advantages of wood chip are:

- Are cheaper than wood pellets and are equivalent in price to gas;
- it is a standardised product with Europe wide quality standards in place – G30 spec;
- fully automated, highly efficient boiler systems are available;
- it can be made from a wide range of raw materials, often sourced locally.

Their disadvantages are:

- fuel quality is often variable, since suppliers are still inexperienced;
- it can be difficult to find supplies;
- it is a bulky fuel, leading to storage problems in some sites, particularly at the domestic scale.

Woodchips

Wood Pellets

Figure 4.16: - Main Wood Fuel Types

Wood Pellets
Wood pellets are a highly compressed standardised product made from sawdust, normally without other additives.

Their advantages are:

- they are a consistent fuel with low moisture content which can be easily handled in automated systems;
- a wide range of appliances are available to burn pellets. Fully automated boilers are the norm;
- bulk density is around 4 times that of wood chip, requiring less storage room.

Their disadvantages are:

- supplies of locally made wood pellets are hard to find in the UK, most are imported at present;
- they take energy to make and are often transported long distances, reducing the environmental benefits of using a wood fuel;
- they are expensive, twice the price of wood chip.

As shown above, wood pellets have more advantages than the wood chips. However the cost of wood pellet is 0.05 £/kWh; the cost of wood chip is roughly 0.021 £/kWh while the cost of gas is only 0.017 £/kWh. The price of fuel often dependent on local supply chain and is often subject to fluctuations.

Availability of Wood Fuel
Wood pellet is manufactured in the U.K. However, the good availability of the wood raw materials is dependent on the area. The U.K. does not have as many forests as in Europe, where there is good availability of raw materials, and thus the biomass market in the U.K. is far behind that of the European market. Wood pellet can be imported and then distributed, however, this deems itself expensive.

Biomass fuel can be burnt in specially designed boilers to provide heat to cover the base heating load throughout the year. Poor responsiveness to meet fluctuating loads means that it is preferable to use biomass boilers as part of a hybrid multiple boiler installation, with gas boilers to take up the rest of the load.

Biomass is a very effective way to reduce carbon emissions when considering just capital cost, but the client should be aware of and committed to the extra work required in the daily and yearly running of the plant. Biomass is as yet a relatively untried technology in commercial buildings and requires a large amount of maintenance and management.

The supply chain is difficult to control and subject to change over the life of the installation, this is key to the operation and success of the scheme and is likely to require significant time and effort. The difficulties in setting up the supply chain could prove prohibitive to a biomass scheme. More work will be done on identifying a supply chain in the next stage.

The excess space required for the plant and to store the fuel can end up being a significant extra cost pushing up the initial outlay and lengthening the payback time.

Supply Chain Options
Biomass should only be considered where a robust local supply chain for biomass is available.

Advantages of Biomass

- Lower carbon emission, when compared to fossil fuels, as carbon absorbed when re-growing balances the carbon used.
- Coppiced plantations can actually absorb more carbon dioxide than mature trees - since carbon dioxide absorption slows once a tree nears maturity.
- Fewer nutrients from the soil are required compared with other food crops.
- The crop's root structure can absorb contamination from soil.
- Recycled biomass reduces waste to landfill.
- There is the option of not providing gas or oil infrastructure to the building.
- Low initial capital cost
- Possible increased afforestation

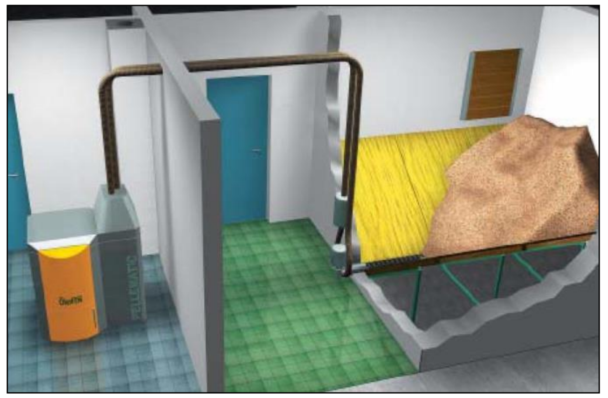
Disadvantage of Biomass

- Requires wood fuel, which can be expensive than gas, thus biomass boiler often never pay for themselves. Also Biomass fuel prices can fluctuate depending on availability.
- The supply of the fuel is subject to availability. Thus a large storage facility can be used to combat the unpredictability of the supply chain, but large deliveries less feasible in dense urban areas.
- Deliveries have a carbon impact, so local supply better.
- Biomass boilers require regular maintenance. Thus maintenance contracts with the suppliers will have to be taken out. Maintenance costs are approximately 1% of initial capital outlay (including store). approx. 2 days per year outside maintenance ~£800 PA.
- Buffer vessel is required, to prevent boiler cycling.
- The NOx emissions of Biomass boilers are higher than gas boilers
- The 0.5-5% ash content by mass created by burning the fuel will have to be disposed of.
- Renewable technologies tend to require a high initial capital investment that often falls outside capital budgets.

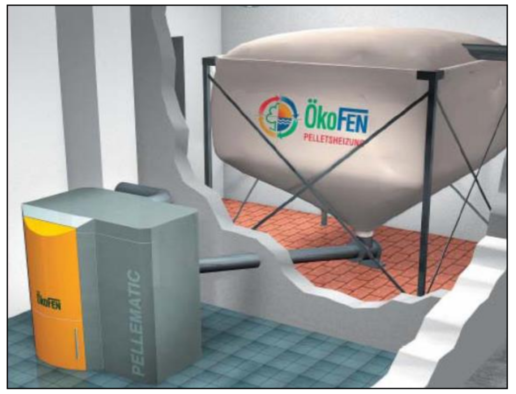
Installation
A typical installation includes a storage area for the fuel, a feeder to deliver the fuel from the store to the boiler, a boiler.

The biomass system requires a separate flue to discharge the waste gas.

Fuel Storage
The wood pellet can be stored in under and above ground silos, storage rooms or bunkers. 6 m³ of wood pellet can last roughly 3 – 4 weeks depending on use. This is equivalent to roughly 2 – 2.5 tonnes of wood pellet. There is currently no space to store wood fuel on the plans, therefore a store local to the building would require planning permission.



Store room with vacuum pump to boiler



Fabric hopper storage facility

The analysis

The table below shows the results of our analysis.

The calculation shows that a boiler sized to deal with 90% of the annual heating load can achieve a 48% reduction target.

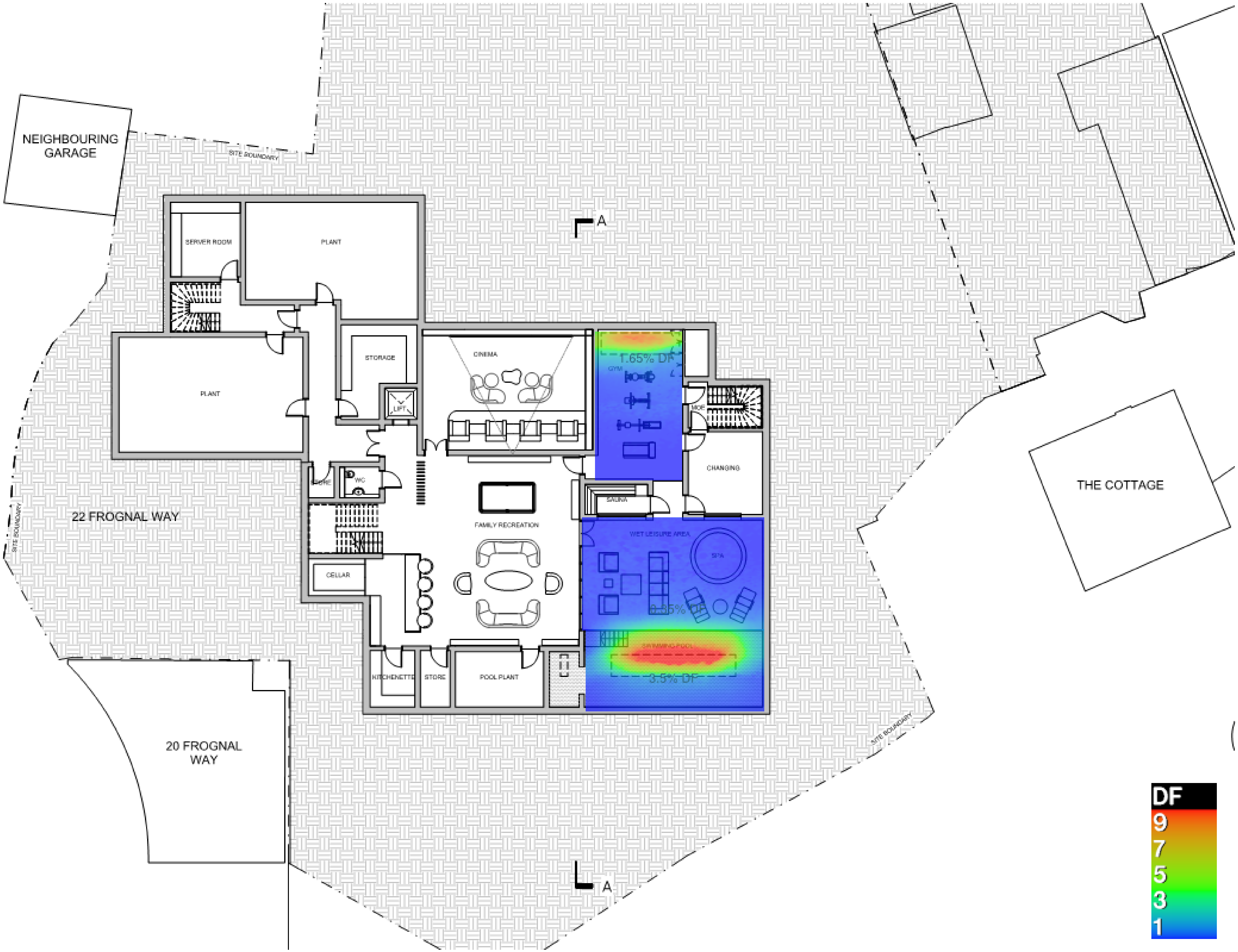
A biomass boiler that would just meet the 20% reduction target would only deal with 38% of the annual reduction target.

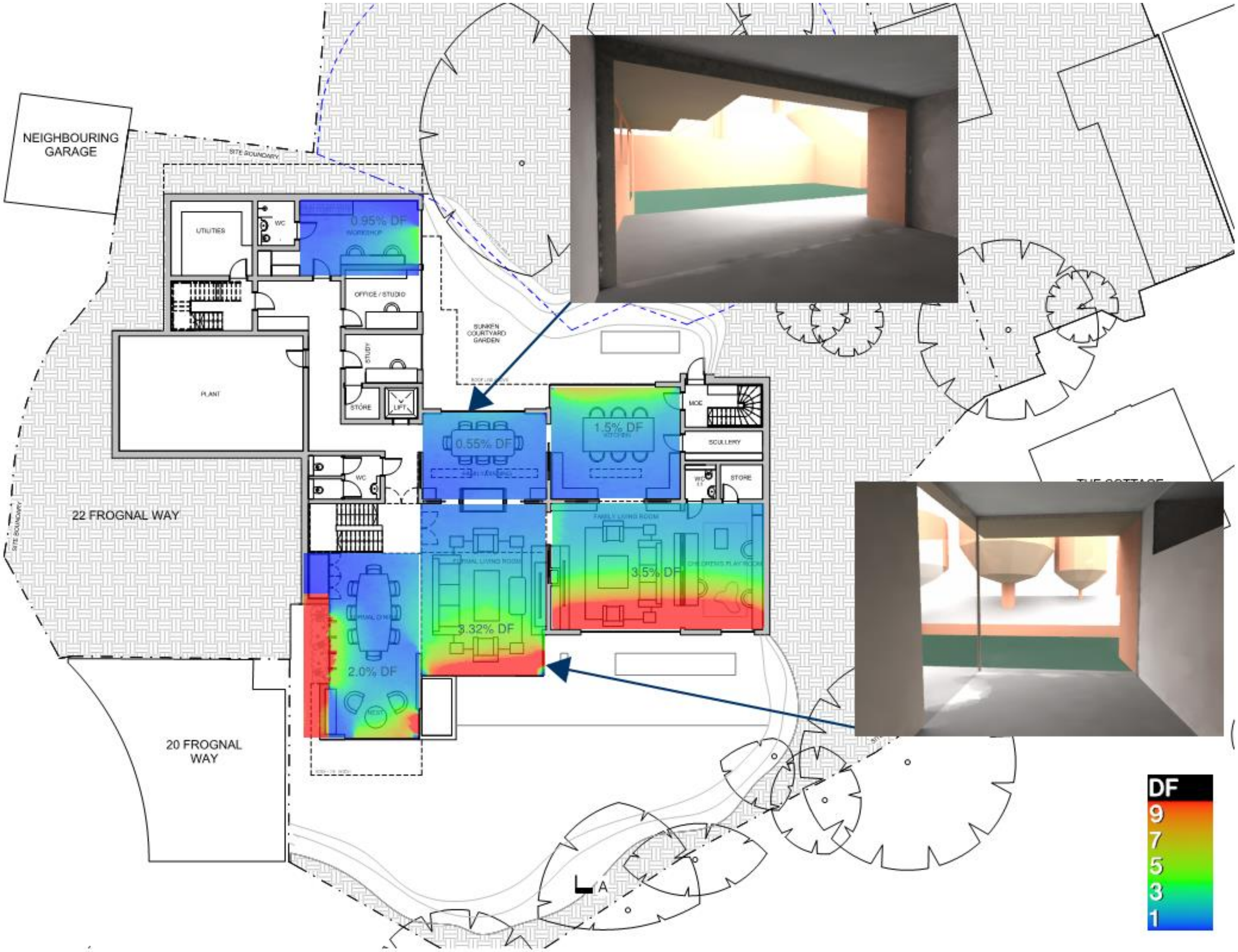
The Boiler could be fuelled by either wood pellets, wood chips or bio-oil (if available). The efficiency of biomass boilers are between 85% and 90%. Options available are the KWB – Multifier and some of the KSM boiler ranges. The NOx emissions are typically 0.6 tonnes/GWh per annum.

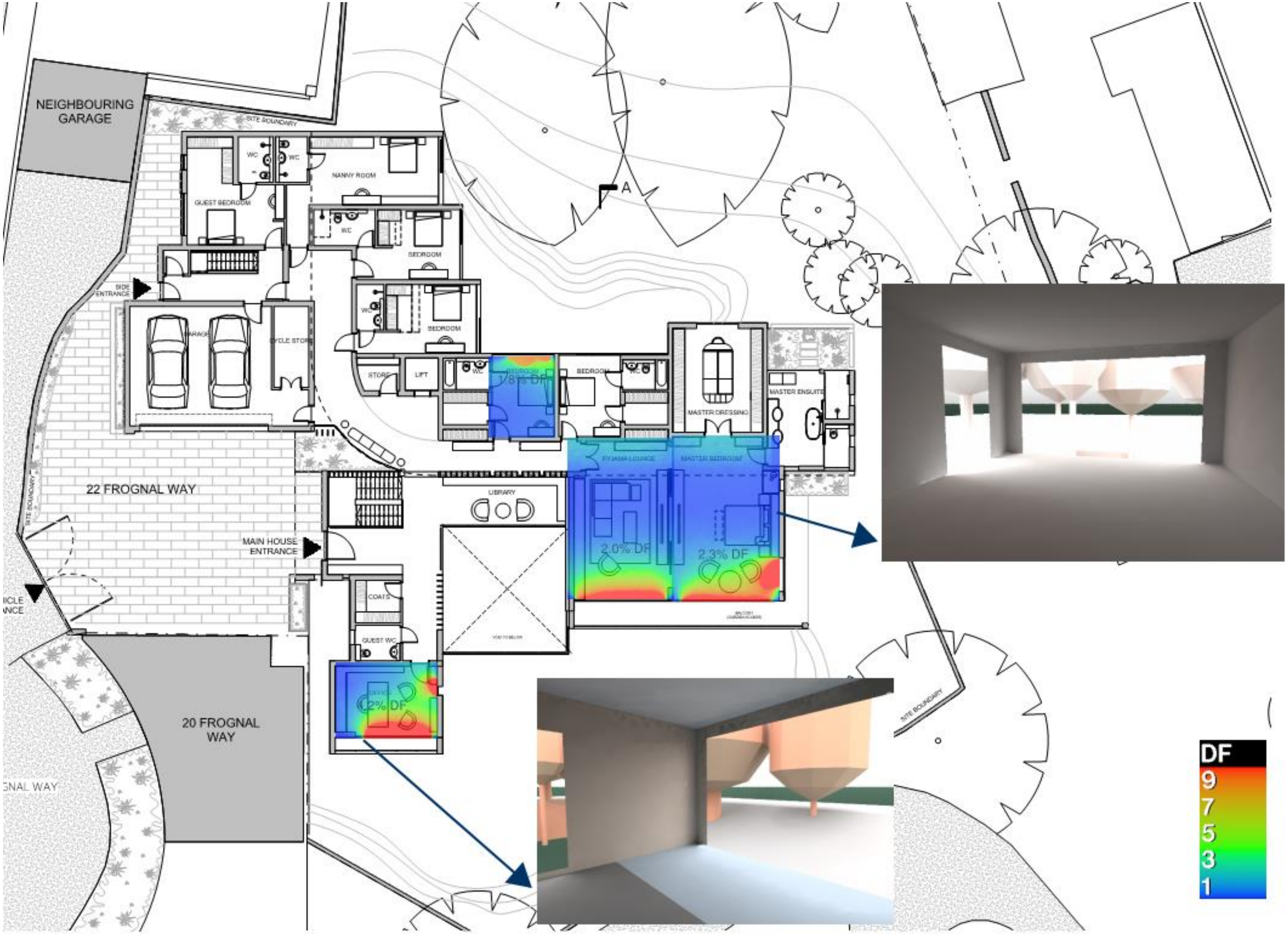
Unfortunately due to the current costs of wood fuel, the potential flue height and air quality issues this system is not considered viable.

		Target
		80 kW Boiler
Renewable Energy %	%	20%
Carbon Offset Required	kgCO2/yr	3,985
Wood Pellets Volume Required per year	kg	4,371
Capital Cost	£	£40,000
Service Life	years	20 years
Renewable Heat Incentive	£/kWh	0.019
Annual Running Costs	£	1,045/year
Cost Efficiency (Life)	£/kgCO2/yr	£13.38/CO_2
Net Income over Life	£	none
Payback		Never

Appendix G - Daylight Study


NEIGHBOURING GARAGE
SITE BOUNDARY
SERVER ROOM
PLANT
PLANT
STORAGE
LIFT
CINEMA
1.65% DF
GYM
MOP
CHANGING
WC
STORE
SAUNA
FAMILY RECREATION
WET LEISURE AREA
SPA
CELLAR
0.35% DF
SWIMMING POOL
3.5% DF
KITCHENETTE
STORE
POOL PLANT
22 FROGNAL WAY
20 FROGNAL WAY
THE COTTAGE
SITE BOUNDARY
SITE BOUNDARY
A
A
DF
9
7
5
3
1


NEIGHBOURING GARAGE
SITE BOUNDARY
UTILITIES
WC
0.95% DF
OFFICE / STUDIO
SUNKEN COURTYARD GARDEN
STUDY
PLANT
STORE
LIFT
0.55% DF
1.5% DF
SCULLERY
STORE
22 FROGNAL WAY
FAMILY LIVING ROOM
3.5% DF
3.32% DF
2.0% DF
20 FROGNAL WAY
A
DF
9
7
5
3
1


NEIGHBOURING GARAGE
SITE BOUNDARY
WC
NANNY ROOM
GUEST BEDROOM
BEDROOM
SIDE ENTRANCE
CYCLE STORE
STORE
LIFT
MASTER DRESSING
MASTER ENSUITE
PYJAMA LOUNGE
MASTER BEDROOM
2.0% DF
2.3% DF
22 FROGNAL WAY
LIBRARY
MAIN HOUSE ENTRANCE
COATS
GUEST WC
2% DF
20 FROGNAL WAY
A
DF
9
7
5
3
1